Cloud-based Simulation of Aerodynamics of Light Aircraft

Matej Andrejašič, Gregor Veble
Pipistrel d.o.o. Slovenia
Nejc Bat
Arctur d.o.o., Slovenia

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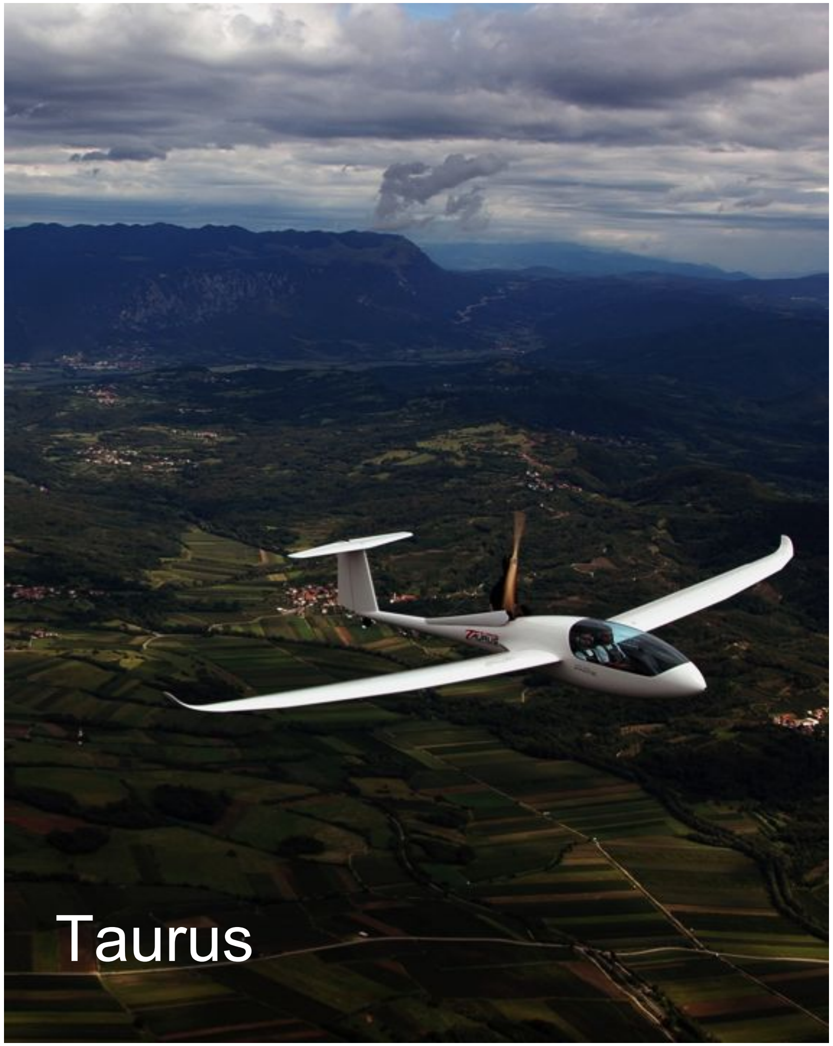
Workshop HPC Methods for Engineering

Outline

- Pipistrel
- Fortissimo
- Motivation
- Experiment
- Simulation
- Mesh
- Results
- Lessons learned, Successes and Impact

Pipistrel, Slovenia


Taurus


Apis

Pipistrel, Slovenia

Sinus

2007 & 2008 WINNER

VirusSW

Pipistrel, Slovenia

Taurus Electro

Alpha Electro

Pipistrel, Slovenia

Taurus G4

Panthera

Pipistrel, Slovenia

- Fortissimo
- rbf4aero
- Mikelangelo
- Hypstair

Fortissimo

I4MS ICT Innovation for Manufacturing SMEs
(within Factories of the Future initiative)

- Fortissimo
  - Experiment:

    Cloud-based simulation of aerodynamics of light aircraft
  - Partners:

    End User: PIPISTREL
    HPC Expert: XLAB
    HPC Provider: ARCTUR
  - Application:

    OpenFOAM

Motivation

- Pipistrel cluster (2014): 2 x (8 cores, 66GB RAM)
- Typical simulations:
  - fully turbulent RANS simulations
  - low-Re airfoil simulations
  - 5M (15M max) cells mesh
- Arctur's HPC (2014):
  - 84 x (12 cores, 32GB RAM)
  - high performance node: 144GB RAM
  - visualization node: 66GB RAM

