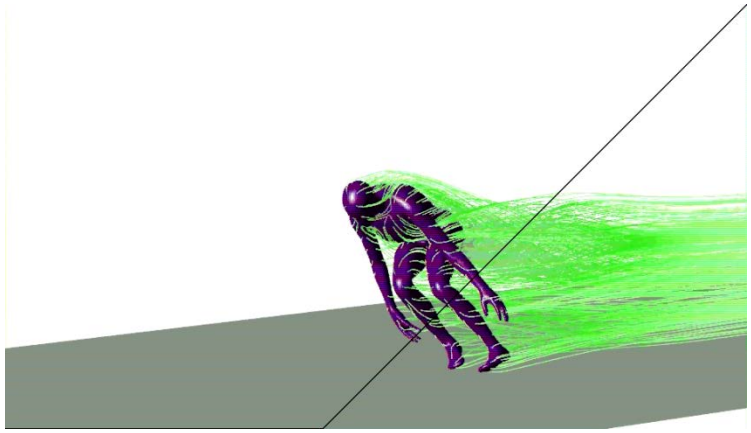
Simulating Strongly Coupled Fluid-Structure Interactions using Abaqus and FlowVision



FlowVision

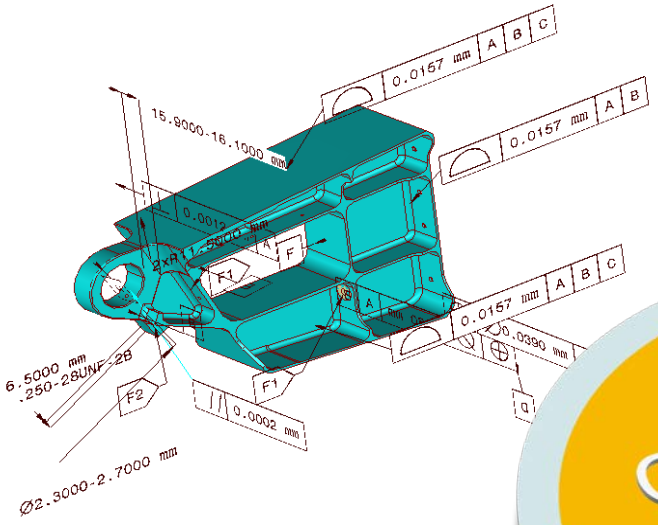
Andrey Aksenov,
Tomasz Luniewski

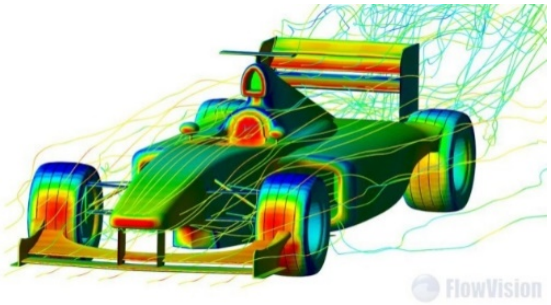
CAPVIDIA Group

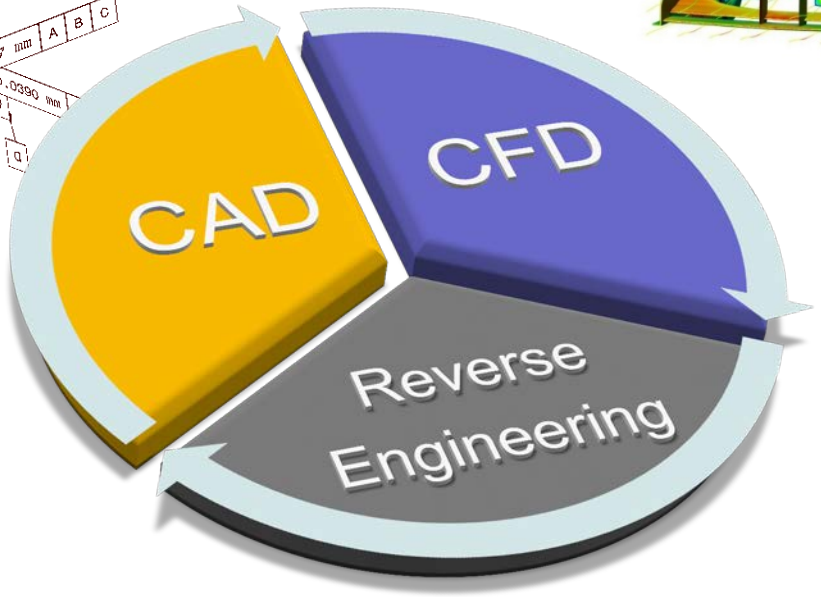
Content

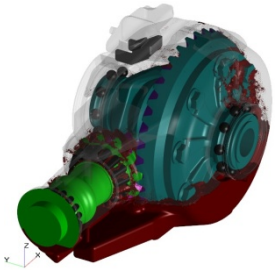
- About Capvidia Group
- What is FlowVision
- FlowVision mesh
- FlowVision-Abaqus Coupling
- Solving engineering FSI problems

Company



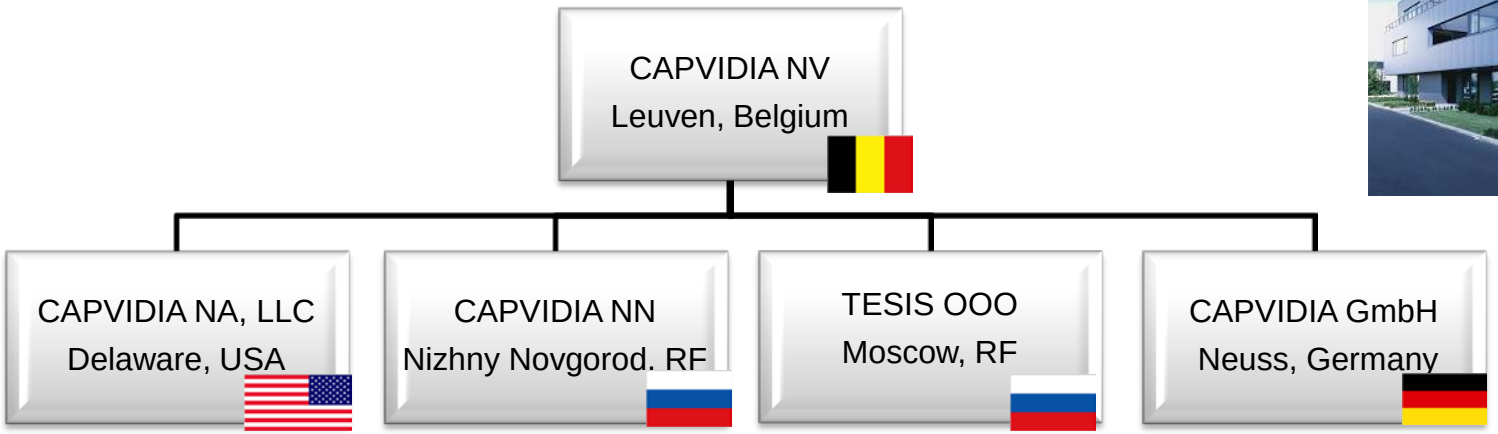






Capvidia provides software solutions for 3D CAD/CAM/CMM data interoperability and CFD simulation to simplify processes, increase quality and reduce costs

