TRUST Tutorial V1.9.6 Solutions

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Contents

1 Flow around an obstacle (2D, VDF)

1.1 Sequentiel calculation

1.1.1 First part: basic calculation

```
# Hydraulique 2D laminar with Quick scheme #
# PARALLEL RUNS #
# lance_test 2 ecarts #
dimension 2
Pb_hydraulique pb
Domaine dom
# BEGIN MESH #
Read_file Obstacle.geo ;
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool metis { nb_parts 2 }
    Larg_joint 2
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
# I select a discretization #
VDF ma_discretisation
Scheme_euler_explicit mon_schema
Read mon_schema
{
    tinit 0.
    tmax 5.
    # dt_min=dt_max so dt imposed #
    dt_min 4.e-3
    dt_max 4.e-3
    dt_impr 5.e-3
    dt_sauv 100
    seuil_statio 1.e-8
    # By default facsec equals to 1 #
    # facsec 0.5 #
}
# Association between the different objects #
Associate pb dom
Associate pb mon_schema
Discretize pb ma_discretisation
Read pb
{
# I define a medium #
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 3.7e-05
        rho Champ_Uniforme 1 2
    }
    Navier_Stokes_standard
    {
```

```
    # Pressure matrix solved with #
        solveur_pression GCP {
        precond ssor { omega 1.500000 }
        seuil 1.000000e-06
        impr
    }
    # Two operators are defined #
    convection { quick }
    diffusion { }
    # Uniform initial condition for velocity #
    initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
    # Boundary conditions #
    boundary_conditions
    {
        Square      paroi_fixe
        Upper       symetrie
        Lower       symetrie
        Outlet      frontiere_ouverte_pression_imposee Champ_front_Uniforme 1 0.
        Inlet       frontiere_ouverte_vitesse_imposee Champ_front_Uniforme 2 1. 0.
    }
}
# Post processing block #
Post_processing
{
    # Probes #
    Probes
    {
        sonde_pression  pression     periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_vitesse   vitesse      periode 0.005   points 2 0.14 0.105    0.14 0.115
        sonde_vit       vitesse      periode 0.005   segment 22 0.14 0.0 0.14 0.22
        sonde_P         pression     periode 0.01    plan 23 11 0.01 0.005 0.91 0.005 0.01 0.21
        sonde_Pmoy      Moyenne_pression    periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_Pect      Ecart_type_pression periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_pressure   pression  periode 0.005   segment 22 0.01 0.12 0.91 0.12
        sonde_velocity  vitesse    periode 0.005   segment 22 0.92 0. 0.92 0.22
    }
    # Fields #
    format lata
    fields dt_post 0.5
    {
        pression elem
        pression som
        vitesse elem
        vitesse som
        vorticite elem
        y_plus elem
    }
    # Statistical fields #
    Statistiques dt_post 0.5
    {
        t_deb 1. t_fin 5.
        moyenne vitesse
        ecart_type vitesse
        moyenne pression
        ecart_type pression
    }
```

```
    }
}
# The problem is solved with #
Solve pb
# Not necessary keyword to finish #
End
```

1.1.2 Second part: "reprise"

```
# Hydraulique 2D laminar with Quick scheme #
# PARALLEL RUNS #
# lance_test 2 ecarts #
dimension 2
Pb_hydraulique pb
Domaine dom
# BEGIN MESH #
Read_file Obstacle.geo ;
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool metis { nb_parts 2 }
    Larg_joint 2
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
# I select a discretization #
VDF ma_discretisation
Scheme_euler_explicit mon_schema
Read mon_schema
{
    tinit 5.004
    tmax  6.
    # dt_min=dt_max so dt imposed #
    dt_min 4.e-3
    dt_max 4.e-3
    dt_impr 5.e-3
    dt_sauv 100
    seuil_statio 1.e-8
    # By default facsec equals to 1 #
    # facsec 0.5 #
}
# Association between the different objects #
Associate pb dom
Associate pb mon_schema
Discretize pb ma_discretisation
Read pb
{
    # I define a medium #
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 3.7e-05
        rho Champ_Uniforme 1 2
```

```
}
Navier_Stokes_standard
{
    # Pressure matrix solved with #
        solveur_pression GCP {
        precond ssor { omega 1.500000 }
        seuil 1.000000e-06
        impr
    }
    # Two operators are defined #
    convection { quick }
    diffusion { }
    # Uniform initial condition for velocity #
    initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
    # Boundary conditions #
    boundary_conditions
    {
        Square      paroi_fixe
        Upper       symetrie
        Lower       symetrie
        Outlet      frontiere_ouverte_pression_imposee Champ_front_Uniforme 1 0.
        Inlet       frontiere_ouverte_vitesse_imposee Champ_front_Uniforme 2 1. 0.
    }
}
# Post processing block #
Post_processing
{
    # Probes #
    Probes
    {
        sonde_pression  pression     periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_vitesse   vitesse      periode 0.005   points 2 0.14 0.105    0.14 0.115
        sonde_vit       vitesse      periode 0.005   segment 22 0.14 0.0 0.14 0.22
        sonde_P         pression     periode 0.01    plan 23 11 0.01 0.005 0.91 0.005 0.01 0.21
        sonde_Pmoy      Moyenne_pression    periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_Pect      Ecart_type_pression periode 0.005   points 2 0.13 0.105 0.13 0.115
        sonde_pressure   pression     periode 0.005   segment 22 0.01 0.12 0.91 0.12
        sonde_velocity  vitesse      periode 0.005   segment 22 0.92 0. 0.92 0.22
    }
    # Fields #
    format lata
    fields dt_post 0.5
    {
        pression elem
        pression som
        vitesse elem
        vitesse som
        vorticite elem
        y_plus elem
    }
    # Statistical fields #
    Statistiques dt_post 0.5
    {
        t_deb 1. t_fin 5.
        moyenne vitesse
        ecart_type vitesse
```

```
            moyenne pression
            ecart_type pression
        }
    }
    reprise binaire Obstacle_pb.sauv
}
# The problem is solved with #
Solve pb
# Not necessary keyword to finish #
End
```

1.2 Parallel calculation

1.2.1 DEC_Obstacle.data

```
# Hydraulique 2D laminar with Quick scheme #
# PARALLEL RUNS #
# lance_test 2 ecarts #
dimension 2
Pb_hydraulique pb
Domaine dom
# BEGIN MESH #
Read_file Obstacle.geo ;
# END MESH #
# BEGIN PARTITION #
Partition dom
{
   Partition_tool metis { nb_parts 2 }
   Larg_joint 2
   zones_name DOM
}
End
# END PARTITION #
```

1.2.2 PAR_Obstacle.data

```
# Hydraulique 2D laminar with Quick scheme #
# PARALLEL RUNS #
# lance_test 2 ecarts #
dimension 2
Pb_hydraulique pb
Domaine dom

# Read domain from .Zones files #
Scatter DOM.Zones dom

# I select a discretization #
VDF ma_discretisation
Scheme_euler_explicit mon_schema
Read mon_schema
{
    tinit 0.
    tmax 5.
    # dt_min=dt_max so dt imposed #
    dt_min 4.e-3
    dt_max 4.e-3
    dt_impr 5.e-3
```

```
    dt_sauv 100
    seuil_statio 1.e-8
    # By default facsec equals to 1 #
    # facsec 0.5 #
}
# Association between the different objects #
Associate pb dom
Associate pb mon_schema
Discretize pb ma_discretisation
Read pb
{
    # I define a medium #
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 3.7e-05
        rho Champ_Uniforme 1 2
    }
    Navier_Stokes_standard
    {
        # Pressure matrix solved with #
        solveur_pression GCP {
            precond ssor { omega 1.500000 }
            seuil 1.000000e-06
            impr
        }
        # Two operators are defined #
        convection { quick }
        diffusion { }
        # Uniform initial condition for velocity #
        initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
        # Boundary conditions #
        boundary_conditions {
            Square     paroi_fixe
            Upper      symetrie
            Lower      symetrie
            Outlet     frontiere_ouverte_pression_imposee Champ_front_Uniforme 1 0.
            Inlet      frontiere_ouverte_vitesse_imposee Champ_front_Uniforme 2 1. 0.
        }
    }
    # Post processing block #
    Post_processing
    {
        # Probes #
        Probes
        {
            sonde_pression  pression     periode 0.005   points 2 0.13 0.105 0.13 0.115
            sonde_vitesse   vitesse      periode 0.005   points 2 0.14 0.105    0.14 0.115
            sonde_vit       vitesse      periode 0.005   segment 22 0.14 0.0 0.14 0.22
            sonde_P         pression     periode 0.01    plan 23 11 0.01 0.005 0.91 0.005 0.01 0.21
            sonde_Pmoy      Moyenne_pression    periode 0.005   points 2 0.13 0.105 0.13 0.115
            sonde_Pect      Ecart_type_pression periode 0.005   points 2 0.13 0.105 0.13 0.115
            sonde_pressure   pression     periode 0.005   segment 22 0.01 0.12 0.91 0.12
            sonde_velocity  vitesse      periode 0.005   segment 22 0.92 0. 0.92 0.22
        }
        # Fields #
        format lata
```

```
        fields dt_post 0.5
        {
            pression elem
            pression som
            vitesse elem
            vitesse som
            vorticite
        }
        # Statistical fields #
        Statistiques dt_post 0.5
        {
            t_deb 1. t_fin 5.
            moyenne vitesse
            ecart_type vitesse
            moyenne pression
            ecart_type pression
        }
    }
}
# The problem is solved with #
Solve pb
# Not necessary keyword to finish #
End
```

