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NavierStokes FSA3PbetaIt

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| Date | Aug 26, 2014 6:03:50 AM |

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1. Global

|  |  |
| --- | --- |
| Date | Aug 20, 2014 11:31:47 AM |

Global settings

|  |  |
| --- | --- |
| Name | NavierStokes FSA3PbetaIt.mph |
| Path | /Users/gilliam/Desktop/collect\_15/research\_15/geo\_reg\_mono\_eugenio/Mono\_1\_15/Comsol\_EX\_GitHub/Chapter5/Chap5Ex5\_NS\_Fourier\_beta/NavierStokes\_FSA3PbetaIt.mph |
| Program | COMSOL 4.4 (Build: 150) |

Used products

|  |
| --- |
| COMSOL Multiphysics |

* 1. Definitions
     1. Parameters 1

Parameters

| **Name** | **Expression** | **Value** | **Description** |
| --- | --- | --- | --- |
| D | 0.1 | 0.10000 |  |
| L | 1 | 1.0000 |  |
| nu | 0.005 | 0.0050000 |  |
| A1 | 0.1 | 0.10000 |  |
| M1 | 0.1 | 0.10000 |  |
| alpha | 1 | 1.0000 |  |
| N | 3 | 3.0000 |  |

1. Component 1

Component settings

|  |  |
| --- | --- |
| Unit system | None |

* 1. Definitions
     1. Variables

#### Variables 1a

Selection

|  |  |
| --- | --- |
| Geometric entity level | Entire model |

| **Name** | **Expression** | **Description** |
| --- | --- | --- |
| G | C(U) |  |
| e | yr - C(u) |  |

#### Variables 2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Entire model |

| **Name** | **Expression** | **Description** |
| --- | --- | --- |
| f\_au0 | au0\*au0x + av0\*au0y - 0.5\*(au0\*au0x + 2.\*au1\*au1x + 2.\*au2\*au2x + 2.\*au3\*au3x + 2.\*bu1\*bu1x + 2.\*bu2\*bu2x + 2.\*bu3\*bu3x + av0\*au0y + 2.\*av1\*au1y + 2.\*av2\*au2y + 2.\*av3\*au3y + 2.\*bv1\*bu1y + 2.\*bv2\*bu2y + 2.\*bv3\*bu3y) |  |
| f\_atu0 | atu0\*atu0x + atv0\*atu0y - 0.5\*(au0\*au0x + 2.\*au1\*au1x + 2.\*au2\*au2x + 2.\*au3\*au3x + 2.\*bu1\*bu1x + 2.\*bu2\*bu2x + 2.\*bu3\*bu3x + av0\*au0y + 2.\*av1\*au1y + 2.\*av2\*au2y + 2.\*av3\*au3y + 2.\*bv1\*bu1y + 2.\*bv2\*bu2y + 2.\*bv3\*bu3y) |  |
| f\_av0 | au0\*av0x + av0\*av0y - 0.5\*(au0\*av0x + 2.\*au1\*av1x + 2.\*au2\*av2x + 2.\*au3\*av3x + 2.\*bu1\*bv1x + 2.\*bu2\*bv2x + 2.\*bu3\*bv3x + av0\*av0y + 2.\*av1\*av1y + 2.\*av2\*av2y + 2.\*av3\*av3y + 2.\*bv1\*bv1y + 2.\*bv2\*bv2y + 2.\*bv3\*bv3y) |  |
| f\_atv0 | atu0\*atv0x + atv0\*atv0y - 0.5\*(au0\*av0x + 2.\*au1\*av1x + 2.\*au2\*av2x + 2.\*au3\*av3x + 2.\*bu1\*bv1x + 2.\*bu2\*bv2x + 2.\*bu3\*bv3x + av0\*av0y + 2.\*av1\*av1y + 2.\*av2\*av2y + 2.\*av3\*av3y + 2.\*bv1\*bv1y + 2.\*bv2\*bv2y + 2.\*bv3\*bv3y) |  |
| f\_au1 | au1\*au1x + av1\*au1y - 1\*alpha\*bu1 - 0.5\*(au0\*au1x + au1\*au0x + 0.5\*au1\*au2x + 0.5\*au2\*au1x + 0.5\*au2\*au1x + 0.5\*au1\*au2x + 0.5\*au2\*au3x + 0.5\*au3\*au2x + 0.5\*au3\*au2x + 0.5\*au2\*au3x + 0.5\*bu1\*bu2x + 0.5\*bu2\*bu1x + 0.5\*bu2\*bu1x + 0.5\*bu1\*bu2x + 0.5\*bu2\*bu3x + 0.5\*bu3\*bu2x + 0.5\*bu3\*bu2x + 0.5\*bu2\*bu3x + av0\*au1y + av1\*au0y + 0.5\*av1\*au2y + 0.5\*av2\*au1y + 0.5\*av2\*au1y + 0.5\*av1\*au2y + 0.5\*av2\*au3y + 0.5\*av3\*au2y + 0.5\*av3\*au2y + 0.5\*av2\*au3y + 0.5\*bv1\*bu2y + 0.5\*bv2\*bu1y + 0.5\*bv2\*bu1y + 0.5\*bv1\*bu2y + 0.5\*bv2\*bu3y + 0.5\*bv3\*bu2y + 0.5\*bv3\*bu2y + 0.5\*bv2\*bu3y)\*(N>0) |  |
| f\_atu1 | atu1\*atu1x + atv1\*atu1y - 1\*alpha\*bu1 - 0.5\*(au0\*au1x + au1\*au0x + 0.5\*au1\*au2x + 0.5\*au2\*au1x + 0.5\*au2\*au1x + 0.5\*au1\*au2x + 0.5\*au2\*au3x + 0.5\*au3\*au2x + 0.5\*au3\*au2x + 0.5\*au2\*au3x + 0.5\*bu1\*bu2x + 0.5\*bu2\*bu1x + 0.5\*bu2\*bu1x + 0.5\*bu1\*bu2x + 0.5\*bu2\*bu3x + 0.5\*bu3\*bu2x + 0.5\*bu3\*bu2x + 0.5\*bu2\*bu3x + av0\*au1y + av1\*au0y + 0.5\*av1\*au2y + 0.5\*av2\*au1y + 0.5\*av2\*au1y + 0.5\*av1\*au2y + 0.5\*av2\*au3y + 0.5\*av3\*au2y + 0.5\*av3\*au2y + 0.5\*av2\*au3y + 0.5\*bv1\*bu2y + 0.5\*bv2\*bu1y + 0.5\*bv2\*bu1y + 0.5\*bv1\*bu2y + 0.5\*bv2\*bu3y + 0.5\*bv3\*bu2y + 0.5\*bv3\*bu2y + 0.5\*bv2\*bu3y)\*(N>0) |  |
| f\_av1 | au1\*av1x + av1\*av1y - 1\*alpha\*bv1 - 0.5\*(au0\*av1x + au1\*av0x + 0.5\*au1\*av2x + 0.5\*au2\*av1x + 0.5\*au2\*av1x + 0.5\*au1\*av2x + 0.5\*au2\*av3x + 0.5\*au3\*av2x + 0.5\*au3\*av2x + 0.5\*au2\*av3x + 0.5\*bu1\*bv2x + 0.5\*bu2\*bv1x + 0.5\*bu2\*bv1x + 0.5\*bu1\*bv2x + 0.5\*bu2\*bv3x + 0.5\*bu3\*bv2x + 0.5\*bu3\*bv2x + 0.5\*bu2\*bv3x + av0\*av1y + av1\*av0y + 0.5\*av1\*av2y + 0.5\*av2\*av1y + 0.5\*av2\*av1y + 0.5\*av1\*av2y + 0.5\*av2\*av3y + 0.5\*av3\*av2y + 0.5\*av3\*av2y + 0.5\*av2\*av3y + 0.5\*bv1\*bv2y + 0.5\*bv2\*bv1y + 0.5\*bv2\*bv1y + 0.5\*bv1\*bv2y + 0.5\*bv2\*bv3y + 0.5\*bv3\*bv2y + 0.5\*bv3\*bv2y + 0.5\*bv2\*bv3y)\*(N>0) |  |
| f\_atv1 | atu1\*atv1x + atv1\*atv1y - 1\*alpha\*bv1 - 0.5\*(au0\*av1x + au1\*av0x + 0.5\*au1\*av2x + 0.5\*au2\*av1x + 0.5\*au2\*av1x + 0.5\*au1\*av2x + 0.5\*au2\*av3x + 0.5\*au3\*av2x + 0.5\*au3\*av2x + 0.5\*au2\*av3x + 0.5\*bu1\*bv2x + 0.5\*bu2\*bv1x + 0.5\*bu2\*bv1x + 0.5\*bu1\*bv2x + 0.5\*bu2\*bv3x + 0.5\*bu3\*bv2x + 0.5\*bu3\*bv2x + 0.5\*bu2\*bv3x + av0\*av1y + av1\*av0y + 0.5\*av1\*av2y + 0.5\*av2\*av1y + 0.5\*av2\*av1y + 0.5\*av1\*av2y + 0.5\*av2\*av3y + 0.5\*av3\*av2y + 0.5\*av3\*av2y + 0.5\*av2\*av3y + 0.5\*bv1\*bv2y + 0.5\*bv2\*bv1y + 0.5\*bv2\*bv1y + 0.5\*bv1\*bv2y + 0.5\*bv2\*bv3y + 0.5\*bv3\*bv2y + 0.5\*bv3\*bv2y + 0.5\*bv2\*bv3y)\*(N>0) |  |
| f\_bu1 | bu1\*bu1x + bv1\*bu1y + 1\*alpha\*au1 - 0.5\*(au0\*bu1x + bu1\*au0x + au1\*bu2x + bu2\*au1x - au2\*bu1x - bu1\*au2x + au2\*bu3x + bu3\*au2x - au3\*bu2x - bu2\*au3x + av0\*bu1y + bv1\*au0y + av1\*bu2y + bv2\*au1y - av2\*bu1y - bv1\*au2y + av2\*bu3y + bv3\*au2y - av3\*bu2y - bv2\*au3y)\*(N>0) |  |
| f\_btu1 | btu1\*btu1x + btv1\*btu1y + 1\*alpha\*au1 - 0.5\*(au0\*bu1x + bu1\*au0x + au1\*bu2x + bu2\*au1x - au2\*bu1x - bu1\*au2x + au2\*bu3x + bu3\*au2x - au3\*bu2x - bu2\*au3x + av0\*bu1y + bv1\*au0y + av1\*bu2y + bv2\*au1y - av2\*bu1y - bv1\*au2y + av2\*bu3y + bv3\*au2y - av3\*bu2y - bv2\*au3y)\*(N>0) |  |
| f\_bv1 | bu1\*bv1x + bv1\*bv1y + 1\*alpha\*av1 - 0.5\*(au0\*bv1x + bu1\*av0x + au1\*bv2x + bu2\*av1x - au2\*bv1x - bu1\*av2x + au2\*bv3x + bu3\*av2x - au3\*bv2x - bu2\*av3x + av0\*bv1y + bv1\*av0y + av1\*bv2y + bv2\*av1y - av2\*bv1y - bv1\*av2y + av2\*bv3y + bv3\*av2y - av3\*bv2y - bv2\*av3y)\*(N>0) |  |
| f\_btv1 | btu1\*btv1x + btv1\*btv1y + 1\*alpha\*av1 - 0.5\*(au0\*bv1x + bu1\*av0x + au1\*bv2x + bu2\*av1x - au2\*bv1x - bu1\*av2x + au2\*bv3x + bu3\*av2x - au3\*bv2x - bu2\*av3x + av0\*bv1y + bv1\*av0y + av1\*bv2y + bv2\*av1y - av2\*bv1y - bv1\*av2y + av2\*bv3y + bv3\*av2y - av3\*bv2y - bv2\*av3y)\*(N>0) |  |
| f\_au2 | au2\*au2x + av2\*au2y - 2\*alpha\*bu2 - 0.5\*(au0\*au2x + au2\*au0x + 0.5\*au1\*au1x + 0.5\*au1\*au1x + 0.5\*au1\*au3x + 0.5\*au3\*au1x + 0.5\*au3\*au1x + 0.5\*au1\*au3x - 0.5\*bu1\*bu1x - 0.5\*bu1\*bu1x + 0.5\*bu1\*bu3x + 0.5\*bu3\*bu1x + 0.5\*bu3\*bu1x + 0.5\*bu1\*bu3x + av0\*au2y + av2\*au0y + 0.5\*av1\*au1y + 0.5\*av1\*au1y + 0.5\*av1\*au3y + 0.5\*av3\*au1y + 0.5\*av3\*au1y + 0.5\*av1\*au3y - 0.5\*bv1\*bu1y - 0.5\*bv1\*bu1y + 0.5\*bv1\*bu3y + 0.5\*bv3\*bu1y + 0.5\*bv3\*bu1y + 0.5\*bv1\*bu3y)\*(N>1) |  |
| f\_atu2 | atu2\*atu2x + atv2\*atu2y - 2\*alpha\*bu2 - 0.5\*(au0\*au2x + au2\*au0x + 0.5\*au1\*au1x + 0.5\*au1\*au1x + 0.5\*au1\*au3x + 0.5\*au3\*au1x + 0.5\*au3\*au1x + 0.5\*au1\*au3x - 0.5\*bu1\*bu1x - 0.5\*bu1\*bu1x + 0.5\*bu1\*bu3x + 0.5\*bu3\*bu1x + 0.5\*bu3\*bu1x + 0.5\*bu1\*bu3x + av0\*au2y + av2\*au0y + 0.5\*av1\*au1y + 0.5\*av1\*au1y + 0.5\*av1\*au3y + 0.5\*av3\*au1y + 0.5\*av3\*au1y + 0.5\*av1\*au3y - 0.5\*bv1\*bu1y - 0.5\*bv1\*bu1y + 0.5\*bv1\*bu3y + 0.5\*bv3\*bu1y + 0.5\*bv3\*bu1y + 0.5\*bv1\*bu3y)\*(N>1) |  |
| f\_av2 | au2\*av2x + av2\*av2y - 2\*alpha\*bv2 - 0.5\*(au0\*av2x + au2\*av0x + 0.5\*au1\*av1x + 0.5\*au1\*av1x + 0.5\*au1\*av3x + 0.5\*au3\*av1x + 0.5\*au3\*av1x + 0.5\*au1\*av3x - 0.5\*bu1\*bv1x - 0.5\*bu1\*bv1x + 0.5\*bu1\*bv3x + 0.5\*bu3\*bv1x + 0.5\*bu3\*bv1x + 0.5\*bu1\*bv3x + av0\*av2y + av2\*av0y + 0.5\*av1\*av1y + 0.5\*av1\*av1y + 0.5\*av1\*av3y + 0.5\*av3\*av1y + 0.5\*av3\*av1y + 0.5\*av1\*av3y - 0.5\*bv1\*bv1y - 0.5\*bv1\*bv1y + 0.5\*bv1\*bv3y + 0.5\*bv3\*bv1y + 0.5\*bv3\*bv1y + 0.5\*bv1\*bv3y)\*(N>1) |  |
| f\_atv2 | atu2\*atv2x + atv2\*atv2y - 2\*alpha\*bv2 - 0.5\*(au0\*av2x + au2\*av0x + 0.5\*au1\*av1x + 0.5\*au1\*av1x + 0.5\*au1\*av3x + 0.5\*au3\*av1x + 0.5\*au3\*av1x + 0.5\*au1\*av3x - 0.5\*bu1\*bv1x - 0.5\*bu1\*bv1x + 0.5\*bu1\*bv3x + 0.5\*bu3\*bv1x + 0.5\*bu3\*bv1x + 0.5\*bu1\*bv3x + av0\*av2y + av2\*av0y + 0.5\*av1\*av1y + 0.5\*av1\*av1y + 0.5\*av1\*av3y + 0.5\*av3\*av1y + 0.5\*av3\*av1y + 0.5\*av1\*av3y - 0.5\*bv1\*bv1y - 0.5\*bv1\*bv1y + 0.5\*bv1\*bv3y + 0.5\*bv3\*bv1y + 0.5\*bv3\*bv1y + 0.5\*bv1\*bv3y)\*(N>1) |  |
| f\_bu2 | bu2\*bu2x + bv2\*bu2y + 2\*alpha\*au2 - 0.5\*(au0\*bu2x + bu2\*au0x + au1\*bu1x + bu1\*au1x + au1\*bu3x + bu3\*au1x - au3\*bu1x - bu1\*au3x + av0\*bu2y + bv2\*au0y + av1\*bu1y + bv1\*au1y + av1\*bu3y + bv3\*au1y - av3\*bu1y - bv1\*au3y)\*(N>1) |  |
| f\_btu2 | btu2\*btu2x + btv2\*btu2y + 2\*alpha\*au2 - 0.5\*(au0\*bu2x + bu2\*au0x + au1\*bu1x + bu1\*au1x + au1\*bu3x + bu3\*au1x - au3\*bu1x - bu1\*au3x + av0\*bu2y + bv2\*au0y + av1\*bu1y + bv1\*au1y + av1\*bu3y + bv3\*au1y - av3\*bu1y - bv1\*au3y)\*(N>1) |  |
| f\_bv2 | bu2\*bv2x + bv2\*bv2y + 2\*alpha\*av2 - 0.5\*(au0\*bv2x + bu2\*av0x + au1\*bv1x + bu1\*av1x + au1\*bv3x + bu3\*av1x - au3\*bv1x - bu1\*av3x + av0\*bv2y + bv2\*av0y + av1\*bv1y + bv1\*av1y + av1\*bv3y + bv3\*av1y - av3\*bv1y - bv1\*av3y)\*(N>1) |  |
| f\_btv2 | btu2\*btv2x + btv2\*btv2y + 2\*alpha\*av2 - 0.5\*(au0\*bv2x + bu2\*av0x + au1\*bv1x + bu1\*av1x + au1\*bv3x + bu3\*av1x - au3\*bv1x - bu1\*av3x + av0\*bv2y + bv2\*av0y + av1\*bv1y + bv1\*av1y + av1\*bv3y + bv3\*av1y - av3\*bv1y - bv1\*av3y)\*(N>1) |  |
| f\_au3 | au3\*au3x + av3\*au3y - 3\*alpha\*bu3 - 0.5\*(au0\*au3x + au3\*au0x + 0.5\*au1\*au2x + 0.5\*au2\*au1x + 0.5\*au2\*au1x + 0.5\*au1\*au2x - 0.5\*bu1\*bu2x - 0.5\*bu2\*bu1x - 0.5\*bu2\*bu1x - 0.5\*bu1\*bu2x + av0\*au3y + av3\*au0y + 0.5\*av1\*au2y + 0.5\*av2\*au1y + 0.5\*av2\*au1y + 0.5\*av1\*au2y - 0.5\*bv1\*bu2y - 0.5\*bv2\*bu1y - 0.5\*bv2\*bu1y - 0.5\*bv1\*bu2y)\*(N>2) |  |
| f\_atu3 | atu3\*atu3x + atv3\*atu3y - 3\*alpha\*bu3 - 0.5\*(au0\*au3x + au3\*au0x + 0.5\*au1\*au2x + 0.5\*au2\*au1x + 0.5\*au2\*au1x + 0.5\*au1\*au2x - 0.5\*bu1\*bu2x - 0.5\*bu2\*bu1x - 0.5\*bu2\*bu1x - 0.5\*bu1\*bu2x + av0\*au3y + av3\*au0y + 0.5\*av1\*au2y + 0.5\*av2\*au1y + 0.5\*av2\*au1y + 0.5\*av1\*au2y - 0.5\*bv1\*bu2y - 0.5\*bv2\*bu1y - 0.5\*bv2\*bu1y - 0.5\*bv1\*bu2y)\*(N>2) |  |
| f\_av3 | au3\*av3x + av3\*av3y - 3\*alpha\*bv3 - 0.5\*(au0\*av3x + au3\*av0x + 0.5\*au1\*av2x + 0.5\*au2\*av1x + 0.5\*au2\*av1x + 0.5\*au1\*av2x - 0.5\*bu1\*bv2x - 0.5\*bu2\*bv1x - 0.5\*bu2\*bv1x - 0.5\*bu1\*bv2x + av0\*av3y + av3\*av0y + 0.5\*av1\*av2y + 0.5\*av2\*av1y + 0.5\*av2\*av1y + 0.5\*av1\*av2y - 0.5\*bv1\*bv2y - 0.5\*bv2\*bv1y - 0.5\*bv2\*bv1y - 0.5\*bv1\*bv2y)\*(N>2) |  |
| f\_atv3 | atu3\*atv3x + atv3\*atv3y - 3\*alpha\*bv3 - 0.5\*(au0\*av3x + au3\*av0x + 0.5\*au1\*av2x + 0.5\*au2\*av1x + 0.5\*au2\*av1x + 0.5\*au1\*av2x - 0.5\*bu1\*bv2x - 0.5\*bu2\*bv1x - 0.5\*bu2\*bv1x - 0.5\*bu1\*bv2x + av0\*av3y + av3\*av0y + 0.5\*av1\*av2y + 0.5\*av2\*av1y + 0.5\*av2\*av1y + 0.5\*av1\*av2y - 0.5\*bv1\*bv2y - 0.5\*bv2\*bv1y - 0.5\*bv2\*bv1y - 0.5\*bv1\*bv2y)\*(N>2) |  |
| f\_bu3 | bu3\*bu3x + bv3\*bu3y + 3\*alpha\*au3 - 0.5\*(au0\*bu3x + bu3\*au0x + au1\*bu2x + bu2\*au1x + au2\*bu1x + bu1\*au2x + av0\*bu3y + bv3\*au0y + av1\*bu2y + bv2\*au1y + av2\*bu1y + bv1\*au2y)\*(N>2) |  |
| f\_btu3 | btu3\*btu3x + btv3\*btu3y + 3\*alpha\*au3 - 0.5\*(au0\*bu3x + bu3\*au0x + au1\*bu2x + bu2\*au1x + au2\*bu1x + bu1\*au2x + av0\*bu3y + bv3\*au0y + av1\*bu2y + bv2\*au1y + av2\*bu1y + bv1\*au2y)\*(N>2) |  |
| f\_bv3 | bu3\*bv3x + bv3\*bv3y + 3\*alpha\*av3 - 0.5\*(au0\*bv3x + bu3\*av0x + au1\*bv2x + bu2\*av1x + au2\*bv1x + bu1\*av2x + av0\*bv3y + bv3\*av0y + av1\*bv2y + bv2\*av1y + av2\*bv1y + bv1\*av2y)\*(N>2) |  |
| f\_btv3 | btu3\*btv3x + btv3\*btv3y + 3\*alpha\*av3 - 0.5\*(au0\*bv3x + bu3\*av0x + au1\*bv2x + bu2\*av1x + au2\*bv1x + bu1\*av2x + av0\*bv3y + bv3\*av0y + av1\*bv2y + bv2\*av1y + av2\*bv1y + bv1\*av2y)\*(N>2) |  |
| Gamma\_a0 | (2\*M1 - C(atu0))/G |  |
| Gamma\_a1 | (0 - C(atu1))/G\*(N>0) |  |
| Gamma\_b1 | (A1 - C(btu1))/G\*(N>0) |  |
| Gamma\_a2 | (0 - C(atu2))/G\*(N>1) |  |
| Gamma\_b2 | (0 - C(btu2))/G\*(N>1) |  |
| Gamma\_a3 | (0 - C(atu3))/G\*(N>2) |  |
| Gamma\_b3 | (0 - C(btu3))/G\*(N>2) |  |
| Gamma1 | 0.5\*Gamma\_a0 + Gamma\_a1\*cos(alpha\*1\*t) + Gamma\_b1\*sin(alpha\*1\*t) + Gamma\_a2\*cos(alpha\*2\*t) + Gamma\_b2\*sin(alpha\*2\*t) + Gamma\_a3\*cos(alpha\*3\*t) + Gamma\_b3\*sin(alpha\*3\*t) |  |
| U10 | 0.5\*au0 + au1 + au2 + au3 |  |
| V10 | 0.5\*av0 + av1 + av2 + av3 |  |
| P10 | 0.5\*ap0 + ap1 + ap2 + ap3 |  |
| FU1 | -U1\*U1x - V1\*U1y |  |
| FV1 | -U1\*V1x - V1\*V1y |  |
| U2 | U1 + u2 |  |
| V2 | V1 + v2 |  |
| FU2 | -U2\*d(U2, x) - V2\*d(U2, y) |  |
| Fu2 | u2\*u2x + v2\*u2y + FU2 - FU1 |  |
| Fut2 | ut2t - 0.99\*u2t + ut2\*ut2x + vt2\*ut2y + FU2 - FU1 |  |
| FV2 | -U2\*d(V2, x) - V2\*d(V2, y) |  |
| Fv2 | u2\*v2x + v2\*v2y + FV2 - FV1 |  |
| Fvt2 | vt2t - 0.99\*v2t + ut2\*vt2x + vt2\*vt2y + FV2 - FV1 |  |
| gamma2 | (yr - C(U1) - C(ut2))/G |  |
| gamma | Gamma1 + gamma2 |  |
| yr | M1 + A1\*sin(alpha\*t) |  |

* + 1. Component Couplings

#### Integration 1

|  |  |
| --- | --- |
| Coupling type | Integration |
| Operator name | C |

Source selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

* + 1. Coordinate Systems

#### Boundary System 1

|  |  |
| --- | --- |
| Coordinate system type | Boundary system |
| Tag | sys1 |

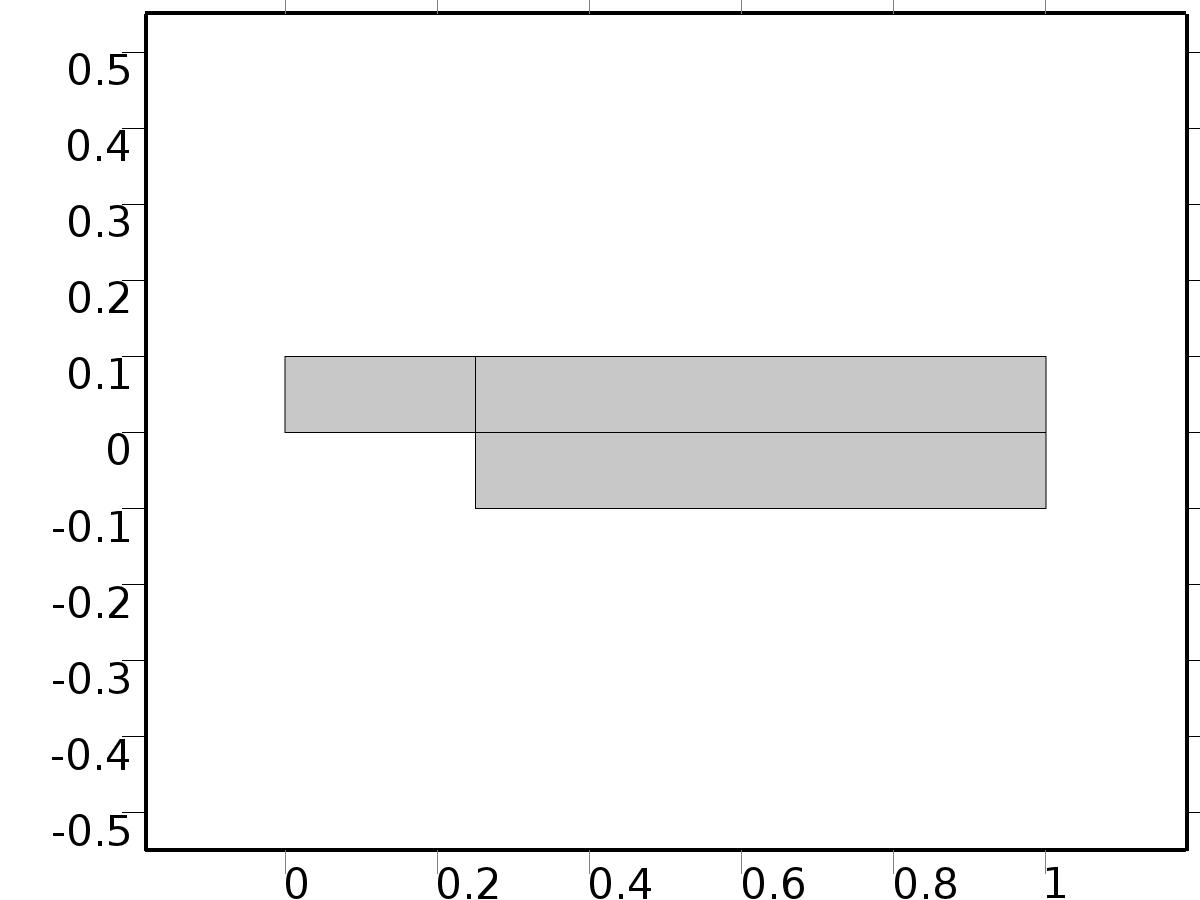
Coordinate names

| **First (t1)** | **Second (n)** | **Third (to)** |
| --- | --- | --- |
| t1 | n | to |

Settings

| **Description** | **Value** |
| --- | --- |
| Create first tangent direction from | Global Cartesian |

* 1. Geometry 1



Geometry 1

Units

|  |  |
| --- | --- |
| Length unit | m |
| Angular unit | deg |

Geometry statistics

| **Description** | **Value** |
| --- | --- |
| Space dimension | 2 |
| Number of domains | 3 |
| Number of boundaries | 10 |
| Number of vertices | 8 |

* + 1. Rectangle 1 (r1)

Position

| **Description** | **Value** |
| --- | --- |
| Position | {0, 0} |
| Layers |  |

Size

| **Description** | **Value** |
| --- | --- |
| Width | L |
| Height | D |

* + 1. Rectangle 2 (r2)

Position

| **Description** | **Value** |
| --- | --- |
| Position | {L/4, -D} |
| Layers |  |