The Capvidia Group



- **Established in 1994**
- **Annual turnover 8.5 million USD**
- **+80 employees**
- **Privately owned**
- **International operation: Europe, USA, China, Korea, India, Japan**

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- What is FlowVision
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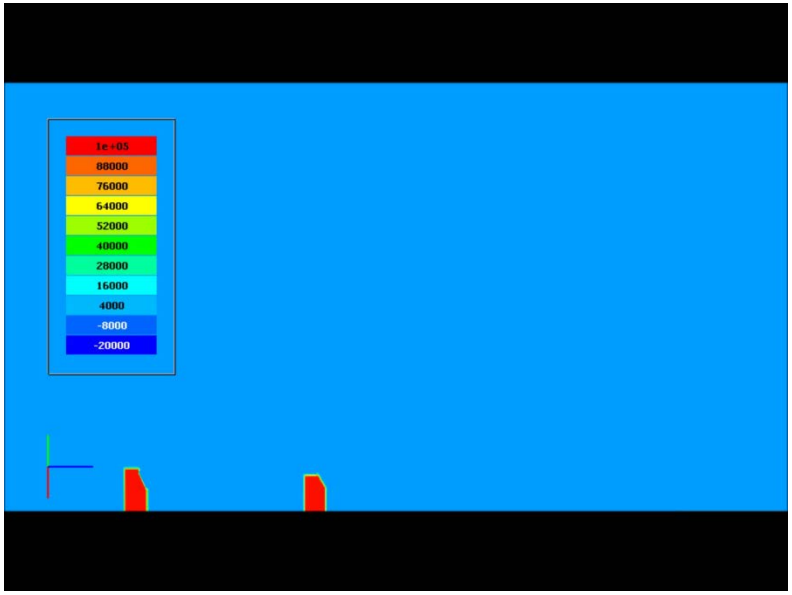
FlowVision: main features

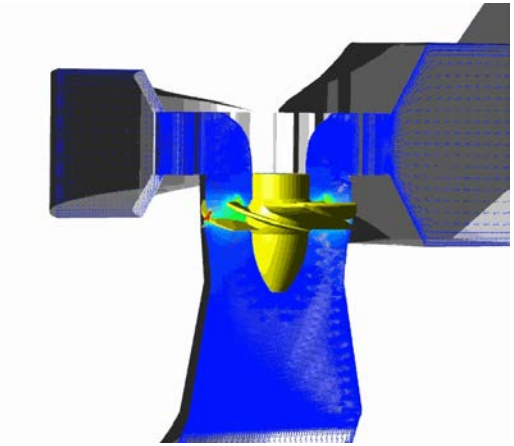
- **Fully Automatic Mesh Generator with Dynamic Adaptation**
- **Steady and Transient State Flow**
- **Moving Rigid and Deformable Bodies**
- **VOF and Free Surface Tracking**
- **Conjugated Heat Transfer**
- **Mass Transfer**
- **Turbulence Modeling**
- **Fluid Structure Interaction**
- **Flow Through Porous Media**
- **Non-Newtonian Fluids**
- **High Scalability HPC**

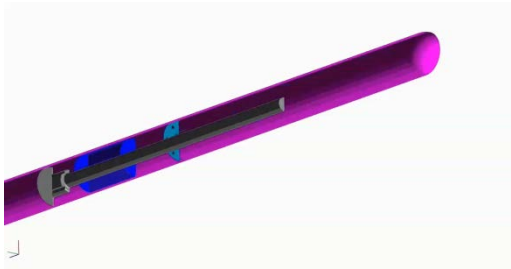


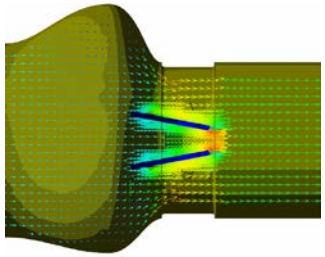
Spacecraft Automatic Rescue System (ARS)

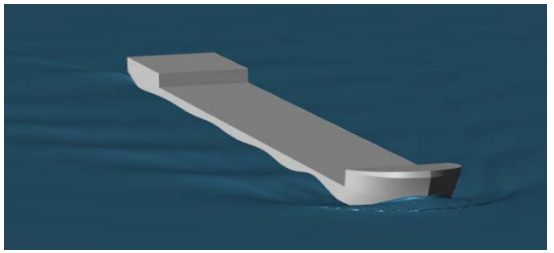
FlowVision: application areas

- Aerospace
- Automotive
- Shipbuilding
- HVAC
- Defense
- Microelectronics
- Nuclear energetics
- Power generation
- Consumer goods
- Turbomachinery
- Life science
- Sport
- Medicine









Content

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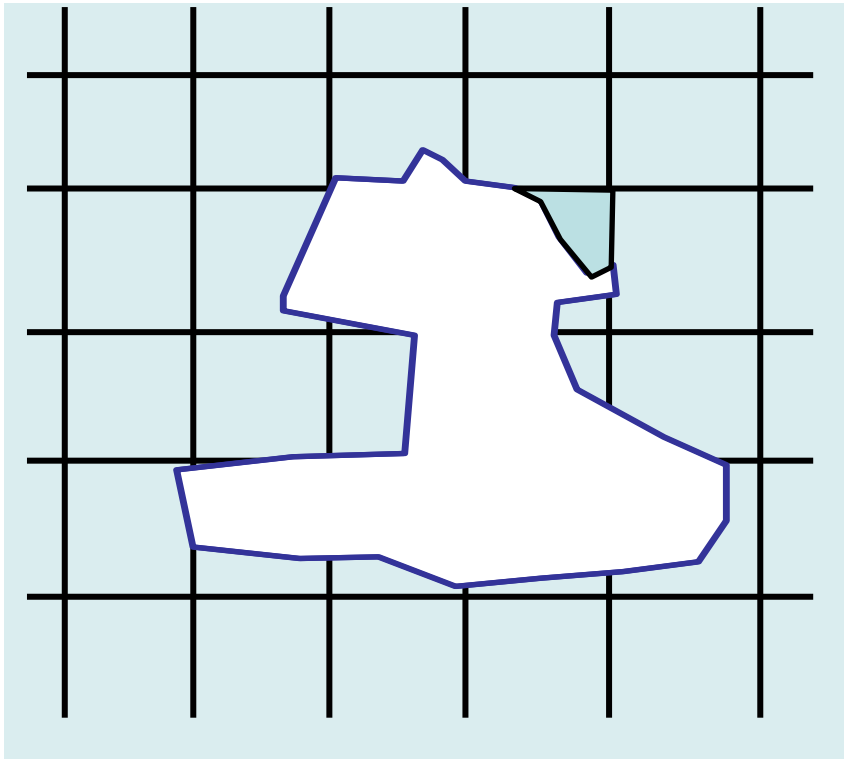
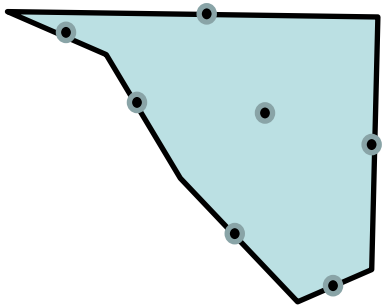
Meshing: SubGrid Geometry Resolution (SGGR)