2 Heat transfer (2D, VDF/VEF)

2.1 With diffusion_implicite

```
# Thermohydraulique 2D couplee a conduction 2D #
# PARALLEL OK 8 #
dimension 2
Scheme_euler_explicit sch
Read sch
{
    tinit 0.
    tmax 300.
    dt_min 0.001
    dt_max 10.
    dt_impr 0.001
    dt_sauv 400.
    seuil_statio 1.e-20
    diffusion_implicite 1
}
Pb_conduction pb1
Pb_Thermohydraulique pb2
Domaine dom_solide
Domaine dom_fluide
# BEGIN MESH #
Mailler dom_solide
{
    Pave Cavite1
    {
        Origine 0. 0.
        Nombre_de_Noeuds 13 41
        Longueurs 0.3 1
    }
```

```
    {
        Bord Gauche1 X = 0.    0.  <= Y <= 1
        Bord Haut1   Y = 1     0.  <= X <= 0.3
        Bord Bas1    Y = 0.    0.  <= X <= 0.3
        Raccord local homogene Droit1  X = 0.3  0.3 <= Y <= 1
    } ,
    Pave Cavite2
    {
        Origine 0.3 0.
        Nombre_de_Noeuds 29 13
        Longueurs 0.7 0.3
    }
    {
        Raccord local homogene Haut2   Y = 0.3  0.3 <= X <= 1
        Bord Bas2    Y = 0.   0.3 <= X <= 1
        Bord Droit2  X = 1    0.  <= Y <= 0.3
    }
}
Mailler dom_fluide
{
    Pave Cavite3
    {
        Origine 0.3 0.3
        Nombre_de_Noeuds 29 29
        Longueurs 0.7 0.7
    }
    {
        Raccord local homogene Droit1 X = 0.3  0.3 <= Y <= 1
        Bord Entree    Y = 1  0.3 <= X <= 0.7
        Bord Haut3     Y = 1  0.7 <= X <= 1
        Raccord local homogene Haut2  Y = 0.3  0.3 <= X <= 1
        Bord Sortie    X = 1  0.3 <= Y <= 0.7
        Bord Droit2    X = 1  0.7 <= Y <= 1
    }
}
trianguler_H dom_fluide
trianguler_H dom_solide
Transformer dom_fluide  X*(1-0.5*Y*Y)  Y*(1+0.1*X*Y)
Transformer dom_solide  X*(1-0.5*Y*Y)  Y*(1+0.1*X*Y)
Postraiter_domaine { format lata fichier dom.lata domaines { dom_solide dom_fluide } }
# END MESH #
# BEGIN PARTITION
Partition dom_solide
{
    Partition_tool tranche { tranches 3 1 }
    Larg_joint 1
    zones_name DOM1
}
Partition dom_fluide
{
    Partition_tool tranche { tranches 3 1 }
    Larg_joint 1
    zones_name DOM2
}
End
END PARTITION #
```

```
# BEGIN SCATTER
Scatter DOM1.Zones dom_solide
Scatter DOM2.Zones dom_fluide
END SCATTER #
VEFPreP1B dis

Associate pb1 dom_solide
Associate pb2 dom_fluide
Probleme_Couple pbc
Associate pbc pb1
Associate pbc pb2
Associate pbc sch
Discretize pbc dis
Read pb1
{
    Solide
    {
        rho Uniform_Field 1 1000.
        lambda Champ_Uniforme 1 250.
        Cp Champ_Uniforme 1 100
    }

    Conduction
    {
        diffusion { }
        initial_conditions { temperature Champ_Uniforme 1 30. }
        boundary_conditions
        {
            Gauche1 paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Haut1   paroi_temperature_imposee   Champ_Front_Uniforme 1 20.
            Bas1    paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Droit1  paroi_contact pb2  Droit1   Haut2   paroi_contact pb2  Haut2
            Bas2    paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Droit2  paroi_temperature_imposee   Champ_Front_Uniforme 1 20.
        }
    }
    Post_processing
    {
        Probes
        {
            sonde_tsol temperature periode 1. points 2     0.15 0.55     0.55 0.15
        }
        Definition_champs
        {
            temperature_elem_dom_solide Interpolation
            {
                localisation elem
                source refChamp { Pb_champ pb1 temperature }
            }
            temperature_som_dom_solide Interpolation
            {
                localisation som
                source refChamp { Pb_champ pb1 temperature }
            }
        }
        Format lata
```

```
        fields dt_post 20.+2.*t
        {
            temperature_elem_dom_solide
            temperature_som_dom_solide
            temperature elem
        }
    }
    sauvegarde formatte solide.rep
}
Read pb2
{
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 0.002
        rho Champ_Uniforme 1 2
        lambda Champ_Uniforme 1 1.0
        Cp Champ_Uniforme 1 500
        beta_th Champ_Uniforme 1 0.0001
        gravite Uniform_field 2 0 -9.81
    }

    Navier_Stokes_standard
    {
        solveur_pression GCP { precond ssor { omega 1.500000 } seuil 1.000000e-14 impr }
        convection { amont }
        diffusion { }
        sources { boussinesq_temperature { T0 30. } }
        initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
        boundary_conditions {
            Entree frontiere_ouverte_vitesse_imposee    Champ_front_Uniforme 2 0. -0.01
            Sortie frontiere_ouverte_pression_imposee   Champ_front_Uniforme 1 0.
            Droit1 paroi_fixe
            Haut3  paroi_fixe
            Haut2  paroi_fixe
            Droit2 paroi_fixe
        }
    }
    Convection_Diffusion_Temperature
    {
        diffusion { }
        convection { amont }
        boundary_conditions
        {
            Entree frontiere_ouverte_temperature_imposee    Champ_front_Uniforme 1 20.
            Sortie frontiere_ouverte_temperature_imposee    Champ_front_Uniforme 1 20.
            Droit1 paroi_contact pb1  Droit1
            Haut3  paroi_temperature_imposee    Champ_front_Uniforme 1 20.
            Haut2  paroi_contact pb1  Haut2
            Droit2 paroi_temperature_imposee    Champ_front_Uniforme 1 20.
        }
        initial_conditions { Temperature Champ_Uniforme 1 30. }
    }
    Post_processing
    {
        Probes
        {
```

```
            sonde_pression  pression periode 1.     points 1    0.55 0.55
            sonde_vitesse   vitesse periode 1.      points 1    0.55 0.55
            sonde_tflu      temperature periode 1.  points 1    0.55 0.55
            sonde_seg       temperature periode 5.  segment 10 0. 0.75 1. 0.75
            sonde_temp_interp_elem temperature_elem_dom_fluide periode 1. points 1   0.55 0.55
            sonde_temp_interp_som  temperature_som_dom_fluide  periode 1. points 1   0.55 0.55
            sonde_seg_temp_interp_elem temperature_elem_dom_fluide periode 5.
                                                            segment 10 0. 0.75 1. 0.75
        }
        Definition_champs
        {
            temperature_elem_dom_fluide Interpolation
            {
                localisation elem
                source refChamp { Pb_champ pb2 temperature }
            }
            temperature_som_dom_fluide Interpolation
            {
                localisation som
                source refChamp { Pb_champ pb2 temperature }
            }
        }
        Format lata
        fields dt_post 20.+2.*t
        {
            pression elem
            pression som
            vitesse elem
            vitesse som
            temperature_elem_dom_fluide
            temperature_som_dom_fluide
        }
    }
    sauvegarde formatte fluide.rep
}
Imprimer_flux dom_fluide { Entree Haut2 }
Imprimer_flux dom_solide { Bas1 Haut2 }
Solve pbc
End
```