Size

| **Description** | **Value** |
| --- | --- |
| Width | L\*3/4 |
| Height | 2\*D |

* 1. Laminar Flow



Laminar Flow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.dz | 1 |  | Thickness | Domains 1–3 |
| X.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| X.pA | P+X.pref |  | Absolute pressure | Domains 1–3 |
| X.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| X.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| X.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| X.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| X.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| X.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| X.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| X.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| X.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| X.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| X.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| X.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| X.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| X.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| X.rho | 1 |  | Density | Domains 1–3 |
| X.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| X.sr | sqrt(0.5\*(4\*Ux^2+2\*(Uy+Vx)^2+4\*Vy^2)+eps) |  | Shear rate | Domains 1–3 |
| X.divu | Ux+Vy |  | Divergence of velocity field | Domains 1–3 |
| X.U | sqrt(U^2+V^2) |  | Velocity magnitude | Domains 1–3 |
| X.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| X.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| X.vorticityz | Vx-Uy |  | Vorticity field, z component | Domains 1–3 |
| X.vort\_magn | sqrt(X.vorticityx^2+X.vorticityy^2+X.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| X.cellRe | 0.25\*X.rho\*sqrt(emetric(U,V)/emetric2)/X.mu |  | Cell Reynolds number | Domains 1–3 |
| X.nu | X.mu/X.rho |  | Kinematic viscosity | Domains 1–3 |
| X.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| X.mu\_eff | X.mu+X.muT |  | Dynamic viscosity | Domains 1–3 |
| X.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| X.T\_stressx | X.K\_stressx-P\*X.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| X.T\_stressy | X.K\_stressy-P\*X.nymesh |  | Total stress, y component | Boundaries 1–10 |
| X.T\_stressz | X.K\_stressz-P\*X.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| X.K\_stressx | X.mu\_eff\*(2\*Ux\*X.nxmesh+(Uy+Vx)\*X.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| X.K\_stressy | X.mu\_eff\*((Vx+Uy)\*X.nxmesh+2\*Vy\*X.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| X.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| X.K\_stress\_tensorxx | 2\*X.mu\_eff\*Ux |  | Viscous stress tensor, xx component | Domains 1–3 |
| X.K\_stress\_tensoryx | X.mu\_eff\*(Vx+Uy) |  | Viscous stress tensor, yx component | Domains 1–3 |
| X.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| X.K\_stress\_tensorxy | X.mu\_eff\*(Uy+Vx) |  | Viscous stress tensor, xy component | Domains 1–3 |
| X.K\_stress\_tensoryy | 2\*X.mu\_eff\*Vy |  | Viscous stress tensor, yy component | Domains 1–3 |
| X.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| X.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| X.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| X.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| X.K\_stress\_tensor\_testxx | 2\*X.mu\_eff\*test(Ux) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| X.K\_stress\_tensor\_testyx | X.mu\_eff\*(test(Vx)+test(Uy)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| X.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| X.K\_stress\_tensor\_testxy | X.mu\_eff\*(test(Uy)+test(Vx)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| X.K\_stress\_tensor\_testyy | 2\*X.mu\_eff\*test(Vy) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| X.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| X.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| X.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| X.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| X.upwind\_helpx | U |  | Upwind term, x component | Domains 1–3 |
| X.upwind\_helpy | V |  | Upwind term, y component | Domains 1–3 |
| X.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| X.tau\_vdxx | 2\*X.mu\*Ux |  | Strain rate, xx component | Domains 1–3 |
| X.tau\_vdyx | X.mu\*(Vx+Uy) |  | Strain rate, yx component | Domains 1–3 |
| X.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| X.tau\_vdxy | X.mu\*(Uy+Vx) |  | Strain rate, xy component | Domains 1–3 |
| X.tau\_vdyy | 2\*X.mu\*Vy |  | Strain rate, yy component | Domains 1–3 |
| X.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| X.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| X.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| X.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| X.Qvd | X.tau\_vdxx\*Ux+X.tau\_vdxy\*Uy+X.tau\_vdyx\*Vx+X.tau\_vdyy\*Vy |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| U | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| V | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| P | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (P-X.K\_stress\_tensorxx)\*test(Ux)-X.K\_stress\_tensorxy\*test(Uy)-X.K\_stress\_tensoryx\*test(Vx)+(P-X.K\_stress\_tensoryy)\*test(Vy) | Material | Domains 1–3 |
| X.Fx\*test(U)+X.Fy\*test(V) | Material | Domains 1–3 |
| X.rho\*(-(Ux\*U+Uy\*V)\*test(U)-(Vx\*U+Vy\*V)\*test(V)) | Material | Domains 1–3 |
| -X.rho\*X.divu\*test(P) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| X.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| X.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -U+X.ubndx | test(-U) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -V+X.ubndy | test(-V) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| X.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin=1



Inflow Bin=1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 1 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*spf.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.f0 | 1 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -X.f0\*(test(U)\*X.nxmesh+test(V)\*X.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*spf.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -X.f0\*(test(U)\*X.nxmesh+test(V)\*X.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| X.Fx | U\*Ux+V\*Uy |  | Volume force, x component | Domains 1–3 |
| X.Fy | U\*Vx+V\*Vy |  | Volume force, y component | Domains 1–3 |
| X.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 1



Laminar Flow 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.dz | 1 |  | Thickness | Domains 1–3 |
| A0.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| A0.pA | ap0+A0.pref |  | Absolute pressure | Domains 1–3 |
| A0.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| A0.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| A0.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A0.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A0.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A0.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| A0.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| A0.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| A0.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A0.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A0.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A0.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| A0.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| A0.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| A0.rho | 1 |  | Density | Domains 1–3 |
| A0.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| A0.sr | sqrt(0.5\*(4\*au0x^2+2\*(au0y+av0x)^2+4\*av0y^2)+eps) |  | Shear rate | Domains 1–3 |
| A0.divu | au0x+av0y |  | Divergence of velocity field | Domains 1–3 |
| A0.U | sqrt(au0^2+av0^2) |  | Velocity magnitude | Domains 1–3 |
| A0.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| A0.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| A0.vorticityz | av0x-au0y |  | Vorticity field, z component | Domains 1–3 |
| A0.vort\_magn | sqrt(A0.vorticityx^2+A0.vorticityy^2+A0.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| A0.cellRe | 0.25\*A0.rho\*sqrt(emetric(au0,av0)/emetric2)/A0.mu |  | Cell Reynolds number | Domains 1–3 |
| A0.nu | A0.mu/A0.rho |  | Kinematic viscosity | Domains 1–3 |
| A0.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| A0.mu\_eff | A0.mu+A0.muT |  | Dynamic viscosity | Domains 1–3 |
| A0.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| A0.T\_stressx | A0.K\_stressx-ap0\*A0.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| A0.T\_stressy | A0.K\_stressy-ap0\*A0.nymesh |  | Total stress, y component | Boundaries 1–10 |
| A0.T\_stressz | A0.K\_stressz-ap0\*A0.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| A0.K\_stressx | A0.mu\_eff\*(2\*au0x\*A0.nxmesh+(au0y+av0x)\*A0.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| A0.K\_stressy | A0.mu\_eff\*((av0x+au0y)\*A0.nxmesh+2\*av0y\*A0.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| A0.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| A0.K\_stress\_tensorxx | 2\*A0.mu\_eff\*au0x |  | Viscous stress tensor, xx component | Domains 1–3 |
| A0.K\_stress\_tensoryx | A0.mu\_eff\*(av0x+au0y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| A0.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| A0.K\_stress\_tensorxy | A0.mu\_eff\*(au0y+av0x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| A0.K\_stress\_tensoryy | 2\*A0.mu\_eff\*av0y |  | Viscous stress tensor, yy component | Domains 1–3 |
| A0.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| A0.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| A0.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| A0.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| A0.K\_stress\_tensor\_testxx | 2\*A0.mu\_eff\*test(au0x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| A0.K\_stress\_tensor\_testyx | A0.mu\_eff\*(test(av0x)+test(au0y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| A0.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| A0.K\_stress\_tensor\_testxy | A0.mu\_eff\*(test(au0y)+test(av0x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| A0.K\_stress\_tensor\_testyy | 2\*A0.mu\_eff\*test(av0y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| A0.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| A0.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| A0.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| A0.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| A0.upwind\_helpx | au0 |  | Upwind term, x component | Domains 1–3 |
| A0.upwind\_helpy | av0 |  | Upwind term, y component | Domains 1–3 |
| A0.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| A0.tau\_vdxx | 2\*A0.mu\*au0x |  | Strain rate, xx component | Domains 1–3 |
| A0.tau\_vdyx | A0.mu\*(av0x+au0y) |  | Strain rate, yx component | Domains 1–3 |
| A0.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| A0.tau\_vdxy | A0.mu\*(au0y+av0x) |  | Strain rate, xy component | Domains 1–3 |
| A0.tau\_vdyy | 2\*A0.mu\*av0y |  | Strain rate, yy component | Domains 1–3 |
| A0.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| A0.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| A0.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| A0.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| A0.Qvd | A0.tau\_vdxx\*au0x+A0.tau\_vdxy\*au0y+A0.tau\_vdyx\*av0x+A0.tau\_vdyy\*av0y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| au0 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| av0 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| ap0 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (ap0-A0.K\_stress\_tensorxx)\*test(au0x)-A0.K\_stress\_tensorxy\*test(au0y)-A0.K\_stress\_tensoryx\*test(av0x)+(ap0-A0.K\_stress\_tensoryy)\*test(av0y) | Material | Domains 1–3 |
| A0.Fx\*test(au0)+A0.Fy\*test(av0) | Material | Domains 1–3 |
| A0.rho\*(-(au0x\*au0+au0y\*av0)\*test(au0)-(av0x\*au0+av0y\*av0)\*test(av0)) | Material | Domains 1–3 |
| -A0.rho\*A0.divu\*test(ap0) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| A0.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| A0.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -au0+A0.ubndx | test(-au0) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -av0+A0.ubndy | test(-av0) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| A0.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_a0



Inflow Bin\*Gamma\_a0

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_a0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.f0 | Gamma\_a0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A0.f0\*(test(au0)\*A0.nxmesh+test(av0)\*A0.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A0.f0\*(test(au0)\*A0.nxmesh+test(av0)\*A0.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A0.Fx | f\_au0 |  | Volume force, x component | Domains 1–3 |
| A0.Fy | f\_av0 |  | Volume force, y component | Domains 1–3 |
| A0.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 2



Laminar Flow 2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.dz | 1 |  | Thickness | Domains 1–3 |
| At0.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| At0.pA | atp0+At0.pref |  | Absolute pressure | Domains 1–3 |
| At0.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| At0.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| At0.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At0.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At0.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At0.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| At0.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| At0.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| At0.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At0.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At0.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At0.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| At0.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| At0.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| At0.rho | 1 |  | Density | Domains 1–3 |
| At0.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| At0.sr | sqrt(0.5\*(4\*atu0x^2+2\*(atu0y+atv0x)^2+4\*atv0y^2)+eps) |  | Shear rate | Domains 1–3 |
| At0.divu | atu0x+atv0y |  | Divergence of velocity field | Domains 1–3 |
| At0.U | sqrt(atu0^2+atv0^2) |  | Velocity magnitude | Domains 1–3 |
| At0.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| At0.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| At0.vorticityz | atv0x-atu0y |  | Vorticity field, z component | Domains 1–3 |
| At0.vort\_magn | sqrt(At0.vorticityx^2+At0.vorticityy^2+At0.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| At0.cellRe | 0.25\*At0.rho\*sqrt(emetric(atu0,atv0)/emetric2)/At0.mu |  | Cell Reynolds number | Domains 1–3 |
| At0.nu | At0.mu/At0.rho |  | Kinematic viscosity | Domains 1–3 |
| At0.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| At0.mu\_eff | At0.mu+At0.muT |  | Dynamic viscosity | Domains 1–3 |
| At0.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| At0.T\_stressx | At0.K\_stressx-atp0\*At0.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| At0.T\_stressy | At0.K\_stressy-atp0\*At0.nymesh |  | Total stress, y component | Boundaries 1–10 |
| At0.T\_stressz | At0.K\_stressz-atp0\*At0.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| At0.K\_stressx | At0.mu\_eff\*(2\*atu0x\*At0.nxmesh+(atu0y+atv0x)\*At0.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| At0.K\_stressy | At0.mu\_eff\*((atv0x+atu0y)\*At0.nxmesh+2\*atv0y\*At0.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| At0.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| At0.K\_stress\_tensorxx | 2\*At0.mu\_eff\*atu0x |  | Viscous stress tensor, xx component | Domains 1–3 |
| At0.K\_stress\_tensoryx | At0.mu\_eff\*(atv0x+atu0y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| At0.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| At0.K\_stress\_tensorxy | At0.mu\_eff\*(atu0y+atv0x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| At0.K\_stress\_tensoryy | 2\*At0.mu\_eff\*atv0y |  | Viscous stress tensor, yy component | Domains 1–3 |
| At0.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| At0.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| At0.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| At0.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| At0.K\_stress\_tensor\_testxx | 2\*At0.mu\_eff\*test(atu0x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| At0.K\_stress\_tensor\_testyx | At0.mu\_eff\*(test(atv0x)+test(atu0y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| At0.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| At0.K\_stress\_tensor\_testxy | At0.mu\_eff\*(test(atu0y)+test(atv0x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| At0.K\_stress\_tensor\_testyy | 2\*At0.mu\_eff\*test(atv0y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| At0.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| At0.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| At0.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| At0.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| At0.upwind\_helpx | atu0 |  | Upwind term, x component | Domains 1–3 |
| At0.upwind\_helpy | atv0 |  | Upwind term, y component | Domains 1–3 |
| At0.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| At0.tau\_vdxx | 2\*At0.mu\*atu0x |  | Strain rate, xx component | Domains 1–3 |
| At0.tau\_vdyx | At0.mu\*(atv0x+atu0y) |  | Strain rate, yx component | Domains 1–3 |
| At0.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| At0.tau\_vdxy | At0.mu\*(atu0y+atv0x) |  | Strain rate, xy component | Domains 1–3 |
| At0.tau\_vdyy | 2\*At0.mu\*atv0y |  | Strain rate, yy component | Domains 1–3 |
| At0.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| At0.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| At0.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| At0.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| At0.Qvd | At0.tau\_vdxx\*atu0x+At0.tau\_vdxy\*atu0y+At0.tau\_vdyx\*atv0x+At0.tau\_vdyy\*atv0y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| atu0 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| atv0 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| atp0 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (atp0-At0.K\_stress\_tensorxx)\*test(atu0x)-At0.K\_stress\_tensorxy\*test(atu0y)-At0.K\_stress\_tensoryx\*test(atv0x)+(atp0-At0.K\_stress\_tensoryy)\*test(atv0y) | Material | Domains 1–3 |
| At0.Fx\*test(atu0)+At0.Fy\*test(atv0) | Material | Domains 1–3 |
| At0.rho\*(-(atu0x\*atu0+atu0y\*atv0)\*test(atu0)-(atv0x\*atu0+atv0y\*atv0)\*test(atv0)) | Material | Domains 1–3 |
| -At0.rho\*At0.divu\*test(atp0) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| At0.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| At0.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -atu0+At0.ubndx | test(-atu0) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -atv0+At0.ubndy | test(-atv0) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| At0.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At0.f0\*(test(atu0)\*At0.nxmesh+test(atv0)\*At0.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At0.f0\*(test(atu0)\*At0.nxmesh+test(atv0)\*At0.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At0.Fx | f\_atu0 |  | Volume force, x component | Domains 1–3 |
| At0.Fy | f\_atv0 |  | Volume force, y component | Domains 1–3 |
| At0.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 3



Laminar Flow 3

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.dz | 1 |  | Thickness | Domains 1–3 |
| A1.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| A1.pA | ap1+A1.pref |  | Absolute pressure | Domains 1–3 |
| A1.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| A1.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| A1.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A1.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A1.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A1.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| A1.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| A1.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| A1.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A1.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A1.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A1.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| A1.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| A1.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| A1.rho | 1 |  | Density | Domains 1–3 |
| A1.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| A1.sr | sqrt(0.5\*(4\*au1x^2+2\*(au1y+av1x)^2+4\*av1y^2)+eps) |  | Shear rate | Domains 1–3 |
| A1.divu | au1x+av1y |  | Divergence of velocity field | Domains 1–3 |
| A1.U | sqrt(au1^2+av1^2) |  | Velocity magnitude | Domains 1–3 |
| A1.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| A1.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| A1.vorticityz | av1x-au1y |  | Vorticity field, z component | Domains 1–3 |
| A1.vort\_magn | sqrt(A1.vorticityx^2+A1.vorticityy^2+A1.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| A1.cellRe | 0.25\*A1.rho\*sqrt(emetric(au1,av1)/emetric2)/A1.mu |  | Cell Reynolds number | Domains 1–3 |
| A1.nu | A1.mu/A1.rho |  | Kinematic viscosity | Domains 1–3 |
| A1.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| A1.mu\_eff | A1.mu+A1.muT |  | Dynamic viscosity | Domains 1–3 |
| A1.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| A1.T\_stressx | A1.K\_stressx-ap1\*A1.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| A1.T\_stressy | A1.K\_stressy-ap1\*A1.nymesh |  | Total stress, y component | Boundaries 1–10 |
| A1.T\_stressz | A1.K\_stressz-ap1\*A1.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| A1.K\_stressx | A1.mu\_eff\*(2\*au1x\*A1.nxmesh+(au1y+av1x)\*A1.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| A1.K\_stressy | A1.mu\_eff\*((av1x+au1y)\*A1.nxmesh+2\*av1y\*A1.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| A1.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| A1.K\_stress\_tensorxx | 2\*A1.mu\_eff\*au1x |  | Viscous stress tensor, xx component | Domains 1–3 |
| A1.K\_stress\_tensoryx | A1.mu\_eff\*(av1x+au1y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| A1.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| A1.K\_stress\_tensorxy | A1.mu\_eff\*(au1y+av1x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| A1.K\_stress\_tensoryy | 2\*A1.mu\_eff\*av1y |  | Viscous stress tensor, yy component | Domains 1–3 |
| A1.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| A1.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| A1.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| A1.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| A1.K\_stress\_tensor\_testxx | 2\*A1.mu\_eff\*test(au1x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| A1.K\_stress\_tensor\_testyx | A1.mu\_eff\*(test(av1x)+test(au1y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| A1.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| A1.K\_stress\_tensor\_testxy | A1.mu\_eff\*(test(au1y)+test(av1x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| A1.K\_stress\_tensor\_testyy | 2\*A1.mu\_eff\*test(av1y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| A1.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| A1.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| A1.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| A1.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| A1.upwind\_helpx | au1 |  | Upwind term, x component | Domains 1–3 |
| A1.upwind\_helpy | av1 |  | Upwind term, y component | Domains 1–3 |
| A1.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| A1.tau\_vdxx | 2\*A1.mu\*au1x |  | Strain rate, xx component | Domains 1–3 |
| A1.tau\_vdyx | A1.mu\*(av1x+au1y) |  | Strain rate, yx component | Domains 1–3 |
| A1.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| A1.tau\_vdxy | A1.mu\*(au1y+av1x) |  | Strain rate, xy component | Domains 1–3 |
| A1.tau\_vdyy | 2\*A1.mu\*av1y |  | Strain rate, yy component | Domains 1–3 |
| A1.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| A1.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| A1.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| A1.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| A1.Qvd | A1.tau\_vdxx\*au1x+A1.tau\_vdxy\*au1y+A1.tau\_vdyx\*av1x+A1.tau\_vdyy\*av1y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| au1 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| av1 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| ap1 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (ap1-A1.K\_stress\_tensorxx)\*test(au1x)-A1.K\_stress\_tensorxy\*test(au1y)-A1.K\_stress\_tensoryx\*test(av1x)+(ap1-A1.K\_stress\_tensoryy)\*test(av1y) | Material | Domains 1–3 |
| A1.Fx\*test(au1)+A1.Fy\*test(av1) | Material | Domains 1–3 |
| A1.rho\*(-(au1x\*au1+au1y\*av1)\*test(au1)-(av1x\*au1+av1y\*av1)\*test(av1)) | Material | Domains 1–3 |
| -A1.rho\*A1.divu\*test(ap1) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| A1.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| A1.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -au1+A1.ubndx | test(-au1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -av1+A1.ubndy | test(-av1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| A1.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_a1



Inflow Bin\*Gamma\_a1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_a1 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.f0 | Gamma\_a1 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A1.f0\*(test(au1)\*A1.nxmesh+test(av1)\*A1.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A1.f0\*(test(au1)\*A1.nxmesh+test(av1)\*A1.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A1.Fx | f\_au1 |  | Volume force, x component | Domains 1–3 |
| A1.Fy | f\_av1 |  | Volume force, y component | Domains 1–3 |
| A1.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 4



Laminar Flow 4

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.dz | 1 |  | Thickness | Domains 1–3 |
| At1.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| At1.pA | atp1+At1.pref |  | Absolute pressure | Domains 1–3 |
| At1.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| At1.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| At1.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At1.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At1.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At1.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| At1.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| At1.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| At1.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At1.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At1.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At1.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| At1.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| At1.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| At1.rho | 1 |  | Density | Domains 1–3 |
| At1.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| At1.sr | sqrt(0.5\*(4\*atu1x^2+2\*(atu1y+atv1x)^2+4\*atv1y^2)+eps) |  | Shear rate | Domains 1–3 |
| At1.divu | atu1x+atv1y |  | Divergence of velocity field | Domains 1–3 |
| At1.U | sqrt(atu1^2+atv1^2) |  | Velocity magnitude | Domains 1–3 |
| At1.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| At1.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| At1.vorticityz | atv1x-atu1y |  | Vorticity field, z component | Domains 1–3 |
| At1.vort\_magn | sqrt(At1.vorticityx^2+At1.vorticityy^2+At1.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| At1.cellRe | 0.25\*At1.rho\*sqrt(emetric(atu1,atv1)/emetric2)/At1.mu |  | Cell Reynolds number | Domains 1–3 |
| At1.nu | At1.mu/At1.rho |  | Kinematic viscosity | Domains 1–3 |
| At1.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| At1.mu\_eff | At1.mu+At1.muT |  | Dynamic viscosity | Domains 1–3 |
| At1.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| At1.T\_stressx | At1.K\_stressx-atp1\*At1.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| At1.T\_stressy | At1.K\_stressy-atp1\*At1.nymesh |  | Total stress, y component | Boundaries 1–10 |
| At1.T\_stressz | At1.K\_stressz-atp1\*At1.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| At1.K\_stressx | At1.mu\_eff\*(2\*atu1x\*At1.nxmesh+(atu1y+atv1x)\*At1.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| At1.K\_stressy | At1.mu\_eff\*((atv1x+atu1y)\*At1.nxmesh+2\*atv1y\*At1.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| At1.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| At1.K\_stress\_tensorxx | 2\*At1.mu\_eff\*atu1x |  | Viscous stress tensor, xx component | Domains 1–3 |
| At1.K\_stress\_tensoryx | At1.mu\_eff\*(atv1x+atu1y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| At1.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| At1.K\_stress\_tensorxy | At1.mu\_eff\*(atu1y+atv1x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| At1.K\_stress\_tensoryy | 2\*At1.mu\_eff\*atv1y |  | Viscous stress tensor, yy component | Domains 1–3 |
| At1.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| At1.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| At1.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| At1.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| At1.K\_stress\_tensor\_testxx | 2\*At1.mu\_eff\*test(atu1x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| At1.K\_stress\_tensor\_testyx | At1.mu\_eff\*(test(atv1x)+test(atu1y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| At1.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| At1.K\_stress\_tensor\_testxy | At1.mu\_eff\*(test(atu1y)+test(atv1x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| At1.K\_stress\_tensor\_testyy | 2\*At1.mu\_eff\*test(atv1y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| At1.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| At1.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| At1.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| At1.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| At1.upwind\_helpx | atu1 |  | Upwind term, x component | Domains 1–3 |
| At1.upwind\_helpy | atv1 |  | Upwind term, y component | Domains 1–3 |
| At1.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| At1.tau\_vdxx | 2\*At1.mu\*atu1x |  | Strain rate, xx component | Domains 1–3 |
| At1.tau\_vdyx | At1.mu\*(atv1x+atu1y) |  | Strain rate, yx component | Domains 1–3 |
| At1.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| At1.tau\_vdxy | At1.mu\*(atu1y+atv1x) |  | Strain rate, xy component | Domains 1–3 |
| At1.tau\_vdyy | 2\*At1.mu\*atv1y |  | Strain rate, yy component | Domains 1–3 |
| At1.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| At1.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| At1.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| At1.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| At1.Qvd | At1.tau\_vdxx\*atu1x+At1.tau\_vdxy\*atu1y+At1.tau\_vdyx\*atv1x+At1.tau\_vdyy\*atv1y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| atu1 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| atv1 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| atp1 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (atp1-At1.K\_stress\_tensorxx)\*test(atu1x)-At1.K\_stress\_tensorxy\*test(atu1y)-At1.K\_stress\_tensoryx\*test(atv1x)+(atp1-At1.K\_stress\_tensoryy)\*test(atv1y) | Material | Domains 1–3 |
| At1.Fx\*test(atu1)+At1.Fy\*test(atv1) | Material | Domains 1–3 |
| At1.rho\*(-(atu1x\*atu1+atu1y\*atv1)\*test(atu1)-(atv1x\*atu1+atv1y\*atv1)\*test(atv1)) | Material | Domains 1–3 |
| -At1.rho\*At1.divu\*test(atp1) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| At1.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| At1.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -atu1+At1.ubndx | test(-atu1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -atv1+At1.ubndy | test(-atv1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| At1.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At1.f0\*(test(atu1)\*At1.nxmesh+test(atv1)\*At1.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At1.f0\*(test(atu1)\*At1.nxmesh+test(atv1)\*At1.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At1.Fx | f\_atu1 |  | Volume force, x component | Domains 1–3 |
| At1.Fy | f\_atv1 |  | Volume force, y component | Domains 1–3 |
| At1.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 5



Laminar Flow 5

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.dz | 1 |  | Thickness | Domains 1–3 |
| B1.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| B1.pA | bp1+B1.pref |  | Absolute pressure | Domains 1–3 |
| B1.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| B1.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| B1.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B1.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B1.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B1.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| B1.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| B1.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| B1.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B1.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B1.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B1.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| B1.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| B1.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| B1.rho | 1 |  | Density | Domains 1–3 |
| B1.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| B1.sr | sqrt(0.5\*(4\*bu1x^2+2\*(bu1y+bv1x)^2+4\*bv1y^2)+eps) |  | Shear rate | Domains 1–3 |
| B1.divu | bu1x+bv1y |  | Divergence of velocity field | Domains 1–3 |
| B1.U | sqrt(bu1^2+bv1^2) |  | Velocity magnitude | Domains 1–3 |
| B1.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| B1.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| B1.vorticityz | bv1x-bu1y |  | Vorticity field, z component | Domains 1–3 |
| B1.vort\_magn | sqrt(B1.vorticityx^2+B1.vorticityy^2+B1.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| B1.cellRe | 0.25\*B1.rho\*sqrt(emetric(bu1,bv1)/emetric2)/B1.mu |  | Cell Reynolds number | Domains 1–3 |
| B1.nu | B1.mu/B1.rho |  | Kinematic viscosity | Domains 1–3 |
| B1.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| B1.mu\_eff | B1.mu+B1.muT |  | Dynamic viscosity | Domains 1–3 |
| B1.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| B1.T\_stressx | B1.K\_stressx-bp1\*B1.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| B1.T\_stressy | B1.K\_stressy-bp1\*B1.nymesh |  | Total stress, y component | Boundaries 1–10 |
| B1.T\_stressz | B1.K\_stressz-bp1\*B1.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| B1.K\_stressx | B1.mu\_eff\*(2\*bu1x\*B1.nxmesh+(bu1y+bv1x)\*B1.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| B1.K\_stressy | B1.mu\_eff\*((bv1x+bu1y)\*B1.nxmesh+2\*bv1y\*B1.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| B1.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| B1.K\_stress\_tensorxx | 2\*B1.mu\_eff\*bu1x |  | Viscous stress tensor, xx component | Domains 1–3 |
| B1.K\_stress\_tensoryx | B1.mu\_eff\*(bv1x+bu1y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| B1.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| B1.K\_stress\_tensorxy | B1.mu\_eff\*(bu1y+bv1x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| B1.K\_stress\_tensoryy | 2\*B1.mu\_eff\*bv1y |  | Viscous stress tensor, yy component | Domains 1–3 |
| B1.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| B1.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| B1.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| B1.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| B1.K\_stress\_tensor\_testxx | 2\*B1.mu\_eff\*test(bu1x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| B1.K\_stress\_tensor\_testyx | B1.mu\_eff\*(test(bv1x)+test(bu1y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| B1.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| B1.K\_stress\_tensor\_testxy | B1.mu\_eff\*(test(bu1y)+test(bv1x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| B1.K\_stress\_tensor\_testyy | 2\*B1.mu\_eff\*test(bv1y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| B1.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| B1.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| B1.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| B1.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| B1.upwind\_helpx | bu1 |  | Upwind term, x component | Domains 1–3 |
| B1.upwind\_helpy | bv1 |  | Upwind term, y component | Domains 1–3 |
| B1.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| B1.tau\_vdxx | 2\*B1.mu\*bu1x |  | Strain rate, xx component | Domains 1–3 |
| B1.tau\_vdyx | B1.mu\*(bv1x+bu1y) |  | Strain rate, yx component | Domains 1–3 |
| B1.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| B1.tau\_vdxy | B1.mu\*(bu1y+bv1x) |  | Strain rate, xy component | Domains 1–3 |
| B1.tau\_vdyy | 2\*B1.mu\*bv1y |  | Strain rate, yy component | Domains 1–3 |
| B1.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| B1.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| B1.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| B1.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| B1.Qvd | B1.tau\_vdxx\*bu1x+B1.tau\_vdxy\*bu1y+B1.tau\_vdyx\*bv1x+B1.tau\_vdyy\*bv1y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| bu1 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| bv1 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| bp1 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (bp1-B1.K\_stress\_tensorxx)\*test(bu1x)-B1.K\_stress\_tensorxy\*test(bu1y)-B1.K\_stress\_tensoryx\*test(bv1x)+(bp1-B1.K\_stress\_tensoryy)\*test(bv1y) | Material | Domains 1–3 |
| B1.Fx\*test(bu1)+B1.Fy\*test(bv1) | Material | Domains 1–3 |
| B1.rho\*(-(bu1x\*bu1+bu1y\*bv1)\*test(bu1)-(bv1x\*bu1+bv1y\*bv1)\*test(bv1)) | Material | Domains 1–3 |
| -B1.rho\*B1.divu\*test(bp1) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| B1.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| B1.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -bu1+B1.ubndx | test(-bu1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -bv1+B1.ubndy | test(-bv1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| B1.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_b1