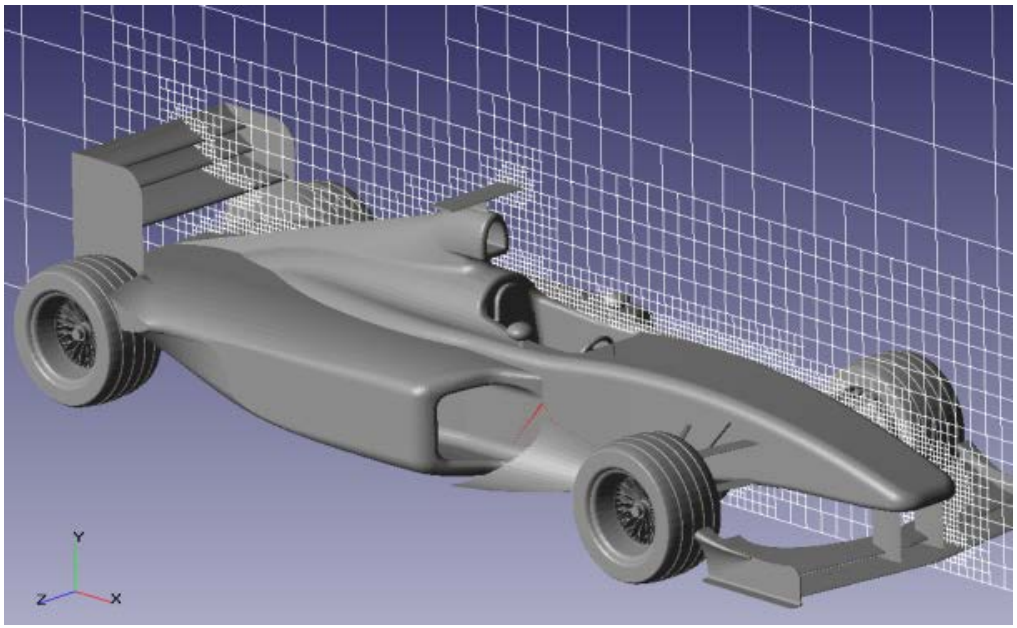


- **Rectangular initial mesh**
- **Shape imported as facet B-rep (STL, WRL)**
- **Boolean subtraction of object volume from initial mesh**
- **Cell is arbitrary polyhedron**

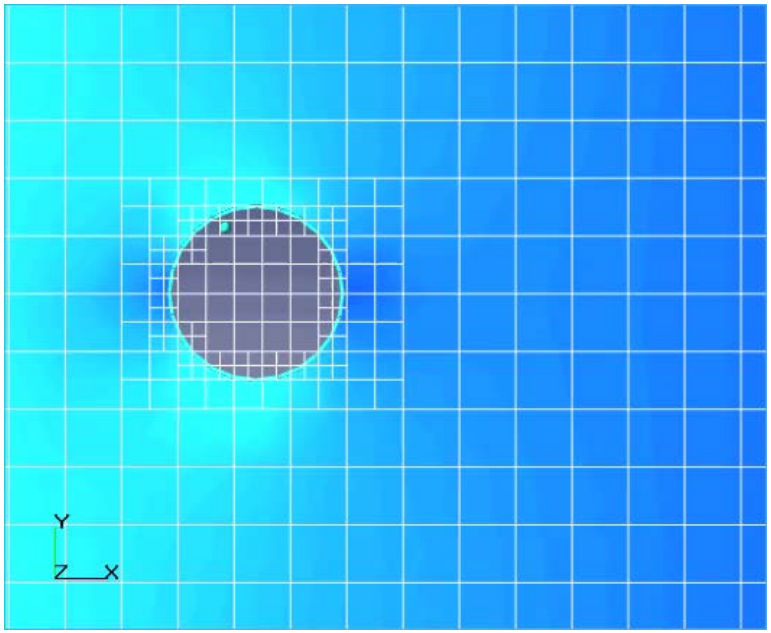
Finite-volume approach is used to approximate equations on this mesh

Meshing: Mesh Adaptation

- to raise simulation accuracy by resolving high gradients of flow variables
- to save computer resources using fine meshes in places where they are need

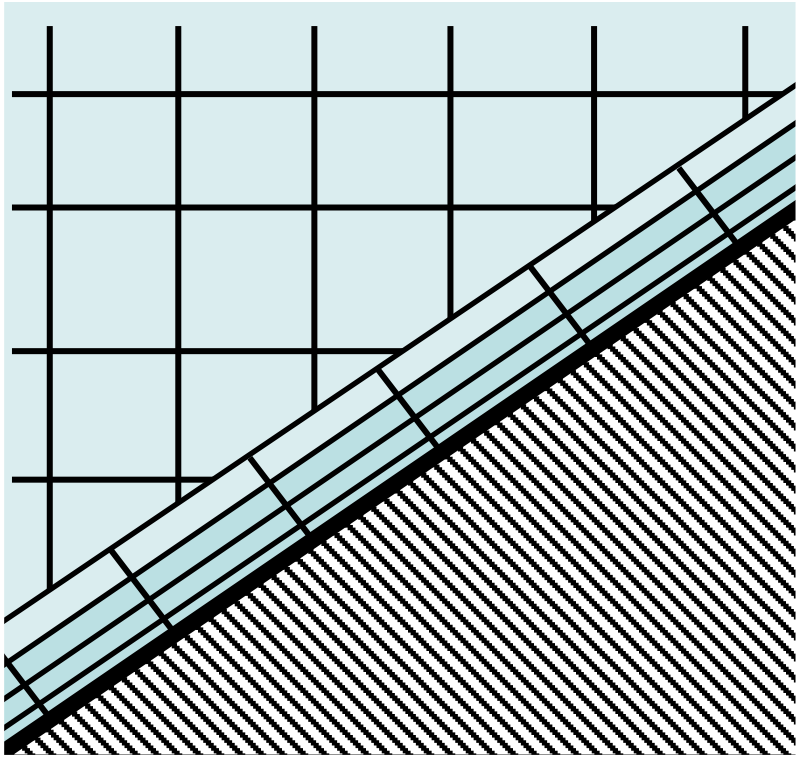


Dynamic adaptation near surfaces

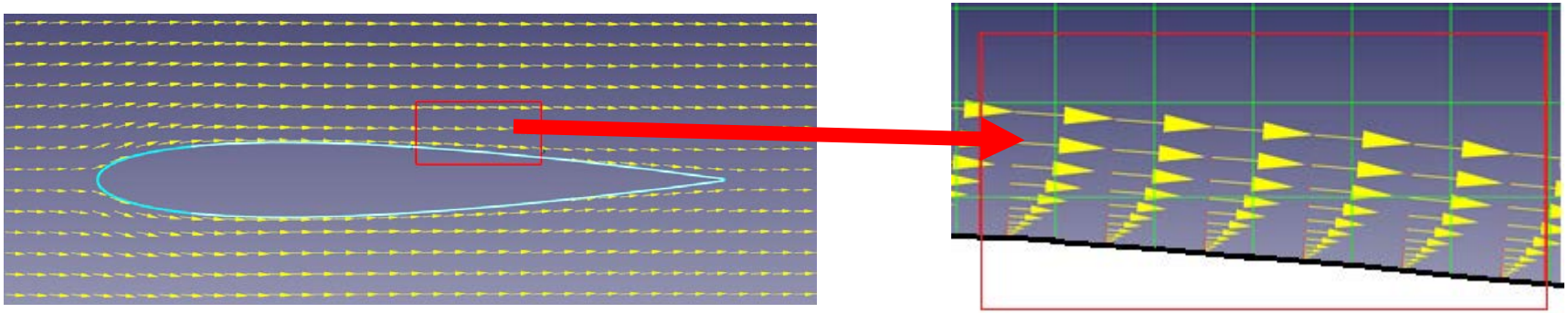


Dynamic adaptation due to a velocity gradient

Meshing: Resolving boundary layers



- For RANS simulation is very important to resolve boundary layer leaving outside mesh rough
- Prismatic mesh for resolving boundary layer generated between body surface and main mesh