2.2 With scheme_euler_implicit

```
# Thermohydraulique 2D couplee a conduction 2D #
# PARALLEL OK 8 #
dimension 2
Scheme_Euler_implicit sch
Read sch
{
    tinit 0.
    tmax 300.
    dt_min 0.001
    dt_max 10.
    dt_impr 0.001
    dt_sauv 400.
    seuil_statio 1.e-20
    facsec 50
    facsec_max 300
```

```
    solveur implicite
    {
        solveur gmres { diag seuil 1e-30 nb_it_max 5 impr }
        seuil_convergence_implicite 0.01
    }
}
Pb_conduction pb1
Pb_Thermohydraulique pb2
Domaine dom_solide
Domaine dom_fluide
# BEGIN MESH #
Mailler dom_solide
{
    Pave Cavite1
    {
        Origine 0. 0.
        Nombre_de_Noeuds 13 41
        Longueurs 0.3 1
    }
    {
        Bord Gauche1 X = 0.    0.  <= Y <= 1
        Bord Haut1   Y = 1     0.  <= X <= 0.3
        Bord Bas1    Y = 0.    0.  <= X <= 0.3
        Raccord local homogene Droit1  X = 0.3  0.3 <= Y <= 1
    } ,
    Pave Cavite2
    {
        Origine 0.3 0.
        Nombre_de_Noeuds 29 13
        Longueurs 0.7 0.3
    }
    {
        Raccord local homogene Haut2   Y = 0.3  0.3 <= X <= 1
        Bord Bas2    Y = 0.   0.3 <= X <= 1
        Bord Droit2  X = 1    0.  <= Y <= 0.3
    }
}
Mailler dom_fluide
{
    Pave Cavite3
    {
        Origine 0.3 0.3
        Nombre_de_Noeuds 29 29
        Longueurs 0.7 0.7
    }
    {
        Raccord local homogene Droit1 X = 0.3  0.3 <= Y <= 1
        Bord Entree    Y = 1  0.3 <= X <= 0.7
        Bord Haut3     Y = 1  0.7 <= X <= 1
        Raccord local homogene Haut2  Y = 0.3  0.3 <= X <= 1
        Bord Sortie    X = 1  0.3 <= Y <= 0.7
        Bord Droit2    X = 1  0.7 <= Y <= 1
    }
}
trianguler_H dom_fluide
trianguler_H dom_solide
```

Transformer dom_fluide X*(1-0.5*Y*Y) Y*(1+0.1*X*Y)
Transformer dom_solide X*(1-0.5*Y*Y) Y*(1+0.1*X*Y)

```
Postraiter_domaine { format lata fichier dom.lata domaines { dom_solide dom_fluide } }
# END MESH #
# BEGIN PARTITION
Partition dom_solide
{
    Partition_tool tranche { tranches 3 1 }
    Larg_joint 1
    zones_name DOM1
}
Partition dom_fluide
{
    Partition_tool tranche { tranches 3 1 }
    Larg_joint 1
    zones_name DOM2
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM1.Zones dom_solide
Scatter DOM2.Zones dom_fluide
END SCATTER #
```

VEFPreP1B dis

```
Associate pb1 dom_solide
Associate pb2 dom_fluide
Probleme_Couple pbc
Associate pbc pb1
Associate pbc pb2
Associate pbc sch
Discretize pbc dis
Read pb1
{
    Solide
    {
        rho Uniform_Field 1 1000.
        lambda Champ_Uniforme 1 250.
        Cp Champ_Uniforme 1 100
    }
    Conduction
    {
        diffusion { }
        initial_conditions { temperature Champ_Uniforme 1 30. }
        boundary_conditions
        {
            Gauche1 paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Haut1   paroi_temperature_imposee   Champ_Front_Uniforme 1 20.
            Bas1    paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Droit1  paroi_contact pb2  Droit1   Haut2   paroi_contact pb2  Haut2
            Bas2    paroi_temperature_imposee   Champ_Front_Uniforme 1 40.
            Droit2  paroi_temperature_imposee   Champ_Front_Uniforme 1 20.
        }
    }
    Post_processing
    {
```

```
        Probes
        {
            sonde_tsol temperature periode 1. points 2     0.15 0.55     0.55 0.15
        }
        Definition_champs
        {
            temperature_elem_dom_solide Interpolation
            {
                localisation elem
                source refChamp { Pb_champ pb1 temperature }
            }
            temperature_som_dom_solide Interpolation
            {
                localisation som
                source refChamp { Pb_champ pb1 temperature }
            }
        }
        Format lata
        fields dt_post 20.+2.*t
        {
            temperature_elem_dom_solide
            temperature_som_dom_solide
            temperature elem
        }
    }
    sauvegarde formatte solide.rep
}
Read pb2
{
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 0.002
        rho Champ_Uniforme 1 2
        lambda Champ_Uniforme 1 1.0
        Cp Champ_Uniforme 1 500
        beta_th Champ_Uniforme 1 0.0001
        gravite Uniform_field 2 0 -9.81
    }

    Navier_Stokes_standard
    {
        solveur_pression GCP { precond ssor { omega 1.500000 } seuil 1.000000e-14 impr }
        convection { amont }
        diffusion { }
        sources { boussinesq_temperature { T0 30. } }
        initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
        boundary_conditions {
            Entree frontiere_ouverte_vitesse_imposee    Champ_front_Uniforme 2 0. -0.01
            Sortie frontiere_ouverte_pression_imposee   Champ_front_Uniforme 1 0.
            Droit1 paroi_fixe
            Haut3  paroi_fixe
            Haut2  paroi_fixe
            Droit2 paroi_fixe
        }
    }
    Convection_Diffusion_Temperature
```

```
    {
        diffusion { }
        convection { amont }
        boundary_conditions
        {
            Entree frontiere_ouverte_temperature_imposee    Champ_front_Uniforme 1 20.
            Sortie frontiere_ouverte_temperature_imposee    Champ_front_Uniforme 1 20.
            Droit1 paroi_contact pb1  Droit1
            Haut3  paroi_temperature_imposee    Champ_front_Uniforme 1 20.
            Haut2  paroi_contact pb1  Haut2
            Droit2 paroi_temperature_imposee    Champ_front_Uniforme 1 20.
        }
        initial_conditions { Temperature Champ_Uniforme 1 30. }
    }
    Post_processing
    {
        Probes
        {
            sonde_pression  pression periode 1.     points 1    0.55 0.55
            sonde_vitesse   vitesse periode 1.      points 1    0.55 0.55
            sonde_tflu      temperature periode 1.  points 1    0.55 0.55
            sonde_seg       temperature periode 5.  segment 10 0. 0.75 1. 0.75
            sonde_temp_interp_elem temperature_elem_dom_fluide periode 1. points 1   0.55 0.55
            sonde_temp_interp_som  temperature_som_dom_fluide  periode 1. points 1   0.55 0.55
            sonde_seg_temp_interp_elem temperature_elem_dom_fluide periode 5.
                                                          segment 10 0. 0.75 1. 0.75
        }
        Definition_champs
        {
            temperature_elem_dom_fluide Interpolation
            {
                localisation elem
                source refChamp { Pb_champ pb2 temperature }
            }
            temperature_som_dom_fluide Interpolation
            {
                localisation som
                source refChamp { Pb_champ pb2 temperature }
            }
        }
        Format lata
        fields dt_post 20.+2.*t
        {
            pression elem
            pression som
            vitesse elem
            vitesse som
            temperature_elem_dom_fluide
            temperature_som_dom_fluide
        }
    }
    sauvegarde formatte fluide.rep
}
Imprimer_flux dom_fluide { Entree Haut2 }
Imprimer_flux dom_solide { Bas1 Haut2 }
Solve pbc
```

```
End
```

3 Low mach number flow (2D)

3.1 With scheme_euler_explicit

```
# Thermohydraulique 2D VEF #
dimension 2
pb_thermohydraulique_qc pb
Domaine dom
# BEGIN MESH #
Mailler dom
{
    Pave Plaques
    {
        Origine 0. 0.
        Nombre_de_Noeuds 41 11
        Longueurs 4. 1.
    }
    {
        Bord Gauche X = 0.  0. <= Y <= 1.
        Bord Droit  X = 4.  0. <= Y <= 1.
        Bord Bas    Y = 0.  0. <= X <= 4.
        Bord Haut   Y = 1.  0. <= X <= 4.
    }
}
Trianguler_H dom
VEFPreP1B dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0.
    # tmax 1. #
    dt_min 1.e-7
    dt_max 0.1
    dt_impr 1.e-7
    dt_sauv 100.
    seuil_statio 10.
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    # properties of helium #
    fluide_quasi_compressible
    {
        mu      Champ_Fonc_fonction   pb  temperature 1   3.95e-7*val^0.687
        lambda  Champ_Fonc_fonction   pb  temperature 1  2.774e-3*val^0.701
        pression   7092750.
        loi_etat gaz_parfait_qc
        {
            Prandtl   0.673
            Cp        5193.
            gamma     1.666
        }
```

```
        Traitement_Pth          constant
        Traitement_rho_gravite  moins_rho_moyen
    }

    Navier_Stokes_qc
    {
        solveur_pression Gcp { precond ssor { omega 1.5 } seuil 1.e-8 impr }
        convection { EF_stab { TdivU } } # Test of TdivU, see documentation #
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 2 1. 0. }
        boundary_conditions
        {
             Bas    Symetrie
             Haut   Symetrie
             Droit  frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
             Gauche frontiere_ouverte_vitesse_imposee Champ_Front_Uniforme 2 1. 0.
        }
        Traitement_particulier { temperature { Bord Droit Direction 0  } }
    }
    Convection_diffusion_chaleur_qc
    {
        convection { EF_stab { } }
        diffusion { }
        boundary_conditions
        {
            Bas    Paroi_flux_impose Champ_front_Uniforme 1 1.e6
            Haut   Paroi_flux_impose Champ_front_Uniforme 1 1e6
            Droit  frontiere_ouverte T_ext champ_front_uniforme  1 500.0
            Gauche Frontiere_ouverte_temperature_imposee Champ_Front_Uniforme 1 100.
        }
        initial_conditions { temperature Champ_Uniforme 1 100. }
    }
    Post_processing
    {
        Probes
        {
            sonde_vitesse   velocity        periode 1. points  1 4. 1.
            sonde_vitesse2  vitesse        periode 1. points  1 4. 1.
            sonde_masse_vol masse_volumique periode 1. points  1 4. 1.
            sonde_temp      temperature     periode 1. points  1 4. 1.
            sonde_temp2     temperature     periode 1. segment 9 4. 0.05    4. 0.95
        }
        format lata
        fields dt_post 1.
        {
            pression
            vitesse
            temperature
        }
    }
}
Solve pb
End
```

