SPH Capabilities in LS-DYNA

Laura Rovira Crespo, Arup

Wednesday, 10 July 2019

SPH and Industry Event

Outline

Arup – LS-DYNA

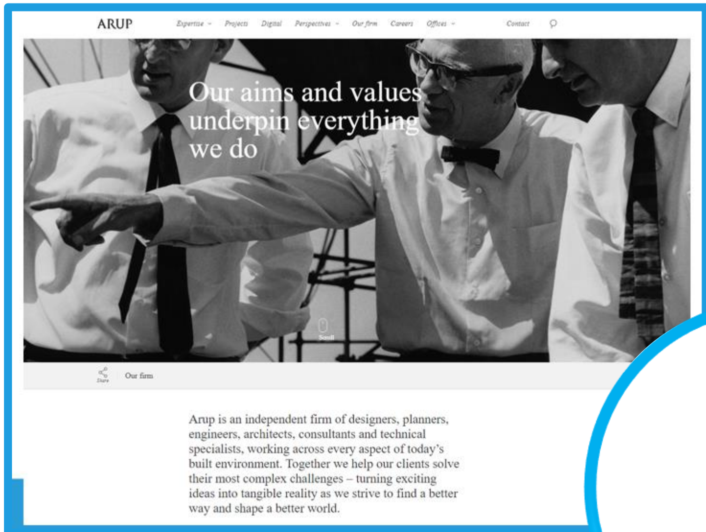
LS-DYNA

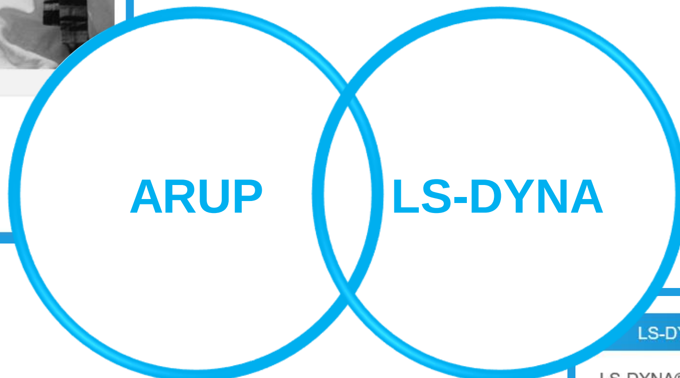
- Capabilities
- Applications

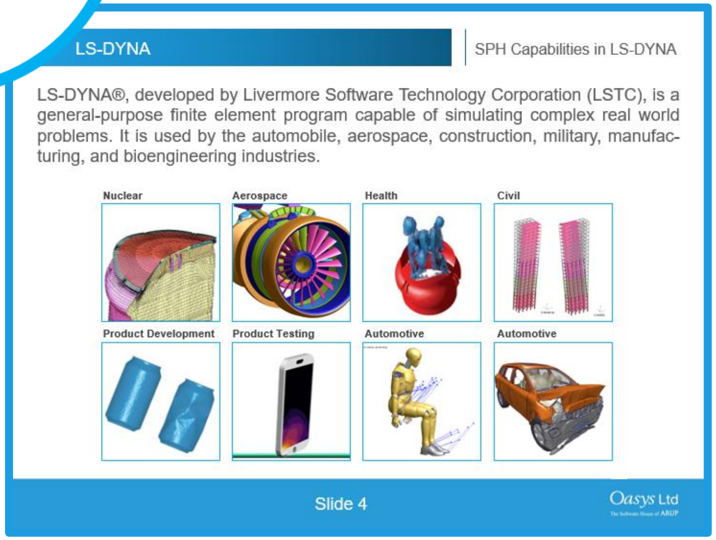
SPH in LS-DYNA

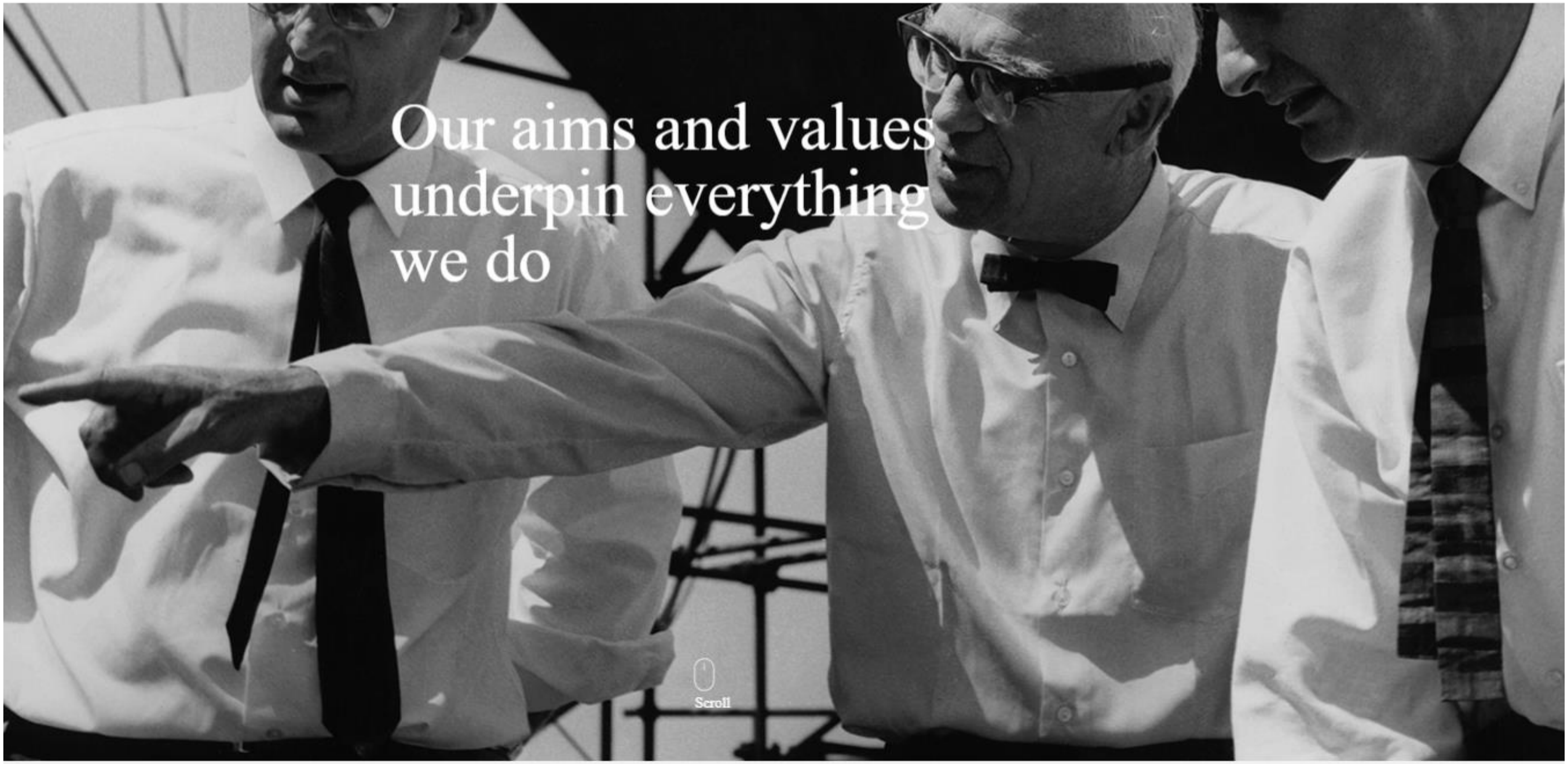
- Capabilities
- Applications

Arup – LS-DYNA


ARUP
Our aims and values underpin everything we do
Our firm
Arup is an independent firm of designers, planners, engineers, architects, consultants and technical specialists, working across every aspect of today's built environment. Together we help our clients solve their most complex challenges – turning exciting ideas into tangible reality as we strive to find a better way and shape a better world.