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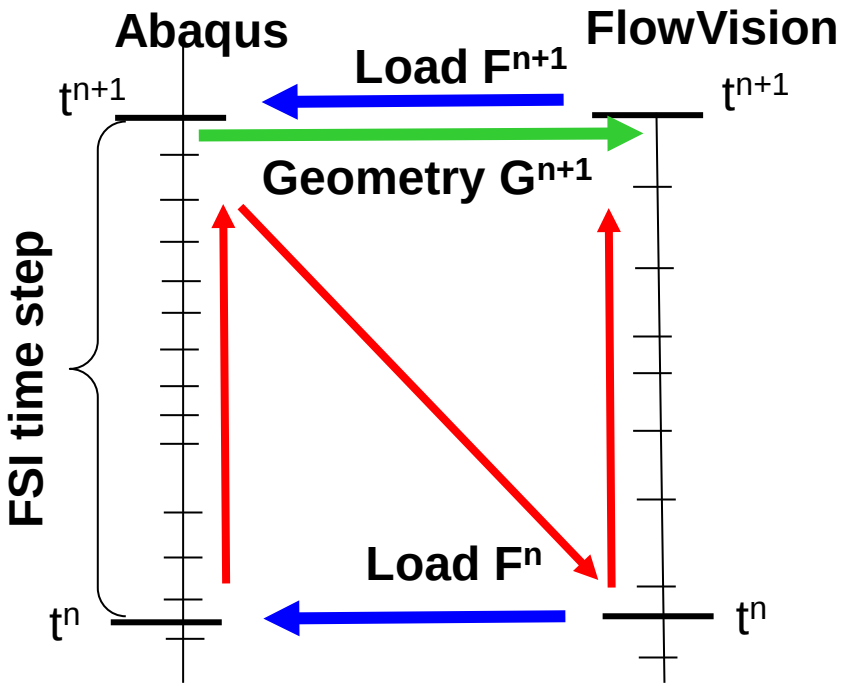
Co-simulation Abaqus and FlowVision

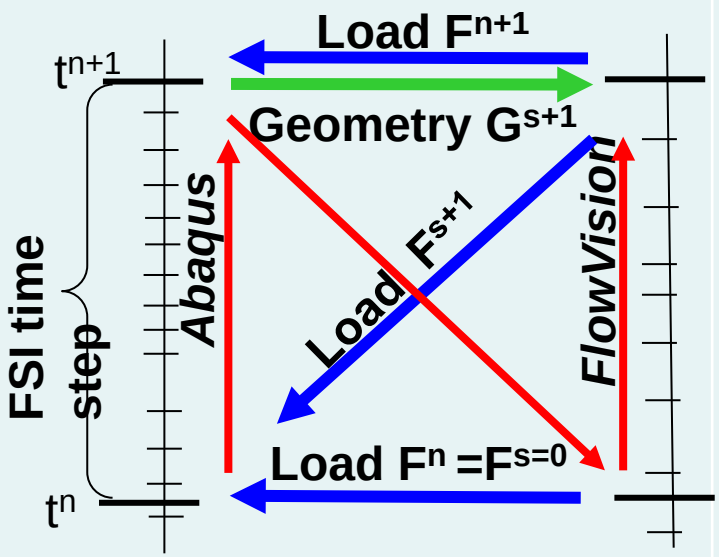
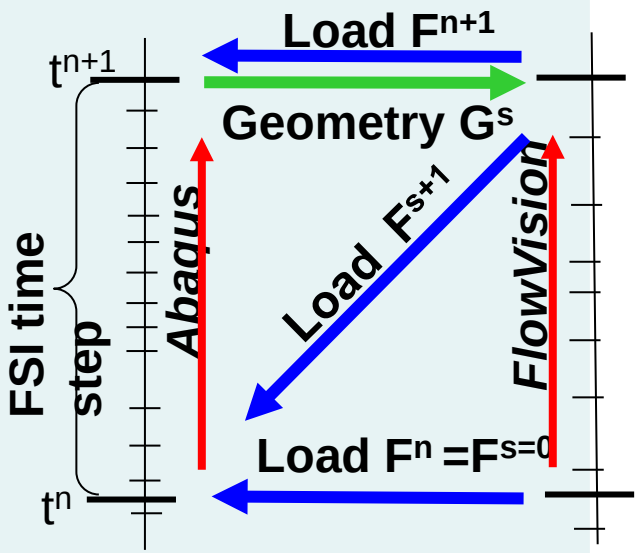
	Explicit Coupling	Implicit Coupling
+	Fast	Stable even for large time steps
-	Limited stability (use small times steps or artificial stabilization methods)	Slow
Implementation Method	DCI (Direct Coupling Interface)	-
	CSE (Co-Simulation Engine)	CSE (Co-Simulation Engine)

