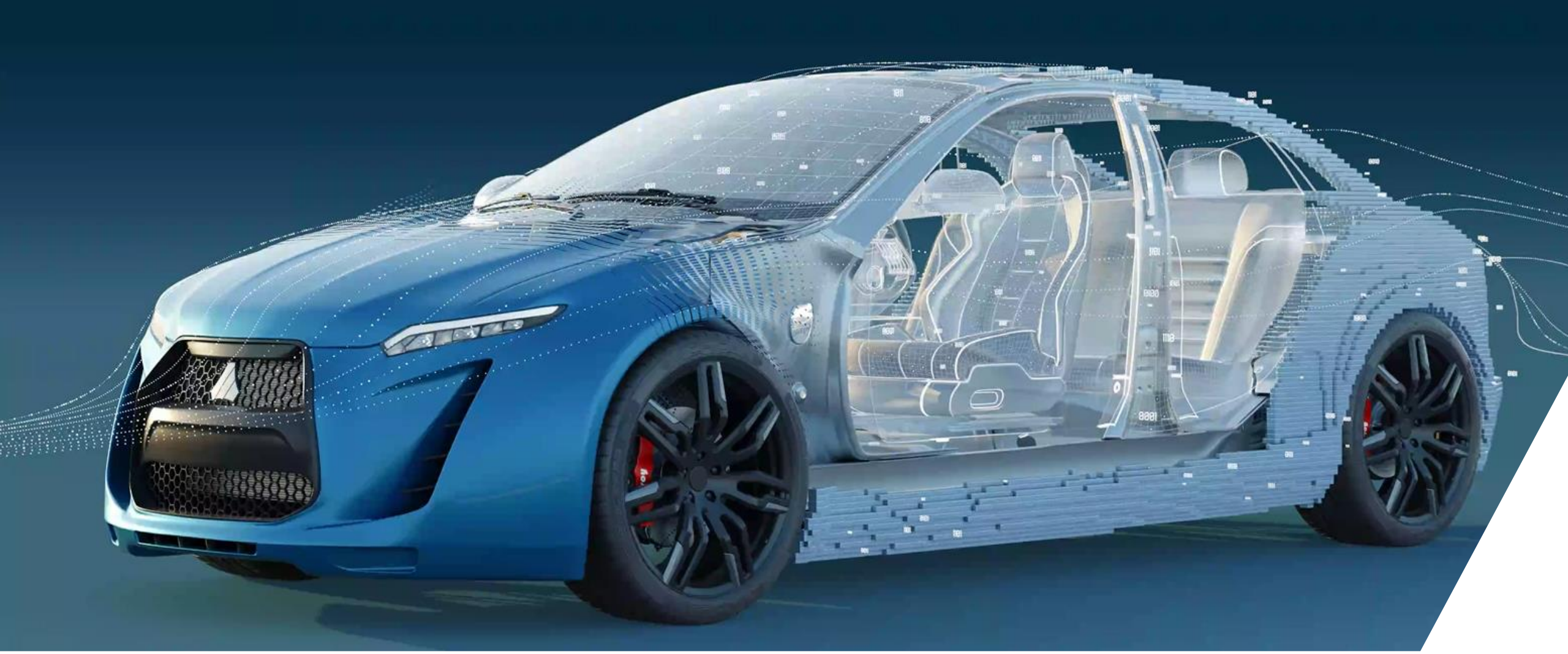


ALTAIR RADIOSS BASICS FOR EXPLICIT DYNAMIC ANALYSIS

FLUID-STRUCTURE INTERACTION IN AIR VALVE APPLICATION

Polyvios Romanidis

2024

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Agenda

Fluid-Structure Interaction in Air Valve Application

1 Altair Solutions

Radioss, HyperWorks

2 Model Setup

Materials, Mesh, Loads, Interface

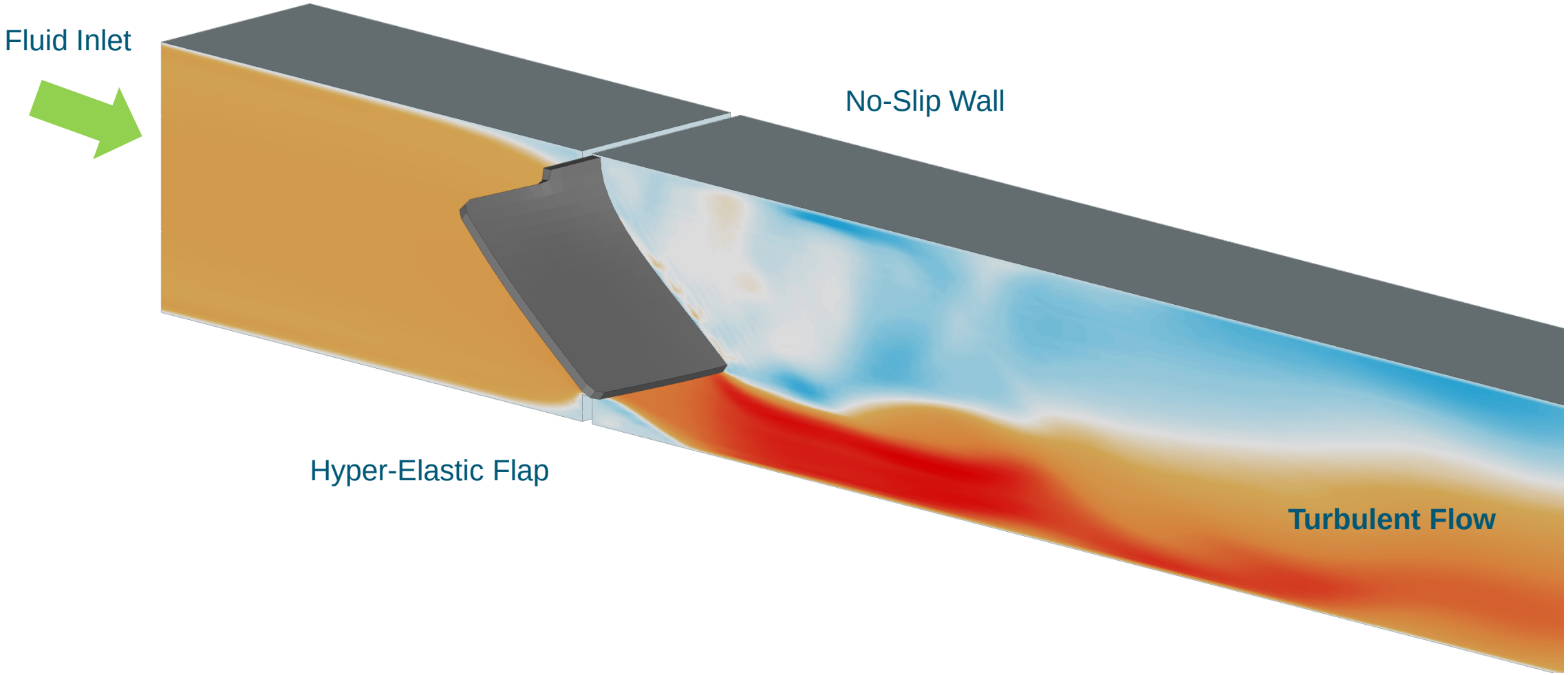
3 Simulation Results

4 Conclusion

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Teaser



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

ALTAIR SOLUTIONS

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

ALTAIR RADIOSS

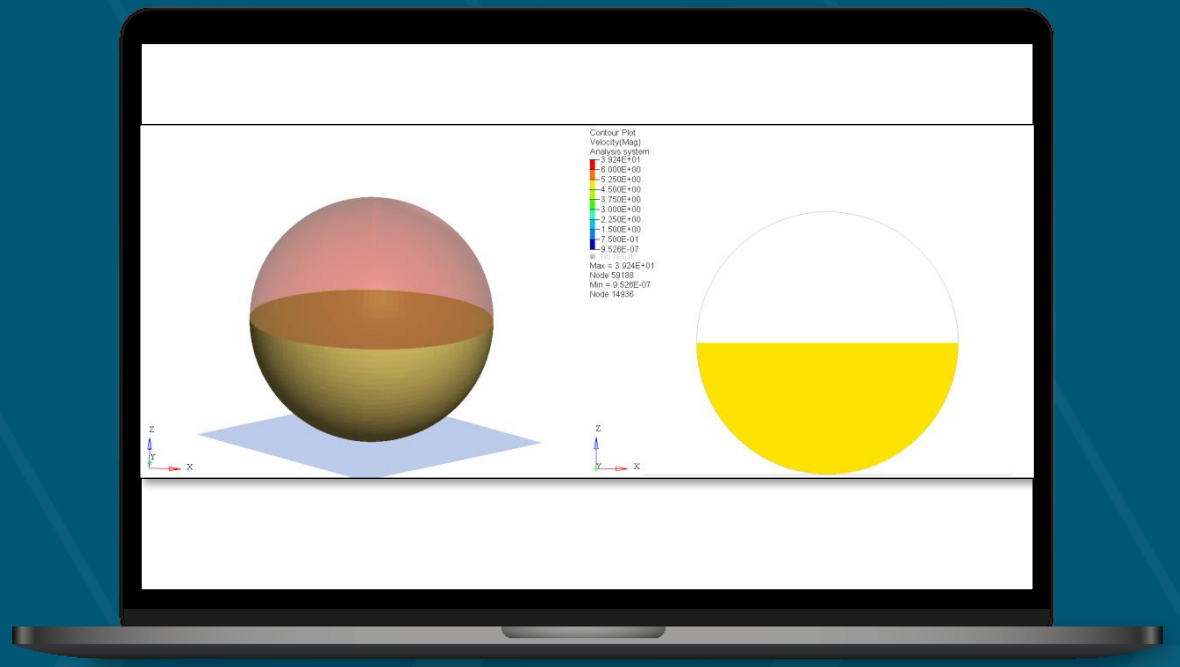
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Altair® Radioss™: The Altair Solution for highly non-linear problems under dynamic loadings

Radioss is a structural and FSI explicit solver

- ✓ *High Scalability, Quality and Robustness*
- ✓ *Supports multiphysics simulation and advanced materials*
- ✓ *For 30+ years an established standard for crash, impact and FSI*
- ✓ *Used across all industries to improve design*



ALTAIR

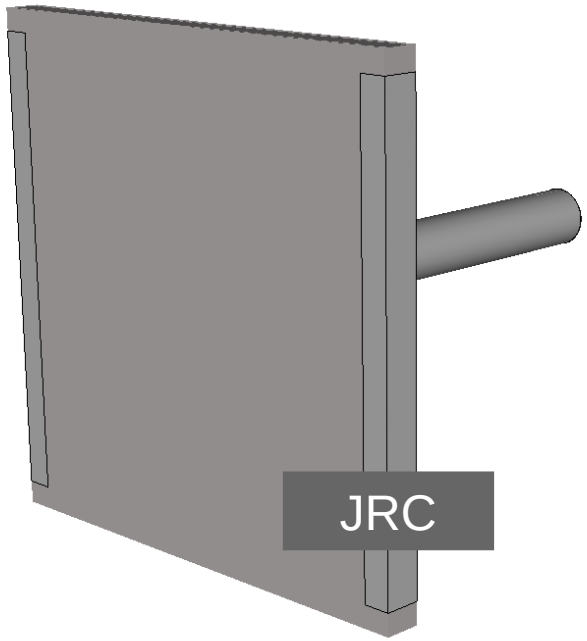
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Materials

More than 300 combinations of materials and failures:

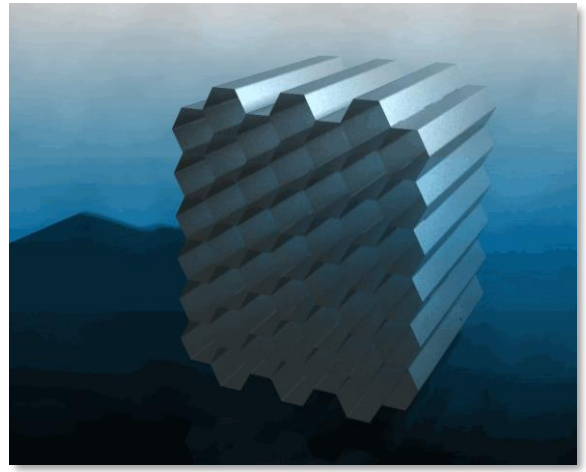
- ✓ *Material identification for various materials including composites*
- ✓ *Rupture characterization for advanced failure models*

Rubber



Impact on reinforced concrete with crack propagation

Helmet dropt test with plastics and composites



Aluminum NIDA for shock absorption

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Equations of State

Altair Radioss includes a large variety of Equations of State covering multiple applications.

Availability	KEYWORDS	Purposes
Version < 2018	/EOS/LINEAR	Linear EoS
	/EOS/POLYNOMIAL	Multiple purposes EoS
	/EOS/GRUNEISEN	Shocked solids v<2km/s
	/EOS/PUFF	Hypervelocity impacts
	/EOS/TILLOTSON	Hypervelocity impacts
	/EOS/SESAME	Phase change
New ones since 2018	/EOS/NOBLE-ABEL	Condensed Gas
	/EOS/IDEAL-GAS	Ideal Gas
	/EOS/STIFF-GAS	liquid gas, water
	/EOS/LSZK	Blast
	/EOS/MURNAGHAN	High Pressure Media
	/EOS/OSBORNE	High Velocity Impact
New ones since 2019.1	/EOS/COMPACTION	Soil
New ones since 2020	/EOS/NASG	liquid gas, water

We can easily implement additional Equations of State depending on your needs.

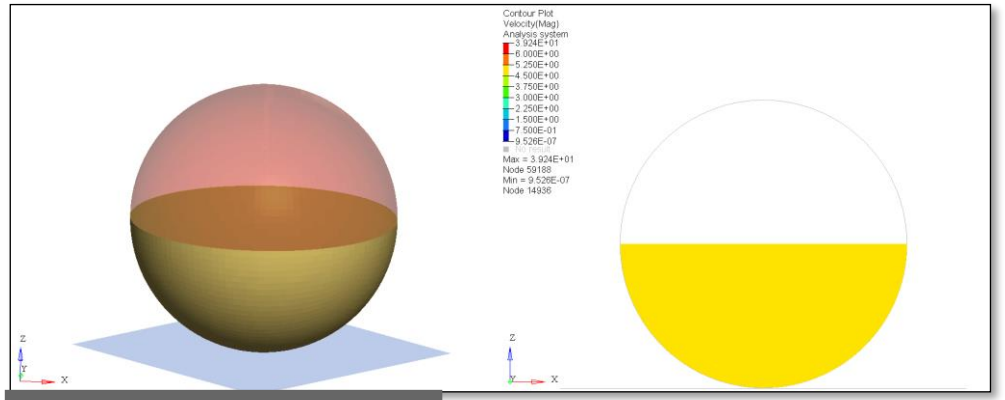
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

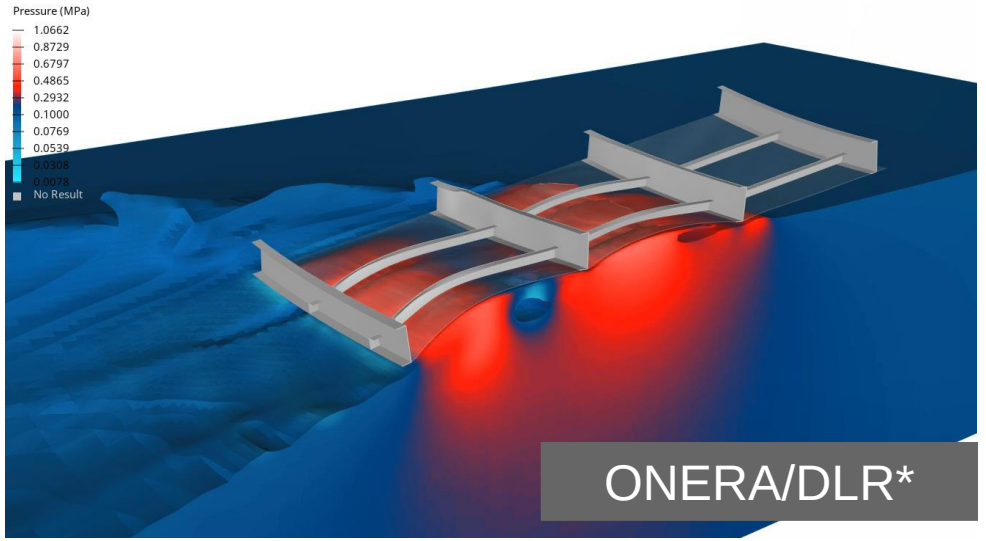
ALE multi-material law using coupled FE & FV solver

/MAT/LAW51 (MULTIMAT)

- **Available for:**
  - 2D analysis with /QUAD elements
  - 3D analysis with /BRICK elements
- **Simple input with iform=12**
  - Sub material identifier and volume fraction
- **Second order scheme for phases**
- **Compatible with:**
  - Initial volume fraction /INIVOL
  - FSI Coupling Interfaces (/INTER/TYPE1 and /INTER/TYPE18)
- **Main benefit:**
  - Compatible with Johnson-Cook and Drücker-Prager yield criteria ➔ useful for sand modeling



BALLOO project



ONERA/DLR*

*M.H. Siemann, D. Kohlgrüber, H. Voggenreiter, Numerical simulation of Flexible aircraft structures under ditching loads, CEAS Aeronautical Journal, Volume 8, Number 3, pages 505-521 (2017)