3.2 With scheme_euler_implicit

```
# Thermohydraulique 2D VEF #
```

```
dimension 2
pb_thermohydraulique_qc pb
Domaine dom
# BEGIN MESH #
Mailler dom
{
    Pave Plaques
    {
        Origine 0. 0.
        Nombre_de_Noeuds 41 11
        Longueurs 4. 1.
    }
    {
        Bord Gauche X = 0.  0. <= Y <= 1.
        Bord Droit  X = 4.  0. <= Y <= 1.
        Bord Bas    Y = 0.  0. <= X <= 4.
        Bord Haut   Y = 1.  0. <= X <= 4.
    }
}
Trianguler_H dom
VEFPreP1B dis
Scheme_euler_implicit sch
Read sch
{
    tinit 3.991476
    dt_min 1.e-7
    dt_max 0.1
    dt_impr 1.e-7
    dt_sauv 100.
    seuil_statio 10.
    facsec 10.
    facsec_max 90
    Solveur Implicite
    {
        solveur gmres { diag seuil 1e-30 nb_it_max 5 impr }
        seuil_convergence_implicite 0.01
    }
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    # properties of helium #
    fluide_quasi_compressible
    {
        mu      Champ_Fonc_fonction  pb temperature 1  3.95e-7*val^0.687
        lambda  Champ_Fonc_fonction  pb   temperature 1  2.774e-3*val^0.701
        pression   7092750.
        loi_etat gaz_parfait_qc
        {
            Prandtl   0.673
            Cp        5193.
            gamma     1.666
        }
        Traitement_Pth          constant
```

```
        Traitement_rho_gravite  moins_rho_moyen
    }
    Navier_Stokes_qc
    {
        solveur_pression Gcp { precond ssor { omega 1.5 } seuil 1.e-8 impr }
        convection { EF_stab { TdivU } } # Test of TdivU, see documentation #
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 2 1. 0. }
        boundary_conditions
        {
             Bas    Symetrie
             Haut   Symetrie
             Droit  frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
             Gauche frontiere_ouverte_vitesse_imposee Champ_Front_Uniforme 2 1. 0.
        }
        Traitement_particulier { temperature { Bord Droit Direction 0  } }
    }
    Convection_diffusion_chaleur_qc
    {
        convection { EF_stab { } }
        diffusion { }
        boundary_conditions
        {
            Bas    Paroi_flux_impose Champ_front_Uniforme 1 1.e6
            Haut   Paroi_flux_impose Champ_front_Uniforme 1 1e6
            Droit  frontiere_ouverte T_ext champ_front_uniforme  1 500.0
            Gauche Frontiere_ouverte_temperature_imposee Champ_Front_Uniforme 1 100.
        }
        initial_conditions { temperature Champ_Uniforme 1 100. }
    }
    Post_processing
    {
        Probes
        {
            sonde_vitesse   velocity        periode 1. points  1 4. 1.
            sonde_vitesse2  vitesse         periode 1. points  1 4. 1.
            sonde_masse_vol masse_volumique periode 1. points  1 4. 1.
            sonde_temp      temperature     periode 1. points  1 4. 1.
            sonde_temp2     temperature     periode 1. segment 9 4. 0.05    4. 0.95
        }
        format lata
        fields dt_post 1.
        {
            pression
            vitesse
            temperature
        }
    }
    reprise binaire TP_Temp_QC_VEF_pb.sauv
}
Solve pb
End
```

4 Periodic channel flow (3D)

4.1 With scheme_euler_explicit

```
# Canal 3D periodique a Re=200 depuis une reprise d'un calcul sur une discretisation plus lache (P1) #
# PARALLEL OK #
dimension 3
Pb_hydraulique pb
Domaine dom
# BEGIN MESH #
Read_file dom cylindre.geom
VerifierCoin dom { }
Dilate dom 1000
RegroupeBord dom perioz { Surfa Surfanz }
Corriger_frontiere_periodique  domaine dom bord perioz
RegroupeBord dom periox { Entree Sortie }
Raffiner_Anisotrope dom
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool metis { Nb_parts 2 }
    Larg_joint 2
    zones_name DOM
    Periodique 1 perioz
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
# Je choisis une discretisation #
VEFPreP1B dis
Scheme_euler_explicit mon_schema
Read mon_schema
{
    nb_pas_dt_max 30
    tinit 0
    tmax 100
    dt_min 1.e-6
    dt_max 1.e6
    dt_impr 1.e-6
    dt_sauv 100
    seuil_statio 1.e-8
    diffusion_implicite 1
}
Associate pb dom
Associate pb mon_schema
Discretize pb dis
Read pb
{
    # Je definis un milieu #
    Fluide_Incompressible
    {
        mu  Champ_Uniforme 1 0.01
        rho Champ_Uniforme 1 2.
    }
```

```
Navier_Stokes_standard
{
    solveur_pression GCP
    {
        precond ssor { omega 1.5 }
        seuil 1.e-6
        impr
    }
    convection { muscl }
    diffusion { }
    sources
    {
        canal_perio { bord periox } ,
        Acceleration
        {
            omega          Champ_Fonc_t     3 0. 0. 1.
            domegadt         Champ_Fonc_t    3 0. 0. 0.
            centre_rotation Champ_Fonc_t     3 0. 0. 0.
        }
    }
    initial_conditions
    {
        # vitesse champ_uniforme 3 1. 0. 0.#
        vitesse champ_fonc_reprise P1toP1Bulle_pb.xyz pb vitesse last time
    }
    boundary_conditions
    {
        perioz periodique
        Bas  paroi_fixe
        Haut paroi_fixe
        Cylindre paroi_fixe  periox periodique
        # Sortie frontiere_ouverte_pression_imposee    Champ_front_Uniforme 1 0.
        Entree frontiere_ouverte_vitesse_imposee   Champ_front_Uniforme 3 1. 0. 0. #
    }
}
Post_processing
{
    Definition_champs
    {
        Energie_cinetique_fluide predefini { pb_champ pb energie_cinetique }
    }
        Probes
        {
            sonde_ec Energie_cinetique_fluide periode 0.005 point 1 0.7 0. 0.
            sonde_pression pression_pa periode 0.005 circle 11 0. 0. 0. 2 0.7 0. 360.
            sonde_vitesse vitesse periode 0.005 point 1 0.7 0. 0.
        }
        format lata
        fields dt_post 1.
        {
            pression_pa som
            vitesse faces
        }
        Statistiques dt_post 1.
        {
            t_deb 1. t_fin 5.
```

```
                moyenne vitesse faces
            }
    }
}
Solve pb
```