Explicit coupling FlowVision-Abaqus

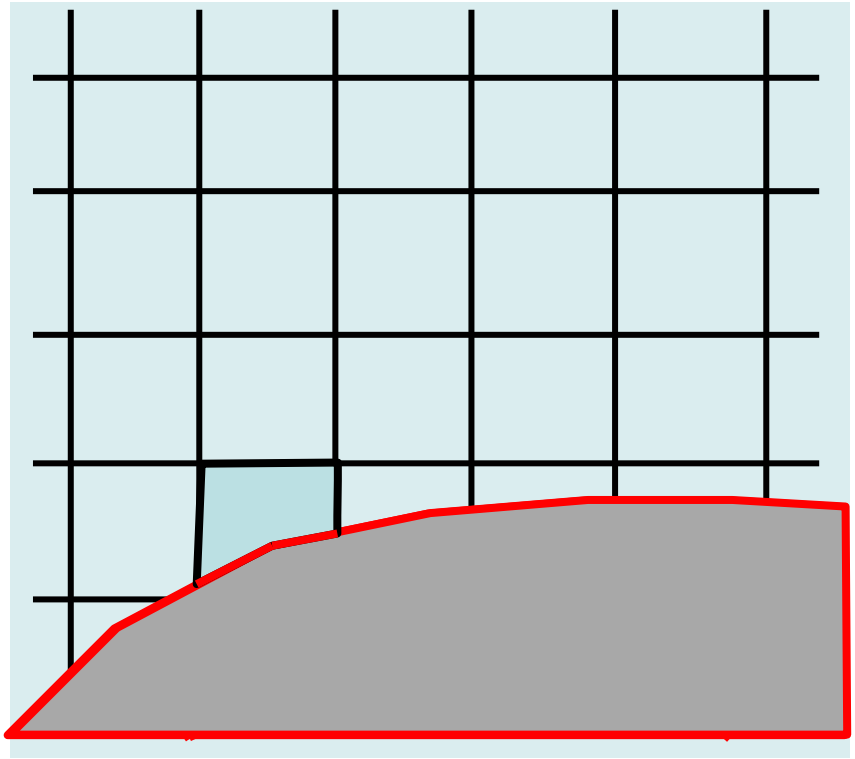


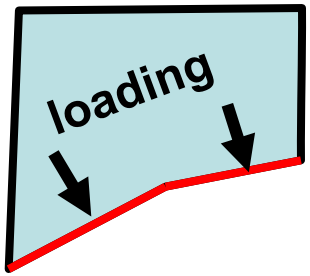
- FlowVision and Abaqus exchange simulation results at some time moments
- FSI time step could be bigger then both Abaqus and FlowVision time increments
- Abaqus makes FSI step first with load F^n and generates geometry G^{n+1}
- FlowVision applying linear changes G^n to G^{n+1} to finish FSI step with new geometry

Implicit coupling FlowVision-Abaqus

	Sequential Scheme	Parallel Scheme
		
+	Robust, requires less iterations for convergence	Codes don't wait for each other
-	Codes wait each other	Requires more iterations for convergence

Matching FE with CFD:
Method 1: Outside FE mesh forms CFD surface

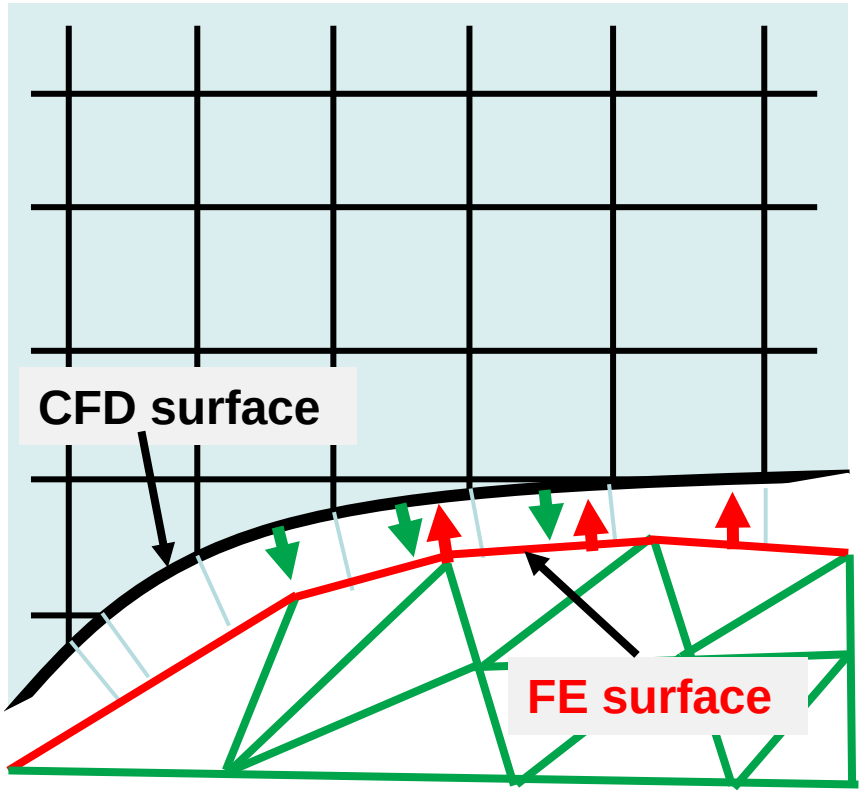




- **Importing FE mesh**
- **Mesh generation: Boolean subtraction of FE mesh volume from CFD mesh. Outside FE mesh==CFD boundary**
- **Each cell contains a piece of FE mesh volume outside border**
- **Easy to calculate loads & to track the surface motion**

Matching FE with CFD

Method 2: Outside FE surface =/= CFD surface



- **CFD (partner) surface not equals to FE surface**
- **CFD and FE surfaces are mapped using FlowVision mapper:**
  - Conservative for forces and fluxes
  - Smooth for node speeds and structure temperature

Mapping forces and fluxes

Mapping node speeds/temperature

Matching FE and CFD mesh

	Method 1	Method 2
+	Direct interpolation of data from CFD to FEA and back	CFD surface and FE surface are independent – fine CFD surface could be used together with rough FE surface
-	Excessive, fine FE mesh is required (e.g. flatter, aeroelasticity)	Mapping between CFD and FE surfaces has unavoidable interpolation errors
Implementation	DCI/CSE	DCI/CSE

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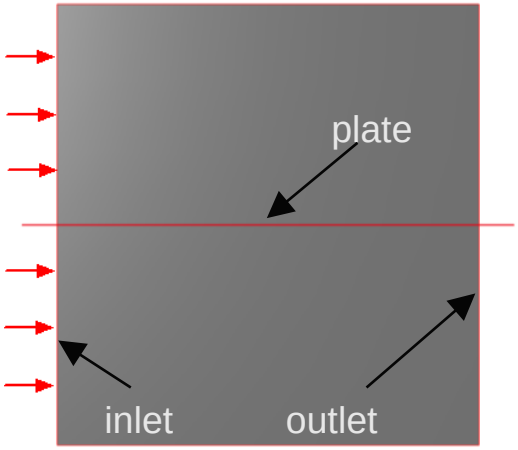
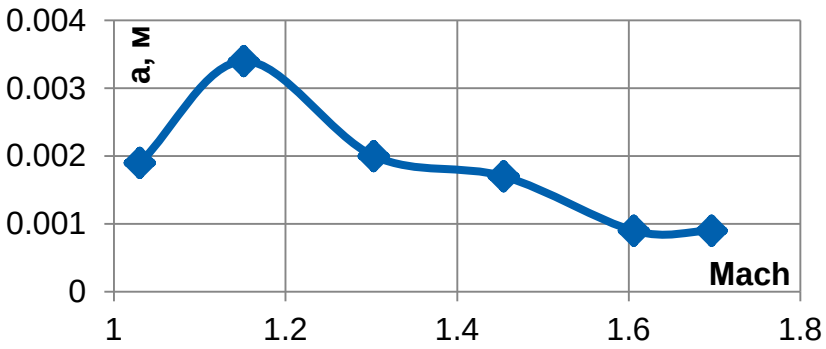
Supersonic flutter of flexible plate

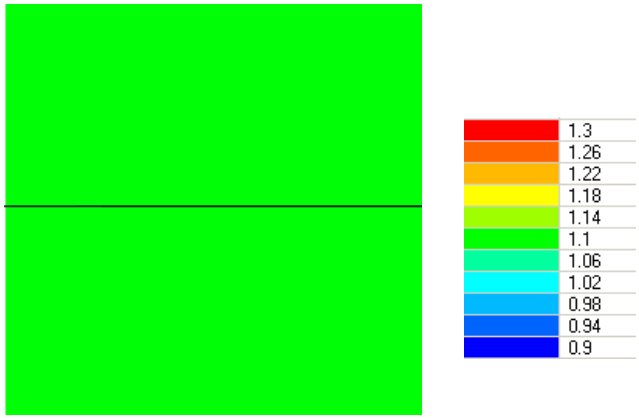
Application: flutter of supersonic airplane surfaces at different Mach
Goal: Understanding physics of this complex phenomena.