Experiment

- Experiment:
  - OpenFOAM 2.2.0
  - laminar-turbulent transition modeling with RANS simulations: k - k_L - *omega* turbulence model
  - complete Panthera aircraft at cruise speed (Re=5.7e6)

- Validation and performance criteria
  - successful scale up from local cluster to HPC
  - working remote visualization directly on HPC (TurboVNC)
  - this routine runs smoothly and completely remote on HPC
  - the same convergence time for much larger cases

Experiment

Course of action:

- Simple test cases with turbulent model k - k_L - *omega*
- A wing at smaller velocities
- A wing at cruise velocity
- Complete Panthera aircraft at smaller velocities
- Complete Panthera aircraft at cruise speed

	In house cluster	Arctur's HPC
mesh size	5 -10M cells	115M cells
thinnest layer	~ 0.1mm	~ 0.006mm
No. cores	8	60 - mesh 180 - simul.
simulation time	1-2 days	2-3 days

Simulation

k - *k_L* - *omega* turbulence model [1]

- low-Re model

- Three additional transport equations:
  k - turbulent kinetic energy
  k_L - laminar kinetic energy = pretransitional (nonturbulent) velocity fluctuations
  omega - specific dissipation rate

- RASProperties:
  RASModel kkLOmega;

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[1] Walters, D. K., and Cokljat, D., "A Three-Equation Eddy-Viscosity Model for Reynolds-Averaged Navier-Stokes Simulations of Transitional Flow," *J. Fluids Eng.*, Vol. 130, Iss. 12, 2008, pp. 1-14, doi:10.1115/1.2979230

Simulation

kl

```
{
    inlet
    {
        type            fixedValue;
        value           uniform 0;
    }
    outlet
    {
        type            zeroGradient;
    }
    symmetry
    {
        type            symmetryPlane;
    }
    body_patch0
    {
        type            fixedValue;
        value            uniform 0;
    }
}
```

kt

```
{
    inlet
    {
        type            fixedValue;
        value      uniform 1.5e-8;
    }
    outlet
    {
        type            zeroGradient;
    }
    symmetry
    {
        type            symmetryPlane;
    }
    body_patch0
    {
        type            fixedValue;
        value            uniform 0;
    }
}
```

omega

```
{
    inlet
    {
        type            fixedValue;
        value      uniform 0.771;
    }
    outlet
    {
        type            zeroGradient;
    }
    symmetry
    {
        type       symmetryPlane;
    }
    body_patch0
    {
        type            zeroGradient;
    }
}
```

Simulation

U

```
{
    inlet
    {
        type            fixedValue;
        value   uniform (1 0 0);
    outlet
    {
        type            zeroGradient;
    }
    symmetry
    {
        type            symmetryPlane;
    }
    body_patch0
    {
        type            fixedValue;
        value            uniform (0 0 0);
    }
}
```

p

```
{
    inlet
    {
        type            zeroGradient;
    }
    outlet
    {
        type            fixedValue;
        value           uniform 0;
    }

    symmetry
    {
        type            symmetryPlane;
    }

    body_patch0
    {
        type            zeroGradient;
    }
}
```