4.2 With scheme_euler_implicit

```
# Canal 3D periodique a Re=200 depuis une reprise d'un calcul sur une discretisation plus lache (P1) #
# PARALLEL OK #
dimension 3
Pb_hydraulique pb
Domaine dom
# BEGIN MESH #
Read_file dom cylindre.geom
VerifierCoin dom { }
Dilate dom 1000
RegroupeBord dom perioz { Surfa Surfanz }
Corriger_frontiere_periodique  domaine dom bord perioz
RegroupeBord dom periox { Entree Sortie }
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool metis { Nb_parts 2 }
    Larg_joint 2
    zones_name DOM
    Periodique 1 perioz
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
# Je choisis une discretisation #
VEFPreP1B dis
Read dis  P1
Scheme_Euler_implicit mon_schema
Read mon_schema
{
    nb_pas_dt_max 30
    tinit 0
    tmax 100
    dt_min 1.e-6
    dt_max 1.e6
    dt_impr 1.e-6
    dt_sauv 100
    seuil_statio 1.e-8
    facsec 1.
    facsec_max 50.
    solveur implicite
    {
        solveur gmres { diag seuil 1e-30 nb_it_max 5 impr }
        seuil_convergence_implicite 0.01
    }
}
Associate pb dom
```

```
Associate pb mon_schema
Discretize pb dis
Read pb
{
    # Je definis un milieu #
    Fluide_Incompressible
    {
        mu  Champ_Uniforme 1 0.01
        rho Champ_Uniforme 1 2.
    }
    Navier_Stokes_standard
    {
        solveur_pression GCP
        {
            precond ssor { omega 1.5 }
            seuil 1.e-6
            impr
        }
        convection { muscl }
        diffusion { }
        sources
        {
            canal_perio { bord periox } ,
            Acceleration
            {
                omega             Champ_Fonc_t     3 0. 0. 1.
                domegadt    Champ_Fonc_t    3 0. 0. 0.
                centre_rotation Champ_Fonc_t     3 0. 0. 0.
            }
        }
        initial_conditions
        {
            vitesse champ_fonc_reprise P1toP1Bulle_pb.xyz  pb  vitesse  last_time
        }
        boundary_conditions
        {
            perioz periodique
            Bas  paroi_fixe
            Haut paroi_fixe
            Cylindre paroi_fixe  periox periodique
            # Sortie frontiere_ouverte_pression_imposee   Champ_front_Uniforme 1 0.
            Entree frontiere_ouverte_vitesse_imposee  Champ_front_Uniforme 3 1. 0. 0. #
        }
    }
    Post_processing
    {
        Definition_champs
        {
            Energie_cinetique_fluide predefini { pb_champ pb energie_cinetique }
        }
            Probes
            {
                sonde_ec Energie_cinetique_fluide periode 0.005 point 1 0.7 0. 0.
                sonde_pression pression_pa periode 0.005 circle 11 0. 0. 0. 2 0.7 0. 360.
                sonde_vitesse vitesse periode 0.005 point 1 0.7 0. 0.
            }
```

```
            format lata
            fields dt_post 1.
            {
                pression_pa som
                vitesse faces
            }
            Statistiques dt_post 1.
            {
                t_deb 1. t_fin 5.
                moyenne vitesse faces
            }
    }
}
Solve pb
```

5 Constituents and turbulent flow

```
# Hydraulique 2D turbulent K-Eps #
# PARALLEL OK 8 #
dimension 2
Pb_Hydraulique_concentration_Turbulent pb
Domaine dom
# BEGIN MESH #
Mailler dom
{
    Pave Entree
    {
        Origine 0. 1.
        Nombre_de_Noeuds 8 6
        Longueurs 7. 1.
    }
    {
        Bord Entree X = 0. 1. <= Y <= 2.
        Bord Haut1  Y = 2. 0. <= X <= 7.
        Bord Bas1   Y = 1. 0. <= X <= 7.
    } ,
    Pave Haut
    {
        Origine 7. 1.
        Nombre_de_Noeuds 11 6
        Longueurs 10. 1.
    }
    {
        Bord Haut2  Y = 2.  7. <= X <= 17.
    } ,
    Pave SHaute
    {
        Origine 17. 1.
        Nombre_de_Noeuds 14 6
        Longueurs 13. 1.
    }
    {
        Bord SortieHaute X = 30.  1. <= Y <= 2.
        Bord Haut3  Y = 2.  17. <= X <= 30.
    } ,
    Pave Bas
```

```
    {
        Origine 7. 0.
        Nombre_de_Noeuds 11 6
        Longueurs 10. 1.
    }
    {
        Bord Bas2   Y = 0.  7. <= X <= 17.
        Bord Gauche X = 7.  0. <= Y <= 1.
    } ,
    Pave SBasse
    {
        Origine 17. 0.
        Nombre_de_Noeuds 14 6
        Longueurs 13. 1.
    }
    {
        Bord SortieBasse X = 30. 0. <= Y <= 1.
        Bord Bas3   Y = 0. 17. <= X <= 30.
    }
}
Sous_Zone zone
Associate zone dom
Read zone
{
    Rectangle
    Origine 15 0.5
    Cotes  1 1
}
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool tranche { tranches 2 1 }
    Larg_joint 1
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
VDF dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0
    tmax 32.
    dt_min 0.01
    dt_max 0.01
    dt_impr 0.1
    dt_sauv 1000.
    seuil_statio 1.e-8
}
Associate pb dom
Associate pb sch
Discretize pb dis
```

```
Read pb
{
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 3.7e-05
        rho Champ_Uniforme 1 2
        beta_co Champ_Uniforme 1 0.
        gravite Champ_Uniforme 2 0 0
    }
    Constituant
    {
          coefficient_diffusion Champ_Uniforme 3 1. 1. 1.
    }

    Navier_Stokes_turbulent
    {
        solveur_pression cholesky { }
        convection { Amont }
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
        boundary_conditions
        {
             Haut1 Paroi_Fixe
             Bas1 Paroi_Fixe
             Haut2 Paroi_Fixe
             Bas2 Paroi_Fixe
             Haut3 Paroi_Fixe
             Bas3 Paroi_Fixe
             Gauche Paroi_Fixe
             SortieBasse frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
             SortieHaute frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
             Entree frontiere_ouverte_vitesse_imposee Champ_Front_Uniforme 2  1. 0.
        }
        modele_turbulence K_Epsilon
        {
            Transport_K_Epsilon
            {
                convection { amont }
                diffusion { }
                sources
                {
                  Source_Transport_K_Eps_aniso_concen { C1_eps 1.44 C2_eps 1.92 C3_eps 1. }
                }
                boundary_conditions
                {
                    Haut1 Paroi
                    Bas1 Paroi
                    Haut2 Paroi
                    Bas2 Paroi
                    Haut3 Paroi
                    Bas3 Paroi
                    Gauche Paroi
                    Entree frontiere_ouverte_K_eps_impose Champ_Front_Uniforme 2 1.e-2 1.e-3
                    SortieBasse frontiere_ouverte K_EPS_EXT Champ_Front_Uniforme 2 0. 0.
                    SortieHaute frontiere_ouverte K_EPS_EXT Champ_Front_Uniforme 2 0. 0.
                }
```

```
            initial_conditions { k_Eps Champ_Uniforme 2 0. 0. }
        }
        Prandtl_K 1
        Prandtl_Eps 1.3
        turbulence_paroi loi_expert_hydr { kappa 0.415 Erugu 9.11 A_plus 26 } dt_impr_ustar 10. eps
    }
}
Convection_diffusion_Concentration_turbulent
{
    diffusion { }
    convection { quick }
    sources { Source_constituant Champ_uniforme_morceaux dom 3 { Defaut 0 0 0 zone 0 1 0 } }
    boundary_conditions
    {
        Haut1       Paroi
        Bas1        Paroi
        Haut2       Paroi
        Bas2        Paroi
        Haut3       Paroi
        Bas3        Paroi
        Gauche      Paroi
        SortieBasse   frontiere_ouverte C_ext Champ_Front_Uniforme 3 0. 0. 0.
        SortieHaute   frontiere_ouverte C_ext Champ_Front_Uniforme 3 0. 0. 0.
        Entree      frontiere_ouverte C_ext Champ_Front_Uniforme 3 0. 0. 0.
    }
    initial_conditions { concentration Champ_Uniforme 3 0. 0. 0. }
    Modele_turbulence Schmidt {
        Turbulence_paroi loi_standard_hydr_scalaire
    }
}
Post_processing
{
    Probes
    {
        sonde_vitesse vitesse periode 0.01 points 1 10. 0.5
        sonde_k k periode 0.01 points 1 9.5 0.5
        sonde_eps eps periode 0.01 points 1 9.5 0.5
        sonde_visc viscosite_turbulente periode 0.01 points 1 9.5 0.5
        sonde_yplus y_plus periode 0.01 segment 9 7.5 0.01 16.5 0.01
        sonde_vorticite vorticite periode 0.01 segment 9 7.5 0.01 16.5 0.01
    }
    format lata
    fields dt_post 20.
    {
        pression elem
        pression som
        vitesse elem
        vitesse som
        k elem
        k som
        eps elem
        eps som
        viscosite_turbulente elem
        viscosite_turbulente som
        concentration0 elem
        concentration1 elem
```

```
            concentration2 elem
        }
    }
}
Solve pb
End
```