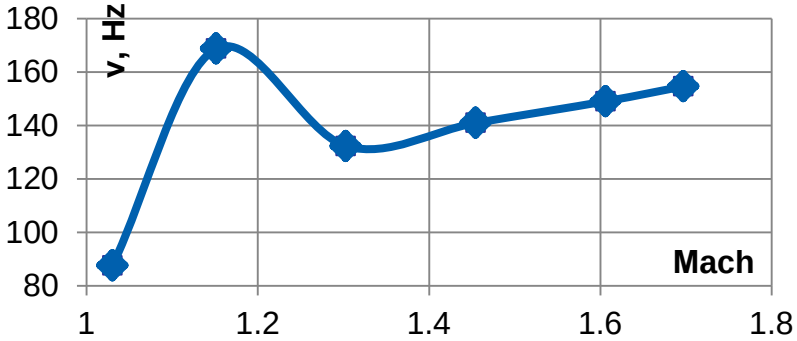
Amplitude of center plate deviation



Mach number



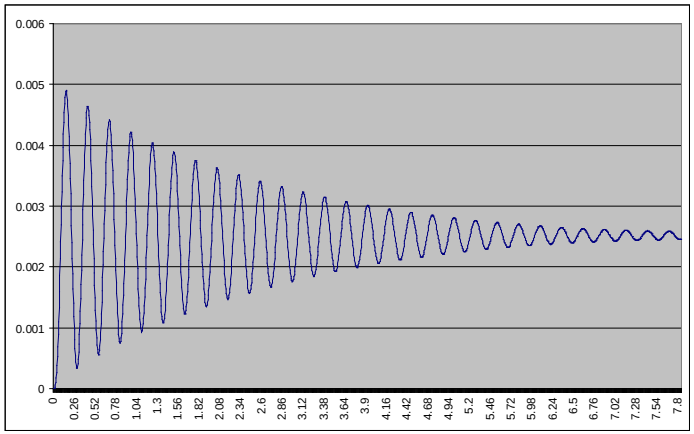
Flatter frequency

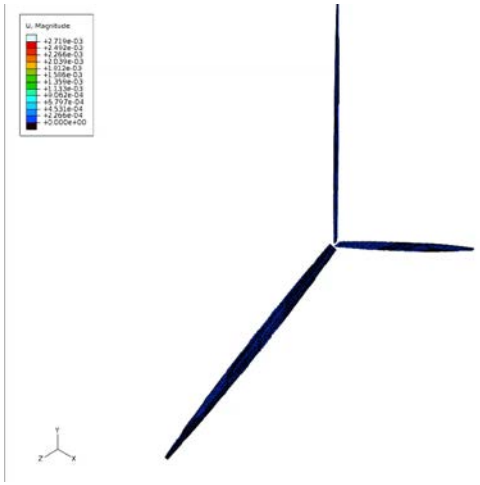


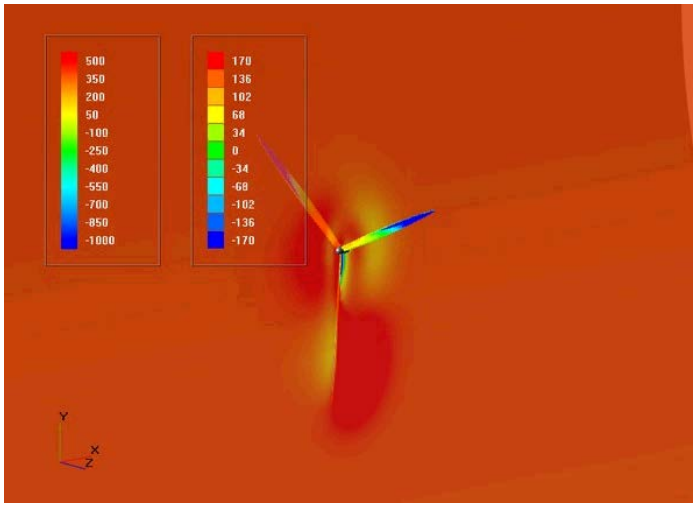
Wind turbine with flexible blades

Application: **Wind turbine**
Goal: **Improvement wind turbine effectiveness with taking into account blade flexibility**

x-direction displacement of the turbine blade



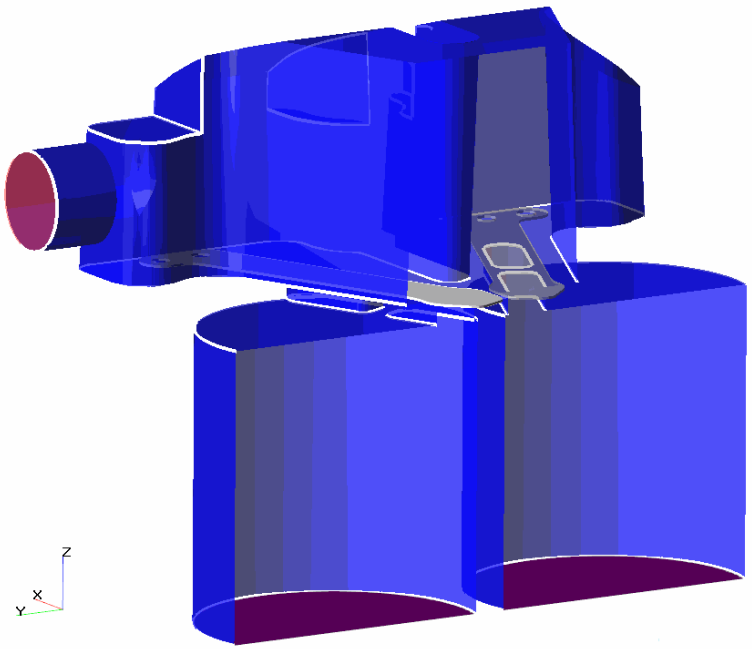




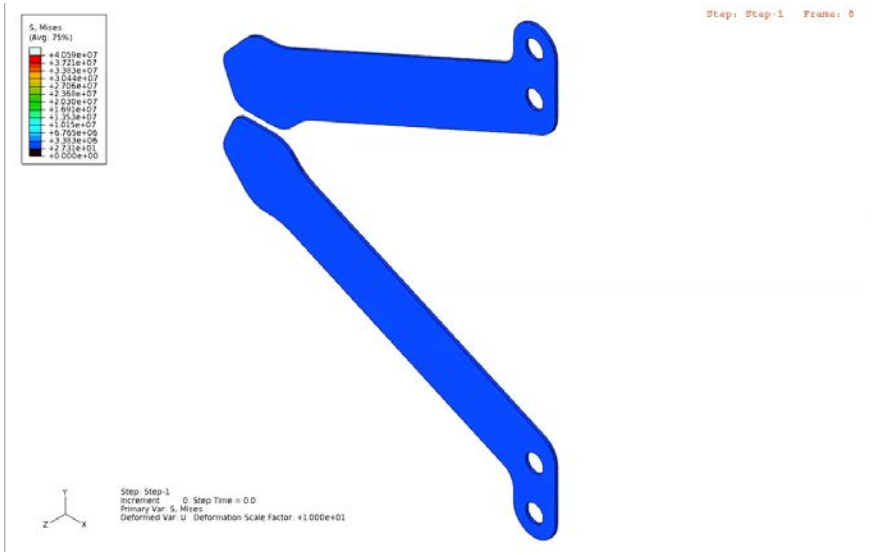
Compressor discharge path

Application: **Air Compressor**
Goal: **define durability of the valve material**

