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

ДЕМОНСТРАЦИЯ: ОБТЕКАНИЕ ОБРАТНОГО УСТУПА

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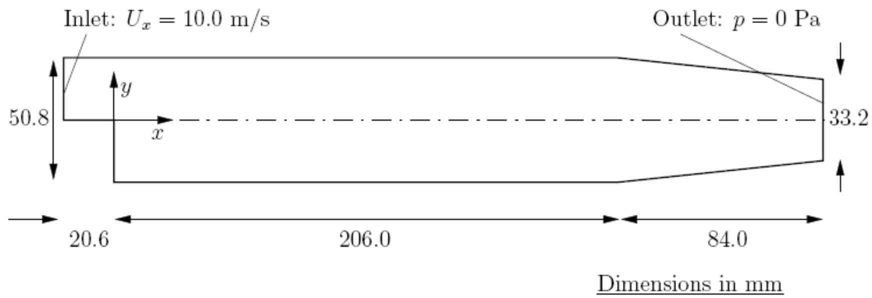
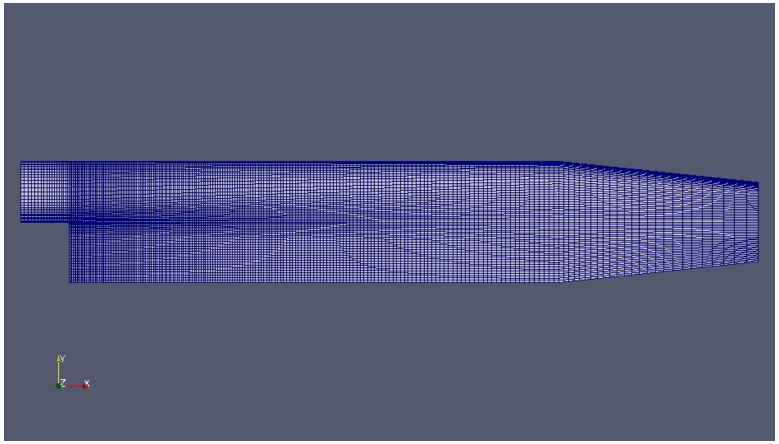
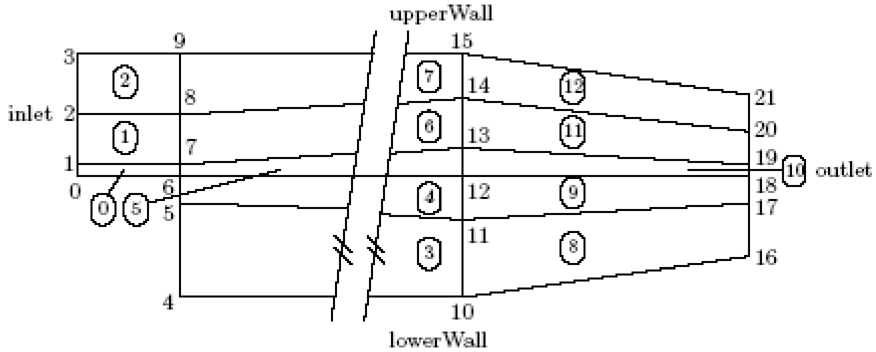
РАСЧЕТНАЯ ОБЛАСТЬ И ИСХОДНЫЕ ДАННЫЕ