6 3D turbulent flow in a curved pipe

Minimal exercise, no need to put a solution

7 Turbulent flow over a backward-facing step (3D)

7.1 Turbulence model Smagorinsky

```
# Hydraulique 3D turbulent sous maille #
# PARALLEL RUNS #
dimension 3
Pb_Hydraulique_Turbulent pb
Domaine dom
# BEGIN MESH #
Read_file Marche3D.geo ;
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool tranche { tranches 2 1 1 }
    Larg_joint 1
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
VDF dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0
    tmax 80.
    dt_min 0.2
    dt_max 0.2
    dt_impr 0.2
    dt_sauv 100.
    seuil_statio 1.e-8
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 2e-05
        rho Champ_Uniforme 1 1
```

```
}
Navier_Stokes_Turbulent
{
    solveur_pression cholesky { }
    convection { quick }
    diffusion { }
    initial_conditions { vitesse Champ_Uniforme 3  0. 0. 0. }
    boundary_conditions {
         Bas1 Paroi_Fixe
         Haut1 Paroi_Fixe
         Haut2 Paroi_Fixe
         Haut3 Paroi_Fixe
         Bas2 Paroi_Fixe
         Gauche Paroi_Fixe
         Bas3 Paroi_Fixe
         Sud1 Paroi_Fixe
         Nord1 Paroi_Fixe
         Sud2 Paroi_Fixe
         Nord2 Paroi_Fixe
         Sud3 Paroi_Fixe
         Nord3 Paroi_Fixe
         Sud4 Paroi_Fixe
         Nord4 Paroi_Fixe
         Sud5 Paroi_Fixe
         Nord5 Paroi_Fixe
         SortieBasse frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
         SortieHaute frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
         Entree frontiere_ouverte_vitesse_imposee Champ_Front_Uniforme 3  1. 0. 0.
    }
    modele_turbulence sous_maille_smago {
        cs 0.1
        turbulence_paroi loi_standard_hydr
    }
}
Post_processing
{
    Probes
    {
        sonde_pression pression periode 0.5 points 1 7.5 0.9 5.5
        sonde_vitesse vitesse periode 0.5 points 1 8.0 0.9 5.5
        sonde_visc viscosite_turbulente periode 0.5 points 2 7.5 0.9 5.5 7.5 1.1 4.5
        sonde_k k periode 0.5 points 2 7.5 0.9 5.5 7.5 1.1 4.5
    }
    format lata
    fields dt_post 50.
    {
        pressure elem
        pression som
        velocity elem
        vitesse som
        viscosite_turbulente elem
        viscosite_turbulente som
        vorticite elem
        vorticite som
        k elem
        k som
```

```
        }
    }
}
Solve pb
End
```

7.2 K-Eps Turbulence model

```
# Hydraulique 3D turbulent sous maille #
# PARALLEL RUNS #
dimension 3
Pb_Hydraulique_Turbulent pb
Domaine dom
# BEGIN MESH #
Read_file Marche3D.geo ;
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool tranche { tranches 2 1 1 }
    Larg_joint 1
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
VDF dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0
    tmax 80.
    dt_min 0.2
    dt_max 0.2
    dt_impr 0.2
    dt_sauv 100.
    seuil_statio 1.e-8
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    Fluide_Incompressible
    {
        mu Champ_Uniforme 1 2e-05
        rho Champ_Uniforme 1 1
    }
    Navier_Stokes_Turbulent
    {
        solveur_pression cholesky { }
        convection { quick }
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 3  0. 0. 0. }
        boundary_conditions {
```

```
        Bas1 Paroi_Fixe
        Haut1 Paroi_Fixe
        Haut2 Paroi_Fixe
        Haut3 Paroi_Fixe
        Bas2 Paroi_Fixe
        Gauche Paroi_Fixe
        Bas3 Paroi_Fixe
        Sud1 Paroi_Fixe
        Nord1 Paroi_Fixe
        Sud2 Paroi_Fixe
        Nord2 Paroi_Fixe
        Sud3 Paroi_Fixe
        Nord3 Paroi_Fixe
        Sud4 Paroi_Fixe
        Nord4 Paroi_Fixe
        Sud5 Paroi_Fixe
        Nord5 Paroi_Fixe
        SortieBasse frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
        SortieHaute frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
        Entree frontiere_ouverte_vitesse_imposee Champ_Front_Uniforme 3  1. 0. 0.
    }
    modele_turbulence K_Epsilon
    {
        Transport_K_Epsilon
        {
            convection { amont }
            diffusion { }
            boundary_conditions
            {
                Bas1 Paroi
                Haut1 Paroi
                Haut2 Paroi
                Haut3 Paroi
                Bas2 Paroi
                Gauche Paroi
                Bas3 Paroi
                Sud1 Paroi
                Nord1 Paroi
                Sud2 Paroi
                Nord2 Paroi
                Sud3 Paroi
                Nord3 Paroi
                Sud4 Paroi
                Nord4 Paroi
                Sud5 Paroi
                Nord5 Paroi
                SortieBasse frontiere_ouverte K_EPS_EXT Champ_Front_Uniforme 2 0. 0.
                SortieHaute frontiere_ouverte K_EPS_EXT Champ_Front_Uniforme 2 0. 0.
                Entree frontiere_ouverte_K_eps_impose Champ_Front_Uniforme 2 0. 0.
            }
            initial_conditions {     k_Eps Champ_Uniforme 2 0. 0. }
        }
        turbulence_paroi loi_standard_hydr
    }
}
Post_processing
```

```
    {
        Probes
        {
            sonde_pression pression periode 0.5 points 1 7.5 0.9 5.5
            sonde_vitesse vitesse periode 0.5 points 1 8.0 0.9 5.5
            sonde_visc viscosite_turbulente periode 0.5 points 2 7.5 0.9 5.5 7.5 1.1 4.5
            sonde_k k periode 0.5 points 2 7.5 0.9 5.5 7.5 1.1 4.5
        }
        format lata
        fields dt_post 50.
        {
            pressure elem
            pression som
            velocity elem
            vitesse som
            viscosite_turbulente elem
            viscosite_turbulente som
            vorticite elem
            vorticite som
            k elem
            k som
        }
    }
}
Solve pb
End
```

8 Tank filling (2D, single-phase flow)

8.1 VDF

```
# Hydraulique 2D avec transport constituant #
# PARALLEL OK 5 #
dimension 2
Pb_hydraulique_concentration pb
Domaine dom
# BEGIN MESH #
Mailler dom
{
    Pave Block1
    {
        Origine 0. 0.03
        Nombre_de_Noeuds 51 106
        Longueurs 0.1 0.21
    }
    {
        Bord Left1    X = 0.    0.03 <= Y <= 0.24
        Bord Outlet    Y = 0.24  0.   <= X <= 0.1
        Bord Right1   X = 0.1   0.03 <= Y <= 0.24
    } ,
    Pave Block2
    {
        Origine 0. 0.02
        Nombre_de_Noeuds 51 6
        Longueurs 0.1 0.01
    }
```

```
    {
        Bord Inlet    X = 0.    0.02 <= Y <= 0.03
        Bord Right2   X = 0.1   0.02 <= Y <= 0.03
    } ,
    Pave Block3
    {
        Origine 0. 0.
        Nombre_de_Noeuds 51 11
        Longueurs 0.1 0.02
    }
    {
        Bord Bottom3   Y = 0.    0. <= X <= 0.1
        Bord Right3    X = 0.1   0. <= Y <= 0.02
        Bord Left3     X = 0.    0. <= Y <= 0.02
    }
}
RegroupeBord dom Wall { Left1 Bottom3 Right1 Right2 Right3 Left3 }
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool tranche { tranches 2 1 }
    Larg_joint 2
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
VDF dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0
    tmax 1.
    dt_min 0.01
    dt_max 0.01
    dt_impr 0.01
    dt_sauv 100
    seuil_statio 1.e-8
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    Fluide_Incompressible
    {
        gravite Champ_Uniforme 2 0 -9.81
        mu Champ_Uniforme 1 1.e-03
        rho Champ_Uniforme 1 1000
        beta_co Champ_Uniforme 1 0.
    }
    Constituant { coefficient_diffusion Champ_Uniforme 1 1.e-09 }
```

```
    Navier_Stokes_standard
    {
        solveur_pression GCP {
            precond ssor { omega 1.500000 }
            seuil 1.000000e-06
            impr
        }
        convection { quick }
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 2 0. 0. }
        boundary_conditions {
            Inlet   frontiere_ouverte_vitesse_imposee Champ_Front_Fonc_txyz 2
                                                    (1-((y-0.025)/0.005)^2)*(t<0.5)   0.
            Wall    paroi_fixe
            Outlet  frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
        }
    }
    Convection_diffusion_Concentration {
        diffusion { }
        convection { quick }
        boundary_conditions
        {
            Inlet  frontiere_ouverte_concentration_imposee Champ_Front_Fonc_txyz 1 (1)*(t<0.5)
            Wall    paroi
            Outlet  frontiere_ouverte C_ext Champ_Front_Uniforme 1 0.
        }
        initial_conditions { concentration Champ_Uniforme 1 0. }
        sources { source_Constituant champ_fonc_fonction pb concentration 1 0 }
    }
    Post_processing
    {
        Probes
        {
            sonde_pres pression periode 0.01 points 1 0.45 0.45
            sonde_vit vitesse periode 0.01 points 1 0.4 0.45
            sonde_conc concentration periode 0.01 points 1 0.55 0.45
            sonde_conc_inlet concentration periode 0.01 points 1 0 0.025
            sonde_velocity_inlet vitesse periode 0.01 segment 5 0 0.021 0 0.029
        }
        format lata
        fields dt_post 0.1
        {
            pression elem
            pression som
            vitesse elem
            vitesse som
            concentration elem
            concentration som
        }
    }
}
Solve pb
End
```