Air velocity distribution

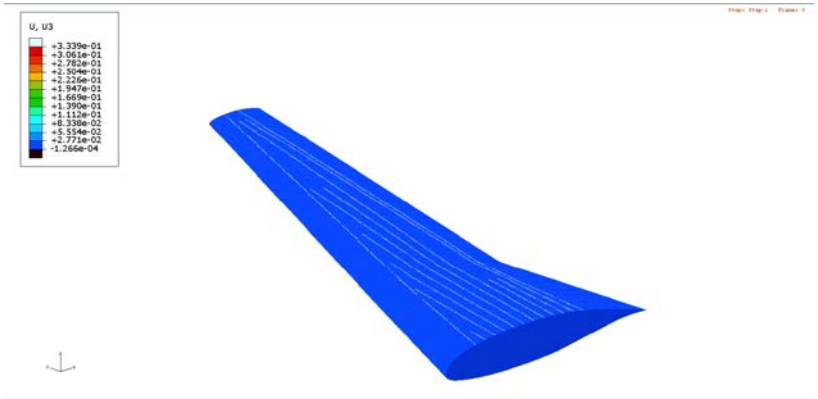


Valve stress distribution



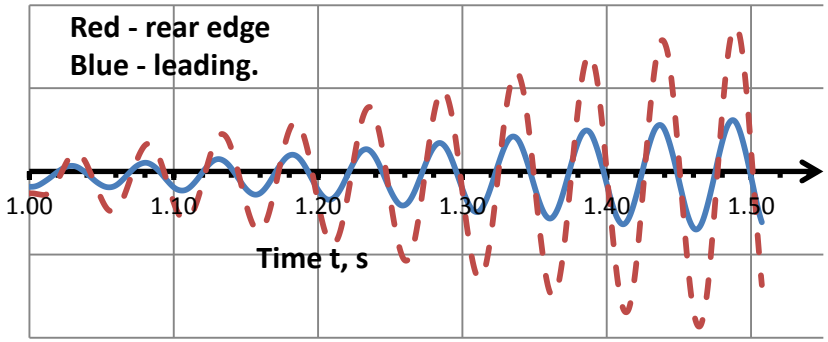
TESTING: Wing aeroelasticity and flutter

Dynamic equilibrium HIRENASD experiment

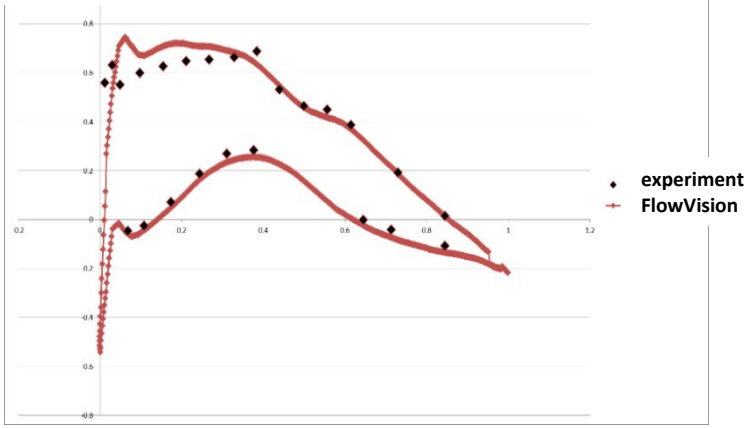


Wing flutter, AGARD 445.6 benchmark

wing edge displacement



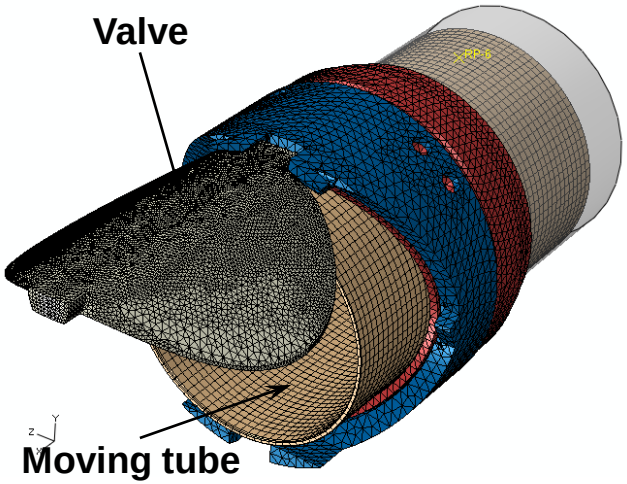
Pressure distribution in wing cross section: comparison with experiment

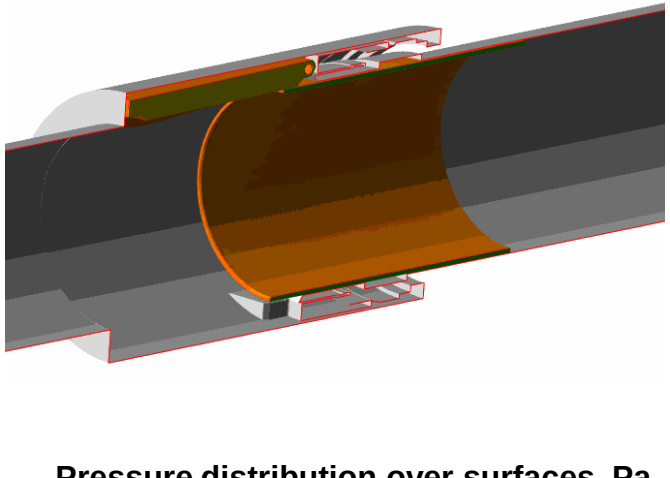


Mach	Experimental frequency, rad/s	Simulation frequency, rad/s	Accuracy %
0.499	128.1	123.65	3.5
0.678	113	115.5	2.21

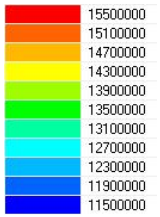
High-pressure valve closing

Application: Simulating high-pressure valve closing at gas pipe
Goal: Define speed of valve closing and load on valve parts