*C. Leon Muñoz, D. Kohlgrueber, and B. Langrand, Analysis of the application of fuselage skin reinforcements with beam element representations in flexible full aircraft models for ditching simulations, 11th EASN International Conference on Innovation in Aviation & Space to the Satisfaction of the European Citizens, Virtual, 1-3 Sept. 2021

ALTAIR

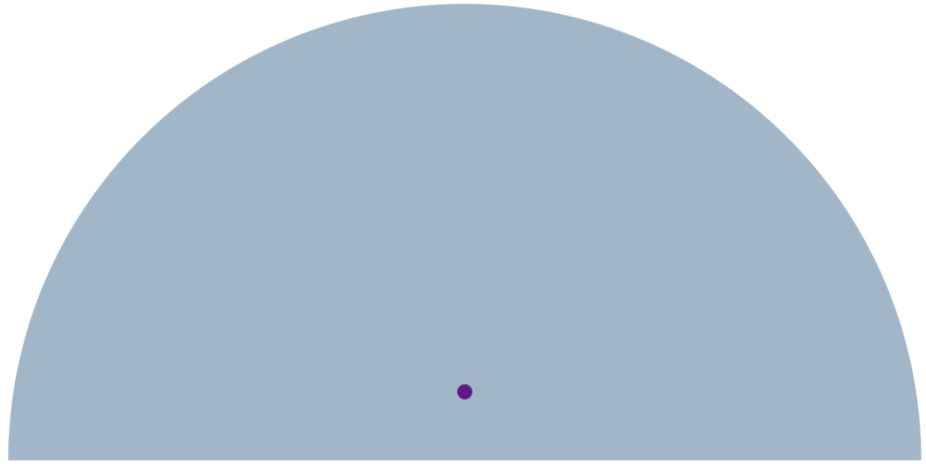
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

ALE multi-material law using finite Volume solver

/MAT/LAW151 (MULTIFLUID)

- **Available for:**
  - 2D analysis with /TRIA and /QUAD elements
  - 3D analysis with /BRICK and /TETRA4 elements
- **Conservation of total energy**
- **Second order scheme**
- **Compatible with:**
  - Initial volume fraction /INIVOL
  - FSI Coupling interface (/INTER/TYPE1 and /INTER/TYPE18)
  - Fluid material only

- **Main benefits:**
  - Dedicated for application with high Mach number
  - Fully second order



TNT charge detonation in air

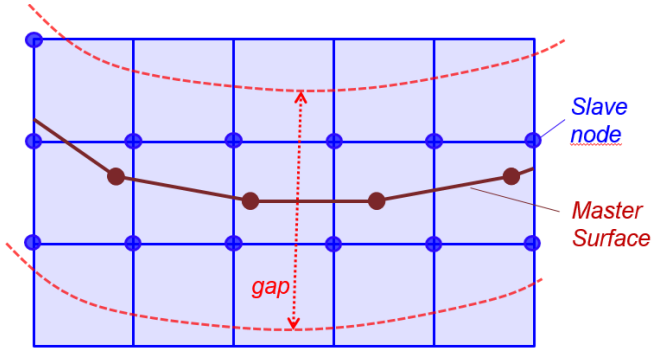
Gun muzzle flow

ALTAIR

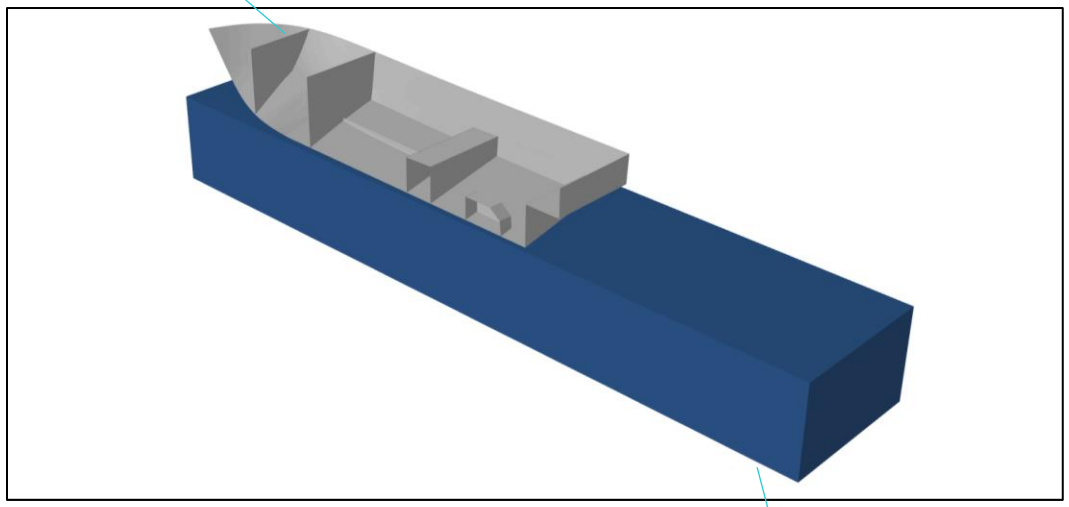
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Coupled Euler-Lagrange Method

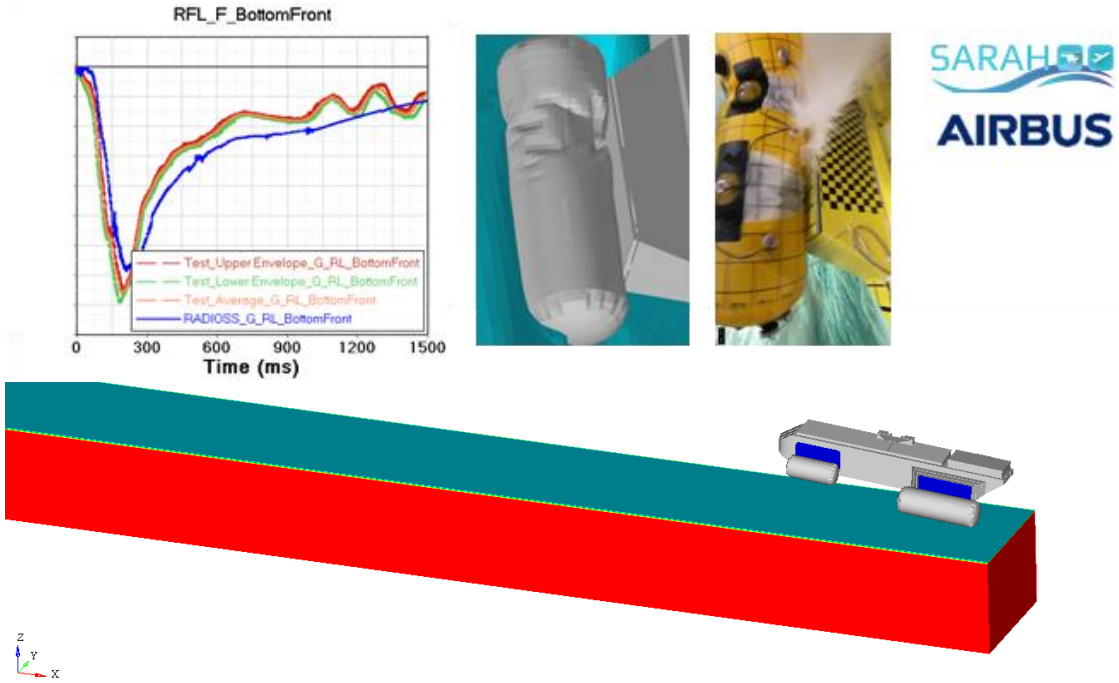
- Lagrangian mesh immersed inside ALE 3D mesh coupled with penalty method
- Adapted to complex geometries



Lagrangian Structure



Eulerian Domain with
Multi-Material Model



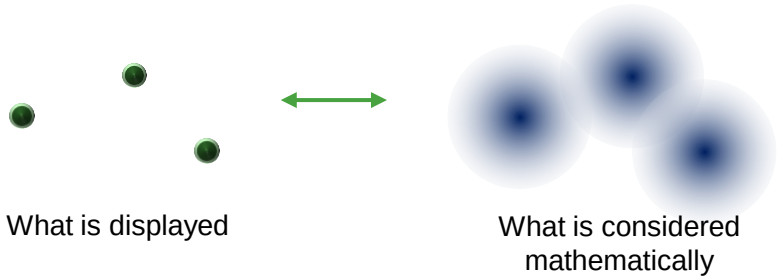
ALTAIR

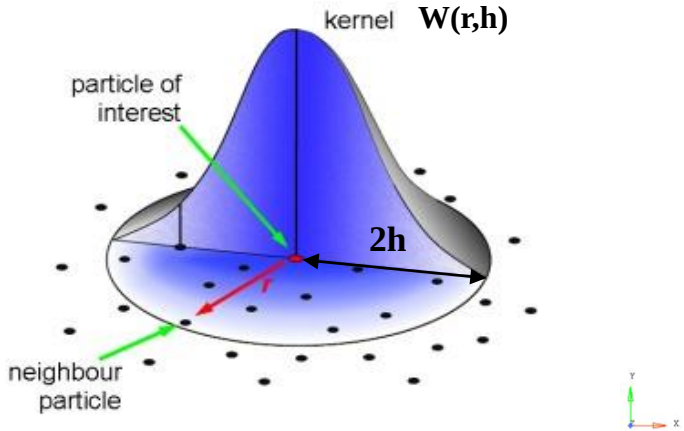
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

SPH

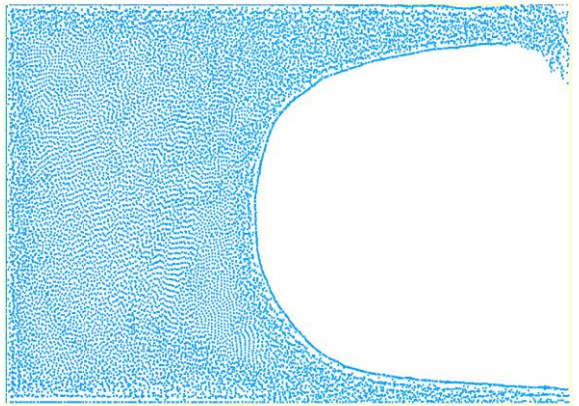
The domain is divided into a set of particles tied to their neighbors by internal forces.

- Physical laws of mechanics of continuum medium are applied.
- Lagrangian approach: material characteristics, velocity and mass assigned to the particles.
- Functions are approximated over the discretization domain with kernel functions W.
- The interaction between particles is limited to particles within a distance 2h.





From http://plaza.ufl.edu/jeffjtd/SitePics/kernelpic.jpg



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

ALTAIR HYPERWORKS

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Model Preparation – Result Analyses

Open, adaptable to ***your*** environment…

CAD

ACIS	JT Precise	SolidWorks
CATIA V4 / V5	Parasolid (in)	STEP
IGES (in)	Parasolid (out)	Tribon
IGES (out)	Pro/E	UG/NX

CAE

Adams	Femfat	Moldflow	Pam-Crash
Abaqus	Fluent	Moldex3D	RADIOSS
Actran	Ls-Dyna	MotionSolve	OptiStruct
AcuSolve	Madymo	Nastran	Samcef
Ansys	Marc	nCode	Simpack
CFD++	Matlab	Permas	StarCD

Custom

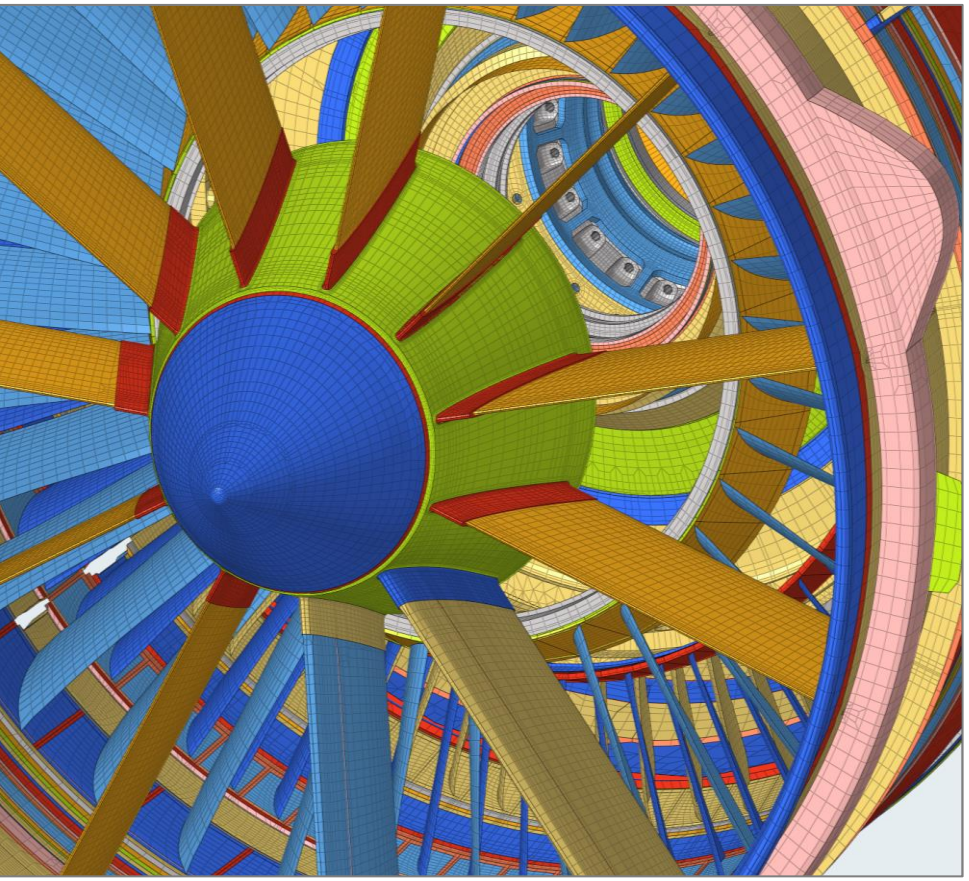
User-defined Interfaces	Scripting	Results Math

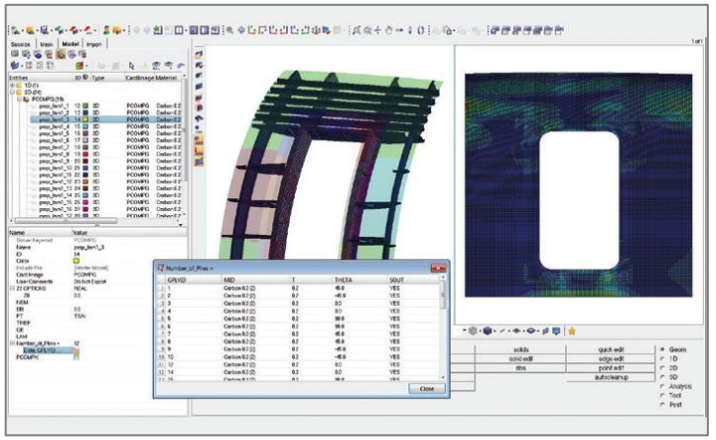
www.altair.com/hyperworks

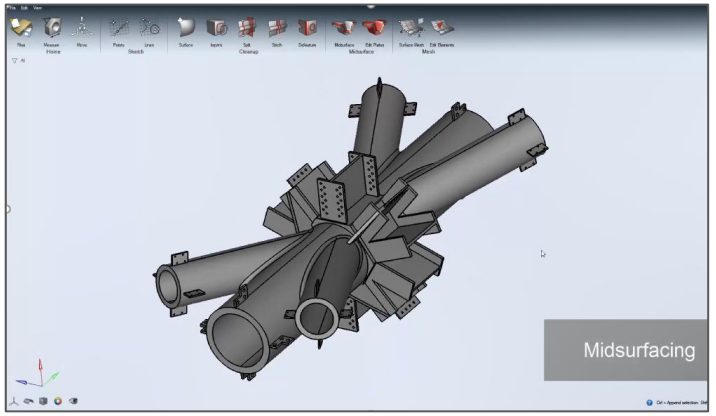
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Altair HyperMesh – Market-leading CAE Pre-processor







HyperMesh is a high-performance CAE pre-processor that provides a highly interactive and visual environment to analyse product design performance.

With the broadest set of direct interfaces to commercial CAD and CAE systems and a rich suite of easy-to-use tools to build and edit CAE models, HyperMesh provides a proven, consistent analysis platform for the entire enterprise.