8.2 VEF

```
# Hydraulique 2D avec transport constituant #
```

```
# PARALLEL OK 5 #
dimension 2
Pb_hydraulique_concentration pb
Domaine dom
# BEGIN MESH #
Mailler dom
{
    Pave Block1
    {
        Origine 0. 0.03
        Nombre_de_Noeuds 51 106
        Longueurs 0.1 0.21
    }
    {
        Bord Left1    X = 0.    0.03 <= Y <= 0.24
        Bord Outlet     Y = 0.24  0.   <= X <= 0.1
        Bord Right1   X = 0.1   0.03 <= Y <= 0.24
    } ,
    Pave Block2
    {
        Origine 0. 0.02
        Nombre_de_Noeuds 51 6
        Longueurs 0.1 0.01
    }
    {
        Bord Inlet    X = 0.    0.02 <= Y <= 0.03
        Bord Right2   X = 0.1   0.02 <= Y <= 0.03
    } ,
    Pave Block3
    {
        Origine 0. 0.
        Nombre_de_Noeuds 51 11
        Longueurs 0.1 0.02
    }
    {
        Bord Bottom3   Y = 0.    0. <= X <= 0.1
        Bord Right3    X = 0.1   0. <= Y <= 0.02
        Bord Left3     X = 0.    0. <= Y <= 0.02
    }
}
RegroupeBord dom Wall { Left1 Bottom3 Right1 Right2 Right3 Left3 }
Trianguler_h dom
# VerifierCoin dom { Read_file diagonale_VEF.decoupage_som } #
# END MESH #
# BEGIN PARTITION
Partition dom
{
    Partition_tool tranche { tranches 2 1 }
    Larg_joint 2
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones dom
END SCATTER #
```

```
VEFPreP1B dis
Scheme_euler_explicit sch
Read sch
{
    tinit 0
    tmax 0.01
    dt_impr 0.01
    dt_sauv 100
    seuil_statio 1.e-8
}
Associate pb dom
Associate pb sch
Discretize pb dis
Read pb
{
    Fluide_Incompressible
    {
        gravite Champ_Uniforme 2 0 -9.81
        mu Champ_Uniforme 1 3.7e-05
        rho Champ_Uniforme 1 2
        beta_co Champ_Uniforme 1 0.
    }
    Constituant { coefficient_diffusion Champ_Uniforme 1 0.01 }

    Navier_Stokes_standard
    {
        solveur_pression Petsc Cholesky { }
        convection { muscl }
        diffusion { }
        initial_conditions { vitesse Champ_Uniforme 2 1. 1. }
        boundary_conditions {
            Inlet   frontiere_ouverte_vitesse_imposee Champ_Front_Fonc_txyz 2 (1-((y-0.025)/0.005)^2)*(t
            Wall    paroi_fixe
            Outlet  frontiere_ouverte_pression_imposee Champ_Front_Uniforme 1 0.
        }
    }
    Convection_diffusion_Concentration {
        diffusion { }
        convection { muscl }
        boundary_conditions {
            Inlet   frontiere_ouverte_concentration_imposee Champ_Front_Fonc_txyz 1 (1)*(t<0.5)
            Wall    paroi
            Outlet  frontiere_ouverte C_ext Champ_Front_Uniforme 1 0.
        }
        initial_conditions { concentration Champ_Uniforme 1 0.5 }
        sources { source_Constituant champ_fonc_fonction pb concentration 1 0 }
    }
    Post_processing
    {
        Probes
        {
            sonde_pres pression periode 0.01 points 1 0.45 0.45
            sonde_vit  vitesse periode 0.01 points 1 0.4 0.45
            sonde_conc concentration periode 0.01 points 1 0.55 0.45
            sonde_conc_inlet     concentration periode 0.01 points 1 0 0.025
            sonde_velocity_inlet vitesse periode 0.01 segment 5 0 0.021 0 0.029
```

```
        }
        format lata
        fields dt_post 0.1
        {
            pression elem
            pression som
            vitesse elem
            vitesse som
            concentration elem
            concentration som
        }
    }
}
Solve pb
End
```

9 Tank filling (3D, two-phases flow)

```
#
 Cas test Front-tracking discontinu VDF.

  Cas test avec interface liquide-vapeur "interf"
                solide mobile           "body"
                concentration
  Interface liquide-vapeur initiale : un demi-plan + une goutte
  Remaillage, barycentrage, lissage, test collision, gravite,
  tension superficielle.
  Ecriture des resultats au format lata: un fichier lata avec
  les champs volumiques et les interfaces liquide-vapeur(lata1),
  un fichier avec uniquement le solide mobile (lata2)
 Les algorithmes de remaillage avec changement de connectivite
 ne sont pas strictement equivalents entre sequentiel et parallele.
 Il y a donc des ecarts entre le sequentiel et le parallele.
 PARALLEL RUNS
#
dimension 3
# Generic problem used for Front Tracking calculation #
Probleme_FT_Disc_gen pb
Domaine DOM
# BEGIN MESH #
Mailler DOM
{
    Pave pave1
    {
        origine 0. 0. 0.
        longueurs 0.04 0.04 0.12
        nombre_de_noeuds 11 11 16
    }
    {
        bord paroi X = 0.   0. <= Y <= 0.04 0. <= Z <= 0.12
        bord paroi X = 0.04 0. <= Y <= 0.04 0. <= Z <= 0.12
        bord paroi Y = 0.   0. <= X <= 0.04 0. <= Z <= 0.12
        bord paroi Y = 0.04 0. <= X <= 0.04 0. <= Z <= 0.12
        bord bas   Z = 0.   0. <= X <= 0.04 0. <= Y <= 0.04
        bord haut  Z = 0.12 0. <= X <= 0.04 0. <= Y <= 0.04
    }
```

```
}
# END MESH #
# BEGIN PARTITION
Partition DOM
{
    Partition_tool tranche { tranches 2 1 1 }
    Larg_joint 2
    zones_name DOM
}
End
END PARTITION #
# BEGIN SCATTER
Scatter DOM.Zones DOM
END SCATTER #
VDF dis
Scheme_euler_explicit  sch
Read sch
{
    tinit 0.
    tmax  0.1
    dt_min 1.e-7
    dt_max 0.5e-2
    dt_impr 10.
    dt_sauv 100
    seuil_statio -1
}
# First phase: liquid #
Fluide_Incompressible liquide
Read liquide
{
    mu  Champ_Uniforme 1 0.282e-3
    rho Champ_Uniforme 1 1000.
}
# Second phase: gas #
Fluide_Incompressible gaz
Read gaz
{
    mu  Champ_Uniforme 1 0.282e-3
    rho Champ_Uniforme 1 100.
}
# Definition of the two phase media #
Fluide_Diphasique fluide
Read fluide
{
    # Give a number for each phase #
    fluide0 liquide
    fluide1 gaz
    # Surface tension #
    sigma   Champ_Uniforme 1 0.05
}
# Add a constituent #
Constituant constituant
Read constituant { coefficient_diffusion Champ_Uniforme 1 1e-6 }
# Gravity field #
Champ_Uniforme gravite
Read gravite 3 0. 0. -9.81
```

```
Associate fluide gravite
# Navier Stokes equation #
Navier_Stokes_FT_Disc              hydraulique
# One equation for the two phase flow interface #
Transport_Interfaces_FT_Disc       interf
# One equation for a moving body #
Transport_Interfaces_FT_Disc       body
# One equation for the constituent #
Convection_Diffusion_Concentration concentration
Associate pb hydraulique
Associate pb interf
Associate pb body
Associate pb concentration
Associate pb DOM
Associate pb sch
Associate pb fluide
Associate pb constituant
Discretize pb dis

# Define the front tracking problem #
Read pb
{
    hydraulique
    {
        # Turbulence model needed and zeroed for laminar flow #
        # modele_turbulence nul #
        modele_turbulence sous_maille_wale
        {
            Cw               1.e-16
            turbulence_paroi negligeable
        }
        solveur_pression GCP { precond ssor { omega 1.5 } seuil 1e-12 impr }
        convection           { quick }
        diffusion            { }
        initial_conditions { vitesse champ_uniforme 3 0. 0. 0. }
        # Relation beetween Navier Stokes equation and interface equations #
        # The velocity field moves the gas-liquid interface #
        equation_interfaces_proprietes_fluide interf
        # The body has an imposed velocity field, so moves the fluid #
        equation_interfaces_vitesse_imposee   body
        boundary_conditions
        {
            # Outlet boundary condition for FT model #
            haut   Sortie_libre_rho_variable champ_front_uniforme 1 0.
            paroi  paroi_fixe
            bas    Frontiere_ouverte_vitesse_imposee champ_front_uniforme 3 0.0 0.0 0.001
        }
        Traitement_particulier { Ec { Ec periode 1.e-7 } }
    }
    interf
    {
        # Definition of the transport method of the interface: velocity #
        # from the Navier Stokes equation #
        methode_transport vitesse_interpolee hydraulique
        # Initial position of the water-gas interface and a drop of water #
        initial_conditions
```

```
    {
        fonction z-0.03-((x-0.02)^2+(y-0.02)^2)*10 ,
        fonction ajout_phase0 (x-0.02)^2+(y-0.02)^2+(z-0.045)^2-(0.01)^2 ,
        fonction ajout_phase0 (x-0.02)^2+(y-0.02)^2+(z-0.08)^2-(0.01)^2
    }
    # Options for the meshing algorithm #
    iterations_correction_volume 1
    n_iterations_distance 2
    remaillage
    {
        pas 0.000001
        nb_iter_remaillage 1
        critere_arete 0.35
        critere_remaillage 0.2
        pas_lissage 0.000001
        lissage_courbure_iterations 3
        lissage_courbure_coeff -0.1
        nb_iter_barycentrage 3
        relax_barycentrage 1
        facteur_longueur_ideale 0.85
        nb_iter_correction_volume 3
        seuil_dvolume_residuel 1e-12
    }
    # Algorithm for the collision algorithm between interfaces #
    collisions
    {
        active
        juric_pour_tout
        type_remaillage Juric { source_isovaleur indicatrice }
    }
    # Boundary condition, variable contact angle is possible #
    boundary_conditions
    {
        paroi Paroi_FT_disc symetrie
        haut  Paroi_FT_disc symetrie
        bas   Paroi_FT_disc symetrie
    }
}
body
{
    # Initial position of the moving body #
    initial_conditions
        { fonction -(((x-0.02))^2+((y-0.02)/0.6)^2+((z-0.02)/0.6)^2-(0.015^2)) }
    remaillage
    {
        pas 1e8
        nb_iter_remaillage 5
        critere_arete 0.5
        critere_remaillage 0.2
        pas_lissage -1
        nb_iter_barycentrage 5
        relax_barycentrage 1
        facteur_longueur_ideale 1
    }
    boundary_conditions
    {
```

```
        haut  Paroi_FT_disc symetrie
        paroi Paroi_FT_disc symetrie
        bas   Paroi_FT_disc symetrie
    }
    # 2 methods to move the body: velocity(x,y,z)=f(x,y,z) or velocity(x,y,z)=f(t) #
    methode_transport vitesse_imposee  -(y-0.02)*10  (x-0.02)*10  0.
}
# Constituent equation #
concentration
{
    diffusion { negligeable }
    convection { quick }
    initial_conditions { concentration champ_fonc_xyz DOM 1
                                EXP(-((x-0.02)^2+(y-0.02)^2+(z-0.03)^2)/0.03^2) }
    boundary_conditions
    {
        haut  frontiere_ouverte C_ext Champ_Front_Uniforme 1 0.
        paroi paroi
        bas   paroi
    }
}
Post_processing
{
    Definition_champs
    {
        Energie_cinetique_hydro Reduction_0D
        {
            methode somme_ponderee source Transformation
            {
                # Ec=sum[0.5*rho*vol*(u^2+v^2+w^2)dV] #
                methode formule expression 1 0.5*rho*u2_plus_v2_plus_w2
                sources {
                    Transformation
                    {
                        methode produit_scalaire sources
                        {
                            Interpolation {
                                localisation elem
                                source refChamp { Pb_champ pb vitesse } } ,
                            Interpolation {
                                localisation elem
                                source refChamp { Pb_champ pb vitesse } }
                        }
                        nom_source u2_plus_v2_plus_w2
                    } ,
                    refChamp { Pb_champ pb masse_volumique nom_source rho }
                }
            }
        }
    }
    Probes
    {
        vitesse vitesse periode 1.e-7 point 1 0.02 0.02 0.03
        pression pression periode 1.e-7 point 1 0.02 0.02 0.03
        indicatrice_interf indicatrice_interf periode 1.e-7 point 1 0.02 0.02 0.03
        energie_cinetique energie_cinetique_hydro periode 1.e-7 point 1 0.02 0.02 0.03
```

```
        }
        format lata
        fields dt_post 0.01
        {
            indicatrice_interf elem
            concentration elem
            masse_volumique
        }
    }
    liste_postraitements
    {
        # Another keywords to post process FT results #
        Postraitement_ft_lata liquid_gas
        {
            fichier liquid_gas
            format lata

            # Post process the moving grid of the interface #
            interfaces interf {
                courbure som
                vitesse som
                pe elem
            }
        }
        Postraitement_ft_lata body
        {
            nom_fichier body
            format lata
            interfaces body { courbure som }
        }
    }
}
Solve pb
End
```