Simulation

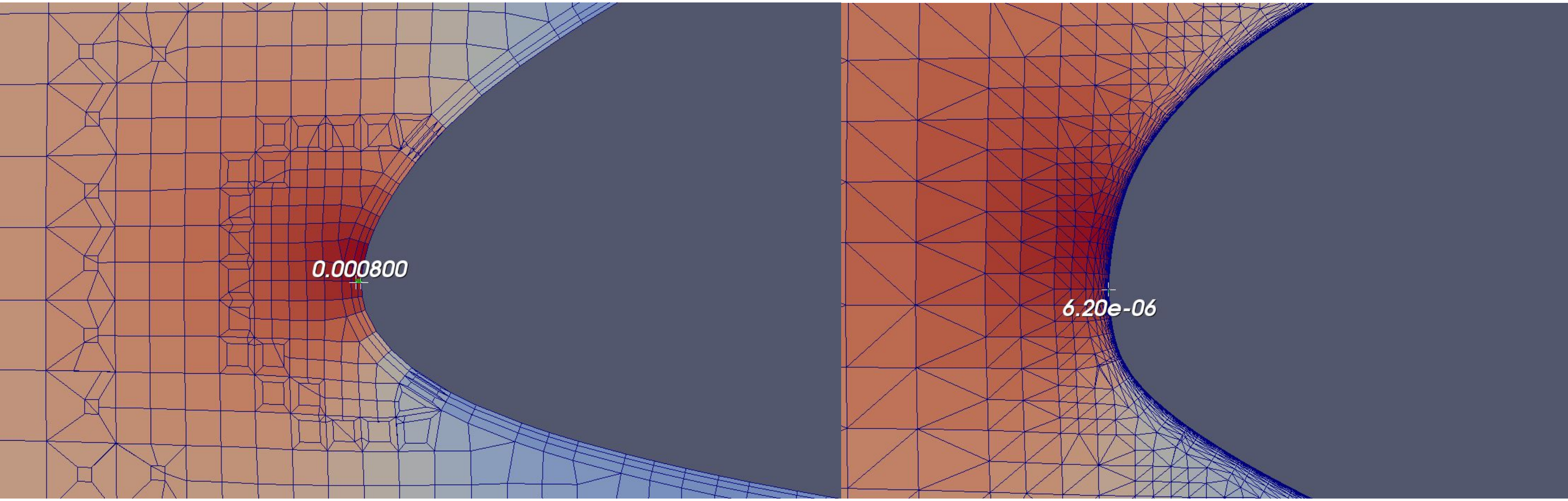
fvSchemes

```
ddtSchemes
{
    default        steadyState;
}
gradSchemes
{
    default        Gauss linear;
}
divSchemes
{
    div(phi,U)                          Gauss linearUpwind grad(U);
    div(phi,kt)                         Gauss linearUpwind grad(turb);
    div(phi,kl)                         Gauss linearUpwind grad(turb);
    div(phi,omega)                      Gauss upwind;
    div((nuEff*dev(grad(U).T()))) Gauss linear;
    div((nuEff*dev(T(grad(U)))))  Gauss linear;
}
laplacianSchemes
{
    default                      none;
}
interpolationSchemes
{
    default        linear;
}
```