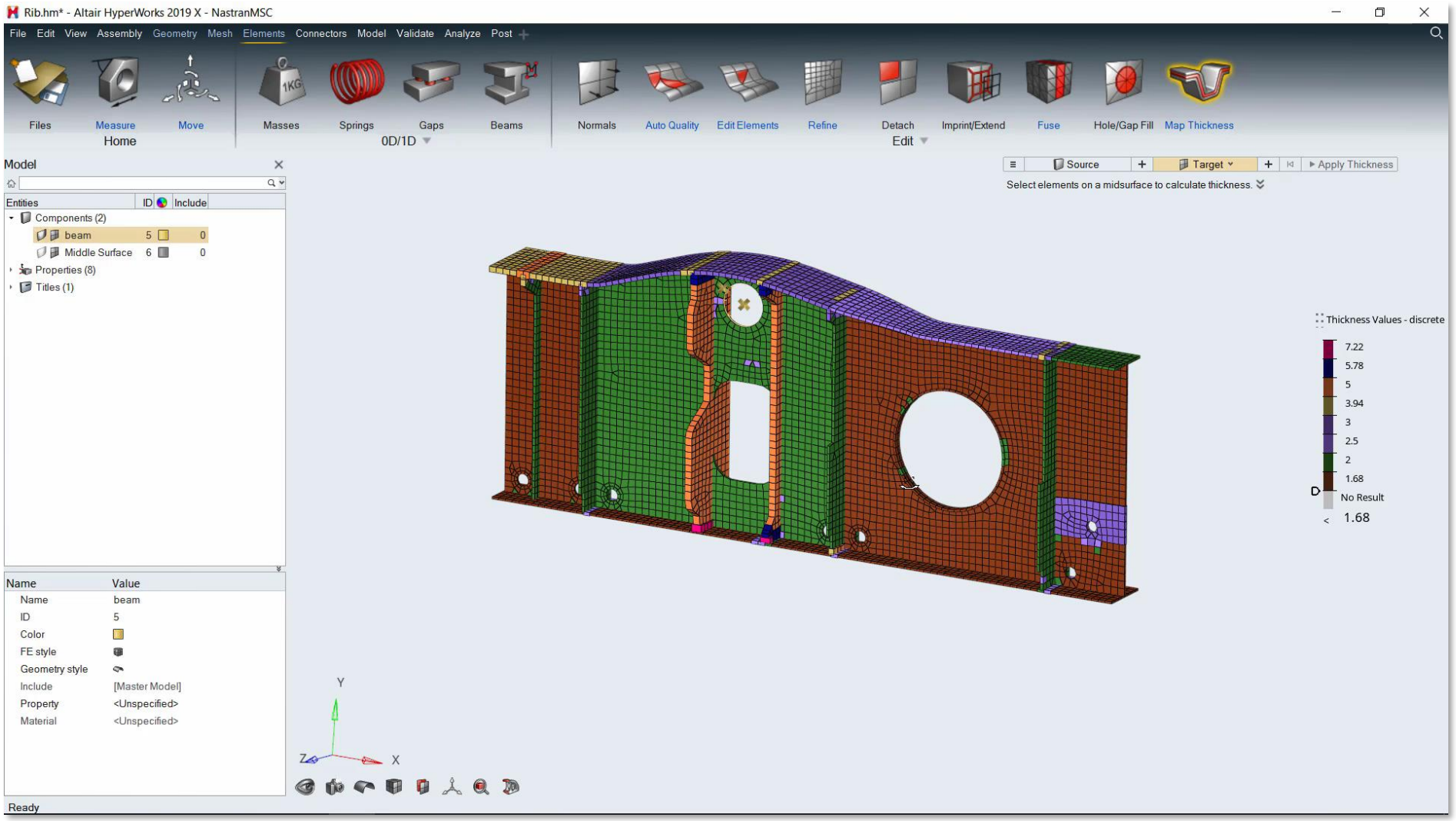
- Pre-processing for complex assemblies
- Open-architecture design
- Automated model build

Learn more at **altair.com/hypermesh**

ALTAIR

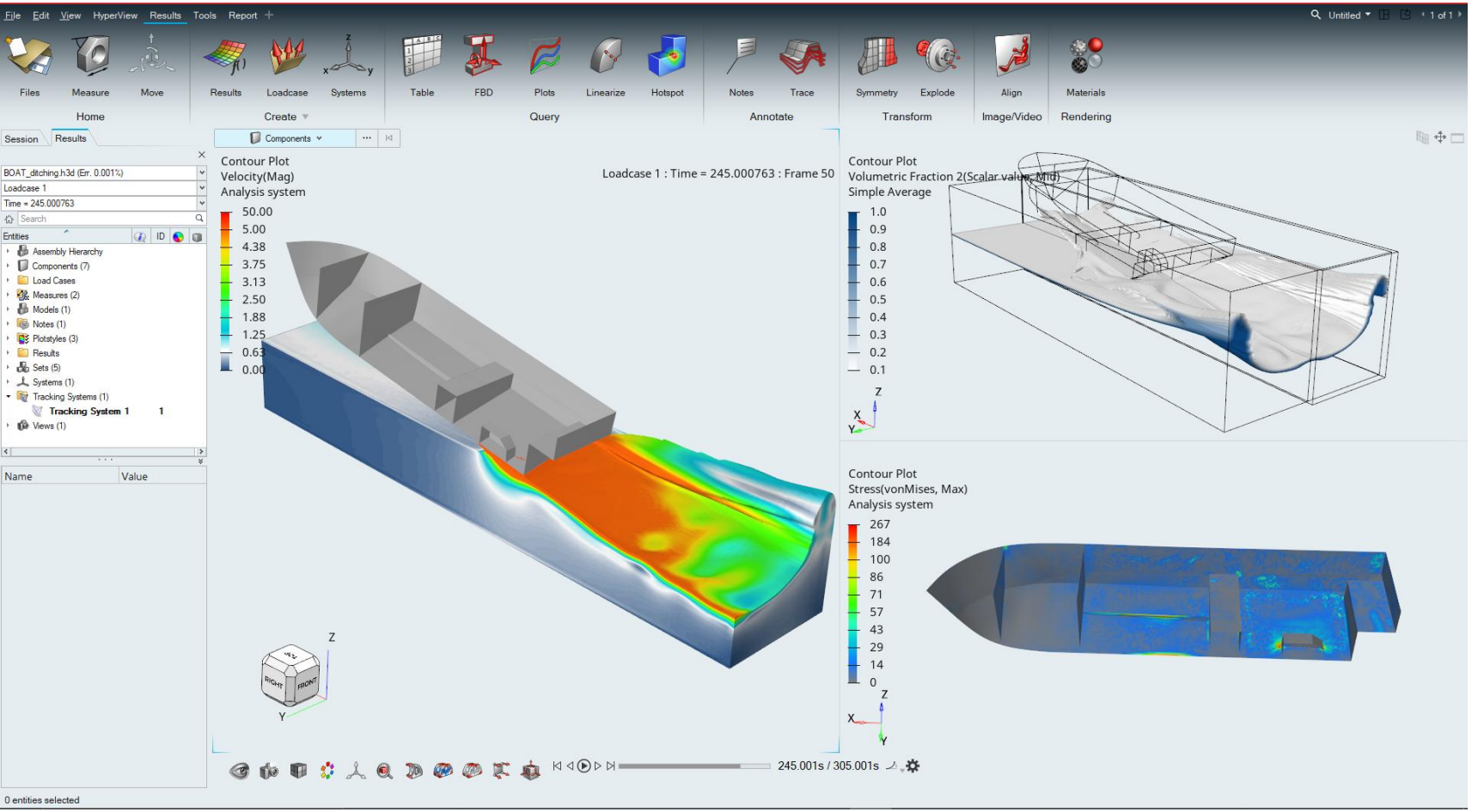
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Altair HyperWorks New Effective Workflows



© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Altair HyperView – CAE Results Visualization & Reporting



HyperView is a complete post-processing and visualization environment for finite element analysis, CFD and multi-body system data. It is the new standard for speed and integration of CAE results post-processing.

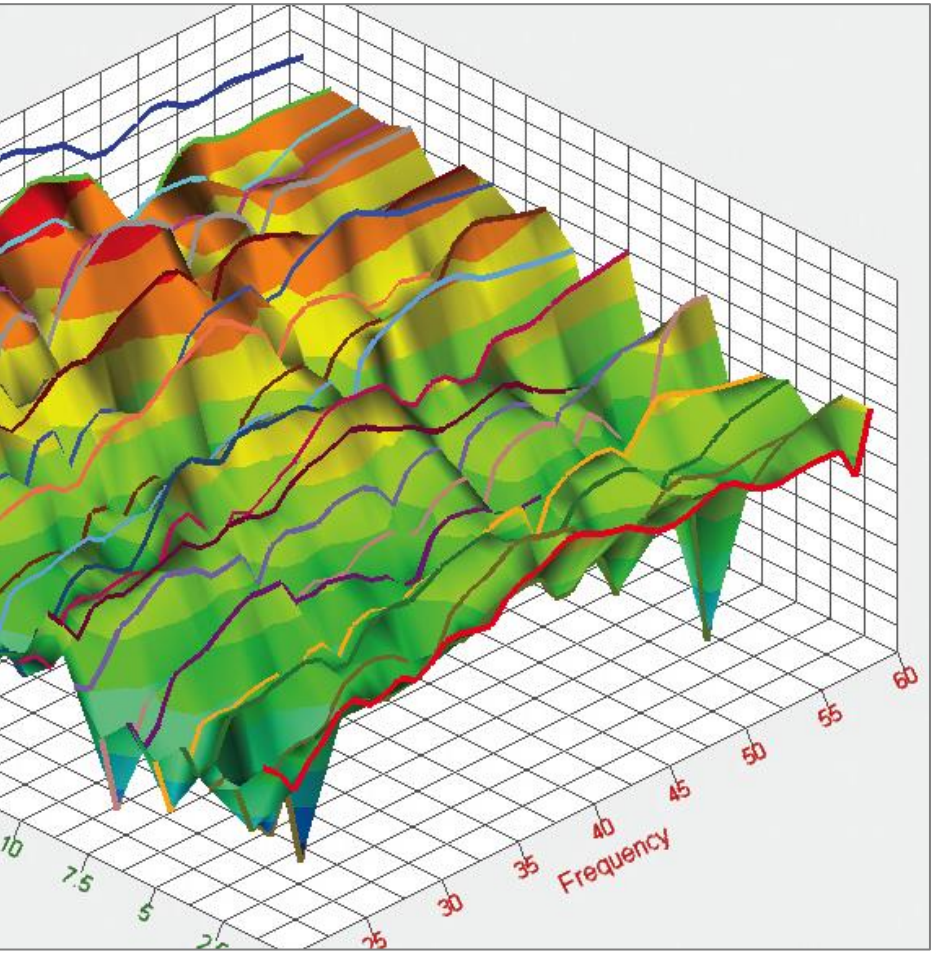
- Multi-page and multi-window post-processing
- Report templates for efficient results evaluation
- Results comparison and correlation with test data

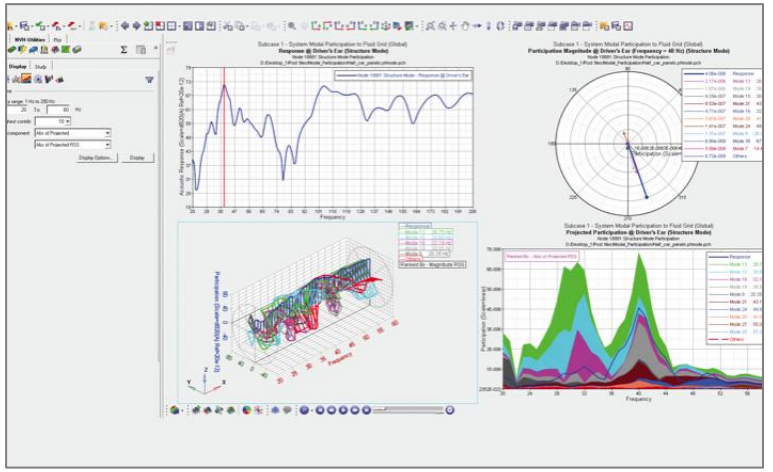
Learn more at **altair.com/hyperview**

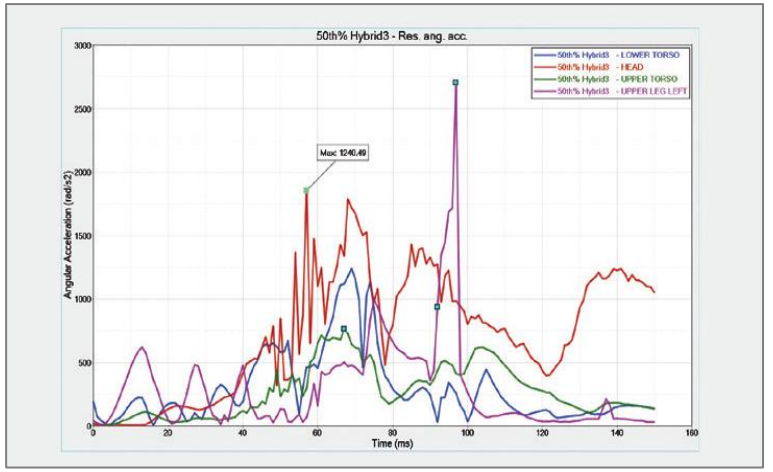
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Altair HyperGraph – 2D & 3D Plotting and Data Analysis







HyperGraph is a powerful data analysis and plotting tool with interfaces to many popular file formats. Its intuitive interface and sophisticated math engine make it easy to process even the most complex mathematical expressions. HyperGraph combines these features with high-quality presentation output and customization capabilities to create a complete data analysis system for any organization.

- Report creation and templates with process automation
- Efficient overlay and comparison of large data sets
- Extremely powerful and customizable math library

Learn more at **altair.com/hypergraph**

ALTAIR

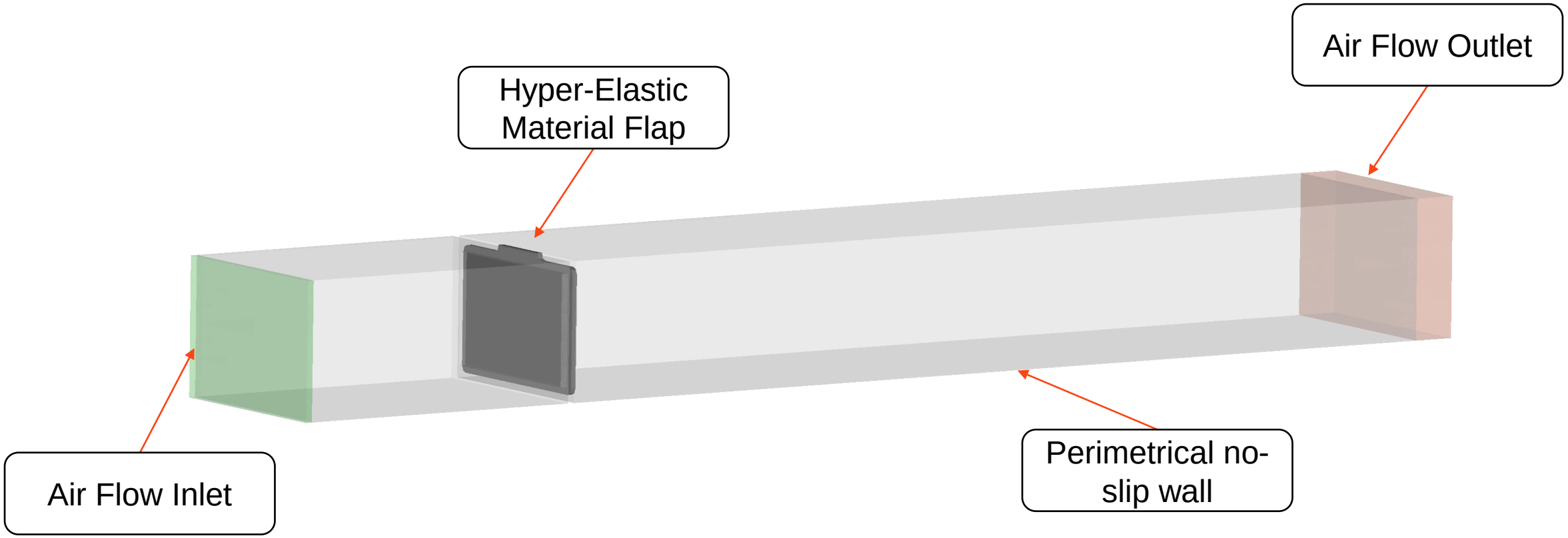
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

MODEL SETUP

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Model Preview



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Model Preview

Description:

- Channel with internal flexible plate
- Transient solution
- Turbulent and incompressible flow

Challenges:

- Strongly coupled problem
- Significant deformation of structure
- Hyper-elastic material behavior

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

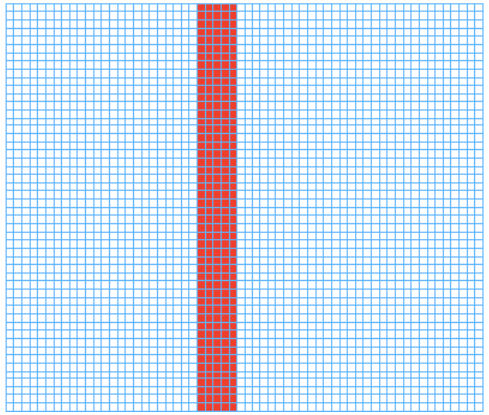
FSI FORMULATION

ALTAIR

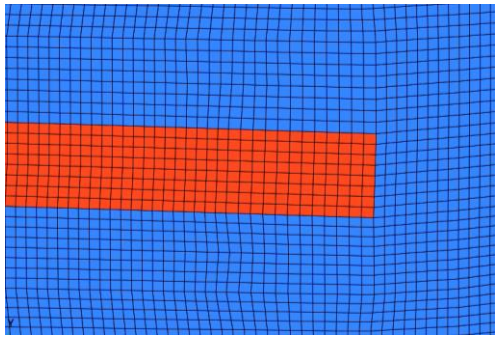
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fluid-Structure Interface Modeling