Inflow Bin\*Gamma\_b1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_b1 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.f0 | Gamma\_b1 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B1.f0\*(test(bu1)\*B1.nxmesh+test(bv1)\*B1.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B1.f0\*(test(bu1)\*B1.nxmesh+test(bv1)\*B1.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B1.Fx | f\_bu1 |  | Volume force, x component | Domains 1–3 |
| B1.Fy | f\_bv1 |  | Volume force, y component | Domains 1–3 |
| B1.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 6



Laminar Flow 6

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.dz | 1 |  | Thickness | Domains 1–3 |
| Bt1.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| Bt1.pA | btp1+Bt1.pref |  | Absolute pressure | Domains 1–3 |
| Bt1.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| Bt1.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| Bt1.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt1.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt1.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt1.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| Bt1.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| Bt1.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| Bt1.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt1.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt1.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt1.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| Bt1.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| Bt1.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| Bt1.rho | 1 |  | Density | Domains 1–3 |
| Bt1.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| Bt1.sr | sqrt(0.5\*(4\*btu1x^2+2\*(btu1y+btv1x)^2+4\*btv1y^2)+eps) |  | Shear rate | Domains 1–3 |
| Bt1.divu | btu1x+btv1y |  | Divergence of velocity field | Domains 1–3 |
| Bt1.U | sqrt(btu1^2+btv1^2) |  | Velocity magnitude | Domains 1–3 |
| Bt1.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| Bt1.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| Bt1.vorticityz | btv1x-btu1y |  | Vorticity field, z component | Domains 1–3 |
| Bt1.vort\_magn | sqrt(Bt1.vorticityx^2+Bt1.vorticityy^2+Bt1.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| Bt1.cellRe | 0.25\*Bt1.rho\*sqrt(emetric(btu1,btv1)/emetric2)/Bt1.mu |  | Cell Reynolds number | Domains 1–3 |
| Bt1.nu | Bt1.mu/Bt1.rho |  | Kinematic viscosity | Domains 1–3 |
| Bt1.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| Bt1.mu\_eff | Bt1.mu+Bt1.muT |  | Dynamic viscosity | Domains 1–3 |
| Bt1.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| Bt1.T\_stressx | Bt1.K\_stressx-btp1\*Bt1.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| Bt1.T\_stressy | Bt1.K\_stressy-btp1\*Bt1.nymesh |  | Total stress, y component | Boundaries 1–10 |
| Bt1.T\_stressz | Bt1.K\_stressz-btp1\*Bt1.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| Bt1.K\_stressx | Bt1.mu\_eff\*(2\*btu1x\*Bt1.nxmesh+(btu1y+btv1x)\*Bt1.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| Bt1.K\_stressy | Bt1.mu\_eff\*((btv1x+btu1y)\*Bt1.nxmesh+2\*btv1y\*Bt1.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| Bt1.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| Bt1.K\_stress\_tensorxx | 2\*Bt1.mu\_eff\*btu1x |  | Viscous stress tensor, xx component | Domains 1–3 |
| Bt1.K\_stress\_tensoryx | Bt1.mu\_eff\*(btv1x+btu1y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| Bt1.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| Bt1.K\_stress\_tensorxy | Bt1.mu\_eff\*(btu1y+btv1x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| Bt1.K\_stress\_tensoryy | 2\*Bt1.mu\_eff\*btv1y |  | Viscous stress tensor, yy component | Domains 1–3 |
| Bt1.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| Bt1.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| Bt1.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| Bt1.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testxx | 2\*Bt1.mu\_eff\*test(btu1x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testyx | Bt1.mu\_eff\*(test(btv1x)+test(btu1y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testxy | Bt1.mu\_eff\*(test(btu1y)+test(btv1x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testyy | 2\*Bt1.mu\_eff\*test(btv1y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| Bt1.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| Bt1.upwind\_helpx | btu1 |  | Upwind term, x component | Domains 1–3 |
| Bt1.upwind\_helpy | btv1 |  | Upwind term, y component | Domains 1–3 |
| Bt1.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| Bt1.tau\_vdxx | 2\*Bt1.mu\*btu1x |  | Strain rate, xx component | Domains 1–3 |
| Bt1.tau\_vdyx | Bt1.mu\*(btv1x+btu1y) |  | Strain rate, yx component | Domains 1–3 |
| Bt1.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| Bt1.tau\_vdxy | Bt1.mu\*(btu1y+btv1x) |  | Strain rate, xy component | Domains 1–3 |
| Bt1.tau\_vdyy | 2\*Bt1.mu\*btv1y |  | Strain rate, yy component | Domains 1–3 |
| Bt1.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| Bt1.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| Bt1.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| Bt1.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| Bt1.Qvd | Bt1.tau\_vdxx\*btu1x+Bt1.tau\_vdxy\*btu1y+Bt1.tau\_vdyx\*btv1x+Bt1.tau\_vdyy\*btv1y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| btu1 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| btv1 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| btp1 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (btp1-Bt1.K\_stress\_tensorxx)\*test(btu1x)-Bt1.K\_stress\_tensorxy\*test(btu1y)-Bt1.K\_stress\_tensoryx\*test(btv1x)+(btp1-Bt1.K\_stress\_tensoryy)\*test(btv1y) | Material | Domains 1–3 |
| Bt1.Fx\*test(btu1)+Bt1.Fy\*test(btv1) | Material | Domains 1–3 |
| Bt1.rho\*(-(btu1x\*btu1+btu1y\*btv1)\*test(btu1)-(btv1x\*btu1+btv1y\*btv1)\*test(btv1)) | Material | Domains 1–3 |
| -Bt1.rho\*Bt1.divu\*test(btp1) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| Bt1.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| Bt1.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -btu1+Bt1.ubndx | test(-btu1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -btv1+Bt1.ubndy | test(-btv1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| Bt1.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf.kinit |
| Turbulent dissipation rate | spf.epinit |
| Specific dissipation rate | spf.omInit |
| Reciprocal wall distance | spf.G0 |
| Undamped turbulent kinematic viscosity | spf.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt1.f0\*(test(btu1)\*Bt1.nxmesh+test(btv1)\*Bt1.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt1.f0\*(test(btu1)\*Bt1.nxmesh+test(btv1)\*Bt1.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt1.Fx | f\_btu1 |  | Volume force, x component | Domains 1–3 |
| Bt1.Fy | f\_btv1 |  | Volume force, y component | Domains 1–3 |
| Bt1.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 7



Laminar Flow 7

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.dz | 1 |  | Thickness | Domains 1–3 |
| A2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| A2.pA | ap2+A2.pref |  | Absolute pressure | Domains 1–3 |
| A2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| A2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| A2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| A2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| A2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| A2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| A2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| A2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| A2.rho | 1 |  | Density | Domains 1–3 |
| A2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| A2.sr | sqrt(0.5\*(4\*au2x^2+2\*(au2y+av2x)^2+4\*av2y^2)+eps) |  | Shear rate | Domains 1–3 |
| A2.divu | au2x+av2y |  | Divergence of velocity field | Domains 1–3 |
| A2.U | sqrt(au2^2+av2^2) |  | Velocity magnitude | Domains 1–3 |
| A2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| A2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| A2.vorticityz | av2x-au2y |  | Vorticity field, z component | Domains 1–3 |
| A2.vort\_magn | sqrt(A2.vorticityx^2+A2.vorticityy^2+A2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| A2.cellRe | 0.25\*A2.rho\*sqrt(emetric(au2,av2)/emetric2)/A2.mu |  | Cell Reynolds number | Domains 1–3 |
| A2.nu | A2.mu/A2.rho |  | Kinematic viscosity | Domains 1–3 |
| A2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| A2.mu\_eff | A2.mu+A2.muT |  | Dynamic viscosity | Domains 1–3 |
| A2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| A2.T\_stressx | A2.K\_stressx-ap2\*A2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| A2.T\_stressy | A2.K\_stressy-ap2\*A2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| A2.T\_stressz | A2.K\_stressz-ap2\*A2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| A2.K\_stressx | A2.mu\_eff\*(2\*au2x\*A2.nxmesh+(au2y+av2x)\*A2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| A2.K\_stressy | A2.mu\_eff\*((av2x+au2y)\*A2.nxmesh+2\*av2y\*A2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| A2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| A2.K\_stress\_tensorxx | 2\*A2.mu\_eff\*au2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| A2.K\_stress\_tensoryx | A2.mu\_eff\*(av2x+au2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| A2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| A2.K\_stress\_tensorxy | A2.mu\_eff\*(au2y+av2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| A2.K\_stress\_tensoryy | 2\*A2.mu\_eff\*av2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| A2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| A2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| A2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| A2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| A2.K\_stress\_tensor\_testxx | 2\*A2.mu\_eff\*test(au2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| A2.K\_stress\_tensor\_testyx | A2.mu\_eff\*(test(av2x)+test(au2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| A2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| A2.K\_stress\_tensor\_testxy | A2.mu\_eff\*(test(au2y)+test(av2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| A2.K\_stress\_tensor\_testyy | 2\*A2.mu\_eff\*test(av2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| A2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| A2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| A2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| A2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| A2.upwind\_helpx | au2 |  | Upwind term, x component | Domains 1–3 |
| A2.upwind\_helpy | av2 |  | Upwind term, y component | Domains 1–3 |
| A2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| A2.tau\_vdxx | 2\*A2.mu\*au2x |  | Strain rate, xx component | Domains 1–3 |
| A2.tau\_vdyx | A2.mu\*(av2x+au2y) |  | Strain rate, yx component | Domains 1–3 |
| A2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| A2.tau\_vdxy | A2.mu\*(au2y+av2x) |  | Strain rate, xy component | Domains 1–3 |
| A2.tau\_vdyy | 2\*A2.mu\*av2y |  | Strain rate, yy component | Domains 1–3 |
| A2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| A2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| A2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| A2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| A2.Qvd | A2.tau\_vdxx\*au2x+A2.tau\_vdxy\*au2y+A2.tau\_vdyx\*av2x+A2.tau\_vdyy\*av2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| au2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| av2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| ap2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (ap2-A2.K\_stress\_tensorxx)\*test(au2x)-A2.K\_stress\_tensorxy\*test(au2y)-A2.K\_stress\_tensoryx\*test(av2x)+(ap2-A2.K\_stress\_tensoryy)\*test(av2y) | Material | Domains 1–3 |
| A2.Fx\*test(au2)+A2.Fy\*test(av2) | Material | Domains 1–3 |
| A2.rho\*(-(au2x\*au2+au2y\*av2)\*test(au2)-(av2x\*au2+av2y\*av2)\*test(av2)) | Material | Domains 1–3 |
| -A2.rho\*A2.divu\*test(ap2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| A2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| A2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -au2+A2.ubndx | test(-au2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -av2+A2.ubndy | test(-av2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| A2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf2.kinit |
| Turbulent dissipation rate | spf2.epinit |
| Specific dissipation rate | spf2.omInit |
| Reciprocal wall distance | spf2.G0 |
| Undamped turbulent kinematic viscosity | spf2.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_a2



Inflow Bin\*Gamma\_a2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_a2 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.f0 | Gamma\_a2 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A2.f0\*(test(au2)\*A2.nxmesh+test(av2)\*A2.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A2.f0\*(test(au2)\*A2.nxmesh+test(av2)\*A2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A2.Fx | f\_au2 |  | Volume force, x component | Domains 1–3 |
| A2.Fy | f\_av2 |  | Volume force, y component | Domains 1–3 |
| A2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 8



Laminar Flow 8

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.dz | 1 |  | Thickness | Domains 1–3 |
| At2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| At2.pA | atp2+At2.pref |  | Absolute pressure | Domains 1–3 |
| At2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| At2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| At2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| At2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| At2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| At2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| At2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| At2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| At2.rho | 1 |  | Density | Domains 1–3 |
| At2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| At2.sr | sqrt(0.5\*(4\*atu2x^2+2\*(atu2y+atv2x)^2+4\*atv2y^2)+eps) |  | Shear rate | Domains 1–3 |
| At2.divu | atu2x+atv2y |  | Divergence of velocity field | Domains 1–3 |
| At2.U | sqrt(atu2^2+atv2^2) |  | Velocity magnitude | Domains 1–3 |
| At2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| At2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| At2.vorticityz | atv2x-atu2y |  | Vorticity field, z component | Domains 1–3 |
| At2.vort\_magn | sqrt(At2.vorticityx^2+At2.vorticityy^2+At2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| At2.cellRe | 0.25\*At2.rho\*sqrt(emetric(atu2,atv2)/emetric2)/At2.mu |  | Cell Reynolds number | Domains 1–3 |
| At2.nu | At2.mu/At2.rho |  | Kinematic viscosity | Domains 1–3 |
| At2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| At2.mu\_eff | At2.mu+At2.muT |  | Dynamic viscosity | Domains 1–3 |
| At2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| At2.T\_stressx | At2.K\_stressx-atp2\*At2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| At2.T\_stressy | At2.K\_stressy-atp2\*At2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| At2.T\_stressz | At2.K\_stressz-atp2\*At2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| At2.K\_stressx | At2.mu\_eff\*(2\*atu2x\*At2.nxmesh+(atu2y+atv2x)\*At2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| At2.K\_stressy | At2.mu\_eff\*((atv2x+atu2y)\*At2.nxmesh+2\*atv2y\*At2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| At2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| At2.K\_stress\_tensorxx | 2\*At2.mu\_eff\*atu2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| At2.K\_stress\_tensoryx | At2.mu\_eff\*(atv2x+atu2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| At2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| At2.K\_stress\_tensorxy | At2.mu\_eff\*(atu2y+atv2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| At2.K\_stress\_tensoryy | 2\*At2.mu\_eff\*atv2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| At2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| At2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| At2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| At2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| At2.K\_stress\_tensor\_testxx | 2\*At2.mu\_eff\*test(atu2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| At2.K\_stress\_tensor\_testyx | At2.mu\_eff\*(test(atv2x)+test(atu2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| At2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| At2.K\_stress\_tensor\_testxy | At2.mu\_eff\*(test(atu2y)+test(atv2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| At2.K\_stress\_tensor\_testyy | 2\*At2.mu\_eff\*test(atv2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| At2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| At2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| At2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| At2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| At2.upwind\_helpx | atu2 |  | Upwind term, x component | Domains 1–3 |
| At2.upwind\_helpy | atv2 |  | Upwind term, y component | Domains 1–3 |
| At2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| At2.tau\_vdxx | 2\*At2.mu\*atu2x |  | Strain rate, xx component | Domains 1–3 |
| At2.tau\_vdyx | At2.mu\*(atv2x+atu2y) |  | Strain rate, yx component | Domains 1–3 |
| At2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| At2.tau\_vdxy | At2.mu\*(atu2y+atv2x) |  | Strain rate, xy component | Domains 1–3 |
| At2.tau\_vdyy | 2\*At2.mu\*atv2y |  | Strain rate, yy component | Domains 1–3 |
| At2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| At2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| At2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| At2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| At2.Qvd | At2.tau\_vdxx\*atu2x+At2.tau\_vdxy\*atu2y+At2.tau\_vdyx\*atv2x+At2.tau\_vdyy\*atv2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| atu2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| atv2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| atp2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (atp2-At2.K\_stress\_tensorxx)\*test(atu2x)-At2.K\_stress\_tensorxy\*test(atu2y)-At2.K\_stress\_tensoryx\*test(atv2x)+(atp2-At2.K\_stress\_tensoryy)\*test(atv2y) | Material | Domains 1–3 |
| At2.Fx\*test(atu2)+At2.Fy\*test(atv2) | Material | Domains 1–3 |
| At2.rho\*(-(atu2x\*atu2+atu2y\*atv2)\*test(atu2)-(atv2x\*atu2+atv2y\*atv2)\*test(atv2)) | Material | Domains 1–3 |
| -At2.rho\*At2.divu\*test(atp2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| At2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| At2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -atu2+At2.ubndx | test(-atu2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -atv2+At2.ubndy | test(-atv2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| At2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf3.kinit |
| Turbulent dissipation rate | spf3.epinit |
| Specific dissipation rate | spf3.omInit |
| Reciprocal wall distance | spf3.G0 |
| Undamped turbulent kinematic viscosity | spf3.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At2.f0\*(test(atu2)\*At2.nxmesh+test(atv2)\*At2.nymesh) | Material | Boundary 1 |

* + 1. outflow



outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At2.f0\*(test(atu2)\*At2.nxmesh+test(atv2)\*At2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At2.Fx | f\_atu2 |  | Volume force, x component | Domains 1–3 |
| At2.Fy | f\_atv2 |  | Volume force, y component | Domains 1–3 |
| At2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 9



Laminar Flow 9

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.dz | 1 |  | Thickness | Domains 1–3 |
| B2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| B2.pA | bp2+B2.pref |  | Absolute pressure | Domains 1–3 |
| B2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| B2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| B2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| B2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| B2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| B2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| B2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| B2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| B2.rho | 1 |  | Density | Domains 1–3 |
| B2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| B2.sr | sqrt(0.5\*(4\*bu2x^2+2\*(bu2y+bv2x)^2+4\*bv2y^2)+eps) |  | Shear rate | Domains 1–3 |
| B2.divu | bu2x+bv2y |  | Divergence of velocity field | Domains 1–3 |
| B2.U | sqrt(bu2^2+bv2^2) |  | Velocity magnitude | Domains 1–3 |
| B2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| B2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| B2.vorticityz | bv2x-bu2y |  | Vorticity field, z component | Domains 1–3 |
| B2.vort\_magn | sqrt(B2.vorticityx^2+B2.vorticityy^2+B2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| B2.cellRe | 0.25\*B2.rho\*sqrt(emetric(bu2,bv2)/emetric2)/B2.mu |  | Cell Reynolds number | Domains 1–3 |
| B2.nu | B2.mu/B2.rho |  | Kinematic viscosity | Domains 1–3 |
| B2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| B2.mu\_eff | B2.mu+B2.muT |  | Dynamic viscosity | Domains 1–3 |
| B2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| B2.T\_stressx | B2.K\_stressx-bp2\*B2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| B2.T\_stressy | B2.K\_stressy-bp2\*B2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| B2.T\_stressz | B2.K\_stressz-bp2\*B2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| B2.K\_stressx | B2.mu\_eff\*(2\*bu2x\*B2.nxmesh+(bu2y+bv2x)\*B2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| B2.K\_stressy | B2.mu\_eff\*((bv2x+bu2y)\*B2.nxmesh+2\*bv2y\*B2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| B2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| B2.K\_stress\_tensorxx | 2\*B2.mu\_eff\*bu2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| B2.K\_stress\_tensoryx | B2.mu\_eff\*(bv2x+bu2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| B2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| B2.K\_stress\_tensorxy | B2.mu\_eff\*(bu2y+bv2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| B2.K\_stress\_tensoryy | 2\*B2.mu\_eff\*bv2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| B2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| B2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| B2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| B2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| B2.K\_stress\_tensor\_testxx | 2\*B2.mu\_eff\*test(bu2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| B2.K\_stress\_tensor\_testyx | B2.mu\_eff\*(test(bv2x)+test(bu2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| B2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| B2.K\_stress\_tensor\_testxy | B2.mu\_eff\*(test(bu2y)+test(bv2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| B2.K\_stress\_tensor\_testyy | 2\*B2.mu\_eff\*test(bv2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| B2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| B2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| B2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| B2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| B2.upwind\_helpx | bu2 |  | Upwind term, x component | Domains 1–3 |
| B2.upwind\_helpy | bv2 |  | Upwind term, y component | Domains 1–3 |
| B2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| B2.tau\_vdxx | 2\*B2.mu\*bu2x |  | Strain rate, xx component | Domains 1–3 |
| B2.tau\_vdyx | B2.mu\*(bv2x+bu2y) |  | Strain rate, yx component | Domains 1–3 |
| B2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| B2.tau\_vdxy | B2.mu\*(bu2y+bv2x) |  | Strain rate, xy component | Domains 1–3 |
| B2.tau\_vdyy | 2\*B2.mu\*bv2y |  | Strain rate, yy component | Domains 1–3 |
| B2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| B2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| B2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| B2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| B2.Qvd | B2.tau\_vdxx\*bu2x+B2.tau\_vdxy\*bu2y+B2.tau\_vdyx\*bv2x+B2.tau\_vdyy\*bv2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| bu2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| bv2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| bp2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (bp2-B2.K\_stress\_tensorxx)\*test(bu2x)-B2.K\_stress\_tensorxy\*test(bu2y)-B2.K\_stress\_tensoryx\*test(bv2x)+(bp2-B2.K\_stress\_tensoryy)\*test(bv2y) | Material | Domains 1–3 |
| B2.Fx\*test(bu2)+B2.Fy\*test(bv2) | Material | Domains 1–3 |
| B2.rho\*(-(bu2x\*bu2+bu2y\*bv2)\*test(bu2)-(bv2x\*bu2+bv2y\*bv2)\*test(bv2)) | Material | Domains 1–3 |
| -B2.rho\*B2.divu\*test(bp2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| B2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| B2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -bu2+B2.ubndx | test(-bu2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -bv2+B2.ubndy | test(-bv2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| B2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf4.kinit |
| Turbulent dissipation rate | spf4.epinit |
| Specific dissipation rate | spf4.omInit |
| Reciprocal wall distance | spf4.G0 |
| Undamped turbulent kinematic viscosity | spf4.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_b2



Inflow Bin\*Gamma\_b2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_b2 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.f0 | Gamma\_b2 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B2.f0\*(test(bu2)\*B2.nxmesh+test(bv2)\*B2.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B2.f0\*(test(bu2)\*B2.nxmesh+test(bv2)\*B2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B2.Fx | f\_bu2 |  | Volume force, x component | Domains 1–3 |
| B2.Fy | f\_bv2 |  | Volume force, y component | Domains 1–3 |
| B2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 10



Laminar Flow 10

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.dz | 1 |  | Thickness | Domains 1–3 |
| Bt2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| Bt2.pA | btp2+Bt2.pref |  | Absolute pressure | Domains 1–3 |
| Bt2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| Bt2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| Bt2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| Bt2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| Bt2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| Bt2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| Bt2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| Bt2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| Bt2.rho | 1 |  | Density | Domains 1–3 |
| Bt2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| Bt2.sr | sqrt(0.5\*(4\*btu2x^2+2\*(btu2y+btv2x)^2+4\*btv2y^2)+eps) |  | Shear rate | Domains 1–3 |
| Bt2.divu | btu2x+btv2y |  | Divergence of velocity field | Domains 1–3 |
| Bt2.U | sqrt(btu2^2+btv2^2) |  | Velocity magnitude | Domains 1–3 |
| Bt2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| Bt2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| Bt2.vorticityz | btv2x-btu2y |  | Vorticity field, z component | Domains 1–3 |
| Bt2.vort\_magn | sqrt(Bt2.vorticityx^2+Bt2.vorticityy^2+Bt2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| Bt2.cellRe | 0.25\*Bt2.rho\*sqrt(emetric(btu2,btv2)/emetric2)/Bt2.mu |  | Cell Reynolds number | Domains 1–3 |
| Bt2.nu | Bt2.mu/Bt2.rho |  | Kinematic viscosity | Domains 1–3 |
| Bt2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| Bt2.mu\_eff | Bt2.mu+Bt2.muT |  | Dynamic viscosity | Domains 1–3 |
| Bt2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| Bt2.T\_stressx | Bt2.K\_stressx-btp2\*Bt2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| Bt2.T\_stressy | Bt2.K\_stressy-btp2\*Bt2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| Bt2.T\_stressz | Bt2.K\_stressz-btp2\*Bt2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| Bt2.K\_stressx | Bt2.mu\_eff\*(2\*btu2x\*Bt2.nxmesh+(btu2y+btv2x)\*Bt2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| Bt2.K\_stressy | Bt2.mu\_eff\*((btv2x+btu2y)\*Bt2.nxmesh+2\*btv2y\*Bt2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| Bt2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| Bt2.K\_stress\_tensorxx | 2\*Bt2.mu\_eff\*btu2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| Bt2.K\_stress\_tensoryx | Bt2.mu\_eff\*(btv2x+btu2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| Bt2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| Bt2.K\_stress\_tensorxy | Bt2.mu\_eff\*(btu2y+btv2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| Bt2.K\_stress\_tensoryy | 2\*Bt2.mu\_eff\*btv2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| Bt2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| Bt2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| Bt2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| Bt2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testxx | 2\*Bt2.mu\_eff\*test(btu2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testyx | Bt2.mu\_eff\*(test(btv2x)+test(btu2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testxy | Bt2.mu\_eff\*(test(btu2y)+test(btv2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testyy | 2\*Bt2.mu\_eff\*test(btv2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| Bt2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| Bt2.upwind\_helpx | btu2 |  | Upwind term, x component | Domains 1–3 |
| Bt2.upwind\_helpy | btv2 |  | Upwind term, y component | Domains 1–3 |
| Bt2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| Bt2.tau\_vdxx | 2\*Bt2.mu\*btu2x |  | Strain rate, xx component | Domains 1–3 |
| Bt2.tau\_vdyx | Bt2.mu\*(btv2x+btu2y) |  | Strain rate, yx component | Domains 1–3 |
| Bt2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| Bt2.tau\_vdxy | Bt2.mu\*(btu2y+btv2x) |  | Strain rate, xy component | Domains 1–3 |
| Bt2.tau\_vdyy | 2\*Bt2.mu\*btv2y |  | Strain rate, yy component | Domains 1–3 |
| Bt2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| Bt2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| Bt2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| Bt2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| Bt2.Qvd | Bt2.tau\_vdxx\*btu2x+Bt2.tau\_vdxy\*btu2y+Bt2.tau\_vdyx\*btv2x+Bt2.tau\_vdyy\*btv2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| btu2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| btv2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| btp2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (btp2-Bt2.K\_stress\_tensorxx)\*test(btu2x)-Bt2.K\_stress\_tensorxy\*test(btu2y)-Bt2.K\_stress\_tensoryx\*test(btv2x)+(btp2-Bt2.K\_stress\_tensoryy)\*test(btv2y) | Material | Domains 1–3 |
| Bt2.Fx\*test(btu2)+Bt2.Fy\*test(btv2) | Material | Domains 1–3 |
| Bt2.rho\*(-(btu2x\*btu2+btu2y\*btv2)\*test(btu2)-(btv2x\*btu2+btv2y\*btv2)\*test(btv2)) | Material | Domains 1–3 |
| -Bt2.rho\*Bt2.divu\*test(btp2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| Bt2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| Bt2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -btu2+Bt2.ubndx | test(-btu2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -btv2+Bt2.ubndy | test(-btv2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| Bt2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf5.kinit |
| Turbulent dissipation rate | spf5.epinit |
| Specific dissipation rate | spf5.omInit |
| Reciprocal wall distance | spf5.G0 |
| Undamped turbulent kinematic viscosity | spf5.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt2.f0\*(test(btu2)\*Bt2.nxmesh+test(btv2)\*Bt2.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt2.f0\*(test(btu2)\*Bt2.nxmesh+test(btv2)\*Bt2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt2.Fx | f\_btu2 |  | Volume force, x component | Domains 1–3 |
| Bt2.Fy | f\_btv2 |  | Volume force, y component | Domains 1–3 |
| Bt2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 11