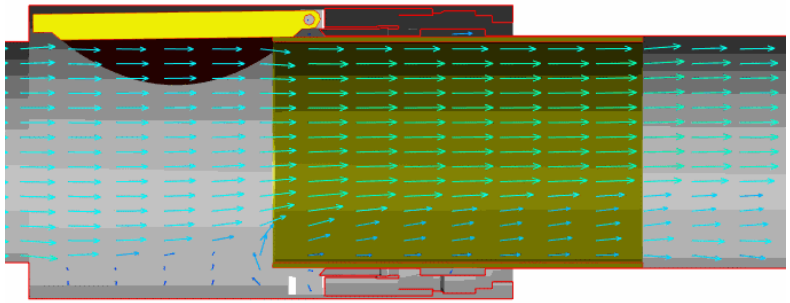




Pressure distribution over surfaces, Pa



Pressure distribution in central plane, Pa

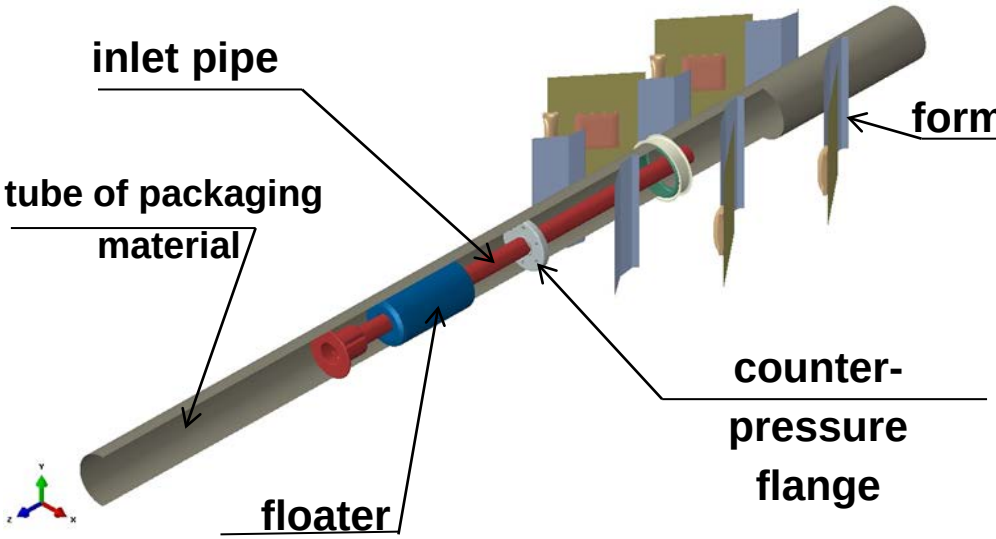


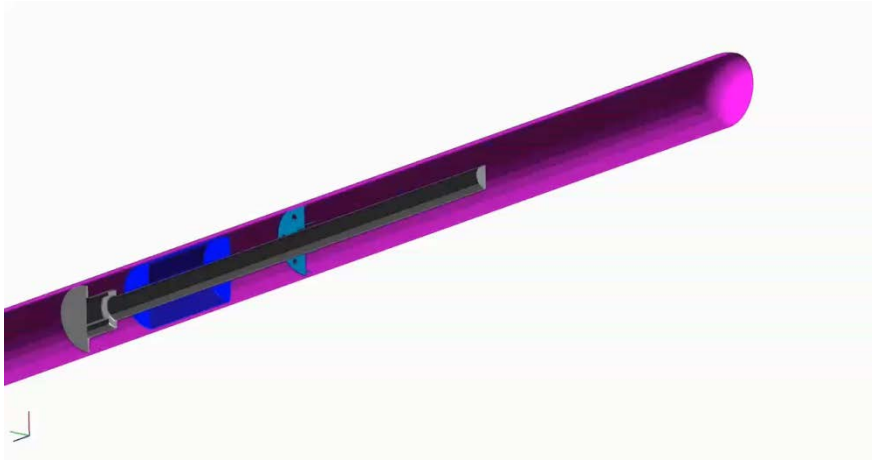
Gas velocity, m/s

Numerical simulation of filling and forming TetraPak packages

Complex FSI problem:

- **Highly flexible packaging material**
- **Free surface (water and air)**
- **Floater moves in computational domain**
- **Liquid consumption depends on floater position**



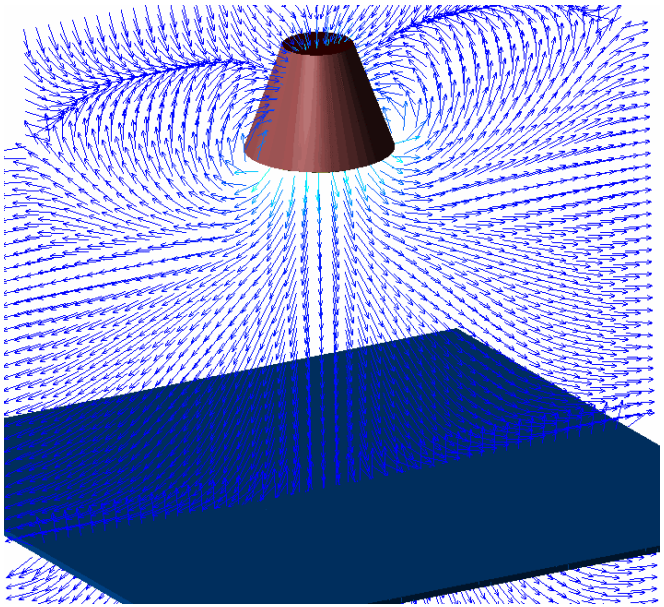


Spacecraft splash down

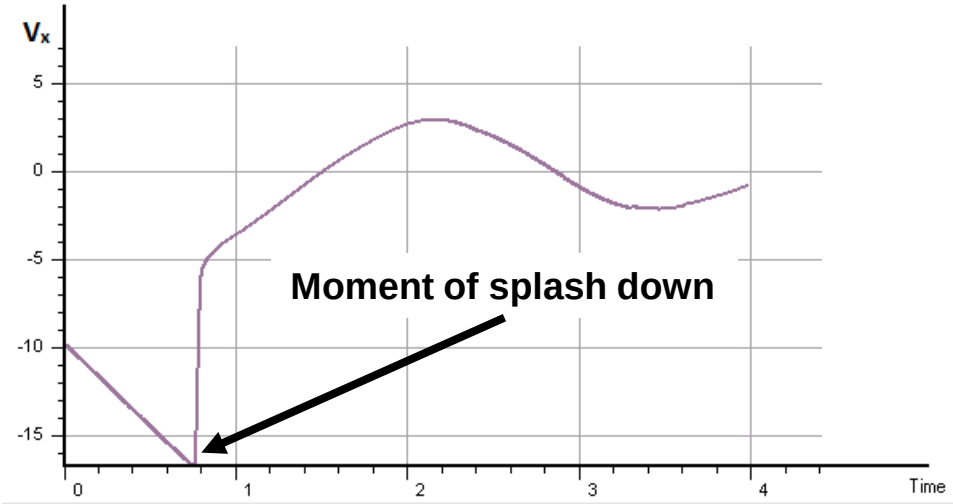
Application: Simulating perspective spacecraft during emergency splash down

Goal: Define forces and acceleration on spacecraft hull to prevent injuring screw and damaging the spacecraft.

Features: Influence air and water compressibility



Vertical speed of spacecraft



Conclusion

FlowVision-Abaqus coupling main benefits:

- **Easy-to-use**
- **Designed for realistic FSI simulations**
- **Solves most complex strong FSI problems**

Also, how to use FlowVision for simulating life-science problems (medicine, sport) you can find on CAPVIDIA exhibition desk.