ALE Tied FSI

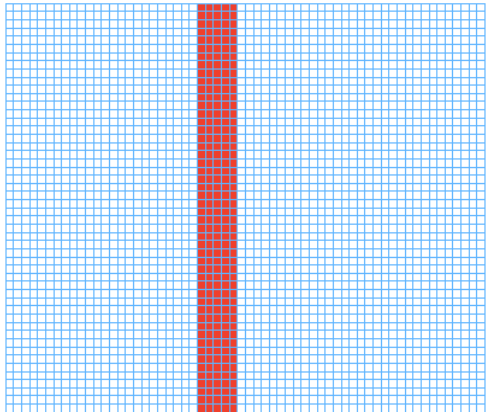


+ Direct forces transfer
+ Material tracking

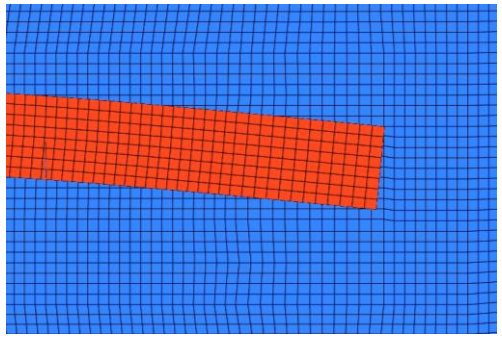


- Meshing of complex geometries
- Mesh deformation

CEL



+ Time step
+ Elem Quality
+ Complex geometries
+ Large deformation with possible rupture
+ Gap closure possible



- Interface Calibration

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

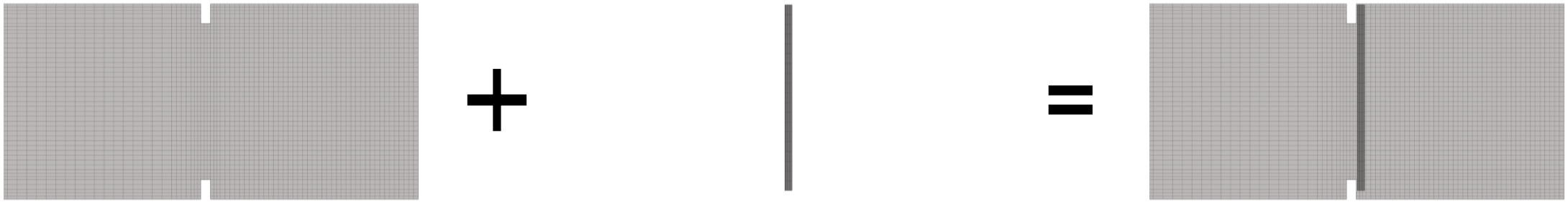
CEL FORMULATION

CEL Formulation (non-conforming mesh):

1. Immersed coupling between Fluid (EULERIAN) and Solid (LAGRANGIAN)
2. Penalty method which requires stiffness and gap values
3. Gap and Stiffness calculated based on specific equations

$$Stf_{val} = \frac{\rho \cdot V_{ref}^2 \cdot S_{solid_elem}}{Gap} \quad \& \quad Gap = 1.5\Delta x_{\text{fluid_elem}}$$

Name	Value
Solver Keyword:	/INTER/TYPE18/
ID:	2
Name:	FSI_Valve_Air
Color:	
Include:	[Main Model]
User Comments:	Hide In Menu/Export
Card Image:	TYPE18
Grbric_id (S):	(5) set3
Surf_id (M):	(6) set4
Igap:	
Ipres:	
Idel:	
Istf:	1: Stiffness value calculated and Stfval must be
Stfval:	0.33
GAP:	0.000375
Tstart:	
Tstop:	
Metadata	



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

MESH

ALTAIR

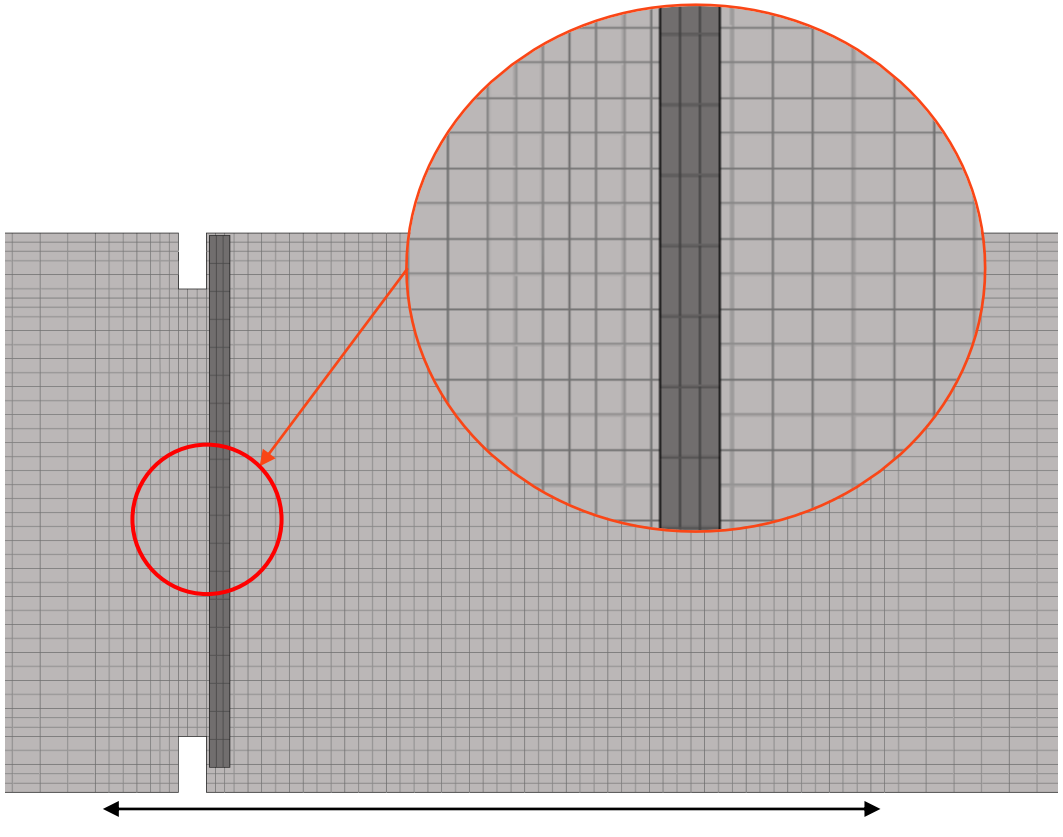
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Meshing Techniques

- Finer mesh near the neck of the channel and the region where the plate can move

- /HEXA elements used to be compatible with /MAT/LAW6

- 3 layers of solid elements throughout the thickness of the plate to capture its deformation accurately



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

MATERIALS & PROPERTIES

ALTAIR

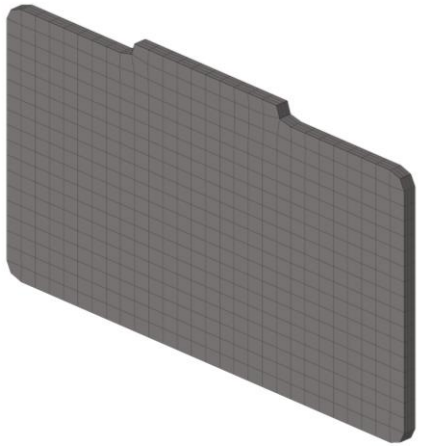
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Plate Modeling

- Hyper-elastic Material Formulation (/MAT/OGDEN – LAW42)
  - Density = 1000 kg/m^3
  - Poisson Ratio = 0.495
  - Shear hyper-elastic modulus parameters:
    - μ_1 = 1600000 Pa
    - μ_2 = -3600000 Pa
  - Material Exponents
    - a_1 = 2
    - a_2 = -2

$$W(\lambda_1,\lambda_2,\lambda_3) = \sum_{p=1}^{5} \frac{\mu_p}{\alpha_p}\left(\bar{\lambda}_1^{\alpha_p} + \bar{\lambda}_2^{\alpha_p} + \bar{\lambda}_3^{\alpha_p} - 3\right) + \frac{K}{2}(J-1)^2$$

- Solid Property (/PROP/SOLID – TYPE14)
  - Isolid = 14 – locking-free 8-node solid element
  - Ismstr = -1 – define best value for each material law (true value = 10)
  - Icpre = -1 - define best value for each material law (true value = 1)
  - Iframe = -1 - define best value for each material law (true value = 2)
  - 2 integration points per direction (set with Inpts_R, Inpts_S and Inpts_T)



Name	Value
Solver Keyword:	/MAT/OGDEN/
ID:	5
Name:	Rubber
Color:	
Include:	[Main Model]
User Comments:	Hide In Menu/Export
Card Image:	M42_OGDEN
Regular_OR_encrypted_flag:	Regular
RefRho_Option:	
Rho_Initial:	1000.0
Nu:	0.495
sigcut:	
f_bulk:	
F_scale:	
M:	
I_form:	
mue1:	1600000.0
mue2:	-3600000.0
mue3:	
mue4:	
mue5:	
alpha1:	2.0
alpha2:	-2.0
alpha3:	
alpha4:	
alpha5:	
VISC_PRONY_option:	

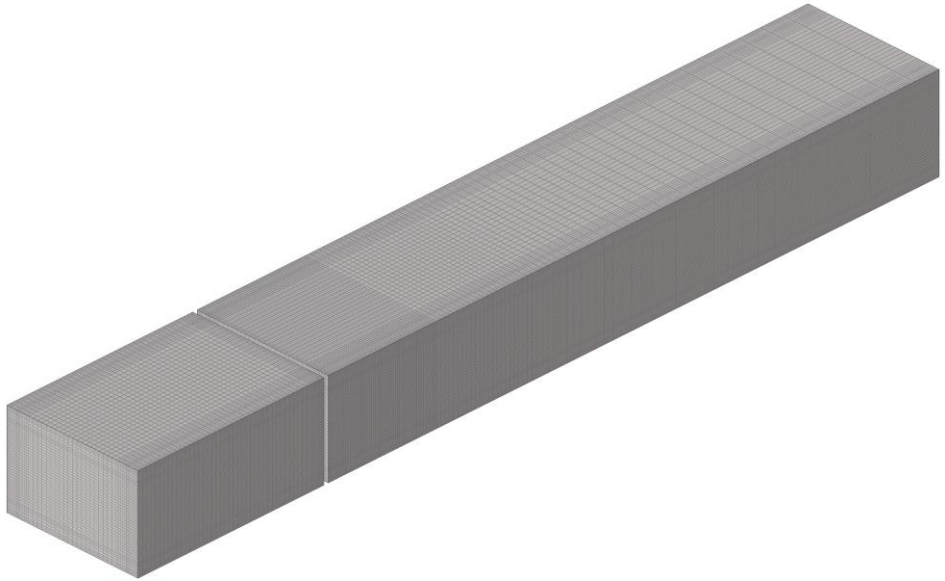
Name	Value
Solver Keyword:	/PROP/SOLID/
ID:	5
Name:	SOLID
Color:	
Include:	[Main Model]
CommentEnumField:	1:Hide in Menu/Export
Card Image:	P14_SOLID
SolidLiquid_Opt:	SOLID
Isolid:	14:HA8 Locking-Free 8-Node Soli...
Ismstr:	-1:Automatically define the best val...
Iale:	
Icpre:	-1:Automatically define the best val...
Itetra10:	
Inpts_R:	2
Inpts_S:	2
Inpts_T:	2
Itetra4:	
Iframe:	-1:Automatically define the best val...
qa:	
qb:	
Lambda:	
Mu:	
deltaT_min:	
Vdef_min:	
Vdef_max:	
ASP_max:	
COL_min:	

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fluid Domain Modeling

- Turbulent Fluid Material (/MAT/K-EPS – LAW6)
  - k – ε turbulence model
  - Density = 1.2 kg/m^3
  - Kinematic viscosity = 1.5 e-05 m^2/s
  - Initial turbulent energy = 0.29 J
  - Equation of State = Ideal Gas (/EOS/IDEAL_GAS)
    - γ = 1.4
    - P0 = 100000 Pa
    - T0 = 293 K
    - Initial Density = 1.2 kg/ m^3
  - ALE CFD Formulation = EULERIAN
- Fluid Property (/PROP/FLUID – TYPE14)



Name	Value
Solver Keyword:	/MAT/K-EPS/
ID:	1
Name:	Air
Color:	
Include:	[Main Model]
User Comments:	Hide In Menu/Export
Card Image:	MLAW6
LAW6 Keys:	K-EPS
Regular_OR_encrypted_flag:	Regular
RefRho_Option:	
Rho_Initial:	1.2
Nu:	1.5e-05
Pmin:	
Rho0_k0:	0.29
SSL:	
c_mu:	
Sigma_k:	
sigma_epsilon:	

C1:	
C2:	
C3:	
kappa:	
E:	
alpha:	
chi_t:	
ALE CFD Formulation:	EULERIAN
FLRD:	
HEAT_Input:	
EOS_Options_Input:	IDEAL_GAS
Gamma:	1.4
P0:	100000.0
PSH:	
T0:	293.0
RHO_0:	1.2

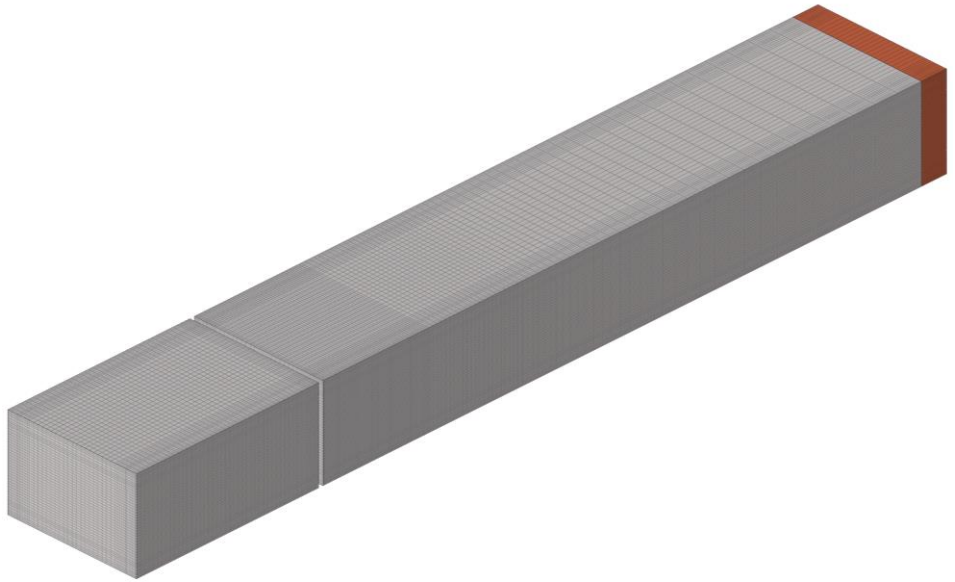
Name	Value
Solver Keyword:	/PROP/FLUID
ID:	1
Name:	FLUID
Color:	
Include:	[Main Model]
CommentEnumField:	1:Hide in Menu/Export
Card Image:	P14_SOLID
SolidLiquid_Opt:	FLUID
Vdef_min:	
Vdef_max:	
ASP_max:	
COL_min:	
qa:	
qb:	
h:	
Element_closure_opt:	
Metadata	

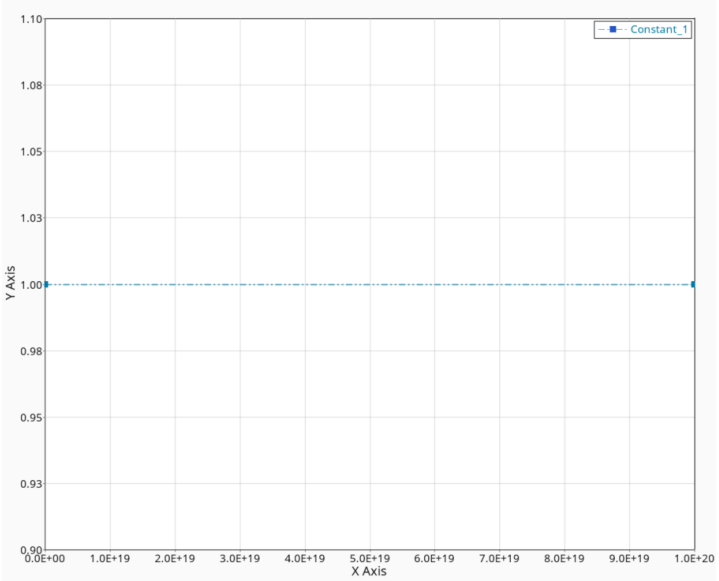
ALTAIR

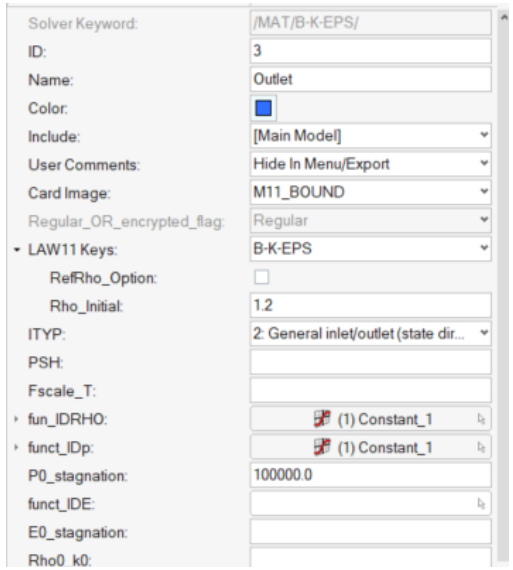
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

