



Школа-семинар
*«Основы использования
OpenFOAM, SALOME и ParaView»*

**ДЕМОНСТРАЦИЯ:
ОБТЕКАНИЕ ОБРАТНОГО
УСТУПА**

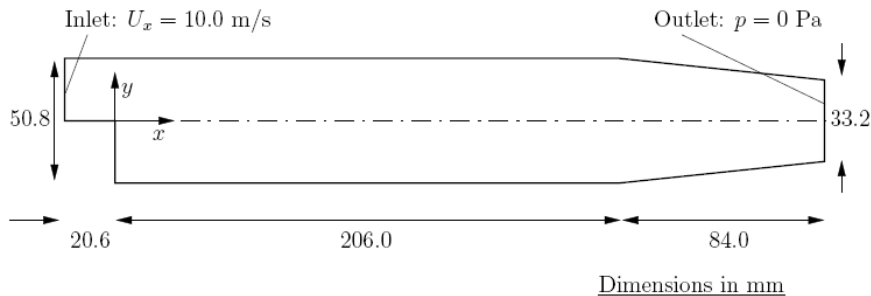
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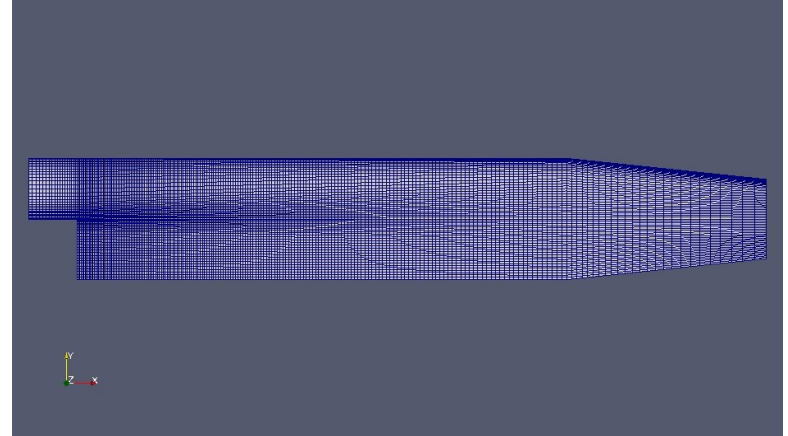
С.В. Стрижак (ГОУ ВПО МГТУ им. Баумана)



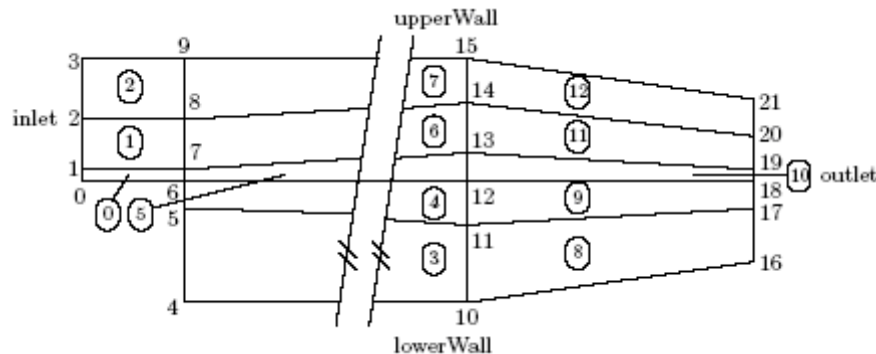
РАСЧЕТНАЯ ОБЛАСТЬ И ИСХОДНЫЕ ДАННЫЕ



Расчетная область и граничные условия



Блочная сетка — *blockMeshDict*



$U = 10 \text{ m/c}$
K-e model
K-omega SST model
LES 1 eq. model
simpleFoam
pisoFoam

Р.В. Питц, Дж.У. Дейли. Горение в турбулентном слое смешения за уступом.
Аэрокосмическая техника. 1984. N7. с.74-82



МАТЕМАТИЧЕСКАЯ МОДЕЛЬ

Governing equations

- Mass continuity for incompressible flow

$$\nabla \cdot \mathbf{U} = 0 \quad (3.4)$$

- Steady flow momentum equation

$$\nabla \cdot (\mathbf{U}\mathbf{U}) + \nabla \cdot \mathbf{R} = -\nabla p \quad (3.5)$$

where p is kinematic pressure and (in slightly over-simplistic terms) $\mathbf{R} = \nu_{eff} \nabla \mathbf{U}$ is the viscous stress term with an effective kinematic viscosity ν_{eff} , calculated from selected transport and turbulence models.

Initial conditions $\mathbf{U} = 0$ m/s, $p = 0$ Pa — required in OpenFOAM input files but not necessary for the solution since the problem is steady-state.

Boundary conditions

- Inlet (left) with fixed velocity $\mathbf{U} = (10, 0, 0)$ m/s;
- Outlet (right) with fixed pressure $p = 0$ Pa;
- No-slip walls on other boundaries.

Transport properties

- Kinematic viscosity of air $\nu = \mu/\rho = 18.1 \times 10^{-6}/1.293 = 14.0 \mu\text{m}^2/\text{s}$

Turbulence model

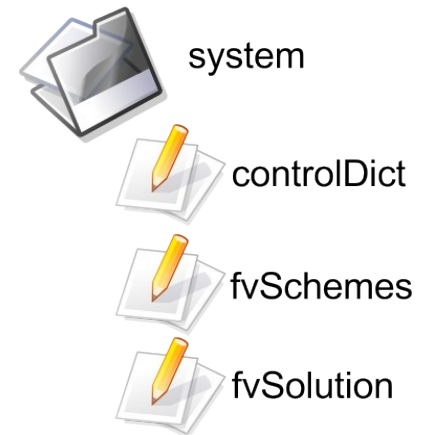
- Standard $k - \epsilon$;
- Coefficients: $C_\mu = 0.09$; $C_1 = 1.44$; $C_2 = 1.92$; $\alpha_k = 1$; $\alpha_\epsilon = 0.76923$.