Laminar Flow 11

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.dz | 1 |  | Thickness | Domains 1–3 |
| A3.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| A3.pA | ap3+A3.pref |  | Absolute pressure | Domains 1–3 |
| A3.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| A3.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| A3.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A3.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A3.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A3.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| A3.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| A3.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| A3.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| A3.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| A3.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| A3.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| A3.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| A3.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| A3.rho | 1 |  | Density | Domains 1–3 |
| A3.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| A3.sr | sqrt(0.5\*(4\*au3x^2+2\*(au3y+av3x)^2+4\*av3y^2)+eps) |  | Shear rate | Domains 1–3 |
| A3.divu | au3x+av3y |  | Divergence of velocity field | Domains 1–3 |
| A3.U | sqrt(au3^2+av3^2) |  | Velocity magnitude | Domains 1–3 |
| A3.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| A3.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| A3.vorticityz | av3x-au3y |  | Vorticity field, z component | Domains 1–3 |
| A3.vort\_magn | sqrt(A3.vorticityx^2+A3.vorticityy^2+A3.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| A3.cellRe | 0.25\*A3.rho\*sqrt(emetric(au3,av3)/emetric2)/A3.mu |  | Cell Reynolds number | Domains 1–3 |
| A3.nu | A3.mu/A3.rho |  | Kinematic viscosity | Domains 1–3 |
| A3.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| A3.mu\_eff | A3.mu+A3.muT |  | Dynamic viscosity | Domains 1–3 |
| A3.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| A3.T\_stressx | A3.K\_stressx-ap3\*A3.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| A3.T\_stressy | A3.K\_stressy-ap3\*A3.nymesh |  | Total stress, y component | Boundaries 1–10 |
| A3.T\_stressz | A3.K\_stressz-ap3\*A3.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| A3.K\_stressx | A3.mu\_eff\*(2\*au3x\*A3.nxmesh+(au3y+av3x)\*A3.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| A3.K\_stressy | A3.mu\_eff\*((av3x+au3y)\*A3.nxmesh+2\*av3y\*A3.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| A3.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| A3.K\_stress\_tensorxx | 2\*A3.mu\_eff\*au3x |  | Viscous stress tensor, xx component | Domains 1–3 |
| A3.K\_stress\_tensoryx | A3.mu\_eff\*(av3x+au3y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| A3.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| A3.K\_stress\_tensorxy | A3.mu\_eff\*(au3y+av3x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| A3.K\_stress\_tensoryy | 2\*A3.mu\_eff\*av3y |  | Viscous stress tensor, yy component | Domains 1–3 |
| A3.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| A3.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| A3.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| A3.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| A3.K\_stress\_tensor\_testxx | 2\*A3.mu\_eff\*test(au3x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| A3.K\_stress\_tensor\_testyx | A3.mu\_eff\*(test(av3x)+test(au3y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| A3.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| A3.K\_stress\_tensor\_testxy | A3.mu\_eff\*(test(au3y)+test(av3x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| A3.K\_stress\_tensor\_testyy | 2\*A3.mu\_eff\*test(av3y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| A3.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| A3.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| A3.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| A3.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| A3.upwind\_helpx | au3 |  | Upwind term, x component | Domains 1–3 |
| A3.upwind\_helpy | av3 |  | Upwind term, y component | Domains 1–3 |
| A3.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| A3.tau\_vdxx | 2\*A3.mu\*au3x |  | Strain rate, xx component | Domains 1–3 |
| A3.tau\_vdyx | A3.mu\*(av3x+au3y) |  | Strain rate, yx component | Domains 1–3 |
| A3.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| A3.tau\_vdxy | A3.mu\*(au3y+av3x) |  | Strain rate, xy component | Domains 1–3 |
| A3.tau\_vdyy | 2\*A3.mu\*av3y |  | Strain rate, yy component | Domains 1–3 |
| A3.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| A3.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| A3.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| A3.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| A3.Qvd | A3.tau\_vdxx\*au3x+A3.tau\_vdxy\*au3y+A3.tau\_vdyx\*av3x+A3.tau\_vdyy\*av3y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| au3 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| av3 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| ap3 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (ap3-A3.K\_stress\_tensorxx)\*test(au3x)-A3.K\_stress\_tensorxy\*test(au3y)-A3.K\_stress\_tensoryx\*test(av3x)+(ap3-A3.K\_stress\_tensoryy)\*test(av3y) | Material | Domains 1–3 |
| A3.Fx\*test(au3)+A3.Fy\*test(av3) | Material | Domains 1–3 |
| A3.rho\*(-(au3x\*au3+au3y\*av3)\*test(au3)-(av3x\*au3+av3y\*av3)\*test(av3)) | Material | Domains 1–3 |
| -A3.rho\*A3.divu\*test(ap3) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| A3.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| A3.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -au3+A3.ubndx | test(-au3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -av3+A3.ubndy | test(-av3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| A3.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf2.kinit |
| Turbulent dissipation rate | spf2.epinit |
| Specific dissipation rate | spf2.omInit |
| Reciprocal wall distance | spf2.G0 |
| Undamped turbulent kinematic viscosity | spf2.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_a3



Inflow Bin\*Gamma\_a3

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_a3 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.f0 | Gamma\_a3 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A3.f0\*(test(au3)\*A3.nxmesh+test(av3)\*A3.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -A3.f0\*(test(au3)\*A3.nxmesh+test(av3)\*A3.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| A3.Fx | f\_au3 |  | Volume force, x component | Domains 1–3 |
| A3.Fy | f\_av3 |  | Volume force, y component | Domains 1–3 |
| A3.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 12



Laminar Flow 12

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.dz | 1 |  | Thickness | Domains 1–3 |
| At3.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| At3.pA | atp3+At3.pref |  | Absolute pressure | Domains 1–3 |
| At3.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| At3.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| At3.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At3.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At3.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At3.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| At3.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| At3.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| At3.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| At3.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| At3.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| At3.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| At3.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| At3.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| At3.rho | 1 |  | Density | Domains 1–3 |
| At3.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| At3.sr | sqrt(0.5\*(4\*atu3x^2+2\*(atu3y+atv3x)^2+4\*atv3y^2)+eps) |  | Shear rate | Domains 1–3 |
| At3.divu | atu3x+atv3y |  | Divergence of velocity field | Domains 1–3 |
| At3.U | sqrt(atu3^2+atv3^2) |  | Velocity magnitude | Domains 1–3 |
| At3.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| At3.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| At3.vorticityz | atv3x-atu3y |  | Vorticity field, z component | Domains 1–3 |
| At3.vort\_magn | sqrt(At3.vorticityx^2+At3.vorticityy^2+At3.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| At3.cellRe | 0.25\*At3.rho\*sqrt(emetric(atu3,atv3)/emetric2)/At3.mu |  | Cell Reynolds number | Domains 1–3 |
| At3.nu | At3.mu/At3.rho |  | Kinematic viscosity | Domains 1–3 |
| At3.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| At3.mu\_eff | At3.mu+At3.muT |  | Dynamic viscosity | Domains 1–3 |
| At3.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| At3.T\_stressx | At3.K\_stressx-atp3\*At3.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| At3.T\_stressy | At3.K\_stressy-atp3\*At3.nymesh |  | Total stress, y component | Boundaries 1–10 |
| At3.T\_stressz | At3.K\_stressz-atp3\*At3.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| At3.K\_stressx | At3.mu\_eff\*(2\*atu3x\*At3.nxmesh+(atu3y+atv3x)\*At3.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| At3.K\_stressy | At3.mu\_eff\*((atv3x+atu3y)\*At3.nxmesh+2\*atv3y\*At3.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| At3.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| At3.K\_stress\_tensorxx | 2\*At3.mu\_eff\*atu3x |  | Viscous stress tensor, xx component | Domains 1–3 |
| At3.K\_stress\_tensoryx | At3.mu\_eff\*(atv3x+atu3y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| At3.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| At3.K\_stress\_tensorxy | At3.mu\_eff\*(atu3y+atv3x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| At3.K\_stress\_tensoryy | 2\*At3.mu\_eff\*atv3y |  | Viscous stress tensor, yy component | Domains 1–3 |
| At3.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| At3.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| At3.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| At3.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| At3.K\_stress\_tensor\_testxx | 2\*At3.mu\_eff\*test(atu3x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| At3.K\_stress\_tensor\_testyx | At3.mu\_eff\*(test(atv3x)+test(atu3y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| At3.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| At3.K\_stress\_tensor\_testxy | At3.mu\_eff\*(test(atu3y)+test(atv3x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| At3.K\_stress\_tensor\_testyy | 2\*At3.mu\_eff\*test(atv3y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| At3.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| At3.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| At3.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| At3.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| At3.upwind\_helpx | atu3 |  | Upwind term, x component | Domains 1–3 |
| At3.upwind\_helpy | atv3 |  | Upwind term, y component | Domains 1–3 |
| At3.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| At3.tau\_vdxx | 2\*At3.mu\*atu3x |  | Strain rate, xx component | Domains 1–3 |
| At3.tau\_vdyx | At3.mu\*(atv3x+atu3y) |  | Strain rate, yx component | Domains 1–3 |
| At3.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| At3.tau\_vdxy | At3.mu\*(atu3y+atv3x) |  | Strain rate, xy component | Domains 1–3 |
| At3.tau\_vdyy | 2\*At3.mu\*atv3y |  | Strain rate, yy component | Domains 1–3 |
| At3.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| At3.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| At3.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| At3.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| At3.Qvd | At3.tau\_vdxx\*atu3x+At3.tau\_vdxy\*atu3y+At3.tau\_vdyx\*atv3x+At3.tau\_vdyy\*atv3y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| atu3 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| atv3 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| atp3 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (atp3-At3.K\_stress\_tensorxx)\*test(atu3x)-At3.K\_stress\_tensorxy\*test(atu3y)-At3.K\_stress\_tensoryx\*test(atv3x)+(atp3-At3.K\_stress\_tensoryy)\*test(atv3y) | Material | Domains 1–3 |
| At3.Fx\*test(atu3)+At3.Fy\*test(atv3) | Material | Domains 1–3 |
| At3.rho\*(-(atu3x\*atu3+atu3y\*atv3)\*test(atu3)-(atv3x\*atu3+atv3y\*atv3)\*test(atv3)) | Material | Domains 1–3 |
| -At3.rho\*At3.divu\*test(atp3) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| At3.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| At3.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -atu3+At3.ubndx | test(-atu3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -atv3+At3.ubndy | test(-atv3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| At3.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf3.kinit |
| Turbulent dissipation rate | spf3.epinit |
| Specific dissipation rate | spf3.omInit |
| Reciprocal wall distance | spf3.G0 |
| Undamped turbulent kinematic viscosity | spf3.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At3.f0\*(test(atu3)\*At3.nxmesh+test(atv3)\*At3.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -At3.f0\*(test(atu3)\*At3.nxmesh+test(atv3)\*At3.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| At3.Fx | f\_atu3 |  | Volume force, x component | Domains 1–3 |
| At3.Fy | f\_atv3 |  | Volume force, y component | Domains 1–3 |
| At3.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 13



Laminar Flow 13

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.dz | 1 |  | Thickness | Domains 1–3 |
| B3.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| B3.pA | bp3+B3.pref |  | Absolute pressure | Domains 1–3 |
| B3.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| B3.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| B3.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B3.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B3.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B3.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| B3.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| B3.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| B3.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| B3.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| B3.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| B3.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| B3.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| B3.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| B3.rho | 1 |  | Density | Domains 1–3 |
| B3.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| B3.sr | sqrt(0.5\*(4\*bu3x^2+2\*(bu3y+bv3x)^2+4\*bv3y^2)+eps) |  | Shear rate | Domains 1–3 |
| B3.divu | bu3x+bv3y |  | Divergence of velocity field | Domains 1–3 |
| B3.U | sqrt(bu3^2+bv3^2) |  | Velocity magnitude | Domains 1–3 |
| B3.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| B3.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| B3.vorticityz | bv3x-bu3y |  | Vorticity field, z component | Domains 1–3 |
| B3.vort\_magn | sqrt(B3.vorticityx^2+B3.vorticityy^2+B3.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| B3.cellRe | 0.25\*B3.rho\*sqrt(emetric(bu3,bv3)/emetric2)/B3.mu |  | Cell Reynolds number | Domains 1–3 |
| B3.nu | B3.mu/B3.rho |  | Kinematic viscosity | Domains 1–3 |
| B3.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| B3.mu\_eff | B3.mu+B3.muT |  | Dynamic viscosity | Domains 1–3 |
| B3.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| B3.T\_stressx | B3.K\_stressx-bp3\*B3.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| B3.T\_stressy | B3.K\_stressy-bp3\*B3.nymesh |  | Total stress, y component | Boundaries 1–10 |
| B3.T\_stressz | B3.K\_stressz-bp3\*B3.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| B3.K\_stressx | B3.mu\_eff\*(2\*bu3x\*B3.nxmesh+(bu3y+bv3x)\*B3.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| B3.K\_stressy | B3.mu\_eff\*((bv3x+bu3y)\*B3.nxmesh+2\*bv3y\*B3.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| B3.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| B3.K\_stress\_tensorxx | 2\*B3.mu\_eff\*bu3x |  | Viscous stress tensor, xx component | Domains 1–3 |
| B3.K\_stress\_tensoryx | B3.mu\_eff\*(bv3x+bu3y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| B3.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| B3.K\_stress\_tensorxy | B3.mu\_eff\*(bu3y+bv3x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| B3.K\_stress\_tensoryy | 2\*B3.mu\_eff\*bv3y |  | Viscous stress tensor, yy component | Domains 1–3 |
| B3.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| B3.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| B3.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| B3.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| B3.K\_stress\_tensor\_testxx | 2\*B3.mu\_eff\*test(bu3x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| B3.K\_stress\_tensor\_testyx | B3.mu\_eff\*(test(bv3x)+test(bu3y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| B3.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| B3.K\_stress\_tensor\_testxy | B3.mu\_eff\*(test(bu3y)+test(bv3x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| B3.K\_stress\_tensor\_testyy | 2\*B3.mu\_eff\*test(bv3y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| B3.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| B3.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| B3.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| B3.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| B3.upwind\_helpx | bu3 |  | Upwind term, x component | Domains 1–3 |
| B3.upwind\_helpy | bv3 |  | Upwind term, y component | Domains 1–3 |
| B3.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| B3.tau\_vdxx | 2\*B3.mu\*bu3x |  | Strain rate, xx component | Domains 1–3 |
| B3.tau\_vdyx | B3.mu\*(bv3x+bu3y) |  | Strain rate, yx component | Domains 1–3 |
| B3.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| B3.tau\_vdxy | B3.mu\*(bu3y+bv3x) |  | Strain rate, xy component | Domains 1–3 |
| B3.tau\_vdyy | 2\*B3.mu\*bv3y |  | Strain rate, yy component | Domains 1–3 |
| B3.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| B3.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| B3.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| B3.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| B3.Qvd | B3.tau\_vdxx\*bu3x+B3.tau\_vdxy\*bu3y+B3.tau\_vdyx\*bv3x+B3.tau\_vdyy\*bv3y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| bu3 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| bv3 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| bp3 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (bp3-B3.K\_stress\_tensorxx)\*test(bu3x)-B3.K\_stress\_tensorxy\*test(bu3y)-B3.K\_stress\_tensoryx\*test(bv3x)+(bp3-B3.K\_stress\_tensoryy)\*test(bv3y) | Material | Domains 1–3 |
| B3.Fx\*test(bu3)+B3.Fy\*test(bv3) | Material | Domains 1–3 |
| B3.rho\*(-(bu3x\*bu3+bu3y\*bv3)\*test(bu3)-(bv3x\*bu3+bv3y\*bv3)\*test(bv3)) | Material | Domains 1–3 |
| -B3.rho\*B3.divu\*test(bp3) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| B3.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| B3.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -bu3+B3.ubndx | test(-bu3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -bv3+B3.ubndy | test(-bv3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| B3.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf4.kinit |
| Turbulent dissipation rate | spf4.epinit |
| Specific dissipation rate | spf4.omInit |
| Reciprocal wall distance | spf4.G0 |
| Undamped turbulent kinematic viscosity | spf4.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow Bin\*Gamma\_b3



Inflow Bin\*Gamma\_b3

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma\_b3 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.f0 | Gamma\_b3 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B3.f0\*(test(bu3)\*B3.nxmesh+test(bv3)\*B3.nymesh) | Material | Boundary 1 |

* + 1. outflow



outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -B3.f0\*(test(bu3)\*B3.nxmesh+test(bv3)\*B3.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| B3.Fx | f\_bu3 |  | Volume force, x component | Domains 1–3 |
| B3.Fy | f\_bv3 |  | Volume force, y component | Domains 1–3 |
| B3.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 14



Laminar Flow 14

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.dz | 1 |  | Thickness | Domains 1–3 |
| Bt3.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| Bt3.pA | btp3+Bt3.pref |  | Absolute pressure | Domains 1–3 |
| Bt3.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| Bt3.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| Bt3.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt3.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt3.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt3.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| Bt3.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| Bt3.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| Bt3.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| Bt3.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| Bt3.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| Bt3.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| Bt3.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| Bt3.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| Bt3.rho | 1 |  | Density | Domains 1–3 |
| Bt3.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| Bt3.sr | sqrt(0.5\*(4\*btu3x^2+2\*(btu3y+btv3x)^2+4\*btv3y^2)+eps) |  | Shear rate | Domains 1–3 |
| Bt3.divu | btu3x+btv3y |  | Divergence of velocity field | Domains 1–3 |
| Bt3.U | sqrt(btu3^2+btv3^2) |  | Velocity magnitude | Domains 1–3 |
| Bt3.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| Bt3.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| Bt3.vorticityz | btv3x-btu3y |  | Vorticity field, z component | Domains 1–3 |
| Bt3.vort\_magn | sqrt(Bt3.vorticityx^2+Bt3.vorticityy^2+Bt3.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| Bt3.cellRe | 0.25\*Bt3.rho\*sqrt(emetric(btu3,btv3)/emetric2)/Bt3.mu |  | Cell Reynolds number | Domains 1–3 |
| Bt3.nu | Bt3.mu/Bt3.rho |  | Kinematic viscosity | Domains 1–3 |
| Bt3.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| Bt3.mu\_eff | Bt3.mu+Bt3.muT |  | Dynamic viscosity | Domains 1–3 |
| Bt3.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| Bt3.T\_stressx | Bt3.K\_stressx-btp3\*Bt3.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| Bt3.T\_stressy | Bt3.K\_stressy-btp3\*Bt3.nymesh |  | Total stress, y component | Boundaries 1–10 |
| Bt3.T\_stressz | Bt3.K\_stressz-btp3\*Bt3.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| Bt3.K\_stressx | Bt3.mu\_eff\*(2\*btu3x\*Bt3.nxmesh+(btu3y+btv3x)\*Bt3.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| Bt3.K\_stressy | Bt3.mu\_eff\*((btv3x+btu3y)\*Bt3.nxmesh+2\*btv3y\*Bt3.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| Bt3.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| Bt3.K\_stress\_tensorxx | 2\*Bt3.mu\_eff\*btu3x |  | Viscous stress tensor, xx component | Domains 1–3 |
| Bt3.K\_stress\_tensoryx | Bt3.mu\_eff\*(btv3x+btu3y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| Bt3.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| Bt3.K\_stress\_tensorxy | Bt3.mu\_eff\*(btu3y+btv3x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| Bt3.K\_stress\_tensoryy | 2\*Bt3.mu\_eff\*btv3y |  | Viscous stress tensor, yy component | Domains 1–3 |
| Bt3.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| Bt3.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| Bt3.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| Bt3.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testxx | 2\*Bt3.mu\_eff\*test(btu3x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testyx | Bt3.mu\_eff\*(test(btv3x)+test(btu3y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testxy | Bt3.mu\_eff\*(test(btu3y)+test(btv3x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testyy | 2\*Bt3.mu\_eff\*test(btv3y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| Bt3.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| Bt3.upwind\_helpx | btu3 |  | Upwind term, x component | Domains 1–3 |
| Bt3.upwind\_helpy | btv3 |  | Upwind term, y component | Domains 1–3 |
| Bt3.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| Bt3.tau\_vdxx | 2\*Bt3.mu\*btu3x |  | Strain rate, xx component | Domains 1–3 |
| Bt3.tau\_vdyx | Bt3.mu\*(btv3x+btu3y) |  | Strain rate, yx component | Domains 1–3 |
| Bt3.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| Bt3.tau\_vdxy | Bt3.mu\*(btu3y+btv3x) |  | Strain rate, xy component | Domains 1–3 |
| Bt3.tau\_vdyy | 2\*Bt3.mu\*btv3y |  | Strain rate, yy component | Domains 1–3 |
| Bt3.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| Bt3.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| Bt3.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| Bt3.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| Bt3.Qvd | Bt3.tau\_vdxx\*btu3x+Bt3.tau\_vdxy\*btu3y+Bt3.tau\_vdyx\*btv3x+Bt3.tau\_vdyy\*btv3y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| btu3 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| btv3 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| btp3 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (btp3-Bt3.K\_stress\_tensorxx)\*test(btu3x)-Bt3.K\_stress\_tensorxy\*test(btu3y)-Bt3.K\_stress\_tensoryx\*test(btv3x)+(btp3-Bt3.K\_stress\_tensoryy)\*test(btv3y) | Material | Domains 1–3 |
| Bt3.Fx\*test(btu3)+Bt3.Fy\*test(btv3) | Material | Domains 1–3 |
| Bt3.rho\*(-(btu3x\*btu3+btu3y\*btv3)\*test(btu3)-(btv3x\*btu3+btv3y\*btv3)\*test(btv3)) | Material | Domains 1–3 |
| -Bt3.rho\*Bt3.divu\*test(btp3) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| Bt3.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| Bt3.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -btu3+Bt3.ubndx | test(-btu3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -btv3+Bt3.ubndy | test(-btv3) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| Bt3.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf5.kinit |
| Turbulent dissipation rate | spf5.epinit |
| Specific dissipation rate | spf5.omInit |
| Reciprocal wall distance | spf5.G0 |
| Undamped turbulent kinematic viscosity | spf5.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt3.f0\*(test(btu3)\*Bt3.nxmesh+test(btv3)\*Bt3.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -Bt3.f0\*(test(btu3)\*Bt3.nxmesh+test(btv3)\*Bt3.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| Bt3.Fx | f\_btu3 |  | Volume force, x component | Domains 1–3 |
| Bt3.Fy | f\_btv3 |  | Volume force, y component | Domains 1–3 |
| Bt3.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 14a



Laminar Flow 14a

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| U1.dz | 1 |  | Thickness | Domains 1–3 |
| U1.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| U1.pA | P1+U1.pref |  | Absolute pressure | Domains 1–3 |
| U1.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| U1.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| U1.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| U1.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| U1.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| U1.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| U1.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| U1.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| U1.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| U1.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| U1.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| U1.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| U1.rho | 1 |  | Density | Domains 1–3 |
| U1.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| U1.sr | sqrt(0.5\*(4\*U1x^2+2\*(U1y+V1x)^2+4\*V1y^2)+eps) |  | Shear rate | Domains 1–3 |
| U1.divu | U1x+V1y |  | Divergence of velocity field | Domains 1–3 |
| U1.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| U1.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| U1.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| U1.U | sqrt(U1^2+V1^2) |  | Velocity magnitude | Domains 1–3 |
| U1.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| U1.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| U1.vorticityz | V1x-U1y |  | Vorticity field, z component | Domains 1–3 |
| U1.vort\_magn | sqrt(U1.vorticityx^2+U1.vorticityy^2+U1.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| U1.cellRe | 0.25\*U1.rho\*sqrt(emetric(U1,V1)/emetric2)/U1.mu |  | Cell Reynolds number | Domains 1–3 |
| U1.nu | U1.mu/U1.rho |  | Kinematic viscosity | Domains 1–3 |
| U1.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| U1.mu\_eff | U1.mu+U1.muT |  | Dynamic viscosity | Domains 1–3 |
| U1.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| U1.T\_stressx | U1.K\_stressx-P1\*U1.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| U1.T\_stressy | U1.K\_stressy-P1\*U1.nymesh |  | Total stress, y component | Boundaries 1–10 |
| U1.T\_stressz | U1.K\_stressz-P1\*U1.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| U1.K\_stressx | U1.mu\_eff\*(2\*U1x\*U1.nxmesh+(U1y+V1x)\*U1.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| U1.K\_stressy | U1.mu\_eff\*((V1x+U1y)\*U1.nxmesh+2\*V1y\*U1.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| U1.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| U1.K\_stress\_tensorxx | 2\*U1.mu\_eff\*U1x |  | Viscous stress tensor, xx component | Domains 1–3 |
| U1.K\_stress\_tensoryx | U1.mu\_eff\*(V1x+U1y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| U1.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| U1.K\_stress\_tensorxy | U1.mu\_eff\*(U1y+V1x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| U1.K\_stress\_tensoryy | 2\*U1.mu\_eff\*V1y |  | Viscous stress tensor, yy component | Domains 1–3 |
| U1.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| U1.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| U1.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| U1.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| U1.K\_stress\_tensor\_testxx | 2\*U1.mu\_eff\*test(U1x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| U1.K\_stress\_tensor\_testyx | U1.mu\_eff\*(test(V1x)+test(U1y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| U1.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| U1.K\_stress\_tensor\_testxy | U1.mu\_eff\*(test(U1y)+test(V1x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| U1.K\_stress\_tensor\_testyy | 2\*U1.mu\_eff\*test(V1y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| U1.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| U1.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| U1.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| U1.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| U1.upwind\_helpx | U1 |  | Upwind term, x component | Domains 1–3 |
| U1.upwind\_helpy | V1 |  | Upwind term, y component | Domains 1–3 |
| U1.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| U1.tau\_vdxx | 2\*U1.mu\*U1x |  | Strain rate, xx component | Domains 1–3 |
| U1.tau\_vdyx | U1.mu\*(V1x+U1y) |  | Strain rate, yx component | Domains 1–3 |
| U1.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| U1.tau\_vdxy | U1.mu\*(U1y+V1x) |  | Strain rate, xy component | Domains 1–3 |
| U1.tau\_vdyy | 2\*U1.mu\*V1y |  | Strain rate, yy component | Domains 1–3 |
| U1.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| U1.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| U1.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| U1.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| U1.Qvd | U1.tau\_vdxx\*U1x+U1.tau\_vdxy\*U1y+U1.tau\_vdyx\*V1x+U1.tau\_vdyy\*V1y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| U1 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| V1 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| P1 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (P1-U1.K\_stress\_tensorxx)\*test(U1x)-U1.K\_stress\_tensorxy\*test(U1y)-U1.K\_stress\_tensoryx\*test(V1x)+(P1-U1.K\_stress\_tensoryy)\*test(V1y) | Material | Domains 1–3 |
| U1.Fx\*test(U1)+U1.Fy\*test(V1) | Material | Domains 1–3 |
| U1.rho\*(-(U1x\*U1+U1y\*V1)\*test(U1)-(V1x\*U1+V1y\*V1)\*test(V1)) | Material | Domains 1–3 |
| -U1.rho\*U1.divu\*test(P1) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| U1.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| U1.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| U1.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -U1+U1.ubndx | test(-U1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -V1+U1.ubndy | test(-V1) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| U1.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf2.kinit |
| Turbulent dissipation rate | spf2.epinit |
| Specific dissipation rate | spf2.omInit |
| Reciprocal wall distance | spf2.G0 |
| Undamped turbulent kinematic viscosity | spf2.nutildeinit |
| Velocity field | {U10, V10, 0} |
| Pressure | P10 |

* + 1. Inflow Bin\*Gamma1



Inflow Bin\*Gamma1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | Gamma1 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*spf2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| U1.f0 | Gamma1 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -U1.f0\*(test(U1)\*U1.nxmesh+test(V1)\*U1.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*spf2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| U1.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -U1.f0\*(test(U1)\*U1.nxmesh+test(V1)\*U1.nymesh) | Material | Boundaries 9–10 |

* 1. Laminar Flow 15



Laminar Flow 15

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.dz | 1 |  | Thickness | Domains 1–3 |
| u2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| u2.pA | p2+u2.pref |  | Absolute pressure | Domains 1–3 |
| u2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| u2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| u2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| u2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| u2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| u2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| u2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| u2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| u2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| u2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| u2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| u2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| u2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| u2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| u2.rho | 1 |  | Density | Domains 1–3 |
| u2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| u2.sr | sqrt(0.5\*(4\*u2x^2+2\*(u2y+v2x)^2+4\*v2y^2)+eps) |  | Shear rate | Domains 1–3 |
| u2.divu | u2x+v2y |  | Divergence of velocity field | Domains 1–3 |
| u2.U | sqrt(u2^2+v2^2) |  | Velocity magnitude | Domains 1–3 |
| u2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| u2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| u2.vorticityz | v2x-u2y |  | Vorticity field, z component | Domains 1–3 |
| u2.vort\_magn | sqrt(u2.vorticityx^2+u2.vorticityy^2+u2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| u2.cellRe | 0.25\*u2.rho\*sqrt(emetric(u2,v2)/emetric2)/u2.mu |  | Cell Reynolds number | Domains 1–3 |
| u2.nu | u2.mu/u2.rho |  | Kinematic viscosity | Domains 1–3 |
| u2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| u2.mu\_eff | u2.mu+u2.muT |  | Dynamic viscosity | Domains 1–3 |
| u2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| u2.T\_stressx | u2.K\_stressx-p2\*u2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| u2.T\_stressy | u2.K\_stressy-p2\*u2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| u2.T\_stressz | u2.K\_stressz-p2\*u2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| u2.K\_stressx | u2.mu\_eff\*(2\*u2x\*u2.nxmesh+(u2y+v2x)\*u2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| u2.K\_stressy | u2.mu\_eff\*((v2x+u2y)\*u2.nxmesh+2\*v2y\*u2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| u2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| u2.K\_stress\_tensorxx | 2\*u2.mu\_eff\*u2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| u2.K\_stress\_tensoryx | u2.mu\_eff\*(v2x+u2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| u2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| u2.K\_stress\_tensorxy | u2.mu\_eff\*(u2y+v2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| u2.K\_stress\_tensoryy | 2\*u2.mu\_eff\*v2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| u2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| u2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| u2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| u2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| u2.K\_stress\_tensor\_testxx | 2\*u2.mu\_eff\*test(u2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| u2.K\_stress\_tensor\_testyx | u2.mu\_eff\*(test(v2x)+test(u2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| u2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| u2.K\_stress\_tensor\_testxy | u2.mu\_eff\*(test(u2y)+test(v2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| u2.K\_stress\_tensor\_testyy | 2\*u2.mu\_eff\*test(v2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| u2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| u2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| u2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| u2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| u2.upwind\_helpx | u2 |  | Upwind term, x component | Domains 1–3 |
| u2.upwind\_helpy | v2 |  | Upwind term, y component | Domains 1–3 |
| u2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| u2.tau\_vdxx | 2\*u2.mu\*u2x |  | Strain rate, xx component | Domains 1–3 |
| u2.tau\_vdyx | u2.mu\*(v2x+u2y) |  | Strain rate, yx component | Domains 1–3 |
| u2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| u2.tau\_vdxy | u2.mu\*(u2y+v2x) |  | Strain rate, xy component | Domains 1–3 |
| u2.tau\_vdyy | 2\*u2.mu\*v2y |  | Strain rate, yy component | Domains 1–3 |
| u2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| u2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| u2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| u2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| u2.Qvd | u2.tau\_vdxx\*u2x+u2.tau\_vdxy\*u2y+u2.tau\_vdyx\*v2x+u2.tau\_vdyy\*v2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| u2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| v2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| p2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (p2-u2.K\_stress\_tensorxx)\*test(u2x)-u2.K\_stress\_tensorxy\*test(u2y)-u2.K\_stress\_tensoryx\*test(v2x)+(p2-u2.K\_stress\_tensoryy)\*test(v2y) | Material | Domains 1–3 |
| u2.Fx\*test(u2)+u2.Fy\*test(v2) | Material | Domains 1–3 |
| u2.rho\*(-(u2x\*u2+u2y\*v2)\*test(u2)-(v2x\*u2+v2y\*v2)\*test(v2)) | Material | Domains 1–3 |
| -u2.rho\*u2.divu\*test(p2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| u2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| u2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -u2+u2.ubndx | test(-u2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -v2+u2.ubndy | test(-v2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| u2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |
| Turbulent kinetic energy | spf2.kinit |
| Turbulent dissipation rate | spf2.epinit |
| Specific dissipation rate | spf2.omInit |
| Reciprocal wall distance | spf2.G0 |
| Undamped turbulent kinematic viscosity | spf2.nutildeinit |