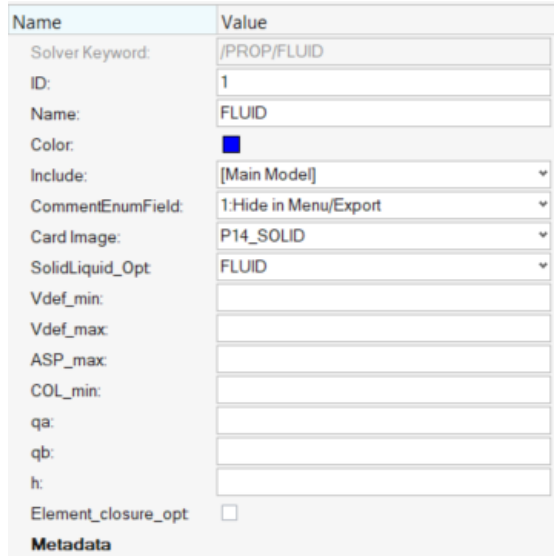
Fluid Outlet Modeling

- Turbulent Fluid Material (/MAT/B-K-EPS – LAW6)
  - k – ε turbulence model
  - Density = 1.2 kg/m^3
  - Ityp = 2 (General Inlet/Outlet)
  - Constant Pressure Value through function
  - ALE CFD Formulation = EULERIAN
- Fluid Property (/PROP/FLUID – TYPE14)







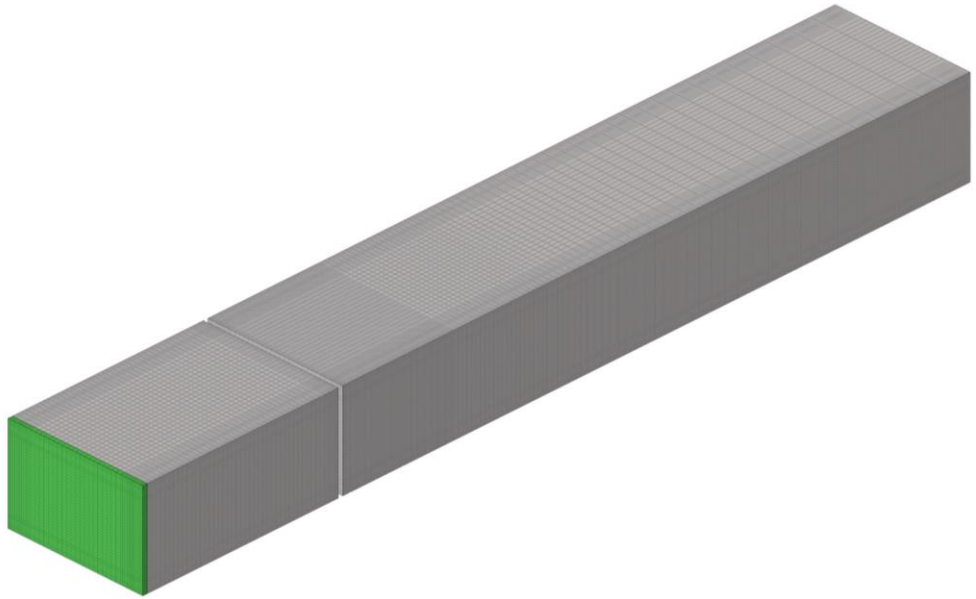


ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fluid Inlet Modeling – Velocity Inlet

- Turbulent Fluid Material (/MAT/B-K-EPS – LAW6)
  - k – ε turbulence model
  - Density = 1.2 kg/m^3
  - Ityp = 2 (General Inlet/Outlet)
  - ALE CFD Formulation = EULERIAN
- Fluid Property (/PROP/FLUID – TYPE14)



Name	Value
Solver Keyword:	/MAT/B-K-EPS/
ID:	2
Name:	Inlet
Color:	
Include:	[Main Model]
User Comments:	Hide In Menu/Export
Card Image:	M11_BOUND
Regular_OR_encrypted_flag:	Regular
LAW11 Keys:	B-K-EPS
RefRho_Option:	
Rho_Initial:	1.2
ITYP:	2: General inlet/outlet (state dir...
PSH:	
Fscale_T:	
fun_IDRHO:	
funct_IDp:	
P0_stagnation:	
funct_IDE:	
E0_stagnation:	
Rho0_k0:	

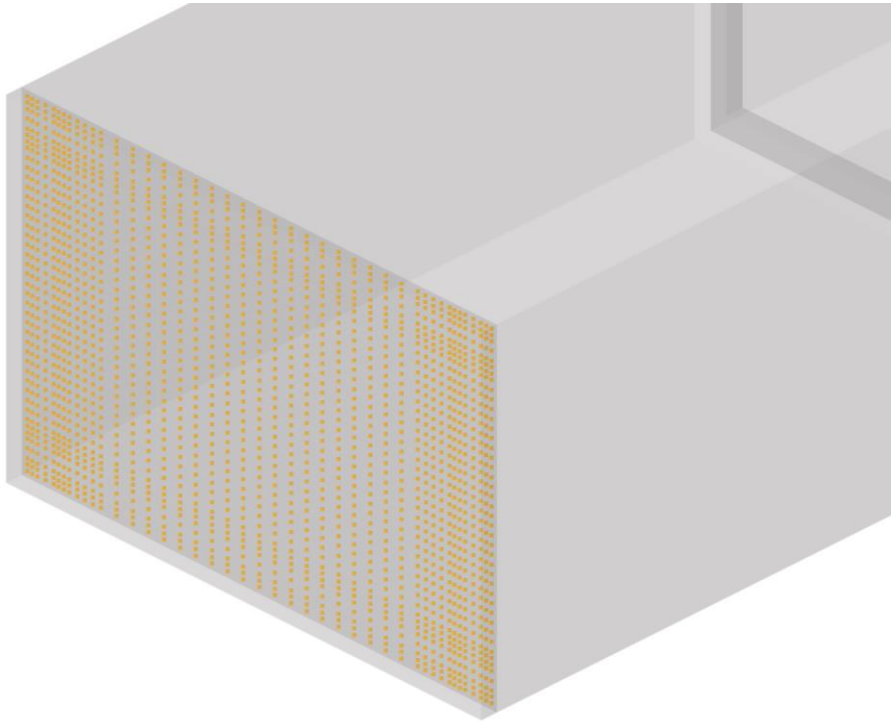
Name	Value
Solver Keyword:	/PROP/FLUID
ID:	1
Name:	FLUID
Color:	
Include:	[Main Model]
CommentEnumField:	1:Hide in Menu/Export
Card Image:	P14_SOLID
SolidLiquid_Opt:	FLUID
Vdef_min:	
Vdef_max:	
ASP_max:	
COL_min:	
qa:	
qb:	
h:	
Element_closure_opt:	
Metadata	

ALTAIR

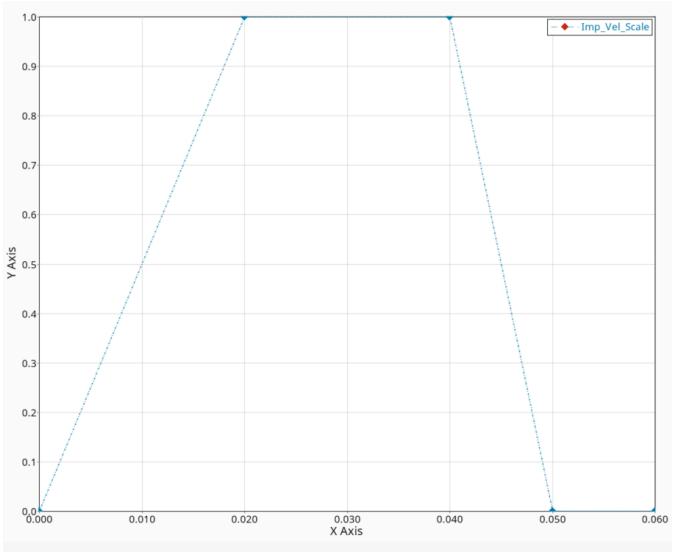
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Inlet Velocity (/IMPVEL) – Velocity Inlet

- Imposed transient velocity (IMPVEL) at the inlet
- Nodes between Inlet and Main Domain material are used for the load implication
- The nodes that belong to both wall and inlet surface are not used to prevent Incompatible Kinematic Condition problem
- Smooth implication of inlet velocity with the use of a function to prevent pressure wave phenomena.



Name	Value
Solver Keyword:	/IMPVEL
ID:	2
Include:	[Main Model]
Engineering type:	Directional Velocity
Type:	IMPVEL
grnd_ID:	(1) inlet_nodes
Title:	Inlet_Vel
User Comments:	Hide In Menu/Export
fct_ID(T):	(2) Imp_Vel_Scale
Dir:	Z
System Input Type:	Skew System
skew_ID:	<Unspecified>
sens_ID:	<Unspecified>
icoor:	0: Cartesian coordinates
Ascale(X):	
Fscale(Y):	1e-08
Tstart:	0.0
Tstop:	
Metadata	

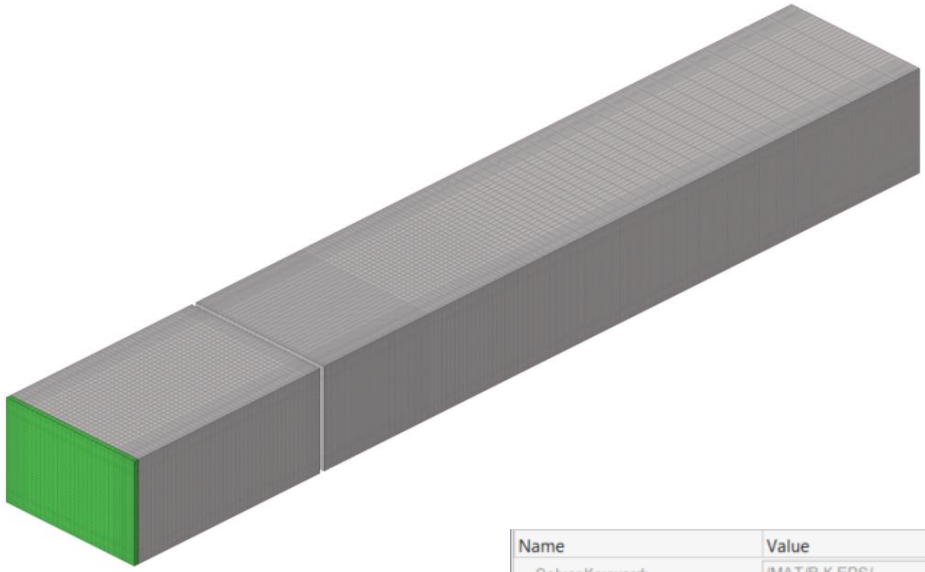


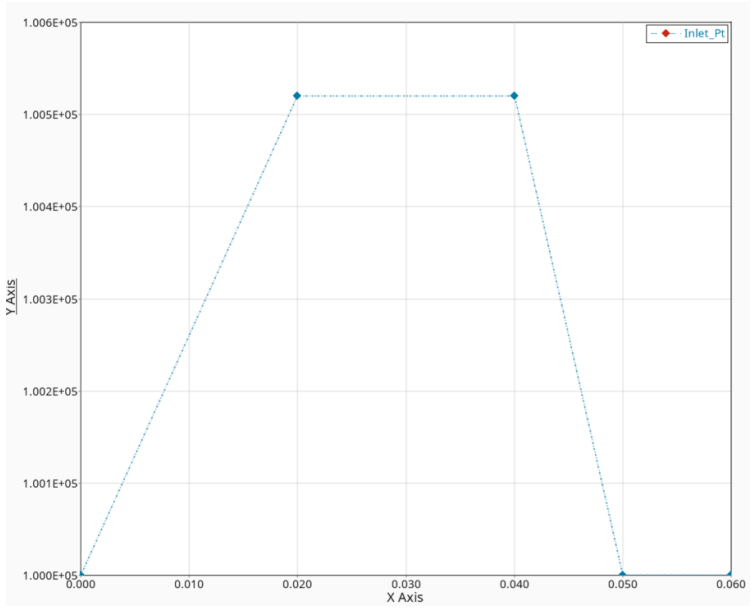
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fluid Inlet Modeling – Pressure Inlet

- Turbulent Fluid Material (/MAT/B-K-EPS – LAW6)
  - k – ε turbulence model
  - Density = 1.2 kg/m^3
  - Ityp = 0 (Gas Inlet)
  - P0 = 1 Pa / γ = 1.4
  - Pressure Inlet Function
  - ALE CFD Formulation = EULERIAN
- Fluid Property (/PROP/FLUID – TYPE14)





Name	Value
Solver Keyword:	/PROP/FLUID
ID:	1
Name:	FLUID
Color:	
Include:	[Main Model]
CommentEnumField:	1:Hide in Menu/Export
Card Image:	P14_SOLID
SolidLiquid_Opt:	FLUID
Vdef_min:	
Vdef_max:	
ASP_max:	
COL_min:	
qa:	
qb:	
h:	
Element_closure_opt:	
Metadata	

Name	Value
Solver Keyword:	/MAT/B-K-EPS/
ID:	2
Name:	Inlet
Color:	
Include:	[Main Model]
Defined:	
User Comments:	Hide In Menu/Export
Card Image:	M11_BOUND
Regular_OR_encrypted_flag:	Regular
LAW11 Keys:	B-K-EPS
RefRho_Option:	
Rho_Initial:	1.2
ITYP:	0: Gas inlet (state computed fr...
PSH:	
Fscale_T:	
node_IDV:	
Gamma:	1.4
Cd:	
fun_IDRHO:	
funct_IDp:	(2) Inlet_Pt
P0_stagnation:	1.0

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

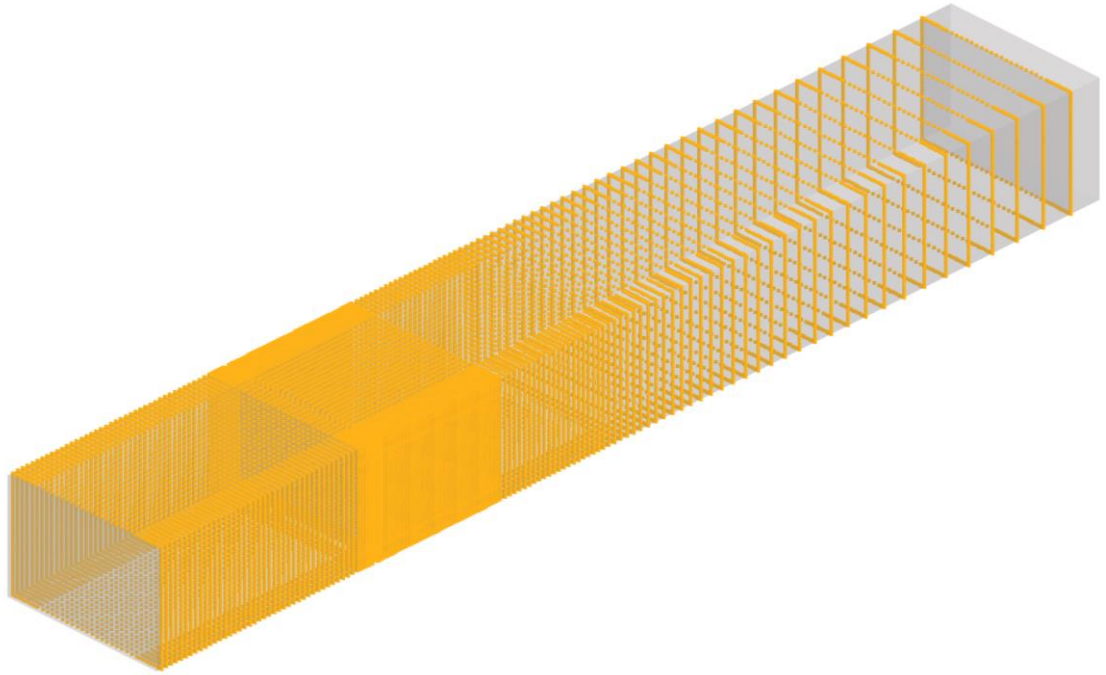
BOUNDARY CONDITIONS

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fixed ALE Domain (/ALE/BCS)

- ALE grid Boundary Conditions
- Fix ALE Domain to keep its shape by keeping outer nodes fixed
- Transform nodes to Lagrangian to interact properly with plate