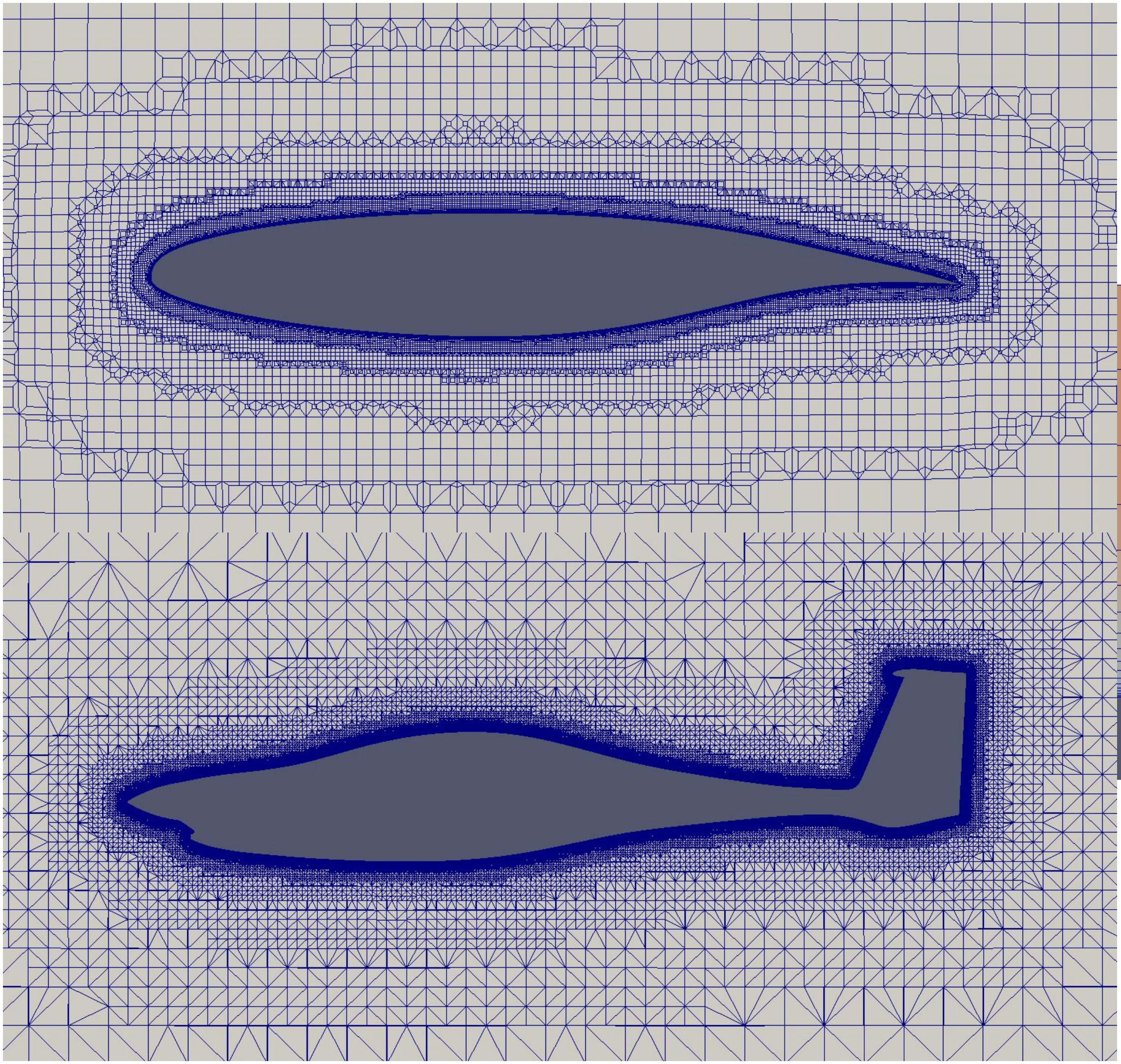
fvSolution

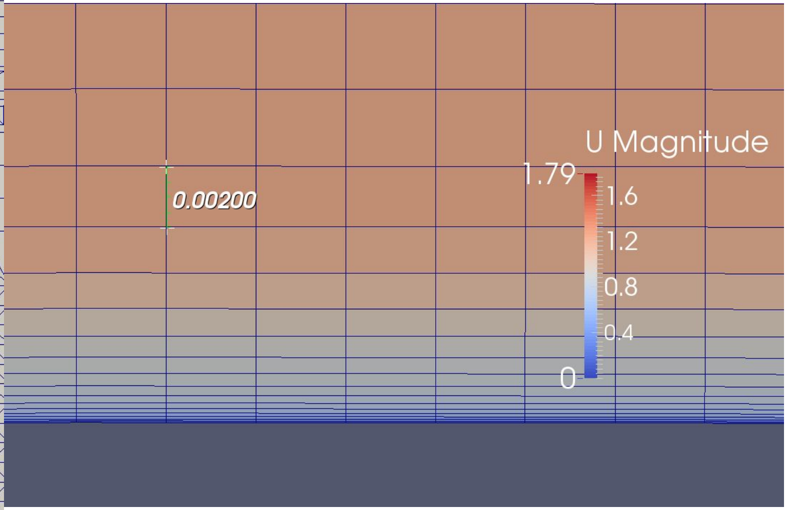
```
solvers
{
    p
    {
        solver         GAMG;
    }
    ("U,kl,kt,omega")
    {
        solver        smoothSolver;
    }
}
SIMPLE
{
    nNonOrthogonalCorrectors 1;
 }

relaxationFactors
{
        p              0.5;
        U              0.2;
        nuTilda        0.3;
        kt             0.5;
        kl              0.5;
        omega          0.5;
}
```