10 Salomé: 3D VEF mesh

cf hdf files in $TRUST_ROOT/doc/TRUST/exercices/salome directory.

- First exercise Cylinder:
  - $TRUST_ROOT/doc/TRUST/exercices/salome/mesh.py
  - $TRUST_ROOT/doc/TRUST/exercices/salome/prism.py
- Second exercise Revolution:
  $TRUST_ROOT/doc/TRUST/exercices/salome/revolution.py
- Third exercise T_shape:
  $TRUST_ROOT/doc/TRUST/exercices/salome/T_shape.py

11 Gmsh meshing tool

11.1 2D VEF mesh

```
// Variables definition
lc = 0.02;
// First cell size (used when points are defined)
lc1 = lc * 8;
// Second cell size
lc2 = lc / 2;
// Circle diameter
//D = 0.14 ;
//E = D ;
//param = 1;
//H = param * 10 * D ;
//X = param * 5 * D ;
//L = param * 10 * D + X + E;
H=2;
L=10;
// Points definition
Point(1)={0,0,0,lc1};
Point(2) = {L,0,0,lc1};
Point(3) = {L,H,0,lc1};
Point(4) = {0,H,0,lc1};
//Point(5) = {X,0,0,lc2};
//Point(8) = {X+E,0,0,lc2};
Point(10)= {1,1,0,lc2};
Point(11)={1.25,1,0,lc2};
Point(12)={1,1.25,0,lc2};
Point(13)={0.75,1,0,lc2};
Point(14)={1,0.75,0,lc2};
// Lines definition
Line(2) = {1,2};
//Line(5) = {8,2};
Line(6) = {3,2};
Line(7) = {3,4};
Line(8) = {4,1};
// 1/4 Circle definition
//Point(6) = {X+D/2,0,0,lc2}; // Center
//Point(7) = {X+D/2,D/2,0,lc2};
// 3 points for the circle arc
//Circle(1) = {5,6,7};
//Line(3) = {7,6};
```

```
//Line(4) = {6,8};
// A circle arc is STRICTLY smaller than Pi
Circle(10)={11,10,12};
Circle(11)={12,10,13};
Circle(12)={13,10,14};
Circle(13)={14,10,11};
// Naming the boundaries
//Physical Line("Shape") = {1,3};
Physical Line("Axis") = {2 ,4,5 };
Physical Line("Outlet") = {6};
Physical Line("Top") = {7};
Physical Line("Wall") = {2,7};
Physical Line("Inlet") = {8};
Physical Line("Circle") = {10,11,12,13};
// A lineloop is a loop on several lines
// for defining/orienting a surface
// Use negative lines to reverse the
// orientation of the line
Line Loop(1) = {2,-6,7,8};
Line Loop(2) = {10,11,12,13};
/// The surface will use the lineloop
Plane Surface(1) = {1,2};
// Naming the domain
Physical Surface("domain") = {1};
```

11.2 3D VEF mesh

```
// Variables definition
lc = 0.02;
// First cell size (used when points are defined)
lc1 = lc * 8;
// Second cell size
lc2 = lc / 2;
// Circle diameter
H=2;
L=10;
// Points definition
Point(1)={0,0,0,lc1};
Point(2) = {L,0,0,lc1};
Point(3) = {L,H,0,lc1};
Point(4) = {0,H,0,lc1};
Point(10)= {1,1,0,lc2};
Point(11)={1.25,1,0,lc2};
Point(12)={1,1.25,0,lc2};
Point(13)={0.75,1,0,lc2};
Point(14)={1,0.75,0,lc2};
// Lines definition
Line(2) = {1,2};
Line(6) = {3,2};
Line(7) = {3,4};
Line(8) = {4,1};
// 1/4 Circle definition
// 3 points for the circle arc
// A circle arc is STRICTLY smaller than Pi
Circle(10)={11,10,12};
Circle(11)={12,10,13};
Circle(12)={13,10,14};
```

```
Circle(13)={14,10,11};
// Naming the boundaries
//Physical Line("Outlet") = {6};
//Physical Line("Wall") = {2,7};
//Physical Line("Inlet") = {8};
//Physical Line("Circle") = {10,11,12,13};
// A lineloop is a loop on several lines
// for defining/orienting a surface
// Use negative lines to reverse the
// orientation of the line
Line Loop(1) = {2,-6,7,8};
Line Loop(2) = {10,11,12,13};
/// The surface will use the lineloop
Plane Surface(1) = {1,2};
Extrude {0,0,1} { Surface{1} ; }
// Naming the domain
Physical Surface("Inlet") = {38};
Physical Surface("Outlet") = {30};
Physical Surface("Wall") = {1,26,34,55};
Physical Surface("Obstacle") = {42,46,50,54};
Physical Volume("dom") = {1};
```