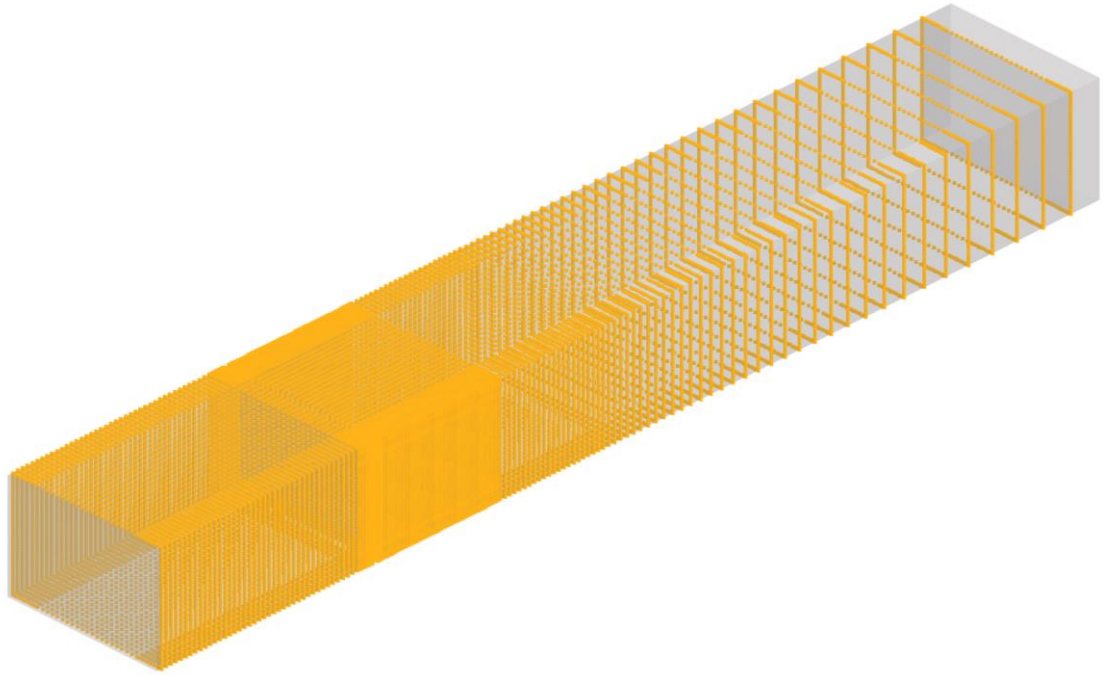
Name	Value
Solver Keyword:	/ALE/BCS
ID:	3
Include:	[Main Model]
Engineering type:	Non Weighted Constraint
Type:	ALE/BCS
grnd_ID:	(2) wall
Title:	Walls
User Comments:	Hide In Menu/Export
DOF1:	☐
DOF2:	☐
DOF3:	☐
DOF4:	☑
DOF5:	☑
DOF6:	☑
skew_ID:	<Unspecified>
Metadata	

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

No-slip Wall (/BCS)

- Same nodes with /ALE/BCS
- Prevent the fluid flow to pass through no-slip wall
- This /BCS refer to fluid DoFs (Degrees of Freedom), while /ALE/BCS refer to mesh nodes DoFs



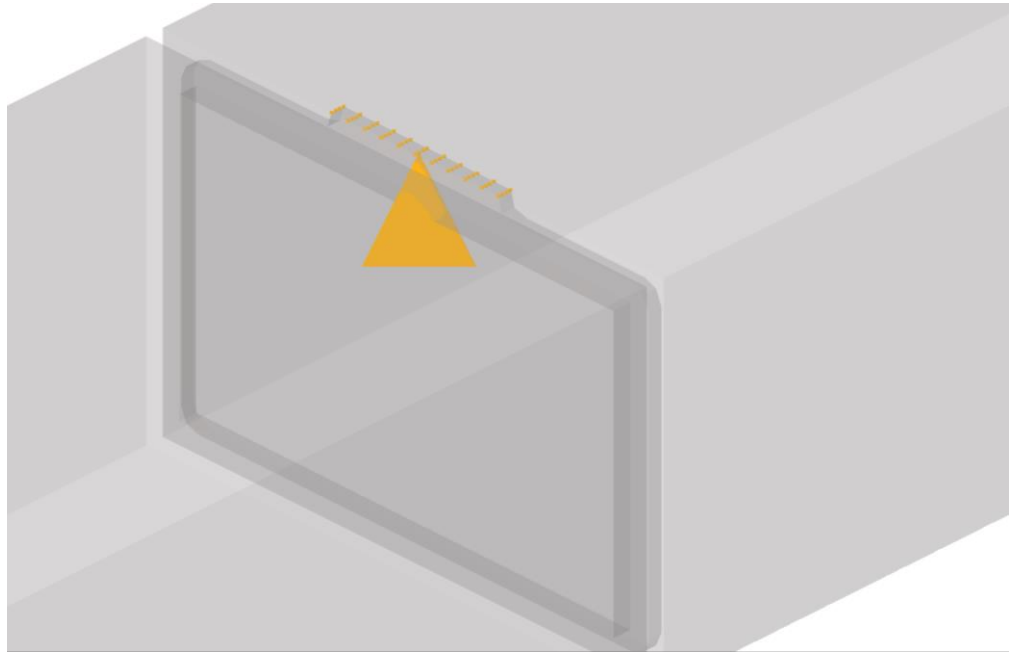
Name	Value
Solver Keyword:	/BCS
ID:	4
Include:	[Main Model]
Engineering type:	Non Weighted Constraint
Type:	BCS
grnd_ID:	(2) wall
Title:	Walls
User Comments:	Hide In Menu/Export
DOF1:	☑
DOF2:	☑
DOF3:	☑
DOF4:	☐
DOF5:	☐
DOF6:	☐
skew_ID:	<Unspecified>
Metadata	

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Fix Plate (/BCS)

- Fix plates top nodes to keep it in place
- Rest of the plate is free to move and deform based on the calculated loads



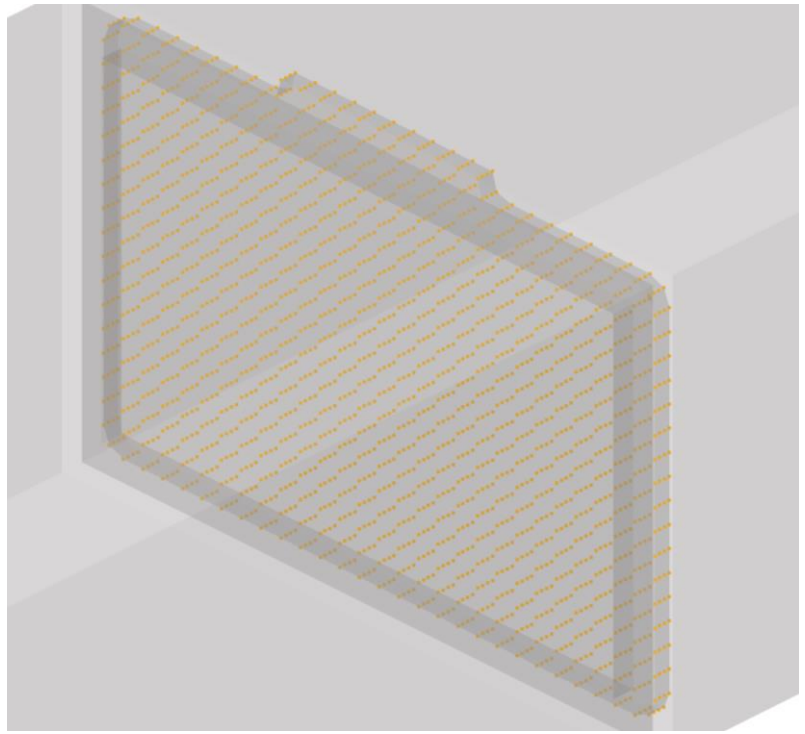
Name	Value
Solver Keyword:	/BCS
ID:	5
Include:	[Main Model]
Engineering type:	Non Weighted Constraint
Type:	BCS
grnd_ID:	(3) set1
Title:	Valve_Fixed
User Comments:	Hide In Menu/Export
DOF1:	☑
DOF2:	☑
DOF3:	☑
DOF4:	☐
DOF5:	☐
DOF6:	☐
skew_ID:	<Unspecified>
Metadata	

ALTAIR

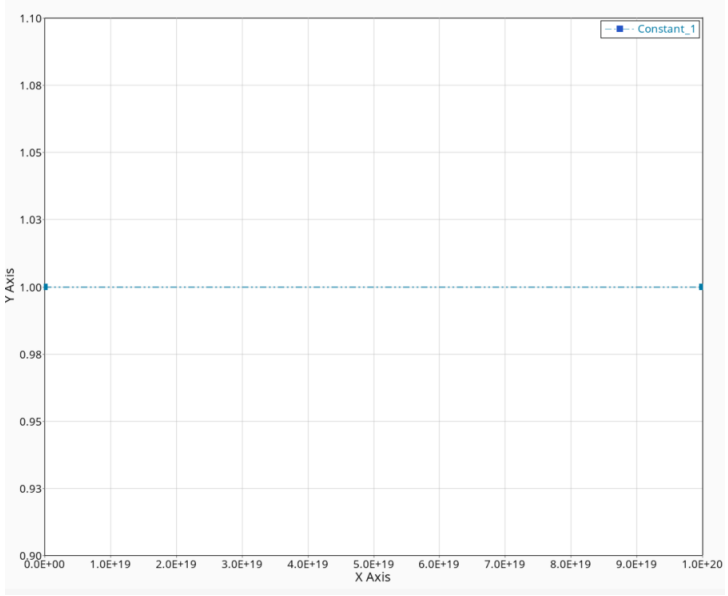
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Gravity (/GRAV)

- Apply Gravity to Valve structure
- Gravity load is crucial for precise simulation of this problem, because this is the load that tends to return structure to its initial position
- Constant function used to showcase constant value of gravity through time



Name	Value
Solver Keyword:	/GRAV
ID:	1
Include:	[Main Model]
Engineering type:	Directional Acceleration
Type:	GRAV
grnd_ID:	(7) set5
Title:	Gravity
User Comments:	Hide In Menu/Export
fct_ID(T):	(1) Constant_1
Dir:	Y
skew_ID:	<Unspecified>
sens_ID:	<Unspecified>
Ascale(X):	
Fscale(Y):	-9.81
Metadata	



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

INTERFACE

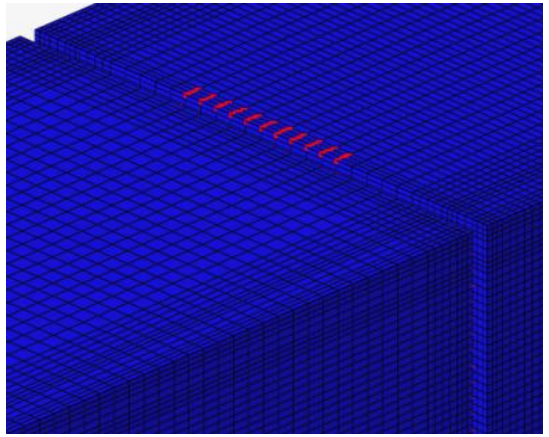
ALTAIR

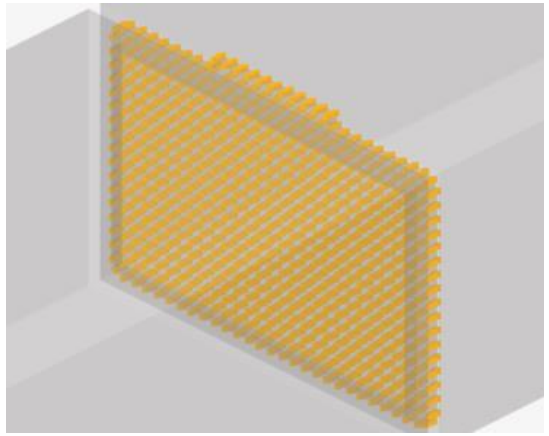
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

Valve – Wall Interface (/INTER/TYPE7)

- Interface between wall and flexible flap
- Not sure that contact exists, but if potentially happen can introduce energy errors and even corruption of the solution
- /INTER/TYPE7 models the non-linear contact force
- SURF_ID = fluid component outer external surfaces
- GRNOD_ID = nodes of flexible flap

Name	Value
Solver Keyword:	/INTER/TYPE7/
ID:	1
Name:	Contact_Valve_Walls
Color:	
Include:	[Main Model]
User Comments:	Hide In Menu/Export
Card Image:	TYPE7
Grnod_id (S):	(10) set8
Surf_id (M):	(11) set9
Istf:	3: Stfac is a stiffness scale factor and the i...
Ithe:	
Igap:	1000: Constant gap, equal to the minimum ...
Ibag:	
Idel:	
Icurv:	
Iadm:	0: Not activated (default)
Fpenmax:	
Stmin:	
Stmax:	
dtmin:	
Irem_gap:	
Irem_i2:	
Stfac:	
Fric:	
Gapmin:	2e-05





ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

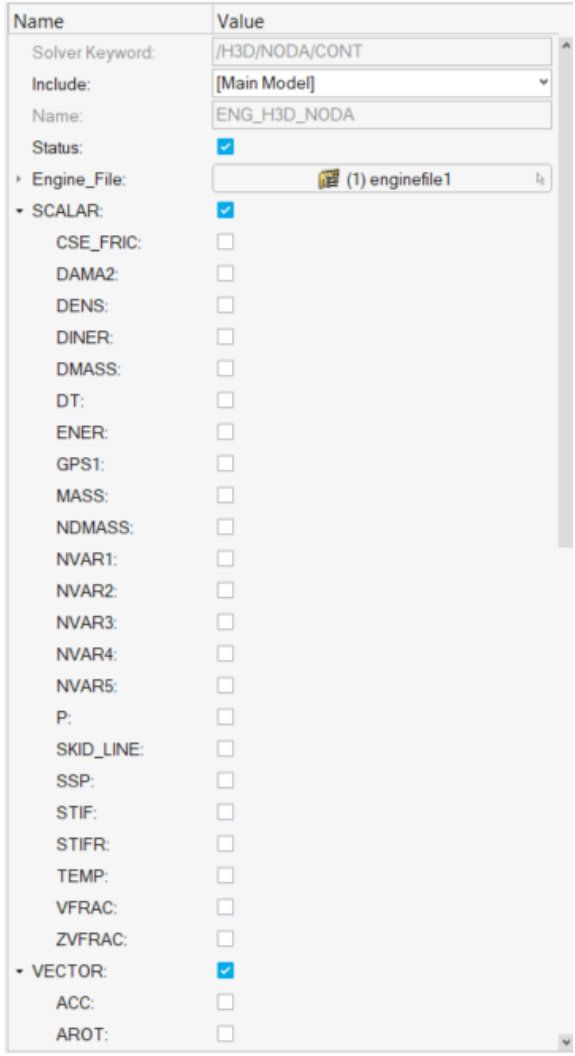
OUTPUT REQUIREMENTS

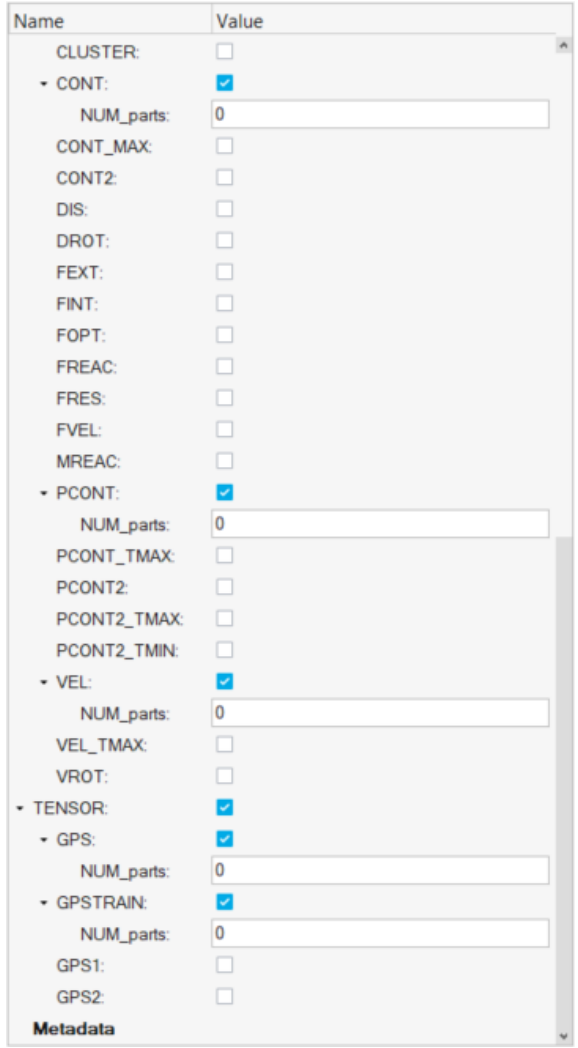
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

OUTPUT REQUIREMENTS - SOLID

- /H3D/NODA/CONT
  - Node Contact Forces
- /H3D/NODA/PCONT
  - Normal/Tangential Contact Force
- /H3D/NODA/GPS
  - Mean Nodal Stress Tensor
- /H3D/NODA/GPSTRAIN
  - Mean Nodal Strain Tensor