Mesh



Mesh





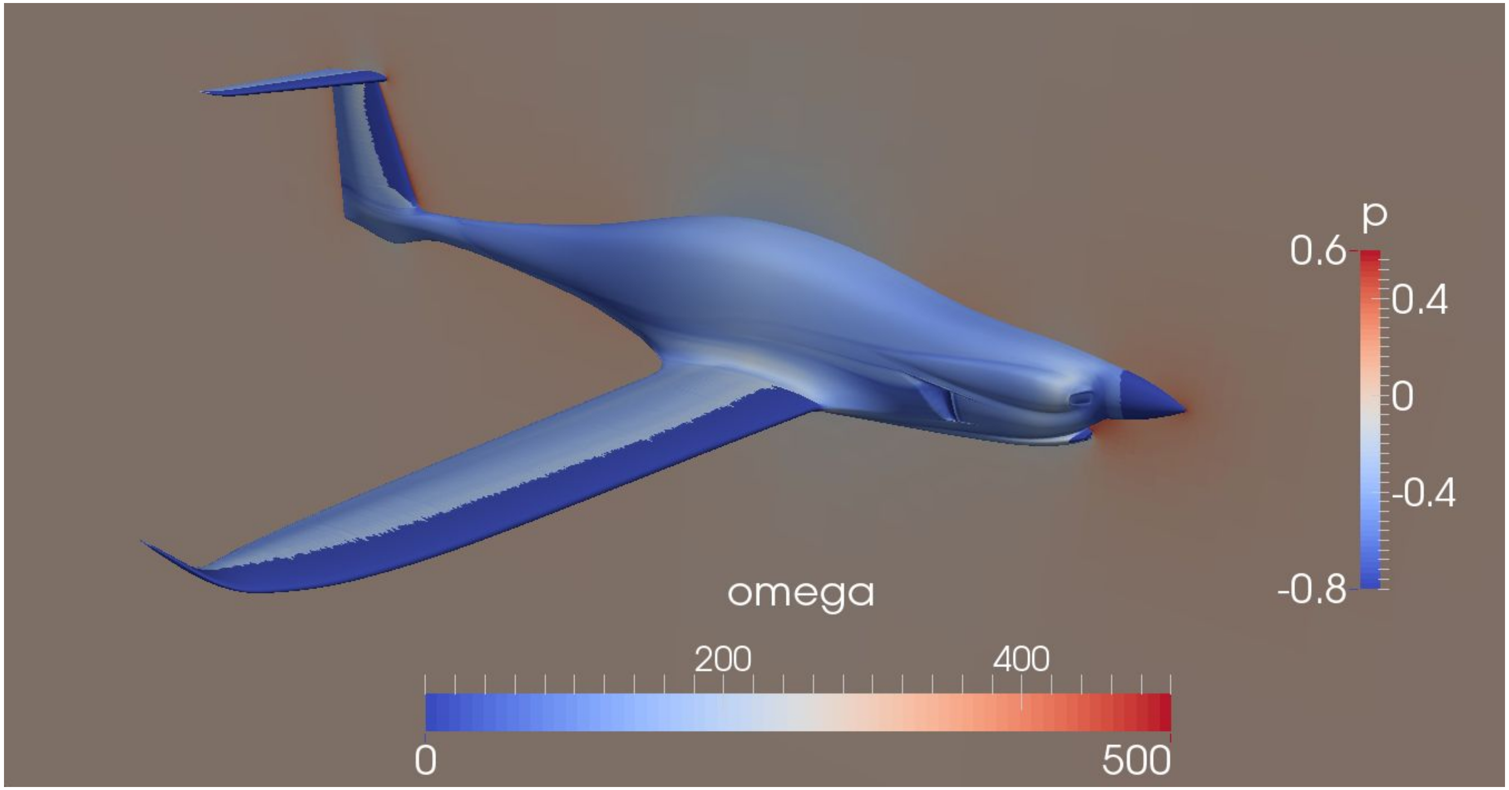
Mesh

snappyHexMeshDict:

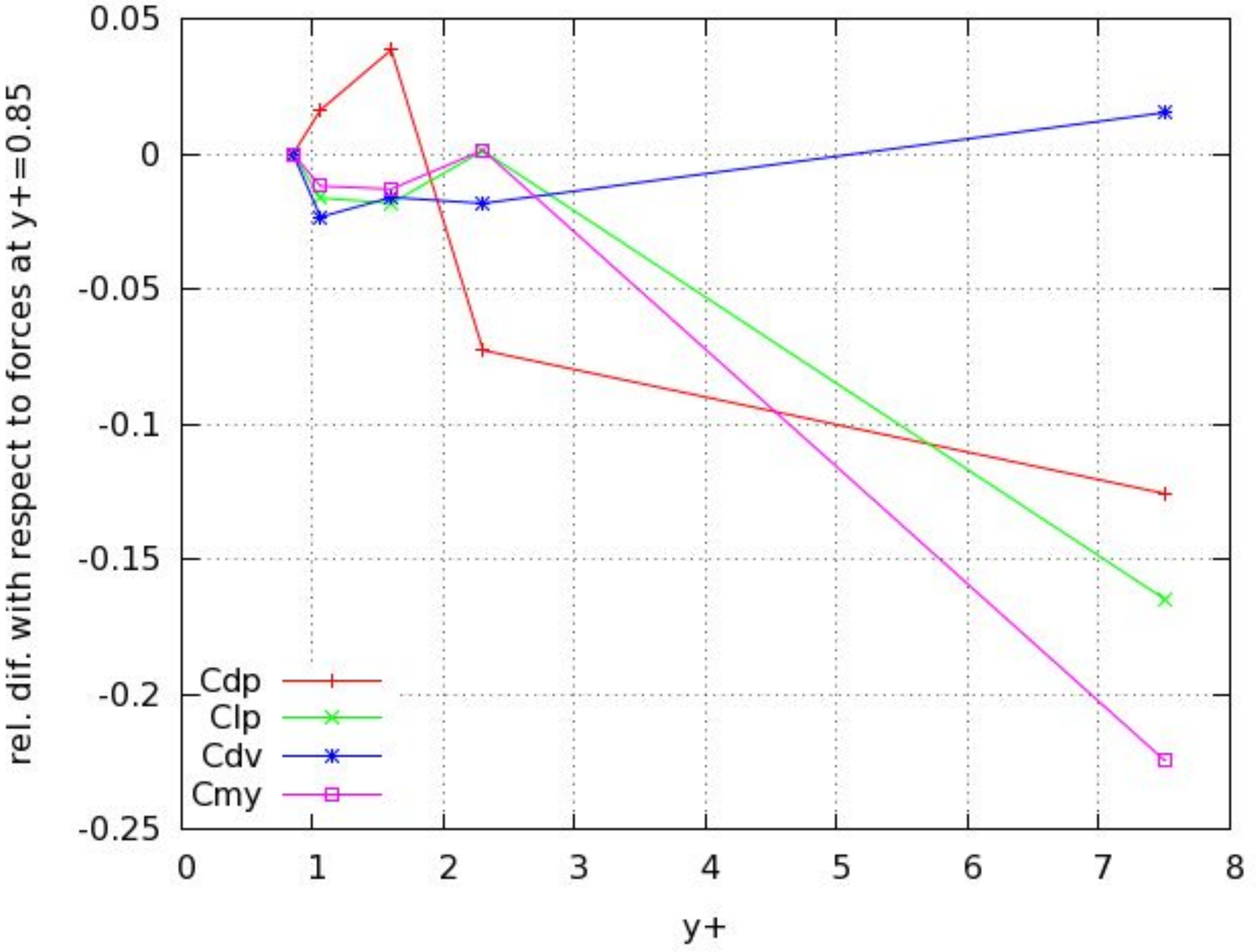
```
addLayersControls
{
    relativeSizes false;
    layers
    {       "(body).*"
            {
                    nSurfaceLayers 13;
            }
    }
    expansionRatio 1.5;
    finalLayerThickness 0.0008;

    featureAngle 30;
    slipFeatureAngle 0;
}
```

```
meshQualityControls
{
    maxNonOrtho 65;

    maxBoundarySkewness -20;
    maxInternalSkewness      -4;

    minDeterminant  1e-6;
}
```

Results



Results


rel. dif. with respect to forces at y+=0.85
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0
1
2
3
4
5
6
7
8
y+
Cdp
Clp
Cdv
Cmy

Lessons learned

Learn how to:

- make a proper mesh - such a fine mesh at the surface
- use symmery plane
- preview the decomposed case – reconstruction takes a lot of time
- extract only necessary data and preview it with paraView
- automaticaly consecutively run all steps of the simulation process
- how to run, handle and postprocess such big cases
- persuade HPC provider to increase RAM

Successes and Impact

- Deeper knowledge of running, handling and postprocessing very big cases
- Better estimate of the time and the cost
- Deeper knowledge of CFD simulations, what are its boundaries and capabilities
- Better designs and faster design cycles

Thank you!!!

Any questions or comments?

Dr. Matej Andrejašič
R&D, Pipistrel, Slovenia
matej.andrejasic@pipistrel.si