* + 1. Inflow Bin\*gamma2



Inflow Bin\*gamma2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | gamma2 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*Beta2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.f0 | gamma2 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -u2.f0\*(test(u2)\*u2.nxmesh+test(v2)\*u2.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*Beta2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -u2.f0\*(test(u2)\*u2.nxmesh+test(v2)\*u2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| u2.Fx | Fu2 |  | Volume force, x component | Domains 1–3 |
| u2.Fy | Fv2 |  | Volume force, y component | Domains 1–3 |
| u2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Laminar Flow 16



Laminar Flow 16

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.dz | 1 |  | Thickness | Domains 1–3 |
| ut2.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| ut2.pA | pt2+ut2.pref |  | Absolute pressure | Domains 1–3 |
| ut2.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| ut2.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| ut2.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| ut2.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| ut2.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| ut2.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| ut2.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| ut2.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| ut2.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| ut2.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| ut2.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| ut2.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| ut2.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| ut2.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| ut2.rho | 1 |  | Density | Domains 1–3 |
| ut2.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| ut2.sr | sqrt(0.5\*(4\*ut2x^2+2\*(ut2y+vt2x)^2+4\*vt2y^2)+eps) |  | Shear rate | Domains 1–3 |
| ut2.divu | ut2x+vt2y |  | Divergence of velocity field | Domains 1–3 |
| ut2.U | sqrt(ut2^2+vt2^2) |  | Velocity magnitude | Domains 1–3 |
| ut2.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| ut2.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| ut2.vorticityz | vt2x-ut2y |  | Vorticity field, z component | Domains 1–3 |
| ut2.vort\_magn | sqrt(ut2.vorticityx^2+ut2.vorticityy^2+ut2.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| ut2.cellRe | 0.25\*ut2.rho\*sqrt(emetric(ut2,vt2)/emetric2)/ut2.mu |  | Cell Reynolds number | Domains 1–3 |
| ut2.nu | ut2.mu/ut2.rho |  | Kinematic viscosity | Domains 1–3 |
| ut2.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| ut2.mu\_eff | ut2.mu+ut2.muT |  | Dynamic viscosity | Domains 1–3 |
| ut2.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| ut2.T\_stressx | ut2.K\_stressx-pt2\*ut2.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| ut2.T\_stressy | ut2.K\_stressy-pt2\*ut2.nymesh |  | Total stress, y component | Boundaries 1–10 |
| ut2.T\_stressz | ut2.K\_stressz-pt2\*ut2.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| ut2.K\_stressx | ut2.mu\_eff\*(2\*ut2x\*ut2.nxmesh+(ut2y+vt2x)\*ut2.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| ut2.K\_stressy | ut2.mu\_eff\*((vt2x+ut2y)\*ut2.nxmesh+2\*vt2y\*ut2.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| ut2.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| ut2.K\_stress\_tensorxx | 2\*ut2.mu\_eff\*ut2x |  | Viscous stress tensor, xx component | Domains 1–3 |
| ut2.K\_stress\_tensoryx | ut2.mu\_eff\*(vt2x+ut2y) |  | Viscous stress tensor, yx component | Domains 1–3 |
| ut2.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| ut2.K\_stress\_tensorxy | ut2.mu\_eff\*(ut2y+vt2x) |  | Viscous stress tensor, xy component | Domains 1–3 |
| ut2.K\_stress\_tensoryy | 2\*ut2.mu\_eff\*vt2y |  | Viscous stress tensor, yy component | Domains 1–3 |
| ut2.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| ut2.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| ut2.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| ut2.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testxx | 2\*ut2.mu\_eff\*test(ut2x) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testyx | ut2.mu\_eff\*(test(vt2x)+test(ut2y)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testxy | ut2.mu\_eff\*(test(ut2y)+test(vt2x)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testyy | 2\*ut2.mu\_eff\*test(vt2y) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| ut2.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| ut2.upwind\_helpx | ut2 |  | Upwind term, x component | Domains 1–3 |
| ut2.upwind\_helpy | vt2 |  | Upwind term, y component | Domains 1–3 |
| ut2.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| ut2.tau\_vdxx | 2\*ut2.mu\*ut2x |  | Strain rate, xx component | Domains 1–3 |
| ut2.tau\_vdyx | ut2.mu\*(vt2x+ut2y) |  | Strain rate, yx component | Domains 1–3 |
| ut2.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| ut2.tau\_vdxy | ut2.mu\*(ut2y+vt2x) |  | Strain rate, xy component | Domains 1–3 |
| ut2.tau\_vdyy | 2\*ut2.mu\*vt2y |  | Strain rate, yy component | Domains 1–3 |
| ut2.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| ut2.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| ut2.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| ut2.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| ut2.Qvd | ut2.tau\_vdxx\*ut2x+ut2.tau\_vdxy\*ut2y+ut2.tau\_vdyx\*vt2x+ut2.tau\_vdyy\*vt2y |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| ut2 | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| vt2 | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| pt2 | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (pt2-ut2.K\_stress\_tensorxx)\*test(ut2x)-ut2.K\_stress\_tensorxy\*test(ut2y)-ut2.K\_stress\_tensoryx\*test(vt2x)+(pt2-ut2.K\_stress\_tensoryy)\*test(vt2y) | Material | Domains 1–3 |
| ut2.Fx\*test(ut2)+ut2.Fy\*test(vt2) | Material | Domains 1–3 |
| ut2.rho\*(-(ut2x\*ut2+ut2y\*vt2)\*test(ut2)-(vt2x\*ut2+vt2y\*vt2)\*test(vt2)) | Material | Domains 1–3 |
| -ut2.rho\*ut2.divu\*test(pt2) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| ut2.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| ut2.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -ut2+ut2.ubndx | test(-ut2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -vt2+ut2.ubndy | test(-vt2) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| ut2.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Turbulent kinetic energy | spf3.kinit |
| Turbulent dissipation rate | spf3.epinit |
| Specific dissipation rate | spf3.omInit |
| Reciprocal wall distance | spf3.G0 |
| Undamped turbulent kinematic viscosity | spf3.nutildeinit |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. Inflow



Inflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*Betat2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.f0 | 0 |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -ut2.f0\*(test(ut2)\*ut2.nxmesh+test(vt2)\*ut2.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |
| Undamped turbulent kinematic viscosity | 3\*Betat2.nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -ut2.f0\*(test(ut2)\*ut2.nxmesh+test(vt2)\*ut2.nymesh) | Material | Boundaries 9–10 |

* + 1. Volume Force 1



Volume Force 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| ut2.Fx | Fut2 |  | Volume force, x component | Domains 1–3 |
| ut2.Fy | Fvt2 |  | Volume force, y component | Domains 1–3 |
| ut2.Fz | 0 |  | Volume force, z component | Domains 1–3 |

* 1. Closed loop system



Closed loop system

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations









Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |
| Value type when using splitting of complex variables | {Real, Real, Real, Real, Real, Real, Real, Real, Real, Real, Real} |
| Isotropic diffusion | Off |
| Compressibility | Incompressible flow |
| Channel thickness | 1 |
| Turbulence model type | None |
| Reference pressure level | 1[atm] |
| Use pseudo time stepping for stationary equation form | Off |
| Local CFL number | 1.3^min(niterCMP, 9) + if(niterCMP>=25, 9\*1.3^min(niterCMP - 25, 9), 0) + if(niterCMP>=45, 90\*1.3^min(niterCMP - 45, 9), 0) |
| Streamline diffusion | Off |
| Crosswind diffusion | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.dz | 1 |  | Thickness | Domains 1–3 |
| spf.pref | 1[atm] |  | Reference pressure level | Domains 1–3 |
| spf.pA | p+spf.pref |  | Absolute pressure | Domains 1–3 |
| spf.nx | nx |  | Normal vector, x component | Boundaries 6–7 |
| spf.ny | ny |  | Normal vector, y component | Boundaries 6–7 |
| spf.nz | 0 |  | Normal vector, z component | Boundaries 6–7 |
| spf.nx | dnx |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| spf.ny | dny |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| spf.nz | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |
| spf.nxmesh | root.nxmesh |  | Normal vector, x component | Boundaries 6–7 |
| spf.nymesh | root.nymesh |  | Normal vector, y component | Boundaries 6–7 |
| spf.nzmesh | 0 |  | Normal vector, z component | Boundaries 6–7 |
| spf.nxmesh | root.dnxmesh |  | Normal vector, x component | Boundaries 1–5, 8–10 |
| spf.nymesh | root.dnymesh |  | Normal vector, y component | Boundaries 1–5, 8–10 |
| spf.nzmesh | 0 |  | Normal vector, z component | Boundaries 1–5, 8–10 |

* + 1. Fluid Properties 1



Fluid Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Density | User defined |
| Density | 1 |
| Dynamic viscosity | User defined |
| Dynamic viscosity | nu |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.rho | 1 |  | Density | Domains 1–3 |
| spf.mu | nu |  | Dynamic viscosity | Domains 1–3 |
| spf.sr | sqrt(0.5\*(4\*ux^2+2\*(uy+vx)^2+4\*vy^2)+eps) |  | Shear rate | Domains 1–3 |
| spf.divu | ux+vy |  | Divergence of velocity field | Domains 1–3 |
| spf.Fx | 0 |  | Volume force, x component | Domains 1–3 |
| spf.Fy | 0 |  | Volume force, y component | Domains 1–3 |
| spf.Fz | 0 |  | Volume force, z component | Domains 1–3 |
| spf.U | sqrt(u^2+v^2) |  | Velocity magnitude | Domains 1–3 |
| spf.vorticityx | 0 |  | Vorticity field, x component | Domains 1–3 |
| spf.vorticityy | 0 |  | Vorticity field, y component | Domains 1–3 |
| spf.vorticityz | vx-uy |  | Vorticity field, z component | Domains 1–3 |
| spf.vort\_magn | sqrt(spf.vorticityx^2+spf.vorticityy^2+spf.vorticityz^2) |  | Vorticity magnitude | Domains 1–3 |
| spf.cellRe | 0.25\*spf.rho\*sqrt(emetric(u,v)/emetric2)/spf.mu |  | Cell Reynolds number | Domains 1–3 |
| spf.nu | spf.mu/spf.rho |  | Kinematic viscosity | Domains 1–3 |
| spf.betaT | 0 |  | Isothermal compressibility coefficient | Domains 1–3 |
| spf.mu\_eff | spf.mu+spf.muT |  | Dynamic viscosity | Domains 1–3 |
| spf.muT | 0 |  | Turbulent dynamic viscosity | Domains 1–3 |
| spf.T\_stressx | spf.K\_stressx-p\*spf.nxmesh |  | Total stress, x component | Boundaries 1–10 |
| spf.T\_stressy | spf.K\_stressy-p\*spf.nymesh |  | Total stress, y component | Boundaries 1–10 |
| spf.T\_stressz | spf.K\_stressz-p\*spf.nzmesh |  | Total stress, z component | Boundaries 1–10 |
| spf.K\_stressx | spf.mu\_eff\*(2\*ux\*spf.nxmesh+(uy+vx)\*spf.nymesh) |  | Viscous stress, x component | Boundaries 1–10 |
| spf.K\_stressy | spf.mu\_eff\*((vx+uy)\*spf.nxmesh+2\*vy\*spf.nymesh) |  | Viscous stress, y component | Boundaries 1–10 |
| spf.K\_stressz | 0 |  | Viscous stress, z component | Boundaries 1–10 |
| spf.K\_stress\_tensorxx | 2\*spf.mu\_eff\*ux |  | Viscous stress tensor, xx component | Domains 1–3 |
| spf.K\_stress\_tensoryx | spf.mu\_eff\*(vx+uy) |  | Viscous stress tensor, yx component | Domains 1–3 |
| spf.K\_stress\_tensorzx | 0 |  | Viscous stress tensor, zx component | Domains 1–3 |
| spf.K\_stress\_tensorxy | spf.mu\_eff\*(uy+vx) |  | Viscous stress tensor, xy component | Domains 1–3 |
| spf.K\_stress\_tensoryy | 2\*spf.mu\_eff\*vy |  | Viscous stress tensor, yy component | Domains 1–3 |
| spf.K\_stress\_tensorzy | 0 |  | Viscous stress tensor, zy component | Domains 1–3 |
| spf.K\_stress\_tensorxz | 0 |  | Viscous stress tensor, xz component | Domains 1–3 |
| spf.K\_stress\_tensoryz | 0 |  | Viscous stress tensor, yz component | Domains 1–3 |
| spf.K\_stress\_tensorzz | 0 |  | Viscous stress tensor, zz component | Domains 1–3 |
| spf.K\_stress\_tensor\_testxx | 2\*spf.mu\_eff\*test(ux) |  | Viscous stress tensor test, xx component | Domains 1–3 |
| spf.K\_stress\_tensor\_testyx | spf.mu\_eff\*(test(vx)+test(uy)) |  | Viscous stress tensor test, yx component | Domains 1–3 |
| spf.K\_stress\_tensor\_testzx | 0 |  | Viscous stress tensor test, zx component | Domains 1–3 |
| spf.K\_stress\_tensor\_testxy | spf.mu\_eff\*(test(uy)+test(vx)) |  | Viscous stress tensor test, xy component | Domains 1–3 |
| spf.K\_stress\_tensor\_testyy | 2\*spf.mu\_eff\*test(vy) |  | Viscous stress tensor test, yy component | Domains 1–3 |
| spf.K\_stress\_tensor\_testzy | 0 |  | Viscous stress tensor test, zy component | Domains 1–3 |
| spf.K\_stress\_tensor\_testxz | 0 |  | Viscous stress tensor test, xz component | Domains 1–3 |
| spf.K\_stress\_tensor\_testyz | 0 |  | Viscous stress tensor test, yz component | Domains 1–3 |
| spf.K\_stress\_tensor\_testzz | 0 |  | Viscous stress tensor test, zz component | Domains 1–3 |
| spf.upwind\_helpx | u |  | Upwind term, x component | Domains 1–3 |
| spf.upwind\_helpy | v |  | Upwind term, y component | Domains 1–3 |
| spf.upwind\_helpz | 0 |  | Upwind term, z component | Domains 1–3 |
| spf.tau\_vdxx | 2\*spf.mu\*ux |  | Strain rate, xx component | Domains 1–3 |
| spf.tau\_vdyx | spf.mu\*(vx+uy) |  | Strain rate, yx component | Domains 1–3 |
| spf.tau\_vdzx | 0 |  | Strain rate, zx component | Domains 1–3 |
| spf.tau\_vdxy | spf.mu\*(uy+vx) |  | Strain rate, xy component | Domains 1–3 |
| spf.tau\_vdyy | 2\*spf.mu\*vy |  | Strain rate, yy component | Domains 1–3 |
| spf.tau\_vdzy | 0 |  | Strain rate, zy component | Domains 1–3 |
| spf.tau\_vdxz | 0 |  | Strain rate, xz component | Domains 1–3 |
| spf.tau\_vdyz | 0 |  | Strain rate, yz component | Domains 1–3 |
| spf.tau\_vdzz | 0 |  | Strain rate, zz component | Domains 1–3 |
| spf.Qvd | spf.tau\_vdxx\*ux+spf.tau\_vdxy\*uy+spf.tau\_vdyx\*vx+spf.tau\_vdyy\*vy |  | Viscous dissipation | Domains 1–3 |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| u | Lagrange (Quadratic) |  | Velocity field, x component | Material | Domains 1–3 |
| v | Lagrange (Quadratic) |  | Velocity field, y component | Material | Domains 1–3 |
| p | Lagrange (Linear) |  | Pressure | Material | Domains 1–3 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| (p-spf.K\_stress\_tensorxx)\*test(ux)-spf.K\_stress\_tensorxy\*test(uy)-spf.K\_stress\_tensoryx\*test(vx)+(p-spf.K\_stress\_tensoryy)\*test(vy) | Material | Domains 1–3 |
| spf.Fx\*test(u)+spf.Fy\*test(v) | Material | Domains 1–3 |
| spf.rho\*(-(ux\*u+uy\*v)\*test(u)-(vx\*u+vy\*v)\*test(v)) | Material | Domains 1–3 |
| -spf.rho\*spf.divu\*test(p) | Material | Domains 1–3 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 2–5, 8 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | No slip |
| Apply reaction terms on | Individual dependent variables |
| Use weak constraints | Off |
| Constraint method | Elemental |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.ubndx | 0 |  | Velocity at boundary, x component | Boundaries 2–5, 8 |
| spf.ubndy | 0 |  | Velocity at boundary, y component | Boundaries 2–5, 8 |
| spf.ubndz | 0 |  | Velocity at boundary, z component | Boundaries 2–5, 8 |

#### Shape functions

| **Constraint** | **Constraint force** | **Shape function** | **Selection** |
| --- | --- | --- | --- |
| -u+spf.ubndx | test(-u) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| -v+spf.ubndy | test(-v) | Lagrange (Quadratic) | Boundaries 2–5, 8 |
| spf.ubndz | 0 |  | Boundaries 2–5, 8 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Domains 1–3 |

Settings

| **Description** | **Value** |
| --- | --- |
| Velocity field | {0, 0, 0} |
| Pressure | 0 |

* + 1. inflow Bin\*gamma



inflow Bin\*gamma

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundary 1 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | gamma |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.f0 | gamma |  | Normal stress | Boundary 1 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -spf.f0\*(test(u)\*spf.nxmesh+test(v)\*spf.nymesh) | Material | Boundary 1 |

* + 1. Outflow



Outflow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Boundaries 9–10 |

Equations

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Normal stress |
| Normal stress | 0 |
| Turbulent intensity | 0.005 |
| Turbulence length scale | 0.1[m] |
| Turbulent kinetic energy | 2.5e-3[m^2/s^2] |
| Turbulent dissipation rate | 1.1e-4[m^2/s^3] |
| Specific dissipation rate | 0.5[1/s] |

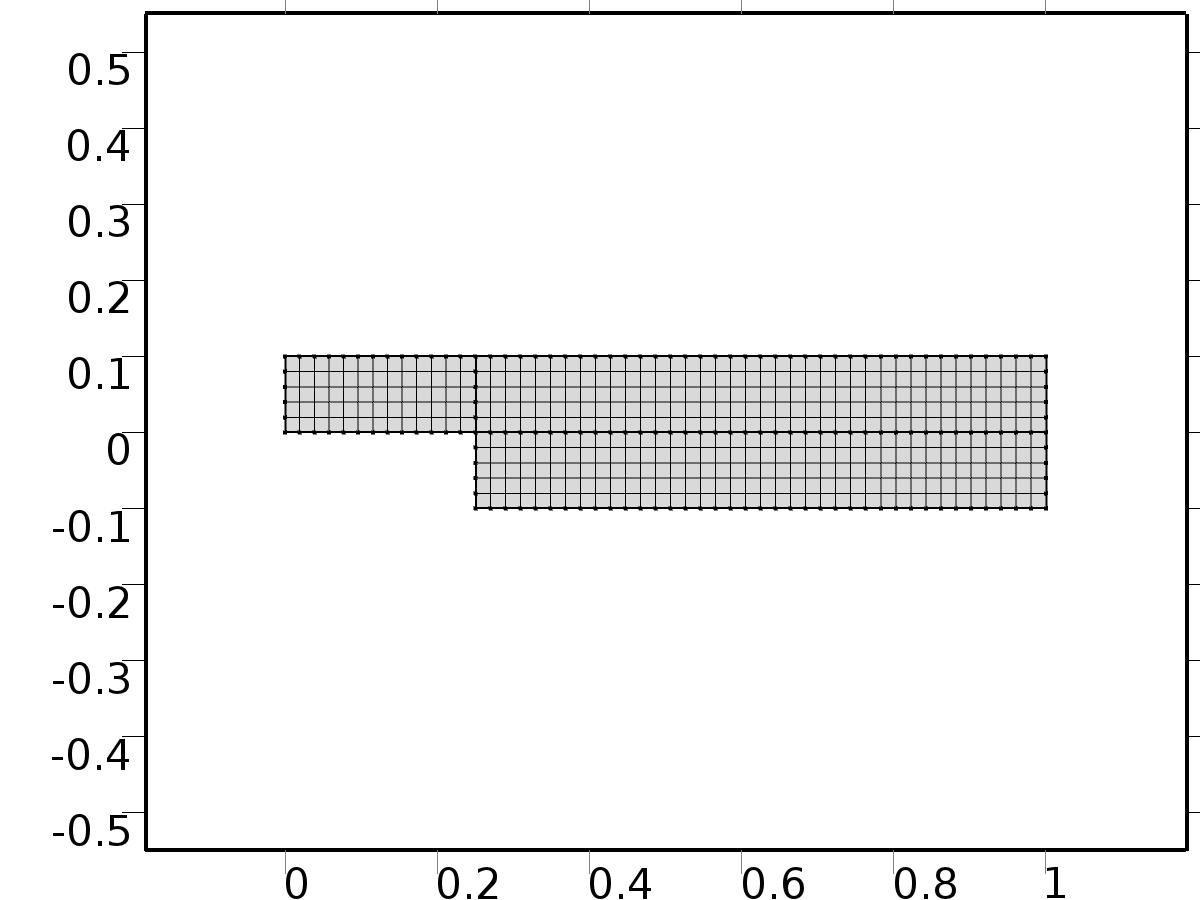
#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.f0 | 0 |  | Normal stress | Boundaries 9–10 |

#### Weak expressions

| **Weak expression** | **Integration frame** | **Selection** |
| --- | --- | --- |
| -spf.f0\*(test(u)\*spf.nxmesh+test(v)\*spf.nymesh) | Material | Boundaries 9–10 |

* 1. Mesh 1



Mesh 1

* + 1. Size (size)

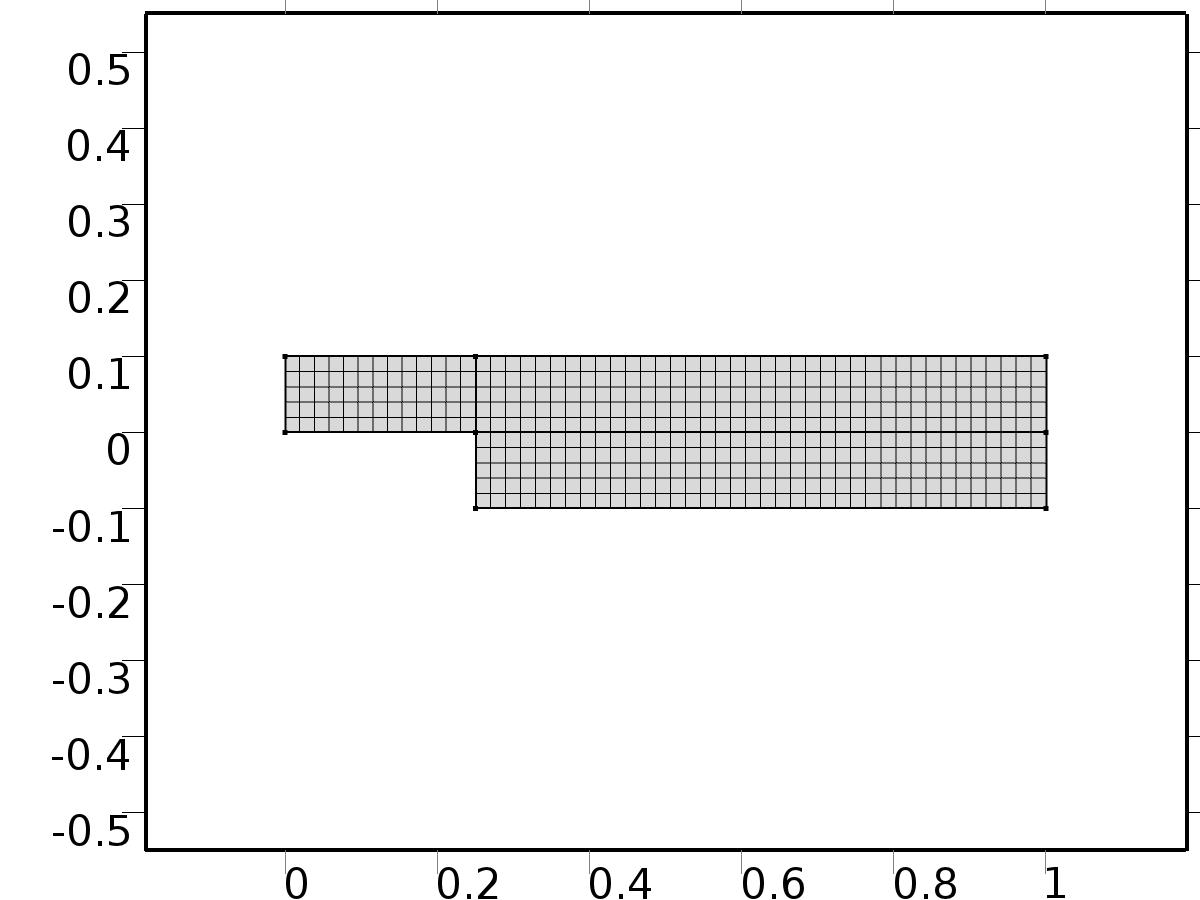
Settings

| **Description** | **Value** |
| --- | --- |
| Maximum element size | 0.067 |
| Minimum element size | 3.0E-4 |
| Curvature factor | 0.3 |
| Maximum element growth rate | 1.3 |

* + 1. Mapped 1 (map1)

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1 |

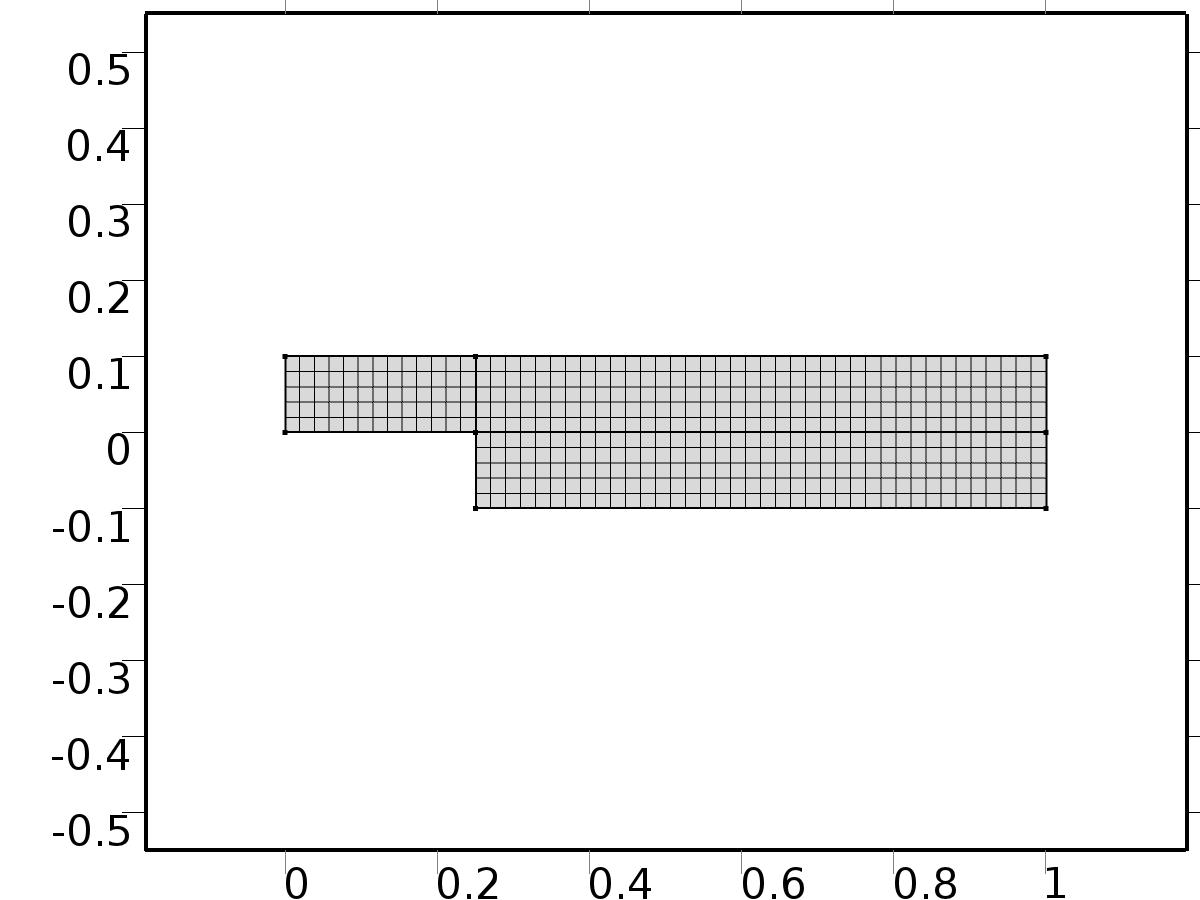


Mapped 1

#### Size 1 (size1)

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1 |



Size 1

Settings

| **Description** | **Value** |
| --- | --- |
| Maximum element size | D/5 |
| Minimum element size | D/5 |
| Curvature factor | 0.3 |
| Curvature factor | Off |
| Resolution of narrow regions | Off |
| Maximum element growth rate | 1.3 |
| Maximum element growth rate | Off |
| Custom element size | Custom |