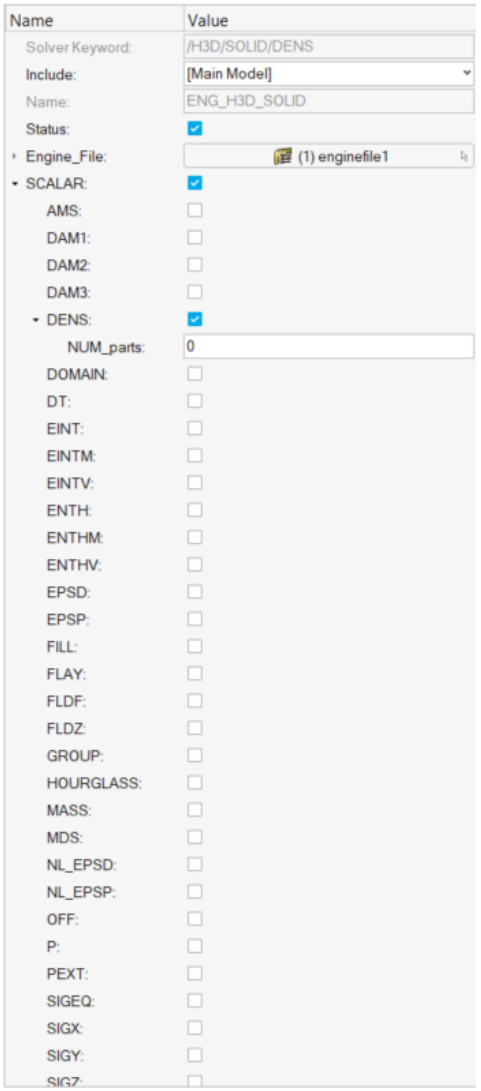


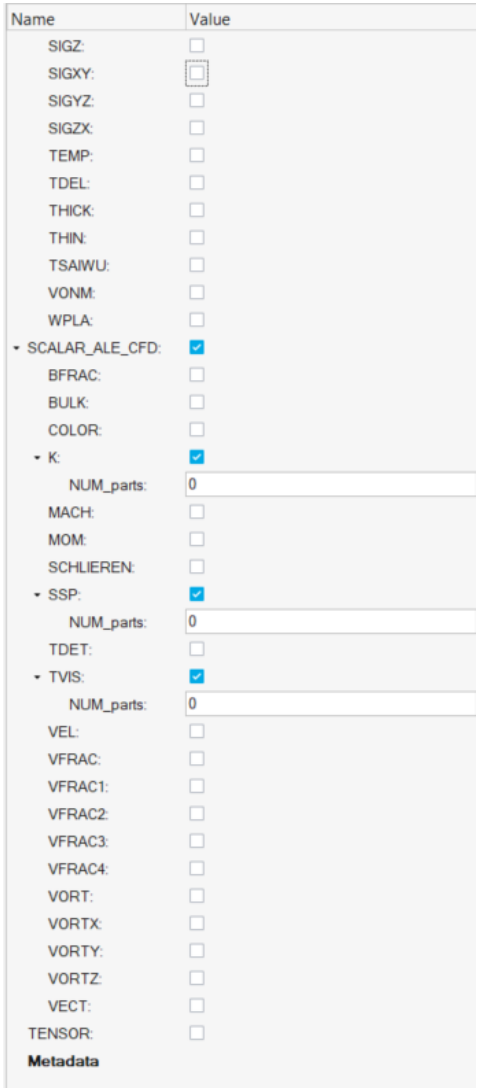
ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

OUTPUT REQUIREMENTS - FLUID

- /H3D/NODA/VEL
  - Node Translational Velocity
- /H3D/SOLID/DENS
  - Element Density
- /H3D/SOLID/K
  - Turbulent Density
- /H3D/SOLID/SSP
  - Speed of Sound
- /H3D/SOLID/TVES
  - Turbulent Viscosity





ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

SIMULATION RESULTS

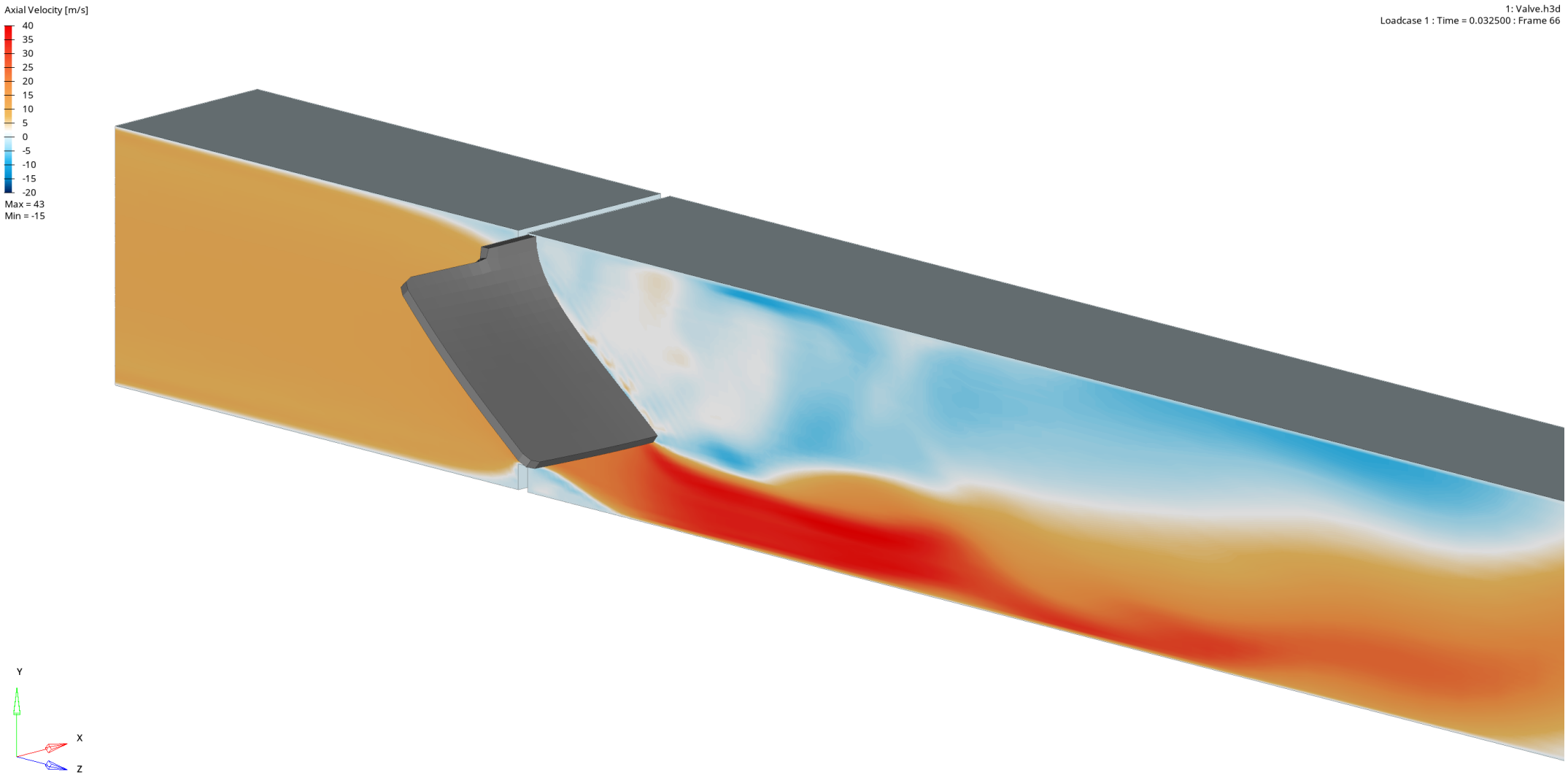
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