Solver name simpleFoam: an implementation for steady incompressible flow.



ИСХОДНЫЕ ДАННЫЕ: КАТАЛОГ ЗАДАЧИ

```
[cfd1@master simpleFoam]$ cd pitzDailyParallel/  
[cfd1@master pitzDailyParallel]$ ll  
total 12  
drwxr-xr-x 2 cfd1 sm3 4096 Dec 22 16:43 0  
drwxr-xr-x 3 cfd1 sm3 4096 Dec 22 16:43 constant  
drwxr-xr-x 2 cfd1 sm3 4096 Dec 22 16:48 system  
[cfd1@master pitzDailyParallel]$  
[cfd1@master pitzDailyParallel]$ cd system/  
[cfd1@master system]$ ll  
total 16  
-rw-r----- 1 cfd1 sm3 1222 Dec 22 16:43 controlDict  
-rw-r----- 1 cfd1 sm3 1206 Dec 22 16:48 decomposeParDict  
-rw-r----- 1 cfd1 sm3 1877 Dec 22 16:43 fvSchemes  
-rw-r----- 1 cfd1 sm3 1940 Dec 22 16:43 fvSolution
```





ГРАНИЧНЫЕ УСЛОВИЯ ДЛЯ СКОРОСТИ

```
dimensions    [0 1 -1 0 0 0 0];
```

```
internalField uniform (0 0 0);
```

```
boundaryField
```

```
{ inlet      { type      fixedValue; value      uniform (10 0 0); }
```

```
outlet      { type      zeroGradient; }
```

```
upperWall   { type      fixedValue; value      uniform (0 0 0); }
```

```
lowerWall   { type      fixedValue; value      uniform (0 0 0); }
```

```
frontAndBack { type      empty; } //
```

```
***** //
```



ГРАНИЧНЫЕ УСЛОВИЯ ДЛЯ КИНЕТИЧЕСКОЙ ЭНЕРГИИ ТУРБУЛЕНТНОСТИ

```
dimensions    [0 2 -2 0 0 0 0];
```

```
internalField  uniform 0.375;
```

```
boundaryField
```

```
{  
  inlet {      type      fixedValue;      value      uniform 0.375;  }  
  outlet {     type      zeroGradient;  }  
  upperWall {  type      kqRWallFunction;  value      uniform 0.375;  }  
  lowerWall {  type      kqRWallFunction;  value      uniform 0.375;  }  
  frontAndBack {  type      empty;  
}  
}
```

// ***** //



УПРАВЛЕНИЕ РАСЧЕТОМ

```
application    simpleFoam;  
startFrom      startTime;  
startTime      0;  
stopAt         endTime;  
endTime        10;  
deltaT         1;  
writeControl    timeStep;  
writeInterval   1;  
purgeWrite     0;  
writeFormat     ascii;  
writePrecision  6;  
writeCompression uncompressed;  
timeFormat      general;  
timePrecision   6;  
runTimeModifiable yes;
```



СХЕМЫ ДИСКРЕТИЗАЦИИ

```
gradSchemes{  default      Gauss linear;
grad(p)      Gauss linear;
grad(U)      Gauss linear;}
divSchemes{  default      none;
div(phi,U)   Gauss GammaV 1.0;
div(phi,k)   Gauss Gamma 1.0;
div(phi,epsilon) Gauss Gamma 1.0;
div(phi,omega) Gauss Gamma 1.0;
div(phi,R)   Gauss Gamma 1.0;
div(R)       Gauss linear;
div(phi,nuTilda) Gauss upwind;
div((nuEff*dev(grad(U).T())) Gauss linear;}
laplacianSchemes{  default      none;
laplacian(nuEff,U) Gauss linear corrected;
laplacian((1|A(U)),p) Gauss linear corrected;
laplacian(DkEff,k) Gauss linear corrected;
laplacian(DepsilonEff,epsilon) Gauss linear corrected;
laplacian(DomegaEff,omega) Gauss linear corrected;
laplacian(DREff,R) Gauss linear corrected;
laplacian(DnuTildaEff,nuTilda) Gauss linear corrected;}
interpolationSchemes{  default      linear;  interpolate(U) linear;}
snGradSchemes{  default      corrected;}
fluxRequired{  default      no;  p;}
```




МЕТОДЫ РЕШЕНИЯ СЛАУ

FoamFile

```
{ version 2.0; format ascii; class dictionary; object fvSolution;}  
// ***** //
```

Solvers {

```
p PCG { preconditioner DIC; tolerance 1e-06; relTol 0.01; };  
U PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };  
k PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };  
epsilon PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };  
omega PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };  
R PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };  
nuTilda PBiCG { preconditioner DILU; tolerance 1e-05; relTol 0.1; };
```

SIMPLE

```
{ nNonOrthogonalCorrectors 0;  
relaxationFactors  
{ p 0.3; U 0.7; k 0.7; epsilon 0.7; omega 0.7; R  
0.7; nuTilda 0.7;}
```

PISO

```
{ nCorrectors 4; nNonOrthogonalCorrectors 0; pRefCell 0; pRefValue 0;}  
// ***** //
```



РЕЗУЛЬТАТЫ РАСЧЕТОВ