1. Study 1
   1. Stationary

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Laminar Flow (spf) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* 1. Solver Configurations
     1. Solver 1

#### Compile Equations: Stationary (st1)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | Study 1 |
| Use study step | Stationary |

#### Dependent Variables 1 (v1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Stationary |
| Constant |  |

Initial values of variables solved for

| **Description** | **Value** |
| --- | --- |
| Solution | Zero |

Values of variables not solved for

| **Description** | **Value** |
| --- | --- |
| Solution | Zero |

##### Pressure (comp1.P) (comp1\_P)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P |

##### Velocity field (comp1.U) (comp1\_U)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U, comp1.V} |

##### Pressure (comp1.ap0) (comp1\_ap0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap0 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.au0) (comp1\_au0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au0, comp1.av0} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.atp0) (comp1\_atp0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp0 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.atu0) (comp1\_atu0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu0, comp1.atv0} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.ap1) (comp1\_ap1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap1 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.au1) (comp1\_au1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au1, comp1.av1} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.atp1) (comp1\_atp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp1 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.atu1) (comp1\_atu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu1, comp1.atv1} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.bp1) (comp1\_bp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp1 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.bu1) (comp1\_bu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu1, comp1.bv1} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.btp1) (comp1\_btp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp1 |
| Solve for this field | Off |
| Field name | comp1\_p |

##### Velocity field (comp1.btu1) (comp1\_btu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu1, comp1.btv1} |
| Solve for this field | Off |
| Field name | comp1\_u |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |
| Solve for this field | Off |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v} |
| Solve for this field | Off |

##### Pressure (comp1.ap2) (comp1\_ap2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap2 |
| Solve for this field | Off |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au2) (comp1\_au2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au2, comp1.av2} |
| Solve for this field | Off |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu2) (comp1\_atu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu2, comp1.atv2} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp2) (comp1\_atp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp2 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu2) (comp1\_bu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu2, comp1.bv2} |
| Solve for this field | Off |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp2) (comp1\_bp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp2 |
| Solve for this field | Off |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu2) (comp1\_btu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu2, comp1.btv2} |
| Solve for this field | Off |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp2) (comp1\_btp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp2 |
| Solve for this field | Off |
| Field name | comp1\_p5 |

##### Pressure (comp1.ap3) (comp1\_ap3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap3 |
| Solve for this field | Off |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au3) (comp1\_au3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au3, comp1.av3} |
| Solve for this field | Off |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu3) (comp1\_atu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu3, comp1.atv3} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp3) (comp1\_atp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp3 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu3) (comp1\_bu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu3, comp1.bv3} |
| Solve for this field | Off |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp3) (comp1\_bp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp3 |
| Solve for this field | Off |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu3) (comp1\_btu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu3, comp1.btv3} |
| Solve for this field | Off |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp3) (comp1\_btp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp3 |
| Solve for this field | Off |
| Field name | comp1\_p5 |

##### Pressure (comp1.p2) (comp1\_p2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p2 |
| Solve for this field | Off |

##### Velocity field (comp1.u2) (comp1\_u2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u2, comp1.v2} |
| Solve for this field | Off |

##### Velocity field (comp1.ut2) (comp1\_ut2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.ut2, comp1.vt2} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.pt2) (comp1\_pt2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.pt2 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.U1) (comp1\_U1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U1, comp1.V1} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.P1) (comp1\_P1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P1 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

#### Stationary Solver 1 (s1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Stationary |
| Relative tolerance | 0.000010 |

Log

| **Description** | **Value** |
| --- | --- |
| Constant |  |

##### Fully Coupled 1 (fc1)

General

| **Description** | **Value** |
| --- | --- |
| Linear solver | Direct 1 |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Initial damping factor | 0.01 |
| Minimum damping factor | 1.0E-6 |

##### Direct 1 (d1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |

1. Study 2
   1. Stationary

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Laminar Flow 1 (phys1) | physics |
| Laminar Flow 2 (phys2) | physics |
| Laminar Flow 3 (phys3) | physics |
| Laminar Flow 4 (spf2) | physics |
| Laminar Flow 5 (phys4) | physics |
| Laminar Flow 6 (phys5) | physics |
| Laminar Flow 7 (phys7) | physics |
| Laminar Flow 8 (spf3) | physics |
| Laminar Flow 9 (spf4) | physics |
| Laminar Flow 10 (spf5) | physics |
| Laminar Flow 11 (phys8) | physics |
| Laminar Flow 12 (phys9) | physics |
| Laminar Flow 13 (phys10) | physics |
| Laminar Flow 14 (phys11) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* 1. Solver Configurations
     1. Solver 2

#### Compile Equations: Stationary (st1)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | Study 2 |
| Use study step | Stationary |

#### Dependent Variables 1 (v1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Stationary |
| Constant |  |

Initial values of variables solved for

| **Description** | **Value** |
| --- | --- |
| Solution | Zero |

Values of variables not solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | Solver 1 |

##### Pressure (comp1.atp0) (comp1\_atp0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp0 |

##### Velocity field (comp1.atu0) (comp1\_atu0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu0, comp1.atv0} |

##### Pressure (comp1.P) (comp1\_P)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P |
| Solve for this field | Off |

##### Pressure (comp1.ap0) (comp1\_ap0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap0 |

##### Velocity field (comp1.au0) (comp1\_au0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au0, comp1.av0} |

##### Velocity field (comp1.U) (comp1\_U)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U, comp1.V} |
| Solve for this field | Off |

##### Pressure (comp1.ap1) (comp1\_ap1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap1 |
| Field name | comp1\_p |

##### Velocity field (comp1.au1) (comp1\_au1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au1, comp1.av1} |
| Field name | comp1\_u |

##### Pressure (comp1.atp1) (comp1\_atp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp1 |
| Field name | comp1\_p |

##### Velocity field (comp1.atu1) (comp1\_atu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu1, comp1.atv1} |
| Field name | comp1\_u |

##### Pressure (comp1.bp1) (comp1\_bp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp1 |
| Field name | comp1\_p |

##### Velocity field (comp1.bu1) (comp1\_bu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu1, comp1.bv1} |
| Field name | comp1\_u |

##### Pressure (comp1.btp1) (comp1\_btp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp1 |
| Field name | comp1\_p |

##### Velocity field (comp1.btu1) (comp1\_btu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu1, comp1.btv1} |
| Field name | comp1\_u |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |
| Solve for this field | Off |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v} |
| Solve for this field | Off |

##### Pressure (comp1.ap2) (comp1\_ap2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap2 |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au2) (comp1\_au2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au2, comp1.av2} |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu2) (comp1\_atu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu2, comp1.atv2} |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp2) (comp1\_atp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp2 |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu2) (comp1\_bu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu2, comp1.bv2} |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp2) (comp1\_bp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp2 |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu2) (comp1\_btu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu2, comp1.btv2} |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp2) (comp1\_btp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp2 |
| Field name | comp1\_p5 |

##### Pressure (comp1.ap3) (comp1\_ap3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap3 |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au3) (comp1\_au3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au3, comp1.av3} |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu3) (comp1\_atu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu3, comp1.atv3} |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp3) (comp1\_atp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp3 |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu3) (comp1\_bu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu3, comp1.bv3} |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp3) (comp1\_bp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp3 |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu3) (comp1\_btu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu3, comp1.btv3} |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp3) (comp1\_btp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp3 |
| Field name | comp1\_p5 |

##### Pressure (comp1.p2) (comp1\_p2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p2 |
| Solve for this field | Off |

##### Velocity field (comp1.u2) (comp1\_u2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u2, comp1.v2} |
| Solve for this field | Off |

##### Velocity field (comp1.ut2) (comp1\_ut2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.ut2, comp1.vt2} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.pt2) (comp1\_pt2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.pt2 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.U1) (comp1\_U1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U1, comp1.V1} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.P1) (comp1\_P1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P1 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

#### Stationary Solver 1 (s1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Stationary |
| Relative tolerance | 0.000010 |

Log

| **Description** | **Value** |
| --- | --- |
| Constant |  |

##### Fully Coupled 1 (fc1)

General

| **Description** | **Value** |
| --- | --- |
| Linear solver | Direct 1 |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Initial damping factor | 0.01 |
| Minimum damping factor | 1.0E-6 |

##### Direct 1 (d1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |

1. Study 3
   1. Time Dependent

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

| **Times** | **Unit** |
| --- | --- |
| range(0,0.1,20) | s |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Laminar Flow 14a (phys14) | physics |
| Laminar Flow 15 (phys12) | physics |
| Laminar Flow 16 (phys13) | physics |
| Closed loop system (phys6) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* 1. Solver Configurations
     1. Solver 3

#### Compile Equations: Time Dependent (st1)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | Study 3 |
| Use study step | Time Dependent |

#### Dependent Variables 1 (v1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Time Dependent |
| Constant |  |

Initial values of variables solved for

| **Description** | **Value** |
| --- | --- |
| Solution | Solver 2 |

Values of variables not solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | Solver 2 |

##### Pressure (comp1.atp0) (comp1\_atp0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp0 |
| Solve for this field | Off |

##### Pressure (comp1.atp1) (comp1\_atp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp1 |
| Solve for this field | Off |

##### Velocity field (comp1.au0) (comp1\_au0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au0, comp1.av0} |
| Solve for this field | Off |

##### Pressure (comp1.bp1) (comp1\_bp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp1 |
| Solve for this field | Off |

##### Velocity field (comp1.atu0) (comp1\_atu0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu0, comp1.atv0} |
| Solve for this field | Off |

##### Velocity field (comp1.au1) (comp1\_au1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au1, comp1.av1} |
| Solve for this field | Off |

##### Pressure (comp1.P) (comp1\_P)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P |
| Solve for this field | Off |

##### Velocity field (comp1.atu1) (comp1\_atu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu1, comp1.atv1} |
| Solve for this field | Off |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |

##### Pressure (comp1.ap0) (comp1\_ap0)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap0 |
| Solve for this field | Off |

##### Velocity field (comp1.btu1) (comp1\_btu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu1, comp1.btv1} |
| Solve for this field | Off |

##### Pressure (comp1.ap1) (comp1\_ap1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap1 |
| Solve for this field | Off |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v} |

##### Velocity field (comp1.U) (comp1\_U)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U, comp1.V} |
| Solve for this field | Off |

##### Velocity field (comp1.bu1) (comp1\_bu1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu1, comp1.bv1} |
| Solve for this field | Off |

##### Pressure (comp1.btp1) (comp1\_btp1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp1 |
| Solve for this field | Off |

##### Pressure (comp1.ap2) (comp1\_ap2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap2 |
| Solve for this field | Off |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au2) (comp1\_au2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au2, comp1.av2} |
| Solve for this field | Off |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu2) (comp1\_atu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu2, comp1.atv2} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp2) (comp1\_atp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp2 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu2) (comp1\_bu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu2, comp1.bv2} |
| Solve for this field | Off |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp2) (comp1\_bp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp2 |
| Solve for this field | Off |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu2) (comp1\_btu2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu2, comp1.btv2} |
| Solve for this field | Off |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp2) (comp1\_btp2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp2 |
| Solve for this field | Off |
| Field name | comp1\_p5 |

##### Pressure (comp1.ap3) (comp1\_ap3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.ap3 |
| Solve for this field | Off |
| Field name | comp1\_p2 |

##### Velocity field (comp1.au3) (comp1\_au3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.au3, comp1.av3} |
| Solve for this field | Off |
| Field name | comp1\_u2 |

##### Velocity field (comp1.atu3) (comp1\_atu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.atu3, comp1.atv3} |
| Solve for this field | Off |
| Field name | comp1\_u3 |

##### Pressure (comp1.atp3) (comp1\_atp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.atp3 |
| Solve for this field | Off |
| Field name | comp1\_p3 |

##### Velocity field (comp1.bu3) (comp1\_bu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.bu3, comp1.bv3} |
| Solve for this field | Off |
| Field name | comp1\_u4 |

##### Pressure (comp1.bp3) (comp1\_bp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.bp3 |
| Solve for this field | Off |
| Field name | comp1\_p4 |

##### Velocity field (comp1.btu3) (comp1\_btu3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.btu3, comp1.btv3} |
| Solve for this field | Off |
| Field name | comp1\_u5 |

##### Pressure (comp1.btp3) (comp1\_btp3)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.btp3 |
| Solve for this field | Off |
| Field name | comp1\_p5 |

##### Pressure (comp1.p2) (comp1\_p2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p2 |

##### Velocity field (comp1.u2) (comp1\_u2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u2, comp1.v2} |

##### Velocity field (comp1.ut2) (comp1\_ut2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.ut2, comp1.vt2} |
| Field name | comp1\_u3 |

##### Pressure (comp1.pt2) (comp1\_pt2)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.pt2 |
| Field name | comp1\_p3 |

##### Velocity field (comp1.U1) (comp1\_U1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.U1, comp1.V1} |
| Field name | comp1\_u3 |

##### Pressure (comp1.P1) (comp1\_P1)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.P1 |
| Field name | comp1\_p3 |

#### Time-Dependent Solver 1 (t1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | Time Dependent |
| Time | {0, 0.1, 0.2, 0.30000000000000004, 0.4, 0.5, 0.6000000000000001, 0.7000000000000001, 0.8, 0.9, 1, 1.1, 1.2000000000000002, 1.3, 1.4000000000000001, 1.5, 1.6, 1.7000000000000002, 1.8, 1.9000000000000001, 2, 2.1, 2.2, 2.3000000000000003, 2.4000000000000004, 2.5, 2.6, 2.7, 2.8000000000000003, 2.9000000000000004, 3, 3.1, 3.2, 3.3000000000000003, 3.4000000000000004, 3.5, 3.6, 3.7, 3.8000000000000003, 3.9000000000000004, 4, 4.1000000000000005, 4.2, 4.3, 4.4, 4.5, 4.6000000000000005, 4.7, 4.800000000000001, 4.9, 5, 5.1000000000000005, 5.2, 5.300000000000001, 5.4, 5.5, 5.6000000000000005, 5.7, 5.800000000000001, 5.9, 6, 6.1000000000000005, 6.2, 6.300000000000001, 6.4, 6.5, 6.6000000000000005, 6.7, 6.800000000000001, 6.9, 7, 7.1000000000000005, 7.2, 7.300000000000001, 7.4, 7.5, 7.6000000000000005, 7.7, 7.800000000000001, 7.9, 8, 8.1, 8.200000000000001, 8.3, 8.4, 8.5, 8.6, 8.700000000000001, 8.8, 8.9, 9, 9.1, 9.200000000000001, 9.3, 9.4, 9.5, 9.600000000000001, 9.700000000000001, 9.8, 9.9, 10, 10.100000000000001, 10.200000000000001, 10.3, 10.4, 10.5, 10.600000000000001, 10.700000000000001, 10.8, 10.9, 11, 11.100000000000001, 11.200000000000001, 11.3, 11.4, 11.5, 11.600000000000001, 11.700000000000001, 11.8, 11.9, 12, 12.100000000000001, 12.200000000000001, 12.3, 12.4, 12.5, 12.600000000000001, 12.700000000000001, 12.8, 12.9, 13, 13.100000000000001, 13.200000000000001, 13.3, 13.4, 13.5, 13.600000000000001, 13.700000000000001, 13.8, 13.9, 14, 14.100000000000001, 14.200000000000001, 14.3, 14.4, 14.5, 14.600000000000001, 14.700000000000001, 14.8, 14.9, 15, 15.100000000000001, 15.200000000000001, 15.3, 15.4, 15.5, 15.600000000000001, 15.700000000000001, 15.8, 15.9, 16, 16.1, 16.2, 16.3, 16.400000000000002, 16.5, 16.6, 16.7, 16.8, 16.900000000000002, 17, 17.1, 17.2, 17.3, 17.400000000000002, 17.5, 17.6, 17.7, 17.8, 17.900000000000002, 18, 18.1, 18.2, 18.3, 18.400000000000002, 18.5, 18.6, 18.7, 18.8, 18.900000000000002, 19, 19.1, 19.200000000000003, 19.3, 19.400000000000002, 19.5, 19.6, 19.700000000000003, 19.8, 19.900000000000002, 20} |
| Relative tolerance | 0.0001 |

Absolute tolerance

| **Description** | **Value** |
| --- | --- |
| Tolerance | 5.0E-4 |

Time stepping

| **Description** | **Value** |
| --- | --- |
| Initial step | 0.0010 |

Advanced

| **Description** | **Value** |
| --- | --- |
| Fraction of initial step for Backward Euler | 0.0010 |
| Error estimation | Exclude algebraic |

Log

| **Description** | **Value** |
| --- | --- |
| Constant |  |

##### Fully Coupled 1 (fc1)

General

| **Description** | **Value** |
| --- | --- |
| Linear solver | Direct 1 |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Jacobian update | Once per time step |
| Maximum number of iterations | 6 |

##### Direct 1 (d1)

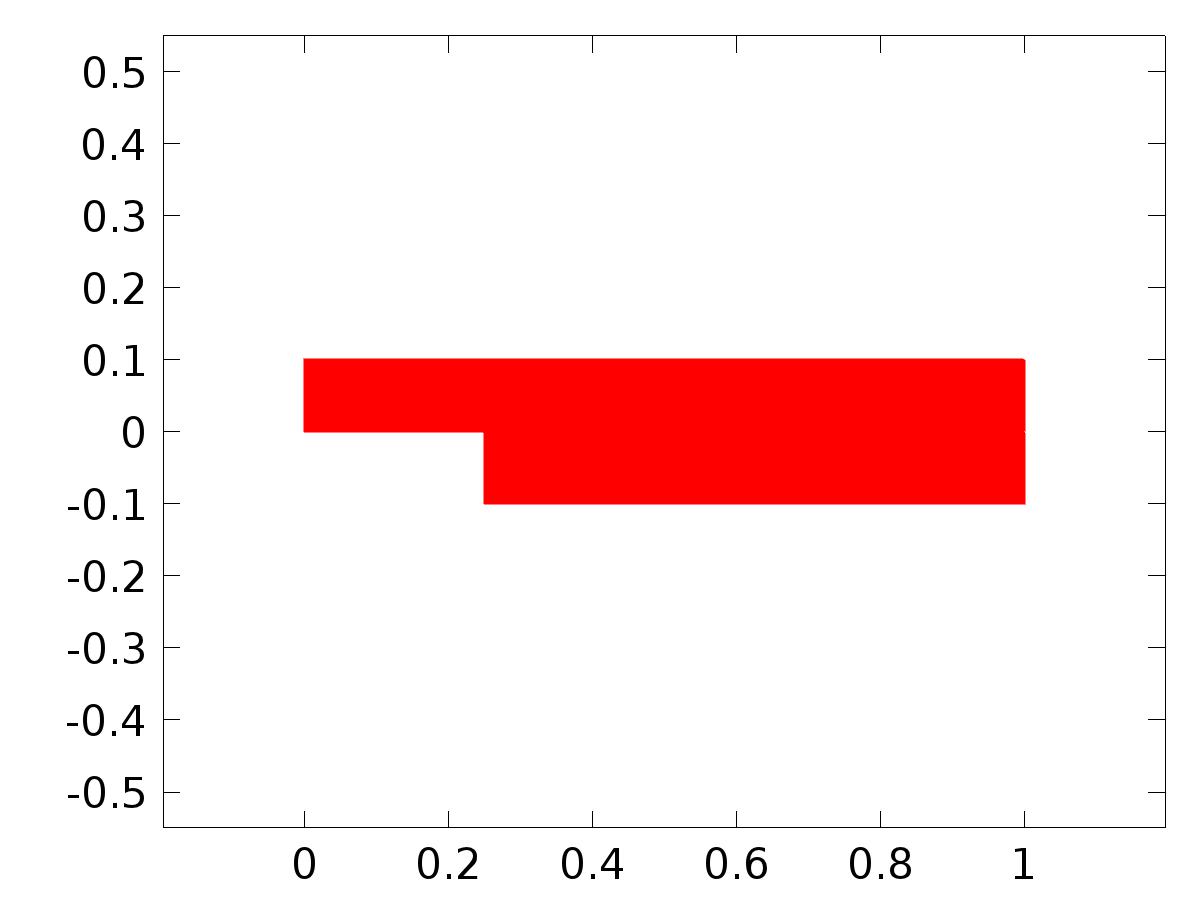
General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |

1. Results
   1. Data Sets
      1. Solution 1

Solution

| **Description** | **Value** |
| --- | --- |
| Solution | Solver 1 |
| Component | Save Point Geometry 1 |

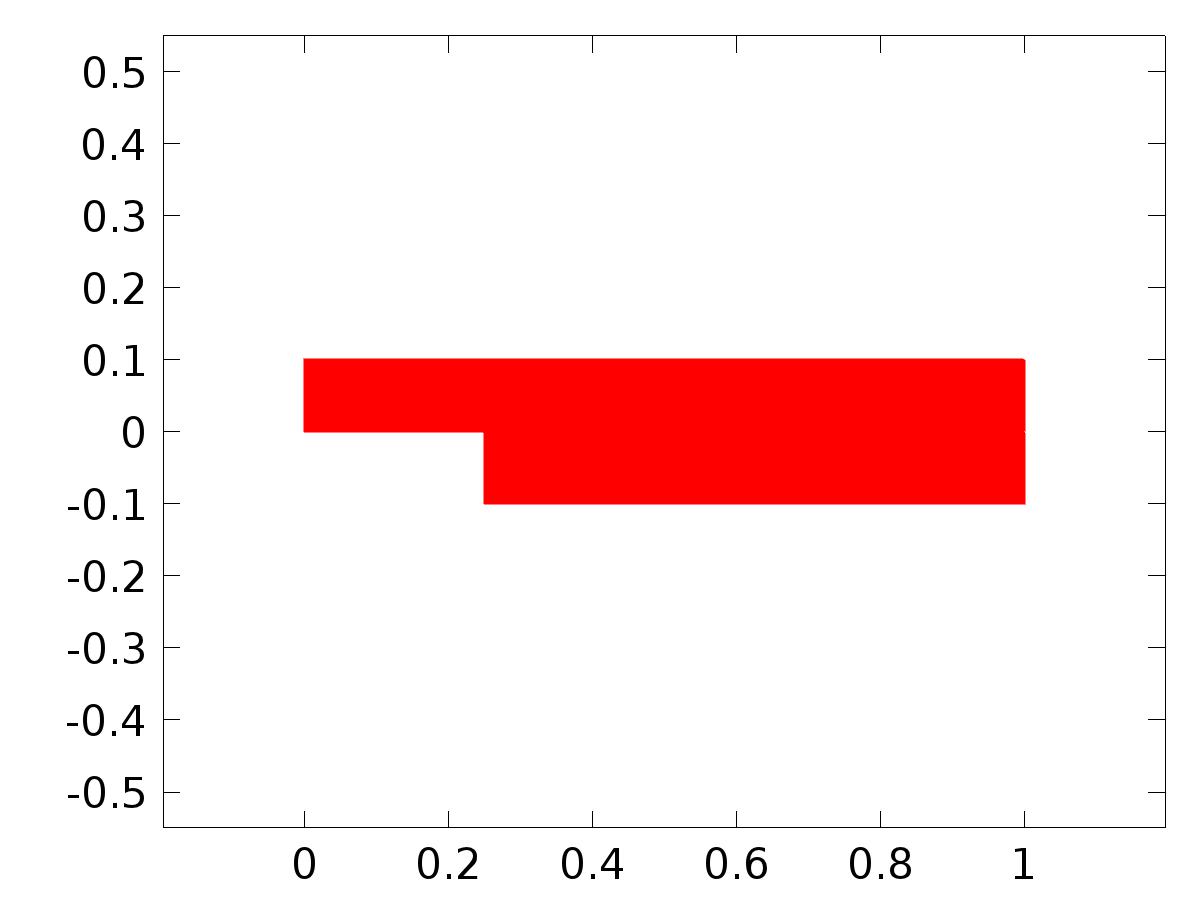


Data set: Solution 1

* + 1. Solution 2

Solution

| **Description** | **Value** |
| --- | --- |
| Solution | Solver 2 |
| Component | Save Point Geometry 1 |

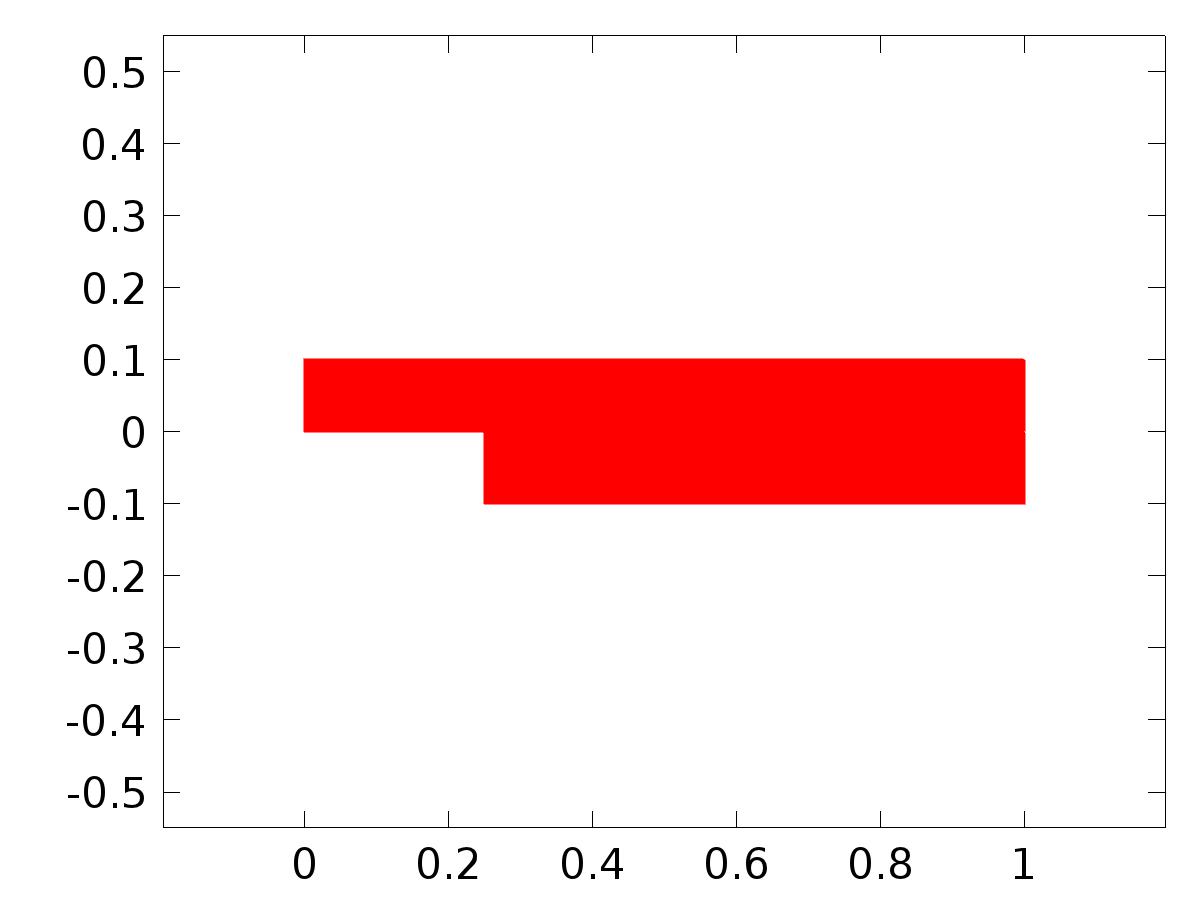


Data set: Solution 2

* + 1. Solution 3

Solution

| **Description** | **Value** |
| --- | --- |
| Solution | Solver 3 |
| Component | Save Point Geometry 1 |