IMPOSED VELOCITY INLET

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

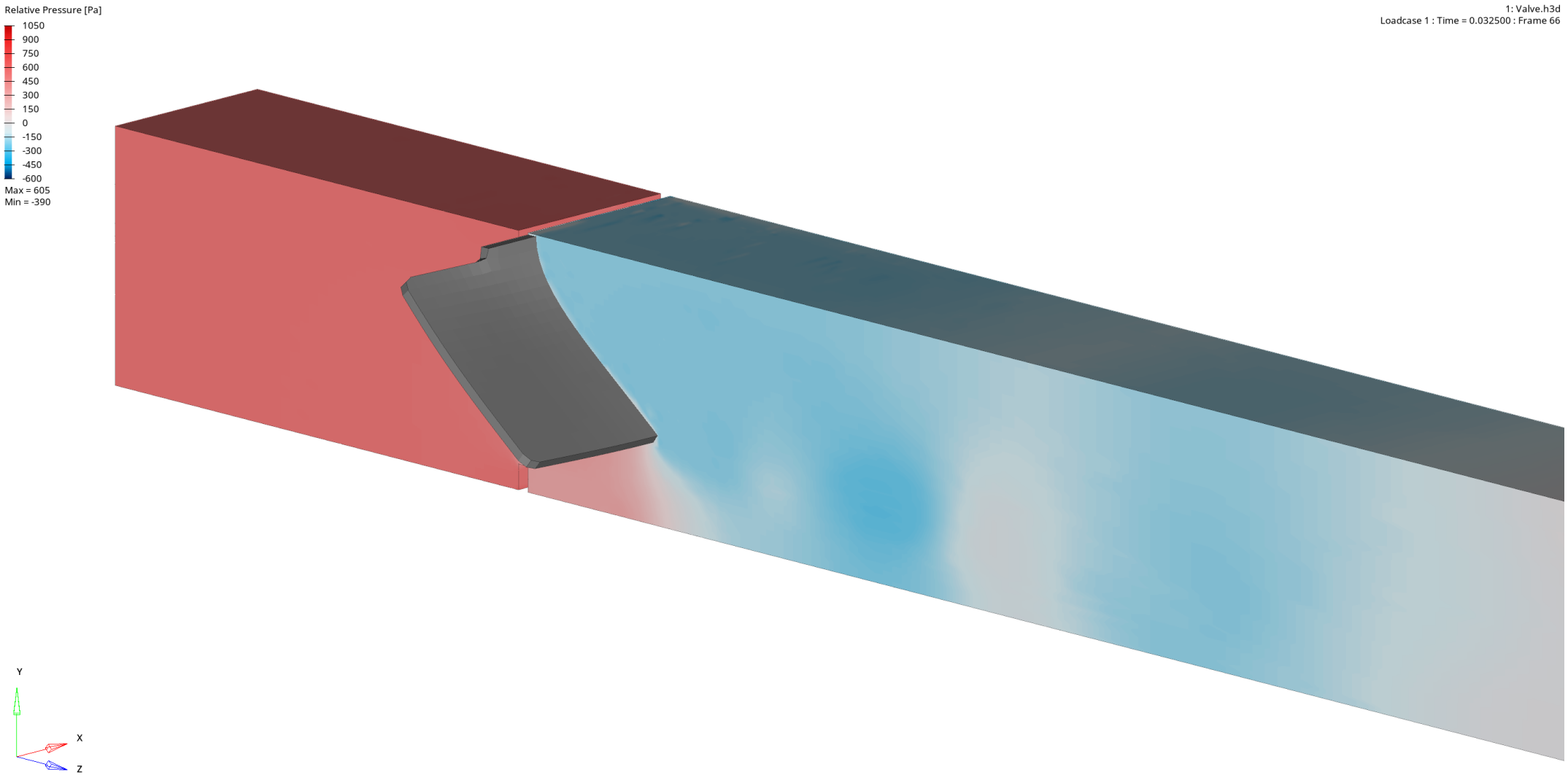
AXIAL VELOCITY



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

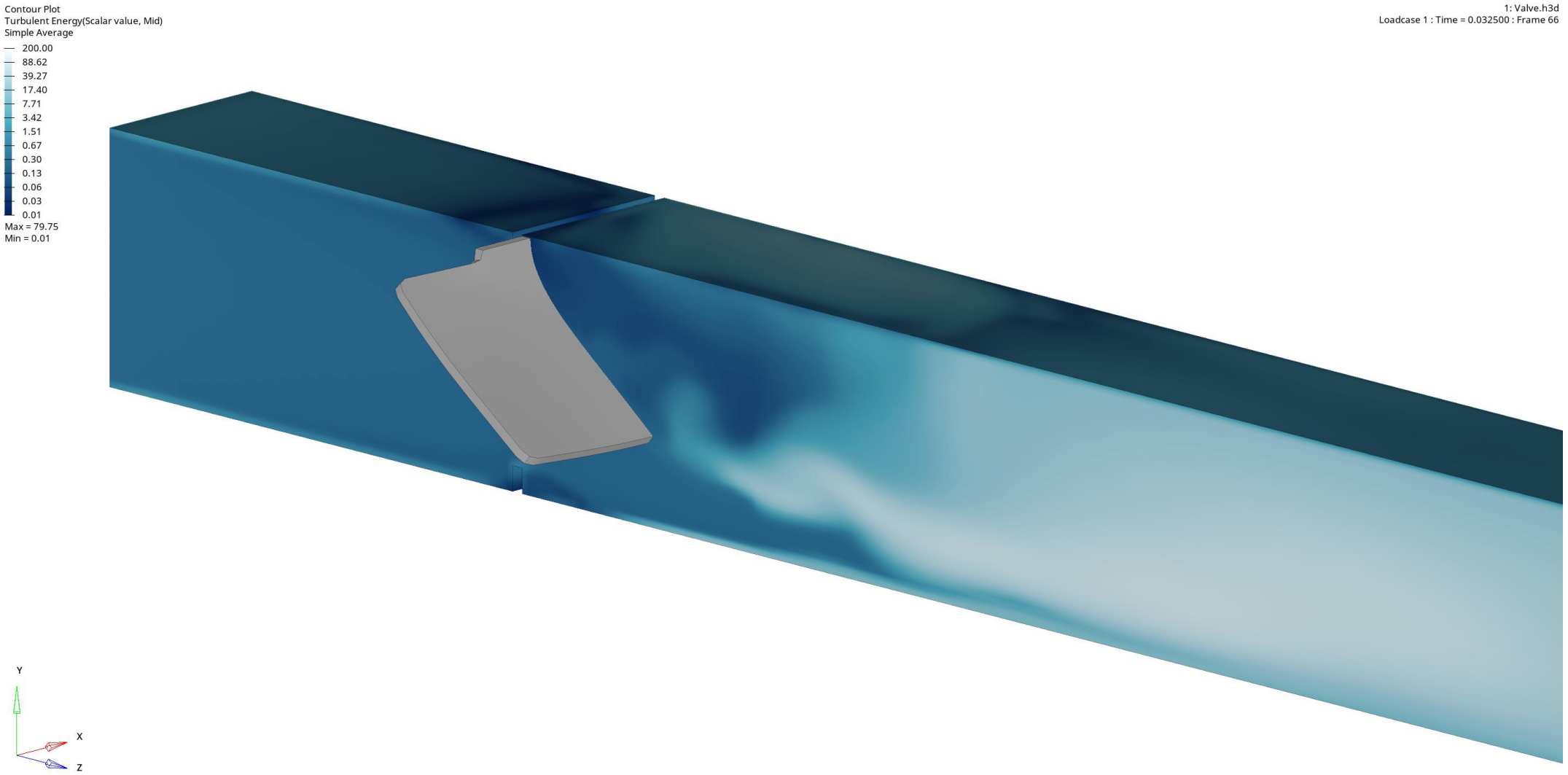
RELATIVE PRESSURE



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

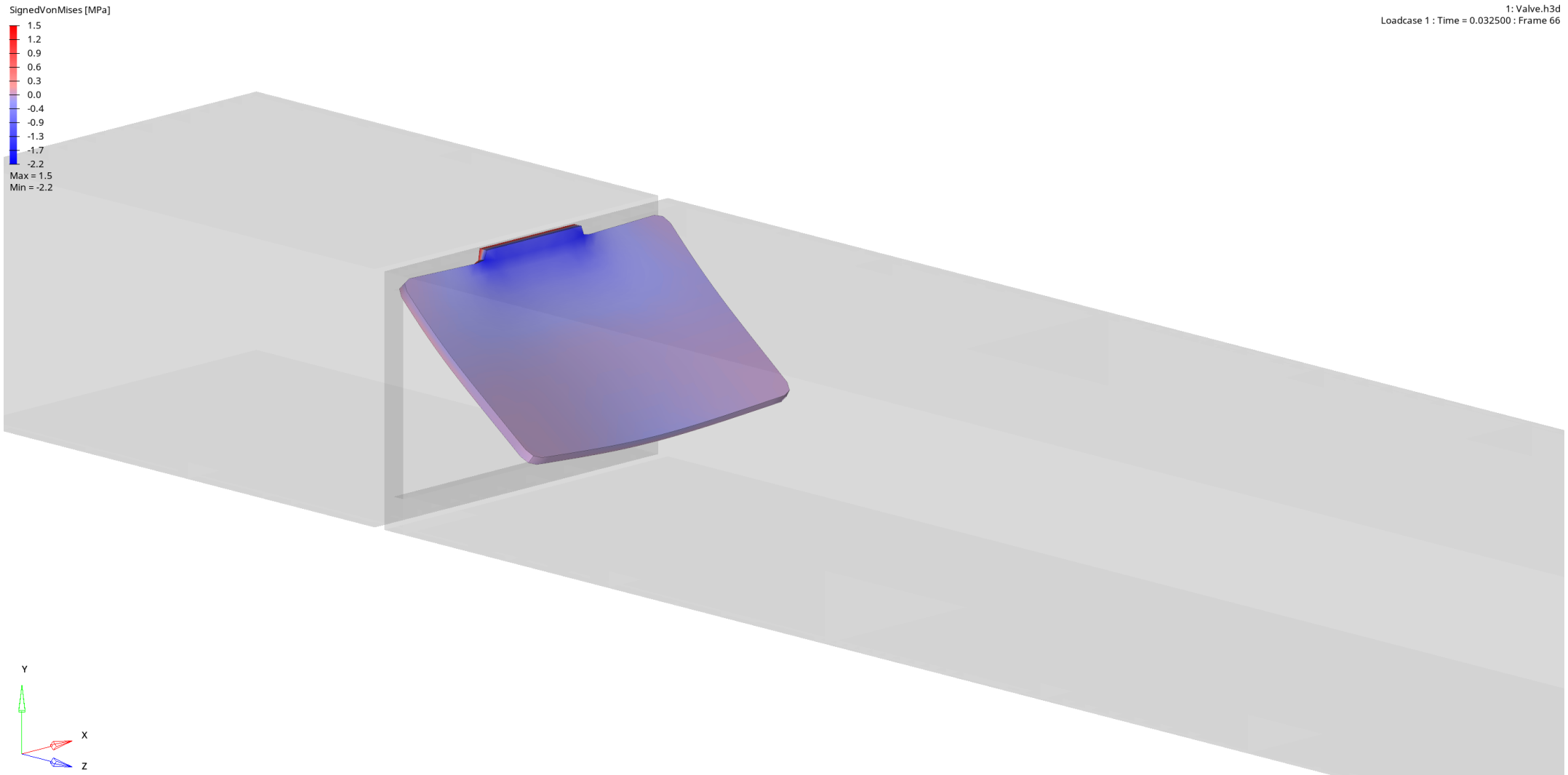
TURBULENT ENERGY



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

VON MISES STRESS



ALTAIR

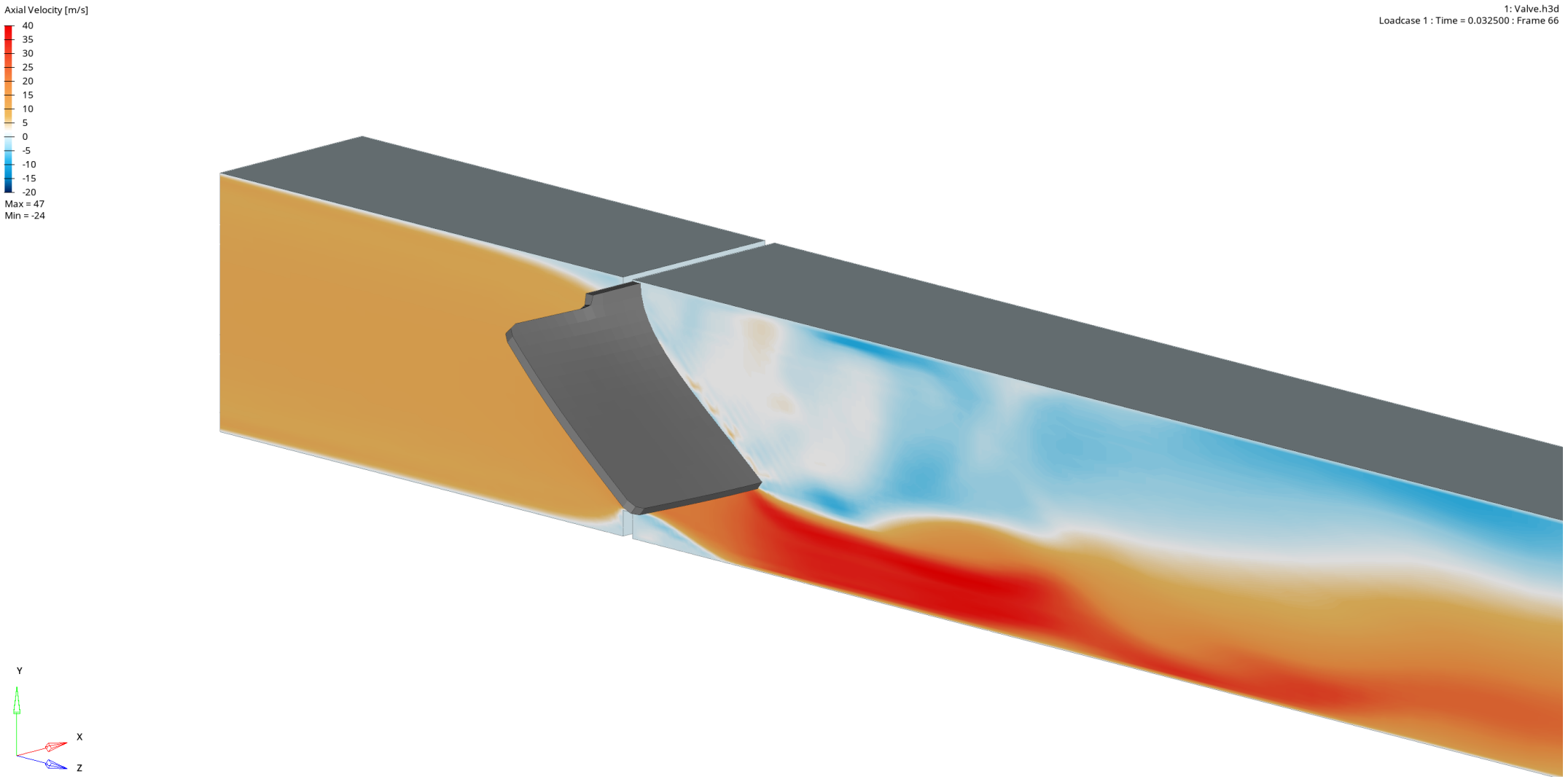
© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

IMPOSED PRESSURE INLET

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

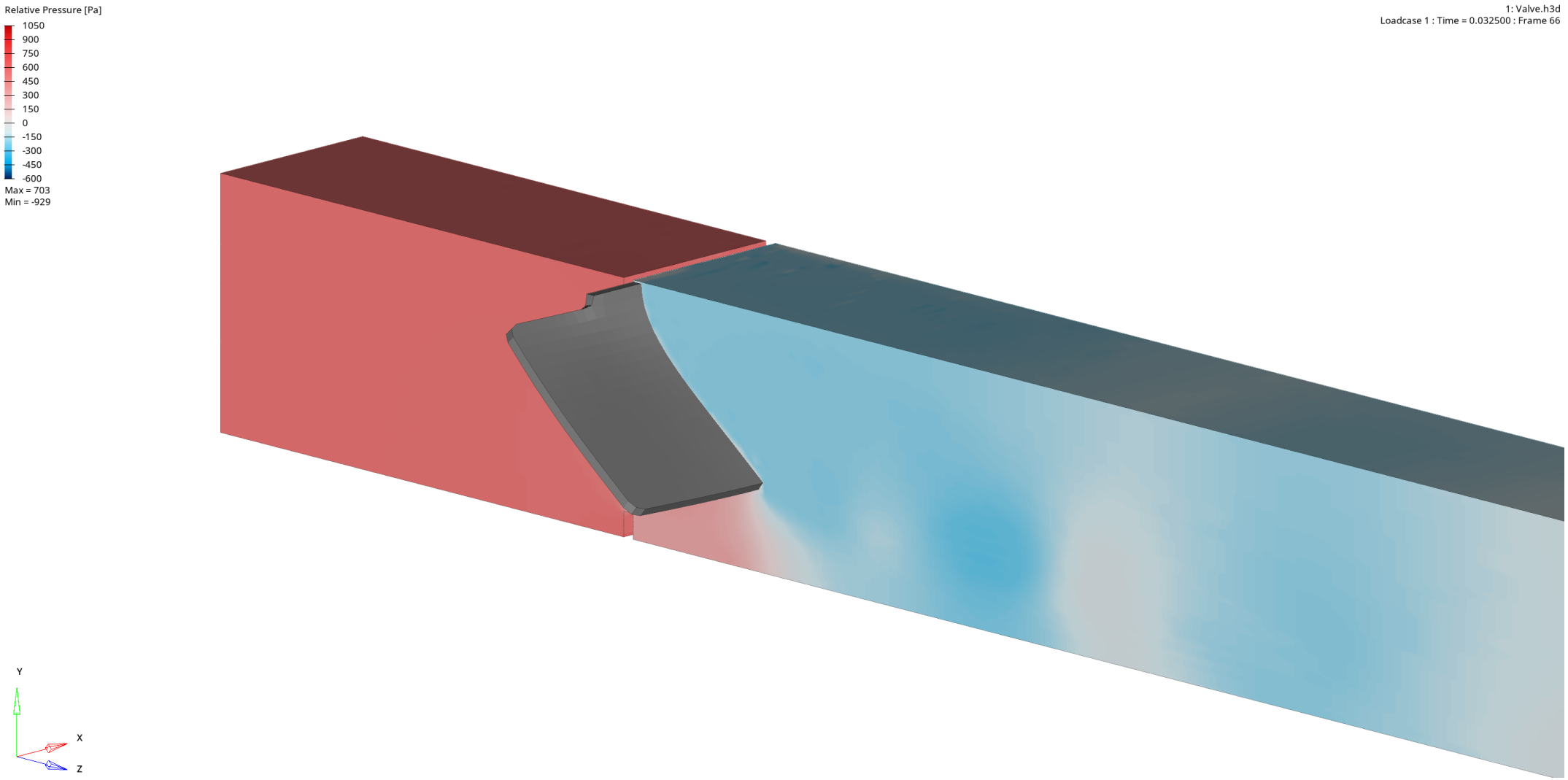
AXIAL VELOCITY



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

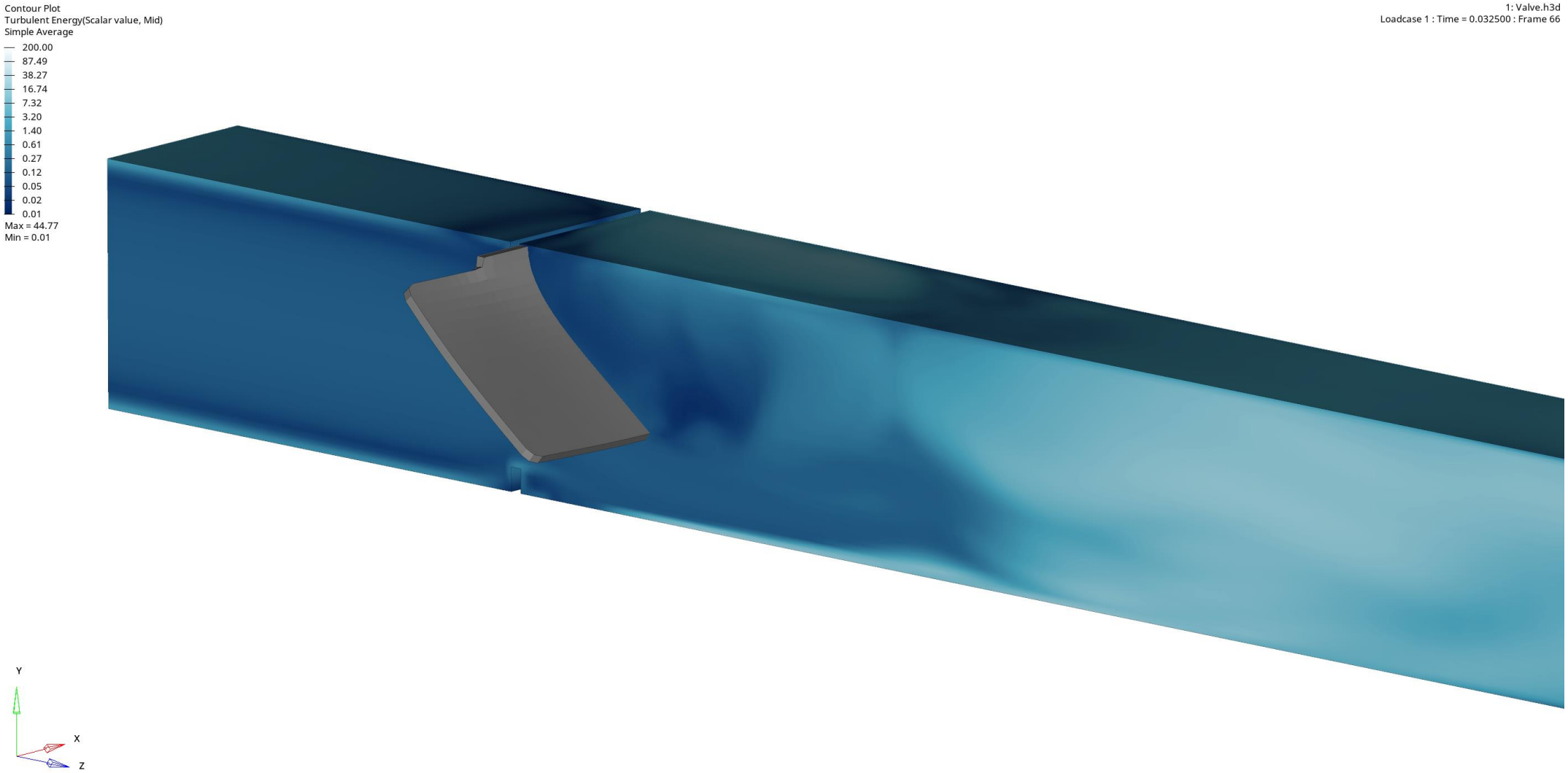
RELATIVE PRESSURE



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

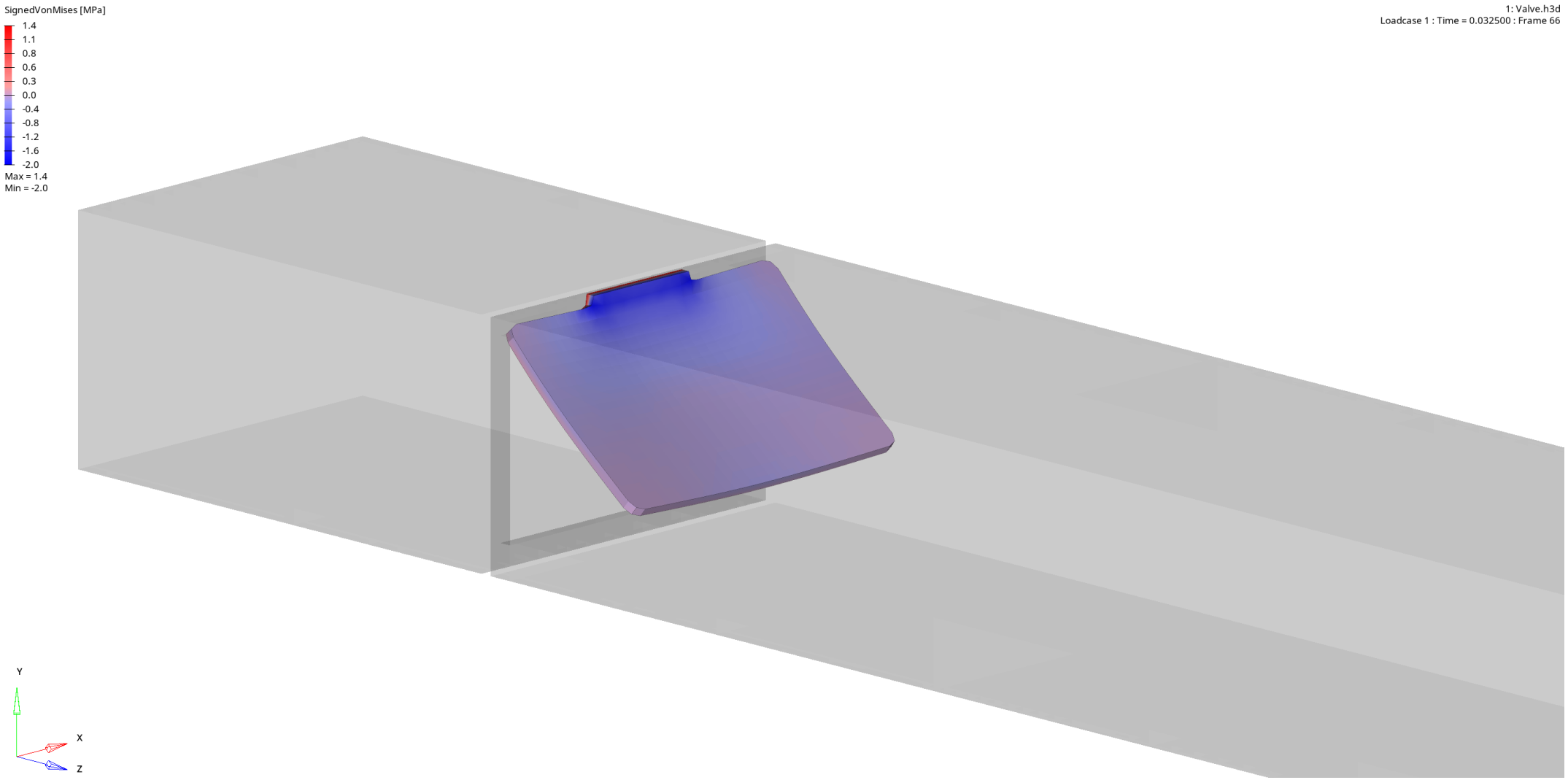
TURBULENT ENERGY



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

VON MISES STRESS



ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

CONCLUSION

ALTAIR

© Altair Engineering, Inc. Proprietary and Confidential. All rights reserved.

CONCLUSION

- Altair® Radioss® can be used to simulate the operation of a valve with both imposed velocity and imposed pressure inlets
- Altair® Radioss® can be used to simulate turbulent flow with the use of /MAT/K-EPS
- Coupled Euler-Lagrange (CEL) Method can be used to produce accurate results with low number of elements and low simulation time
  - RADIOSS 2023.1
  - 3h 50min on 12 cores 13th gen Intel® Core™ i7-13850HX @ 2.53 GHz (x86_64)
- Different output requests (/H3D Keywords) can be used to calculate not only Fluid Pressure, Density and Velocity, but also Turbulent Energy and Viscosity

THANK YOU

altair.com

#ONLYFORWARD

ALTAIR