Расчетная область и граничные условия



Блочная сетка — blockMeshDict



U = 10 м/с
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

$$\nabla \cdot \mathrm{U} = 0 \tag{3.4}$$

- Steady flow momentum equation

$$\nabla \cdot (\mathrm{UU}) + \nabla \cdot \mathrm{R} = -\nabla p \tag{3.5}$$

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

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

Transport properties

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

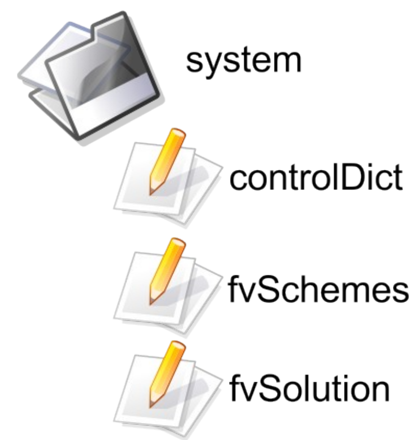
Turbulence model

- 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;
```

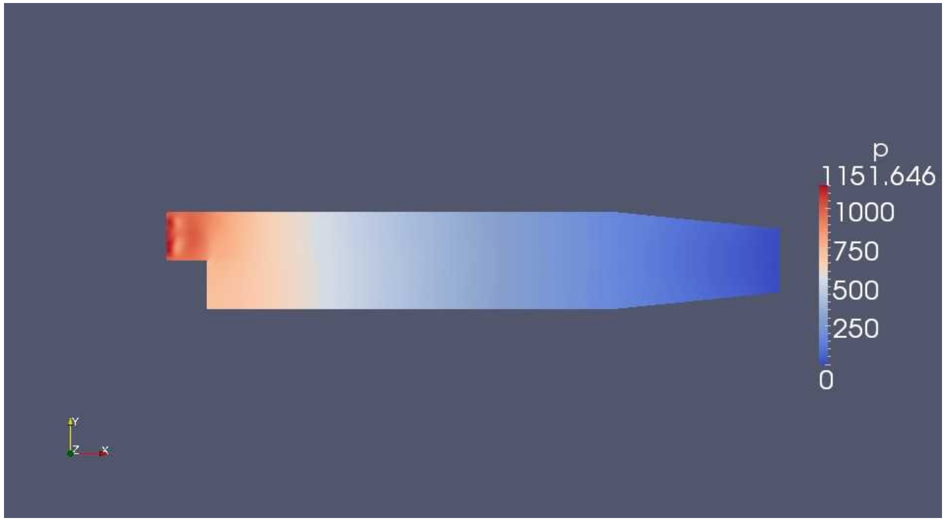
СХЕМЫ ДИСКРЕТИЗАЦИИ

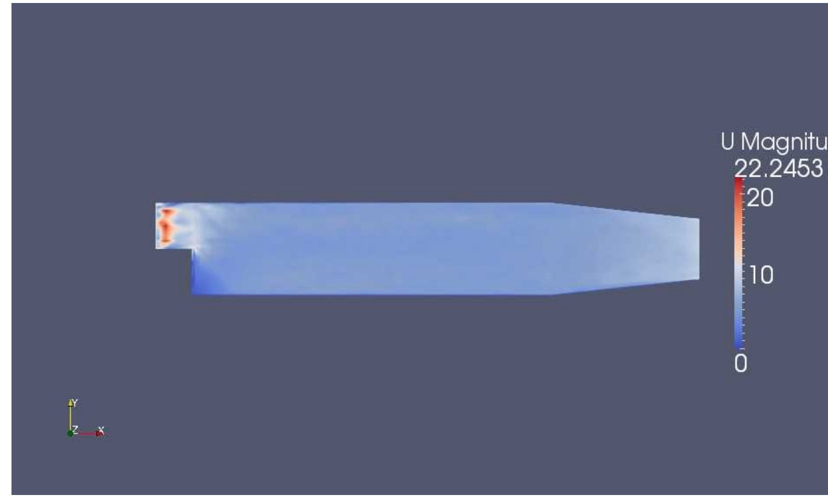
```
gradSchemes{    default         Gauss linear;
grad(p)         Gauss linear;
grad(U)         Gauss linear;}
divSchemes{    default         none;
div(phi,U)      Gauss GammaV 1.0;
div(phi,k)      Gauss Gamma 1.0;
div(phi,epsilon) Gauss Gamma 1.0;
div(phi,omega)  Gauss Gamma 1.0;
 div(phi,R)      Gauss 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;}
```

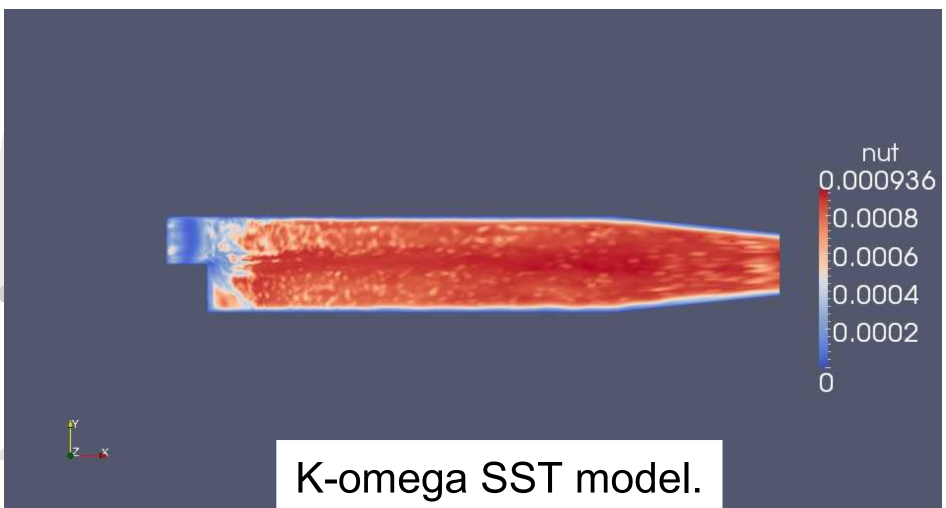
МЕТОДЫ РЕШЕНИЯ СЛАУ

```
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;}
// ************************************************************************* //
```

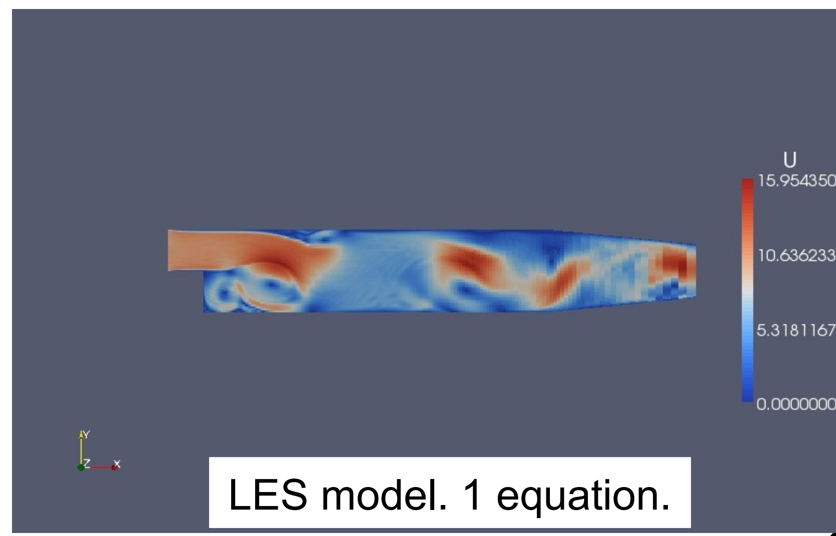
РЕЗУЛЬТАТЫ РАСЧЕТОВ







K-omega SST model.



LES model. 1 equation.