Data set: Solution 3

* 1. Derived Values
     1. Global Evaluation 1

Data

| **Description** | **Value** |
| --- | --- |
| Data set | Solution 3 |

Expression

| **Description** | **Value** |
| --- | --- |
| Expression | gamma |

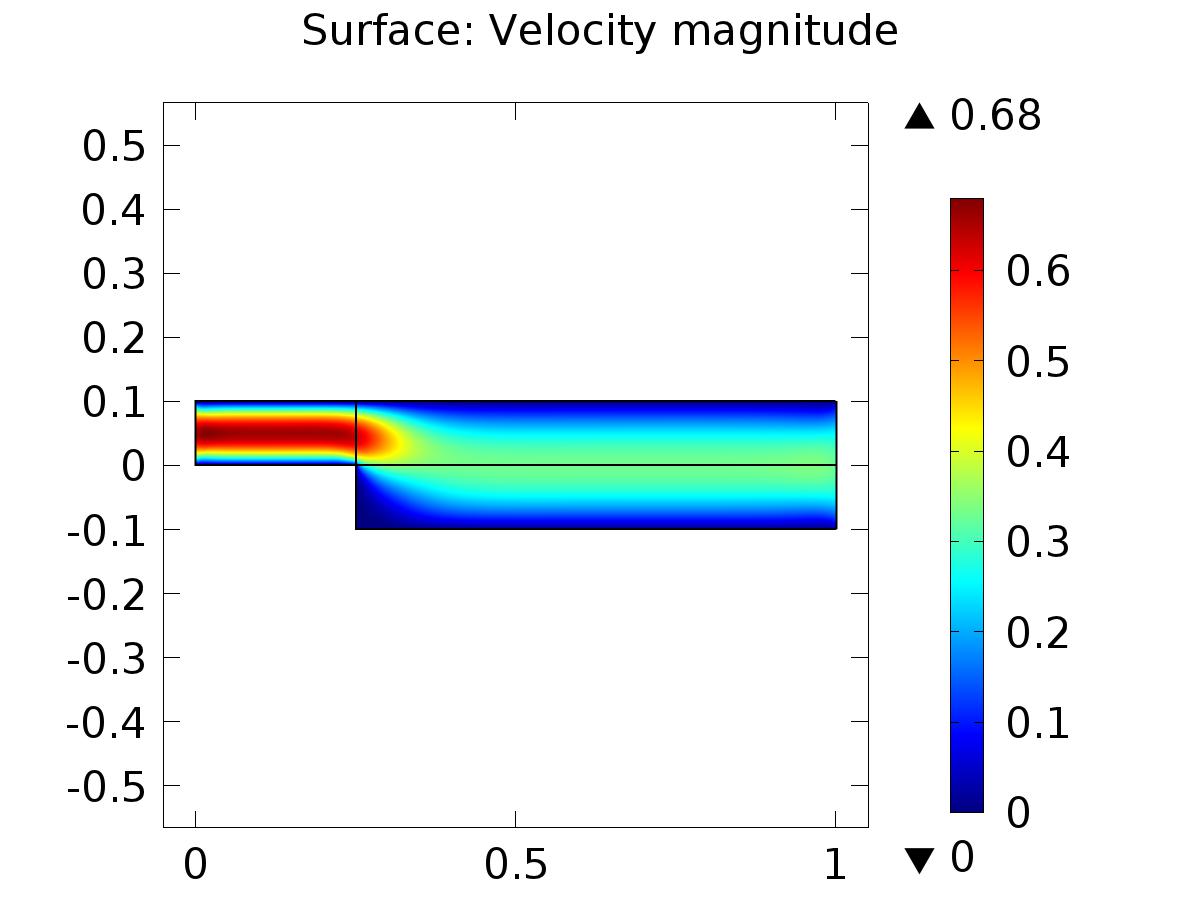
* 1. Tables
     1. Table 1

Global Evaluation 1 (C(au0))

Table 1

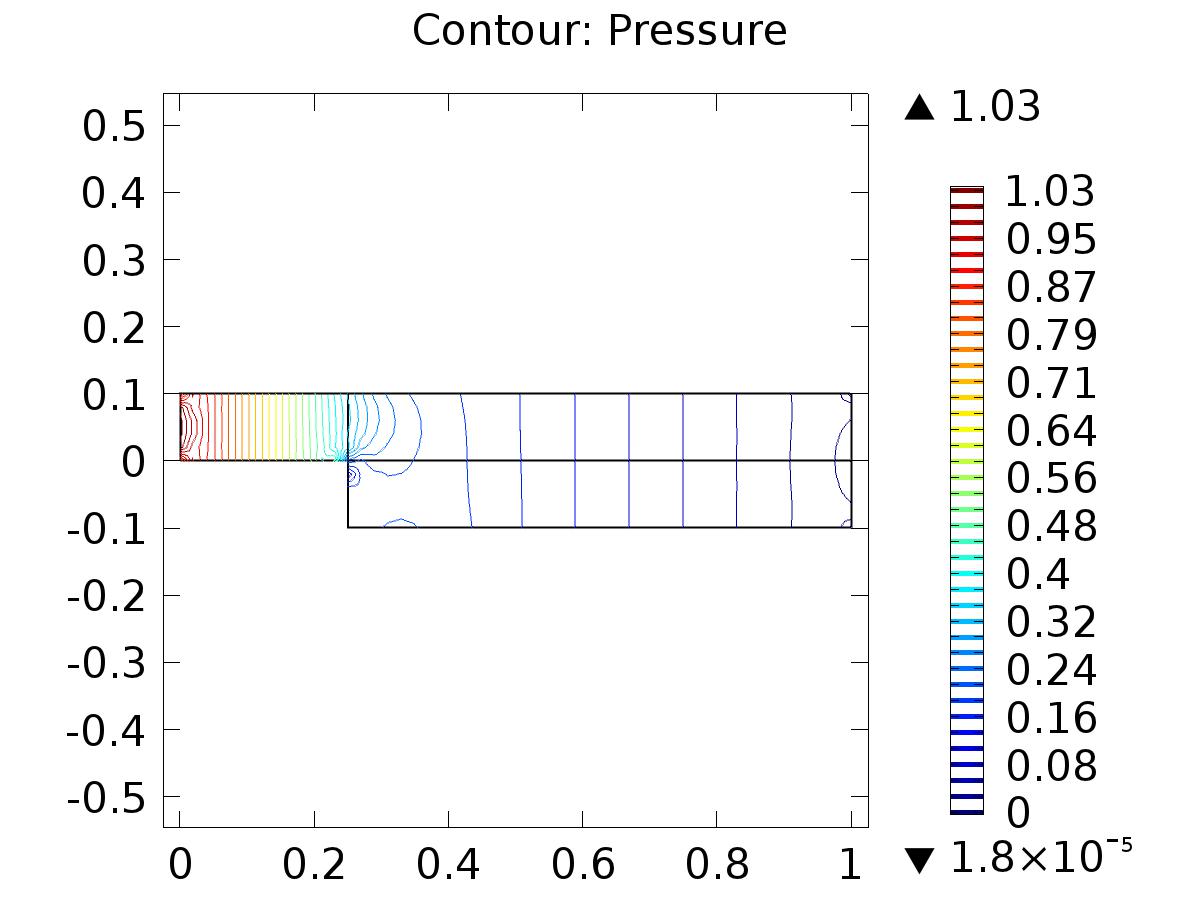
| **Time (s)** | **C(u)** | **C(U1)** | **yr** | **C(U2)** | **gamma** |
| --- | --- | --- | --- | --- | --- |
| 0.0000 | 1.6386E-5 | 0.10000 | 0.10000 | 0.10000 | 2.7552 |
| 0.10000 | 0.032991 | 0.11002 | 0.10998 | 0.10998 | 2.9433 |
| 0.20000 | 0.059461 | 0.11990 | 0.11987 | 0.11987 | 3.1152 |
| 0.30000 | 0.081960 | 0.12958 | 0.12955 | 0.12955 | 3.2751 |
| 0.40000 | 0.10138 | 0.13895 | 0.13894 | 0.13894 | 3.4220 |
| 0.50000 | 0.11828 | 0.14793 | 0.14794 | 0.14794 | 3.5546 |
| 0.60000 | 0.13303 | 0.15643 | 0.15646 | 0.15646 | 3.6718 |
| 0.70000 | 0.14591 | 0.16437 | 0.16442 | 0.16442 | 3.7725 |
| 0.80000 | 0.15712 | 0.17168 | 0.17174 | 0.17174 | 3.8558 |
| 0.90000 | 0.16680 | 0.17828 | 0.17833 | 0.17833 | 3.9211 |
| 1.0000 | 0.17506 | 0.18411 | 0.18415 | 0.18415 | 3.9677 |
| 1.1000 | 0.18197 | 0.18909 | 0.18912 | 0.18912 | 3.9951 |
| 1.2000 | 0.18759 | 0.19319 | 0.19320 | 0.19320 | 4.0027 |
| 1.3000 | 0.19194 | 0.19636 | 0.19636 | 0.19636 | 3.9903 |
| 1.4000 | 0.19509 | 0.19857 | 0.19854 | 0.19855 | 3.9582 |
| 1.5000 | 0.19704 | 0.19978 | 0.19975 | 0.19975 | 3.9062 |
| 1.6000 | 0.19784 | 0.19999 | 0.19996 | 0.19996 | 3.8345 |
| 1.7000 | 0.19752 | 0.19920 | 0.19917 | 0.19917 | 3.7439 |
| 1.8000 | 0.19609 | 0.19742 | 0.19738 | 0.19738 | 3.6353 |
| 1.9000 | 0.19362 | 0.19466 | 0.19463 | 0.19463 | 3.5099 |
| 2.0000 | 0.19014 | 0.19095 | 0.19093 | 0.19093 | 3.3691 |
| 2.1000 | 0.18570 | 0.18633 | 0.18632 | 0.18632 | 3.2144 |
| 2.2000 | 0.18036 | 0.18085 | 0.18085 | 0.18085 | 3.0478 |
| 2.3000 | 0.17419 | 0.17456 | 0.17457 | 0.17457 | 2.8705 |
| 2.4000 | 0.16725 | 0.16753 | 0.16755 | 0.16755 | 2.6848 |
| 2.5000 | 0.15961 | 0.15982 | 0.15985 | 0.15985 | 2.4924 |
| 2.6000 | 0.15136 | 0.15151 | 0.15155 | 0.15155 | 2.2951 |
| 2.7000 | 0.14259 | 0.14270 | 0.14274 | 0.14274 | 2.0948 |
| 2.8000 | 0.13338 | 0.13346 | 0.13350 | 0.13350 | 1.8932 |
| 2.9000 | 0.12384 | 0.12390 | 0.12392 | 0.12393 | 1.6922 |
| 3.0000 | 0.11404 | 0.11411 | 0.11411 | 0.11411 | 1.4936 |
| 3.1000 | 0.10410 | 0.10418 | 0.10416 | 0.10416 | 1.2992 |
| 3.2000 | 0.094119 | 0.094208 | 0.094163 | 0.094163 | 1.1108 |
| 3.3000 | 0.084192 | 0.084294 | 0.084225 | 0.084226 | 0.93003 |
| 3.4000 | 0.074419 | 0.074529 | 0.074446 | 0.074446 | 0.75867 |
| 3.5000 | 0.064900 | 0.065007 | 0.064922 | 0.064922 | 0.59828 |
| 3.6000 | 0.055731 | 0.055820 | 0.055748 | 0.055747 | 0.45034 |
| 3.7000 | 0.047002 | 0.047059 | 0.047016 | 0.047015 | 0.31623 |
| 3.8000 | 0.038802 | 0.038814 | 0.038814 | 0.038813 | 0.19719 |
| 3.9000 | 0.031214 | 0.031173 | 0.031223 | 0.031222 | 0.094367 |
| 4.0000 | 0.024312 | 0.024221 | 0.024320 | 0.024318 | 0.0088575 |
| 4.1000 | 0.018167 | 0.018037 | 0.018172 | 0.018171 | -0.058226 |
| 4.2000 | 0.012839 | 0.012690 | 0.012842 | 0.012842 | -0.10574 |
| 4.3000 | 0.0083813 | 0.0082388 | 0.0083834 | 0.0083840 | -0.13251 |
| 4.4000 | 0.0048391 | 0.0047273 | 0.0048398 | 0.0048412 | -0.13749 |
| 4.5000 | 0.0022474 | 0.0021864 | 0.0022470 | 0.0022490 | -0.11980 |
| 4.6000 | 6.3192E-4 | 6.3298E-4 | 6.3090E-4 | 6.3311E-4 | -0.078928 |
| 4.7000 | 8.8292E-6 | 7.2395E-5 | 7.6742E-6 | 9.7254E-6 | -0.014774 |
| 4.8000 | 3.8440E-4 | 5.0001E-4 | 3.8354E-4 | 3.8508E-4 | 0.072232 |
| 4.9000 | 0.0017550 | 0.0019031 | 0.0017547 | 0.0017555 | 0.18112 |
| 5.0000 | 0.0041070 | 0.0042626 | 0.0041076 | 0.0041074 | 0.31037 |
| 5.1000 | 0.0074172 | 0.0075538 | 0.0074185 | 0.0074175 | 0.45800 |
| 5.2000 | 0.011653 | 0.011747 | 0.011655 | 0.011653 | 0.62163 |
| 5.3000 | 0.016771 | 0.016808 | 0.016773 | 0.016771 | 0.79864 |
| 5.4000 | 0.022721 | 0.022696 | 0.022724 | 0.022721 | 0.98633 |
| 5.5000 | 0.029444 | 0.029364 | 0.029446 | 0.029444 | 1.1821 |
| 5.6000 | 0.036872 | 0.036754 | 0.036873 | 0.036872 | 1.3835 |
| 5.7000 | 0.044931 | 0.044798 | 0.044931 | 0.044931 | 1.5885 |
| 5.8000 | 0.053540 | 0.053417 | 0.053540 | 0.053540 | 1.7952 |
| 5.9000 | 0.062614 | 0.062520 | 0.062612 | 0.062614 | 2.0018 |
| 6.0000 | 0.072060 | 0.072008 | 0.072058 | 0.072060 | 2.2066 |
| 6.1000 | 0.081785 | 0.081778 | 0.081784 | 0.081785 | 2.4078 |
| 6.2000 | 0.091692 | 0.091724 | 0.091691 | 0.091692 | 2.6038 |
| 6.3000 | 0.10168 | 0.10174 | 0.10168 | 0.10168 | 2.7928 |
| 6.4000 | 0.11166 | 0.11172 | 0.11165 | 0.11166 | 2.9730 |
| 6.5000 | 0.12151 | 0.12158 | 0.12151 | 0.12151 | 3.1428 |
| 6.6000 | 0.13115 | 0.13120 | 0.13115 | 0.13115 | 3.3007 |
| 6.7000 | 0.14048 | 0.14051 | 0.14048 | 0.14048 | 3.4454 |
| 6.8000 | 0.14941 | 0.14941 | 0.14941 | 0.14941 | 3.5755 |
| 6.9000 | 0.15784 | 0.15782 | 0.15784 | 0.15784 | 3.6899 |
| 7.0000 | 0.16570 | 0.16566 | 0.16570 | 0.16570 | 3.7877 |
| 7.1000 | 0.17290 | 0.17285 | 0.17290 | 0.17290 | 3.8681 |
| 7.2000 | 0.17937 | 0.17932 | 0.17937 | 0.17937 | 3.9303 |
| 7.3000 | 0.18504 | 0.18501 | 0.18504 | 0.18504 | 3.9737 |
| 7.4000 | 0.18987 | 0.18985 | 0.18987 | 0.18987 | 3.9978 |
| 7.5000 | 0.19380 | 0.19379 | 0.19380 | 0.19380 | 4.0022 |
| 7.6000 | 0.19679 | 0.19680 | 0.19679 | 0.19679 | 3.9866 |
| 7.7000 | 0.19882 | 0.19884 | 0.19882 | 0.19882 | 3.9511 |
| 7.8000 | 0.19985 | 0.19988 | 0.19985 | 0.19985 | 3.8956 |
| 7.9000 | 0.19989 | 0.19992 | 0.19989 | 0.19989 | 3.8207 |
| 8.0000 | 0.19894 | 0.19896 | 0.19894 | 0.19894 | 3.7271 |
| 8.1000 | 0.19699 | 0.19701 | 0.19699 | 0.19699 | 3.6156 |
| 8.2000 | 0.19407 | 0.19409 | 0.19407 | 0.19407 | 3.4875 |
| 8.3000 | 0.19022 | 0.19023 | 0.19022 | 0.19022 | 3.3442 |
| 8.4000 | 0.18546 | 0.18546 | 0.18546 | 0.18546 | 3.1874 |
| 8.5000 | 0.17985 | 0.17984 | 0.17985 | 0.17985 | 3.0187 |
| 8.6000 | 0.17344 | 0.17342 | 0.17344 | 0.17344 | 2.8399 |
| 8.7000 | 0.16630 | 0.16627 | 0.16630 | 0.16630 | 2.6529 |
| 8.8000 | 0.15849 | 0.15846 | 0.15849 | 0.15849 | 2.4596 |
| 8.9000 | 0.15010 | 0.15006 | 0.15010 | 0.15010 | 2.2616 |
| 9.0000 | 0.14121 | 0.14117 | 0.14121 | 0.14121 | 2.0609 |
| 9.1000 | 0.13191 | 0.13187 | 0.13191 | 0.13191 | 1.8593 |
| 9.2000 | 0.12229 | 0.12227 | 0.12229 | 0.12229 | 1.6586 |
| 9.3000 | 0.11245 | 0.11244 | 0.11245 | 0.11245 | 1.4606 |
| 9.4000 | 0.10248 | 0.10250 | 0.10248 | 0.10248 | 1.2671 |
| 9.5000 | 0.092486 | 0.092533 | 0.092485 | 0.092486 | 1.0798 |
| 9.6000 | 0.082568 | 0.082638 | 0.082567 | 0.082568 | 0.90053 |
| 9.7000 | 0.072824 | 0.072907 | 0.072824 | 0.072824 | 0.73090 |
| 9.8000 | 0.063352 | 0.063435 | 0.063352 | 0.063352 | 0.57249 |
| 9.9000 | 0.054246 | 0.054314 | 0.054246 | 0.054246 | 0.42679 |
| 10.000 | 0.045597 | 0.045634 | 0.045598 | 0.045597 | 0.29513 |
| 10.100 | 0.037491 | 0.037484 | 0.037493 | 0.037491 | 0.17874 |
| 10.200 | 0.030011 | 0.029954 | 0.030013 | 0.030011 | 0.078748 |
| 10.300 | 0.023230 | 0.023126 | 0.023231 | 0.023230 | -0.0037424 |
| 10.400 | 0.017216 | 0.017078 | 0.017217 | 0.017216 | -0.067616 |
| 10.500 | 0.012030 | 0.011878 | 0.012030 | 0.012030 | -0.11172 |
| 10.600 | 0.0077232 | 0.0075815 | 0.0077225 | 0.0077232 | -0.13490 |
| 10.700 | 0.0043380 | 0.0042315 | 0.0043365 | 0.0043380 | -0.13612 |
| 10.800 | 0.0019084 | 0.0018558 | 0.0019064 | 0.0019084 | -0.11456 |
| 10.900 | 4.5858E-4 | 4.6926E-4 | 4.5637E-4 | 4.5858E-4 | -0.069764 |
| 11.000 | 2.9681E-6 | 7.5412E-5 | 9.7934E-7 | 2.9681E-6 | -0.0017223 |
| 11.100 | 5.4617E-4 | 6.6815E-4 | 5.4474E-4 | 5.4617E-4 | 0.089045 |
| 11.200 | 0.0020828 | 0.0022336 | 0.0020822 | 0.0020828 | 0.20147 |
| 11.300 | 0.0045978 | 0.0047516 | 0.0045981 | 0.0045978 | 0.33397 |
| 11.400 | 0.0080660 | 0.0081966 | 0.0080671 | 0.0080660 | 0.48446 |
| 11.500 | 0.012453 | 0.012538 | 0.012455 | 0.012453 | 0.65053 |
| 11.600 | 0.017715 | 0.017742 | 0.017717 | 0.017715 | 0.82952 |
| 11.700 | 0.023800 | 0.023764 | 0.023802 | 0.023800 | 1.0187 |
| 11.800 | 0.030646 | 0.030558 | 0.030647 | 0.030646 | 1.2156 |
| 11.900 | 0.038185 | 0.038063 | 0.038186 | 0.038185 | 1.4178 |
| 12.000 | 0.046343 | 0.046210 | 0.046343 | 0.046343 | 1.6232 |
| 12.100 | 0.055036 | 0.054916 | 0.055035 | 0.055036 | 1.8300 |
| 12.200 | 0.064178 | 0.064091 | 0.064177 | 0.064178 | 2.0364 |
| 12.300 | 0.073678 | 0.073634 | 0.073677 | 0.073678 | 2.2407 |
| 12.400 | 0.083441 | 0.083441 | 0.083440 | 0.083441 | 2.4412 |
| 12.500 | 0.093369 | 0.093406 | 0.093368 | 0.093369 | 2.6361 |
| 12.600 | 0.10336 | 0.10342 | 0.10336 | 0.10336 | 2.8237 |
| 12.700 | 0.11332 | 0.11339 | 0.11332 | 0.11332 | 3.0023 |
| 12.800 | 0.12315 | 0.12321 | 0.12315 | 0.12315 | 3.1702 |
| 12.900 | 0.13275 | 0.13279 | 0.13275 | 0.13275 | 3.3260 |
| 13.000 | 0.14202 | 0.14204 | 0.14202 | 0.14202 | 3.4683 |
| 13.100 | 0.15087 | 0.15086 | 0.15087 | 0.15087 | 3.5958 |
| 13.200 | 0.15921 | 0.15918 | 0.15921 | 0.15921 | 3.7075 |
| 13.300 | 0.16696 | 0.16691 | 0.16696 | 0.16696 | 3.8025 |
| 13.400 | 0.17404 | 0.17399 | 0.17404 | 0.17404 | 3.8799 |
| 13.500 | 0.18038 | 0.18033 | 0.18038 | 0.18038 | 3.9389 |
| 13.600 | 0.18592 | 0.18588 | 0.18592 | 0.18592 | 3.9791 |
| 13.700 | 0.19060 | 0.19058 | 0.19060 | 0.19060 | 3.9999 |
| 13.800 | 0.19437 | 0.19437 | 0.19437 | 0.19437 | 4.0009 |
| 13.900 | 0.19720 | 0.19721 | 0.19720 | 0.19720 | 3.9820 |
| 14.000 | 0.19906 | 0.19908 | 0.19906 | 0.19906 | 3.9431 |
| 14.100 | 0.19993 | 0.19996 | 0.19993 | 0.19993 | 3.8844 |
| 14.200 | 0.19980 | 0.19983 | 0.19980 | 0.19980 | 3.8063 |
| 14.300 | 0.19868 | 0.19870 | 0.19868 | 0.19868 | 3.7095 |
| 14.400 | 0.19657 | 0.19659 | 0.19657 | 0.19657 | 3.5951 |
| 14.500 | 0.19349 | 0.19351 | 0.19349 | 0.19349 | 3.4644 |
| 14.600 | 0.18948 | 0.18949 | 0.18948 | 0.18948 | 3.3187 |
| 14.700 | 0.18457 | 0.18458 | 0.18457 | 0.18457 | 3.1598 |
| 14.800 | 0.17882 | 0.17882 | 0.17883 | 0.17882 | 2.9893 |
| 14.900 | 0.17229 | 0.17227 | 0.17229 | 0.17229 | 2.8090 |
| 15.000 | 0.16503 | 0.16500 | 0.16503 | 0.16503 | 2.6208 |
| 15.100 | 0.15712 | 0.15708 | 0.15712 | 0.15712 | 2.4266 |
| 15.200 | 0.14864 | 0.14860 | 0.14864 | 0.14864 | 2.2280 |
| 15.300 | 0.13967 | 0.13963 | 0.13967 | 0.13967 | 2.0271 |
| 15.400 | 0.13031 | 0.13028 | 0.13031 | 0.13031 | 1.8255 |
| 15.500 | 0.12065 | 0.12063 | 0.12065 | 0.12065 | 1.6251 |
| 15.600 | 0.11078 | 0.11078 | 0.11078 | 0.11078 | 1.4277 |
| 15.700 | 0.10080 | 0.10082 | 0.10080 | 0.10080 | 1.2351 |
| 15.800 | 0.090810 | 0.090862 | 0.090809 | 0.090810 | 1.0490 |
| 15.900 | 0.080915 | 0.080988 | 0.080914 | 0.080915 | 0.87128 |
| 16.000 | 0.071210 | 0.071294 | 0.071210 | 0.071210 | 0.70343 |
| 16.100 | 0.061793 | 0.061875 | 0.061793 | 0.061793 | 0.54707 |
| 16.200 | 0.052757 | 0.052821 | 0.052758 | 0.052757 | 0.40363 |
| 16.300 | 0.044193 | 0.044224 | 0.044195 | 0.044193 | 0.27446 |
| 16.400 | 0.036188 | 0.036173 | 0.036189 | 0.036188 | 0.16075 |
| 16.500 | 0.028820 | 0.028754 | 0.028821 | 0.028820 | 0.063624 |
| 16.600 | 0.022163 | 0.022052 | 0.022165 | 0.022163 | -0.015815 |
| 16.700 | 0.016285 | 0.016142 | 0.016286 | 0.016285 | -0.076446 |
| 16.800 | 0.011243 | 0.011091 | 0.011243 | 0.011243 | -0.11711 |
| 16.900 | 0.0070885 | 0.0069511 | 0.0070876 | 0.0070885 | -0.13667 |
| 17.000 | 0.0038619 | 0.0037634 | 0.0038603 | 0.0038619 | -0.13411 |
| 17.100 | 0.0015956 | 0.0015533 | 0.0015935 | 0.0015956 | -0.10866 |
| 17.200 | 3.1219E-4 | 3.3370E-4 | 3.0999E-4 | 3.1219E-4 | -0.059941 |
| 17.300 | 2.4473E-5 | 1.0640E-4 | 2.2557E-5 | 2.4473E-5 | 0.011973 |
| 17.400 | 7.3536E-4 | 8.6384E-4 | 7.3406E-4 | 7.3536E-4 | 0.10647 |
| 17.500 | 0.0024379 | 0.0025910 | 0.0024374 | 0.0024379 | 0.22240 |
| 17.600 | 0.0051151 | 0.0052668 | 0.0051156 | 0.0051151 | 0.35808 |
| 17.700 | 0.0087405 | 0.0088649 | 0.0087418 | 0.0087405 | 0.51137 |
| 17.800 | 0.013278 | 0.013354 | 0.013280 | 0.013278 | 0.67980 |
| 17.900 | 0.018682 | 0.018698 | 0.018684 | 0.018682 | 0.86070 |
| 18.000 | 0.024899 | 0.024854 | 0.024901 | 0.024899 | 1.0514 |
| 18.100 | 0.031867 | 0.031772 | 0.031869 | 0.031867 | 1.2493 |
| 18.200 | 0.039516 | 0.039390 | 0.039517 | 0.039516 | 1.4522 |
| 18.300 | 0.047769 | 0.047637 | 0.047769 | 0.047769 | 1.6579 |
| 18.400 | 0.056544 | 0.056429 | 0.056543 | 0.056544 | 1.8647 |
| 18.500 | 0.065753 | 0.065673 | 0.065752 | 0.065753 | 2.0709 |
| 18.600 | 0.075304 | 0.075268 | 0.075303 | 0.075304 | 2.2747 |
| 18.700 | 0.085102 | 0.085108 | 0.085100 | 0.085102 | 2.4744 |
| 18.800 | 0.095047 | 0.095089 | 0.095046 | 0.095047 | 2.6682 |
| 18.900 | 0.10504 | 0.10511 | 0.10504 | 0.10504 | 2.8544 |
| 19.000 | 0.11499 | 0.11506 | 0.11499 | 0.11499 | 3.0313 |
| 19.100 | 0.12478 | 0.12484 | 0.12478 | 0.12478 | 3.1973 |
| 19.200 | 0.13433 | 0.13437 | 0.13433 | 0.13433 | 3.3509 |
| 19.300 | 0.14354 | 0.14355 | 0.14354 | 0.14354 | 3.4908 |
| 19.400 | 0.15231 | 0.15230 | 0.15231 | 0.15231 | 3.6157 |
| 19.500 | 0.16055 | 0.16052 | 0.16055 | 0.16055 | 3.7247 |
| 19.600 | 0.16820 | 0.16815 | 0.16820 | 0.16820 | 3.8168 |
| 19.700 | 0.17516 | 0.17511 | 0.17516 | 0.17516 | 3.8911 |
| 19.800 | 0.18137 | 0.18132 | 0.18137 | 0.18137 | 3.9470 |
| 19.900 | 0.18676 | 0.18673 | 0.18676 | 0.18676 | 3.9840 |
| 20.000 | 0.19130 | 0.19128 | 0.19129 | 0.19130 | 4.0015 |

* 1. Plot Groups
     1. Velocity (spf)



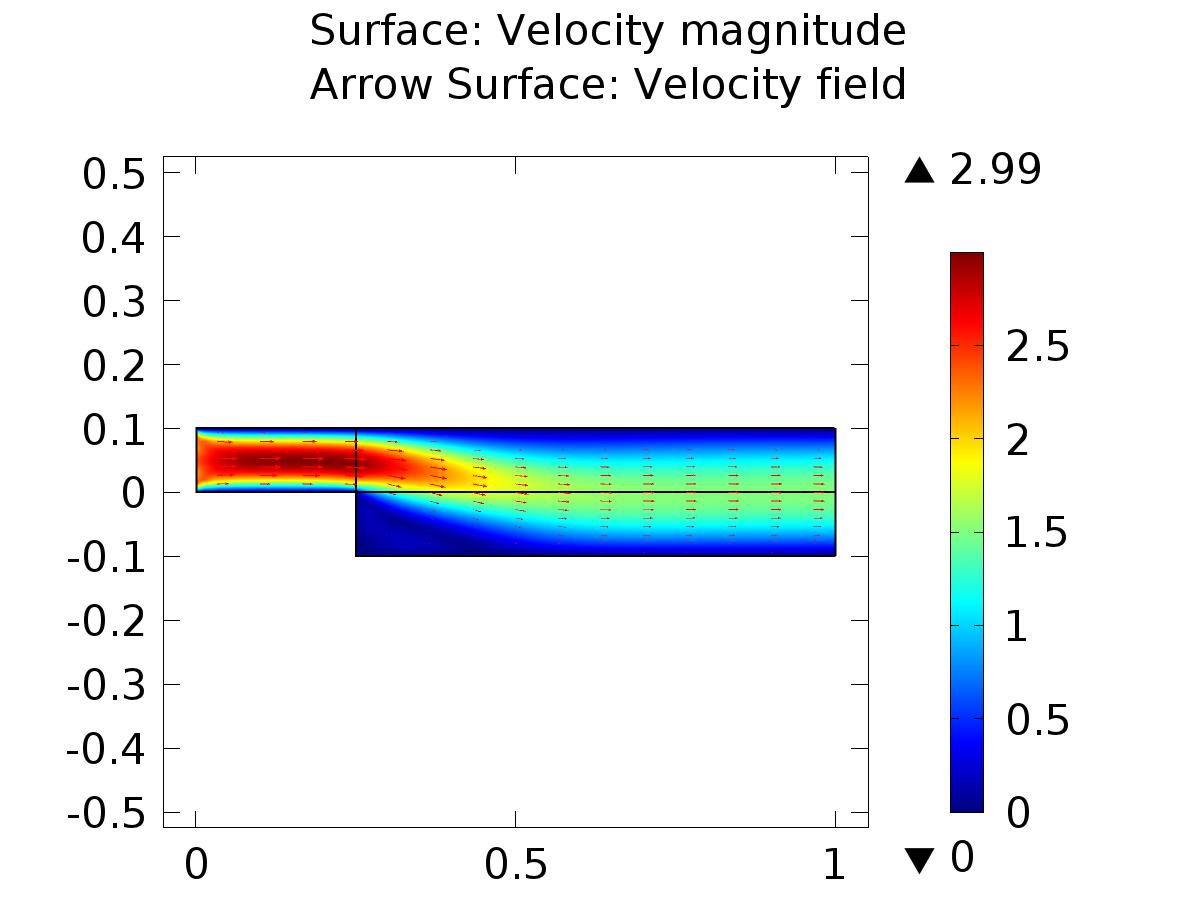
Surface: Velocity magnitude

* + 1. Pressure (spf)



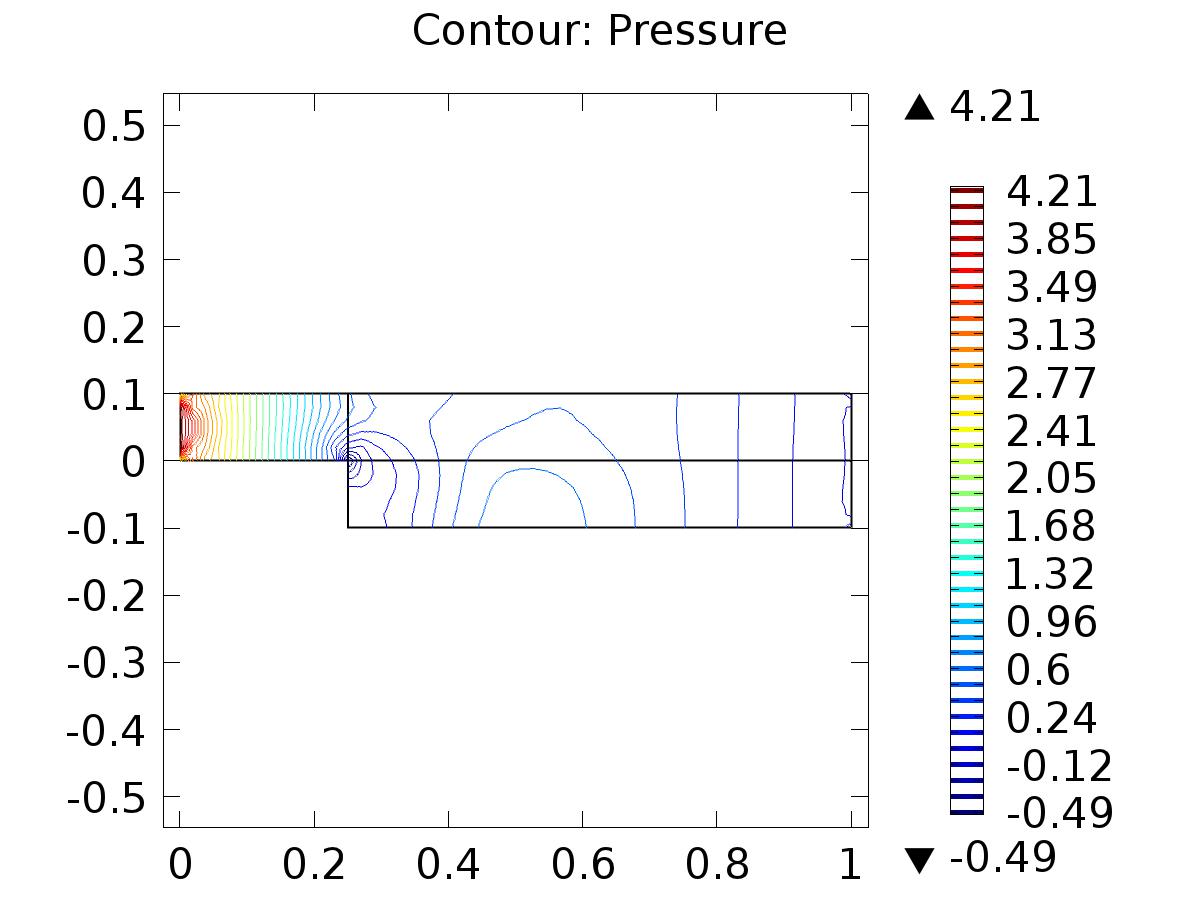
Contour: Pressure

* + 1. Velocity (phys1)



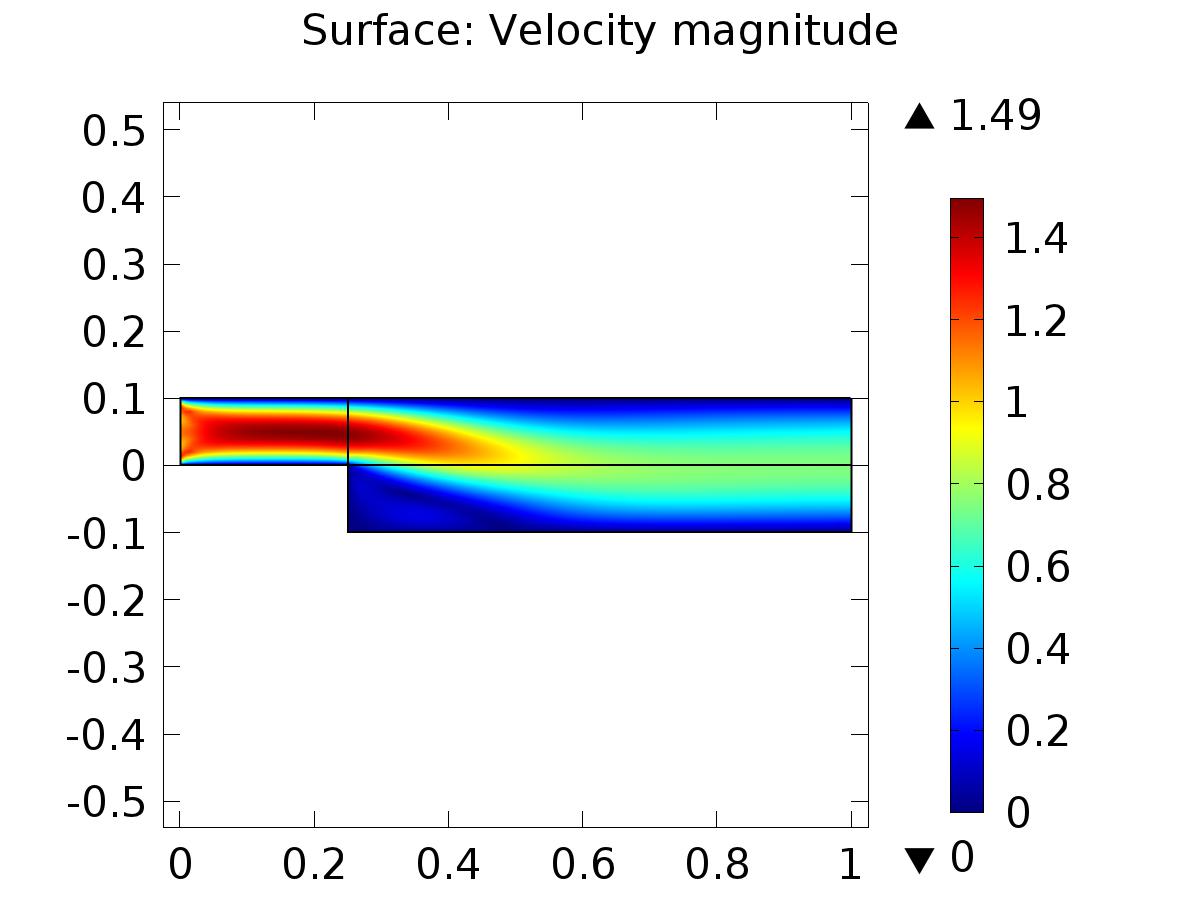
Surface: Velocity magnitude Arrow Surface: Velocity field

* + 1. Pressure (phys1)



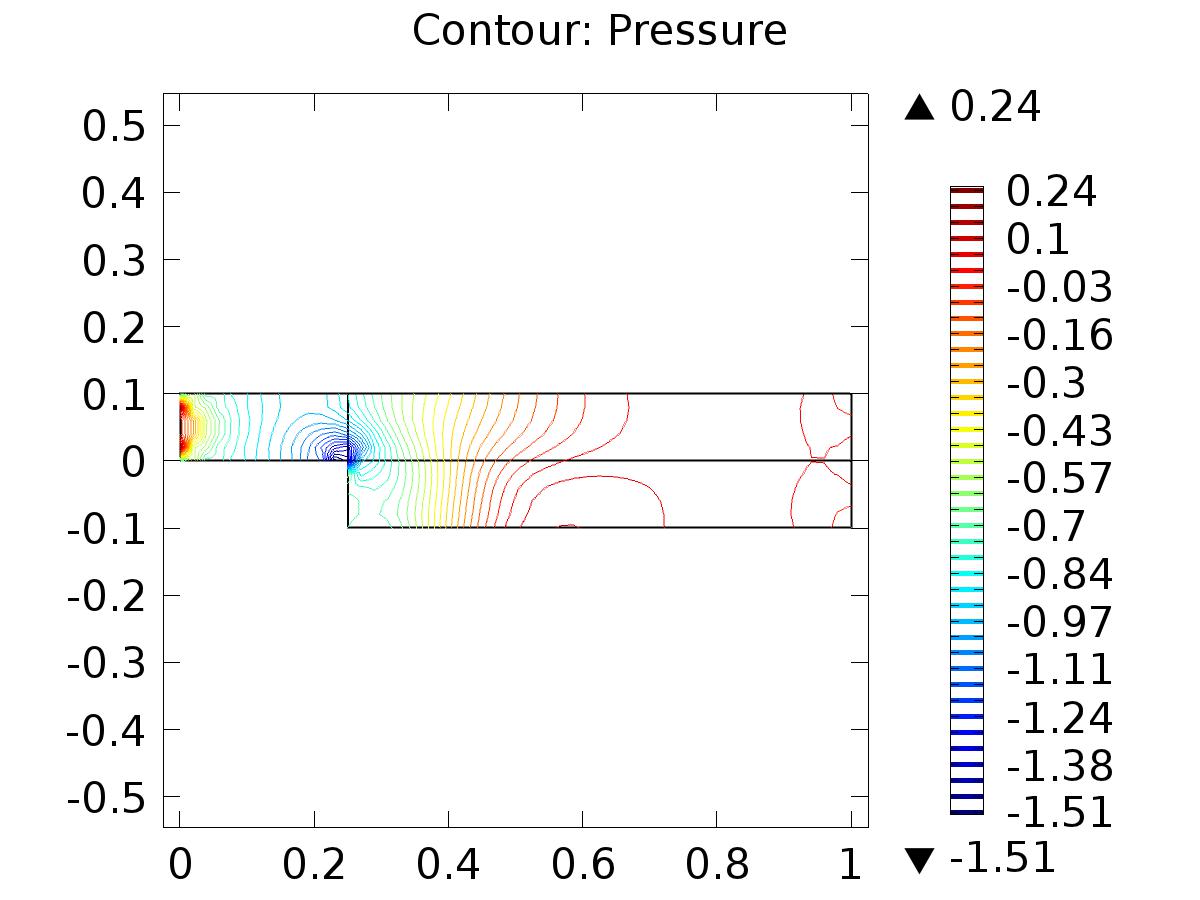
Contour: Pressure

* + 1. Velocity (phys2)



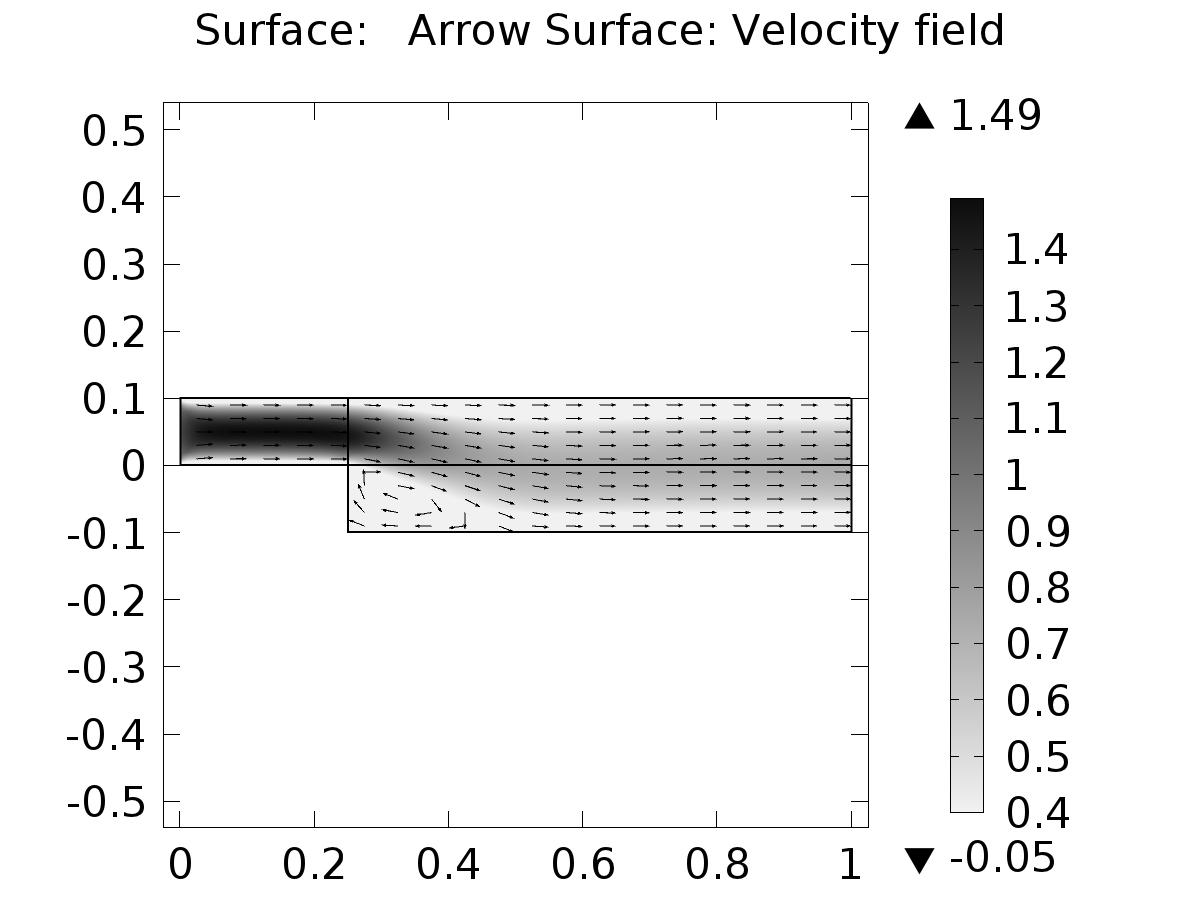
Surface: Velocity magnitude

* + 1. Pressure (phys2)



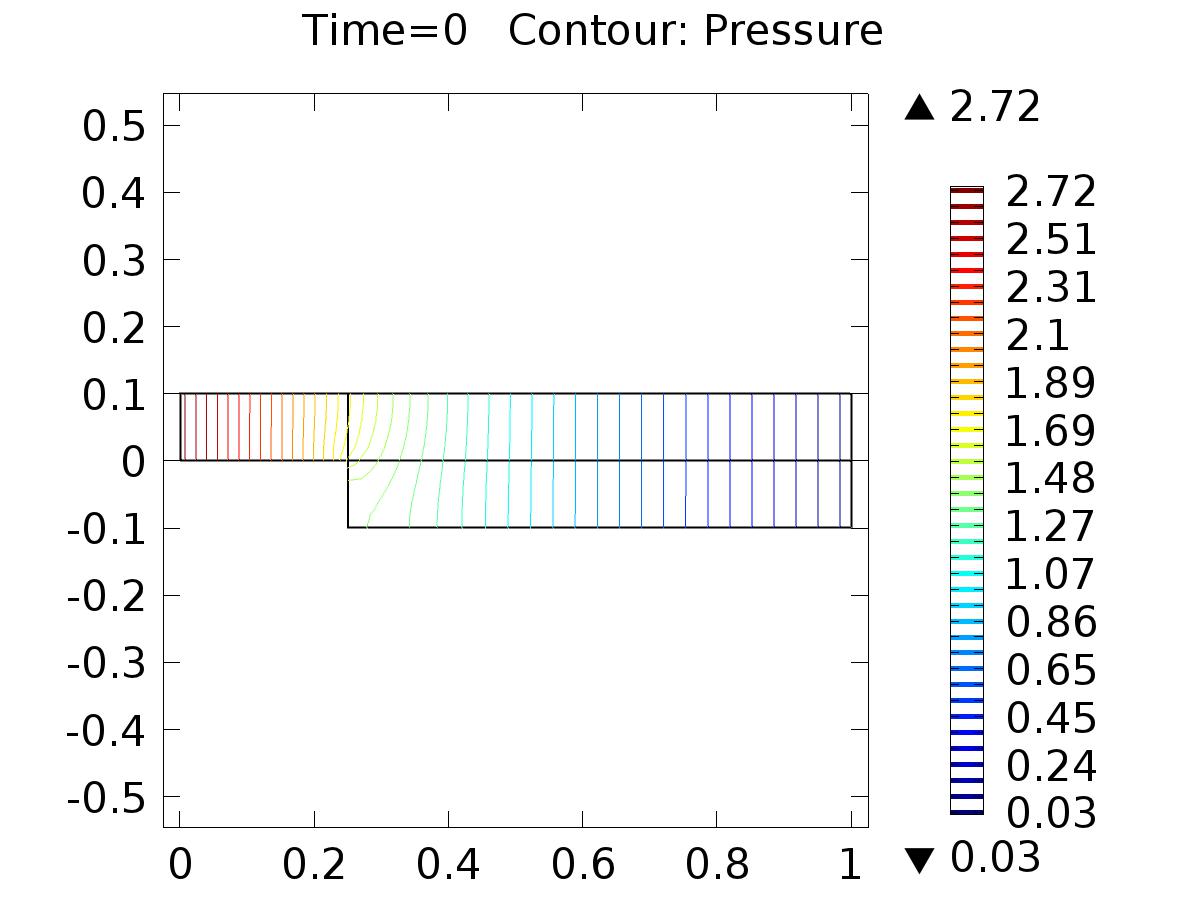
Contour: Pressure

* + 1. Velocity (phys6)



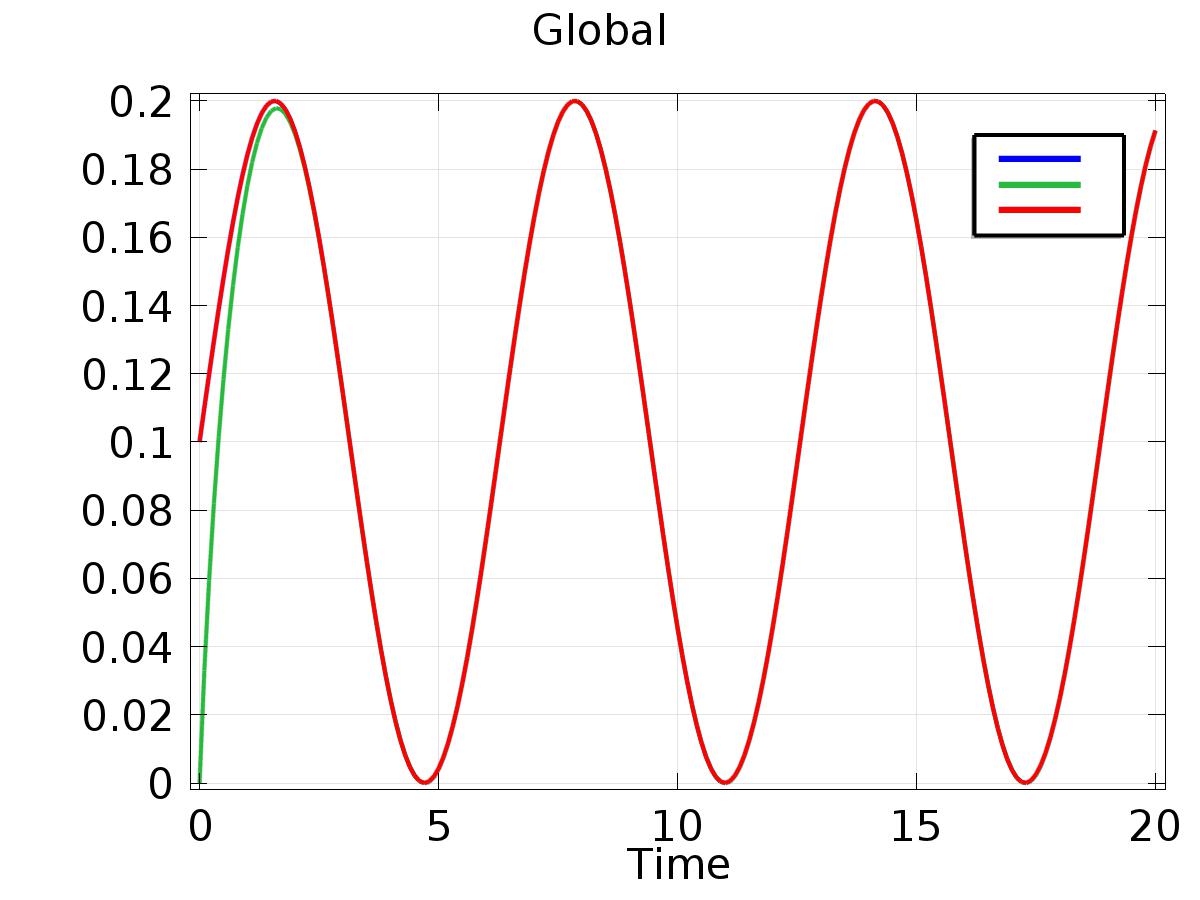
Surface: Arrow Surface: Velocity field

* + 1. Pressure (phys6)



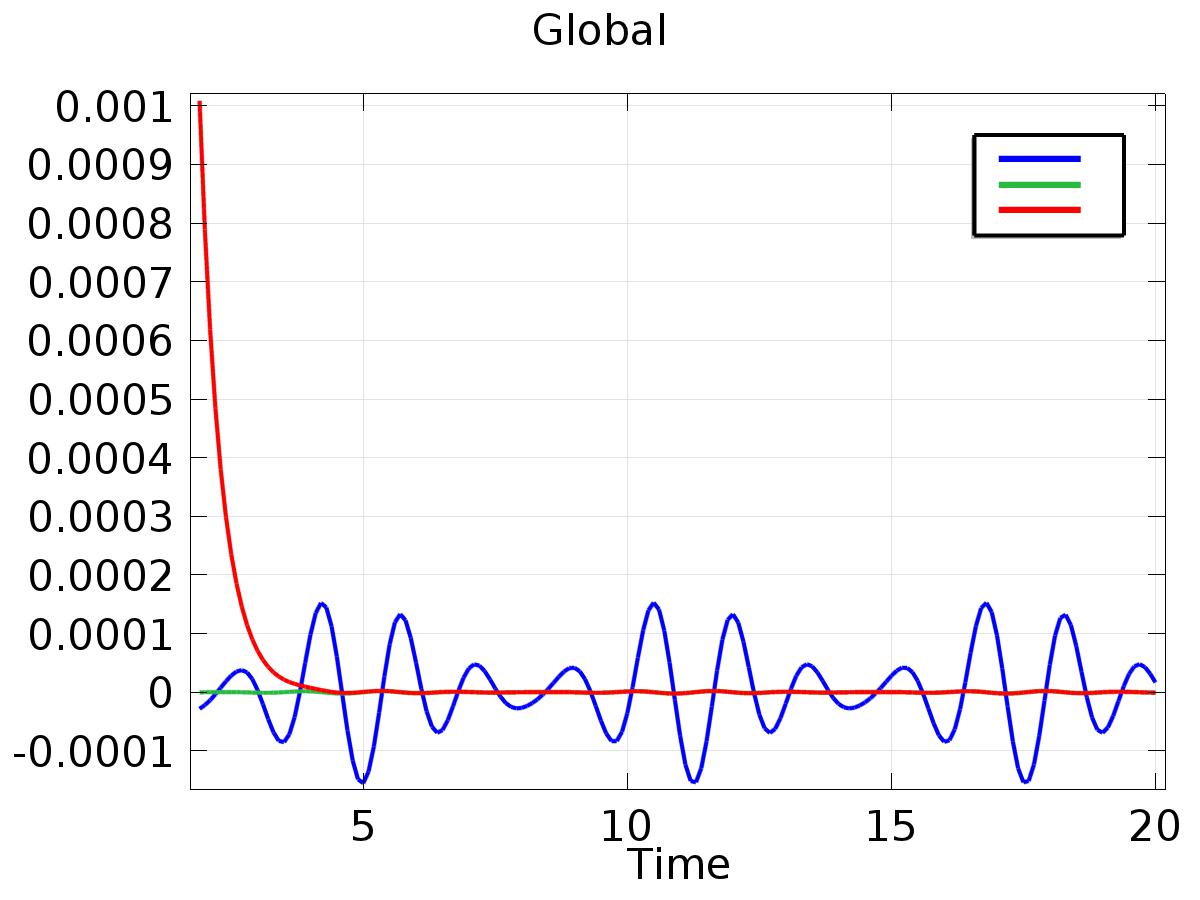
Time=0 Contour: Pressure

* + 1. 1D Plot Group 9



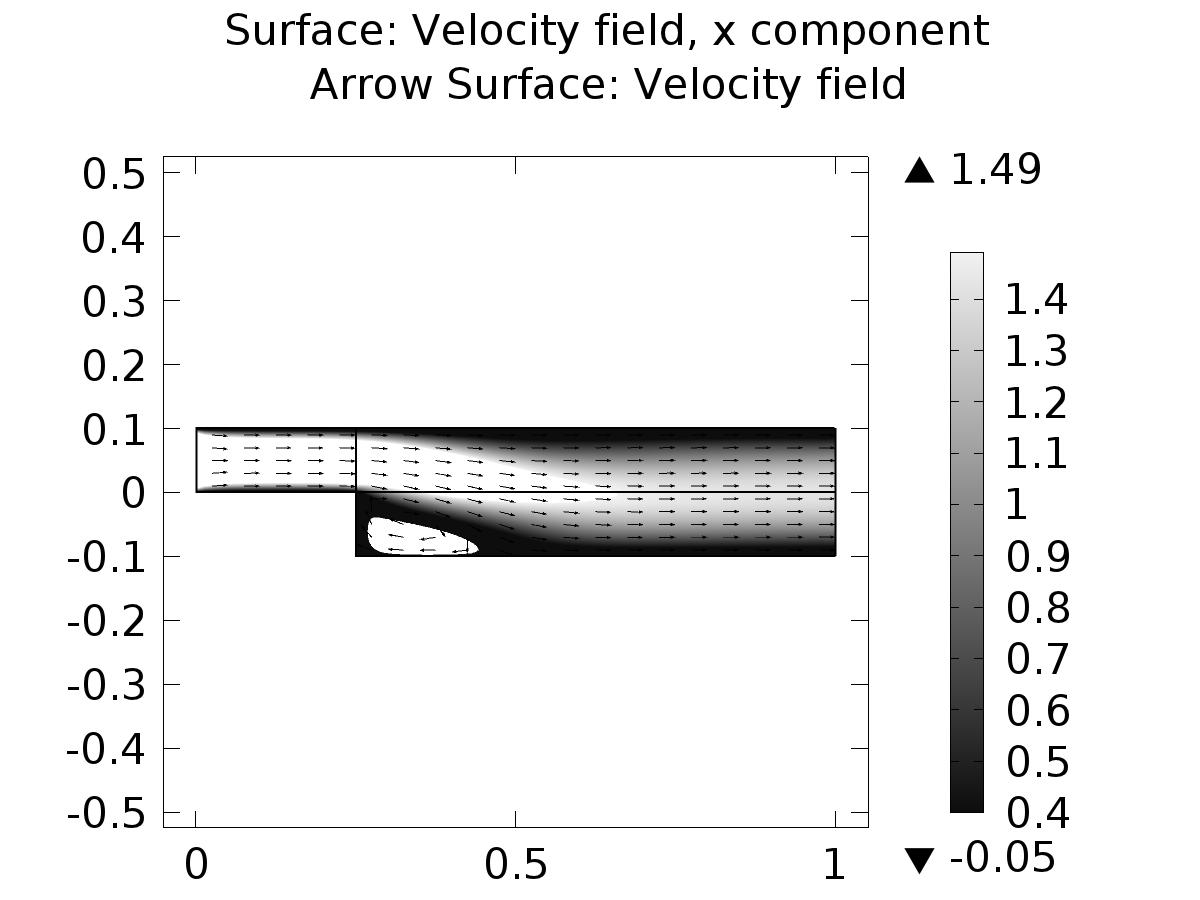
Global

* + 1. 1D Plot Group 10



Global

* + 1. Velocity (phys6) 1



Surface: Velocity field, x component Arrow Surface: Velocity field