ARUP
LS-DYNA


LS-DYNA
SPH Capabilities in LS-DYNA
LS-DYNA®, developed by Livermore Software Technology Corporation (LSTC), is a general-purpose finite element program capable of simulating complex real world problems. It is used by the automobile, aerospace, construction, military, manufacturing, and bioengineering industries.
Nuclear
Aerospace
Health
Civil
Product Development
Product Testing
Automotive
Automotive
Slide 4
Oasys Ltd



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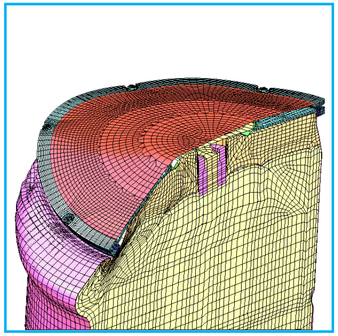
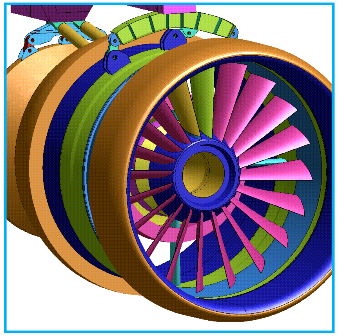
Nuclear

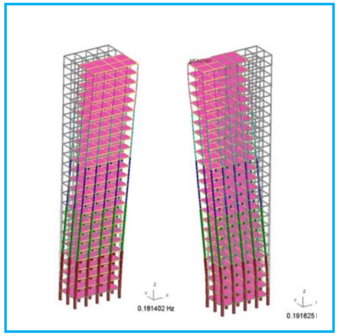


Aerospace



Health

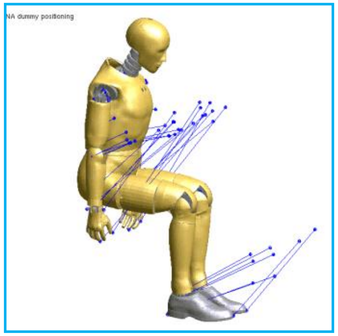
Civil



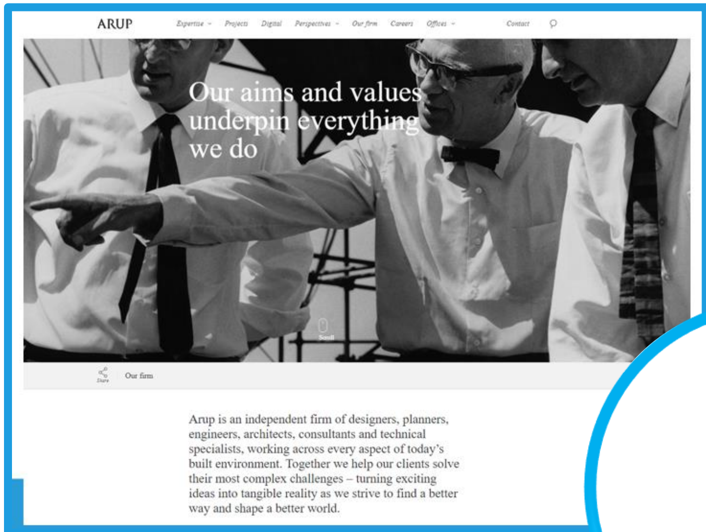
Product Development

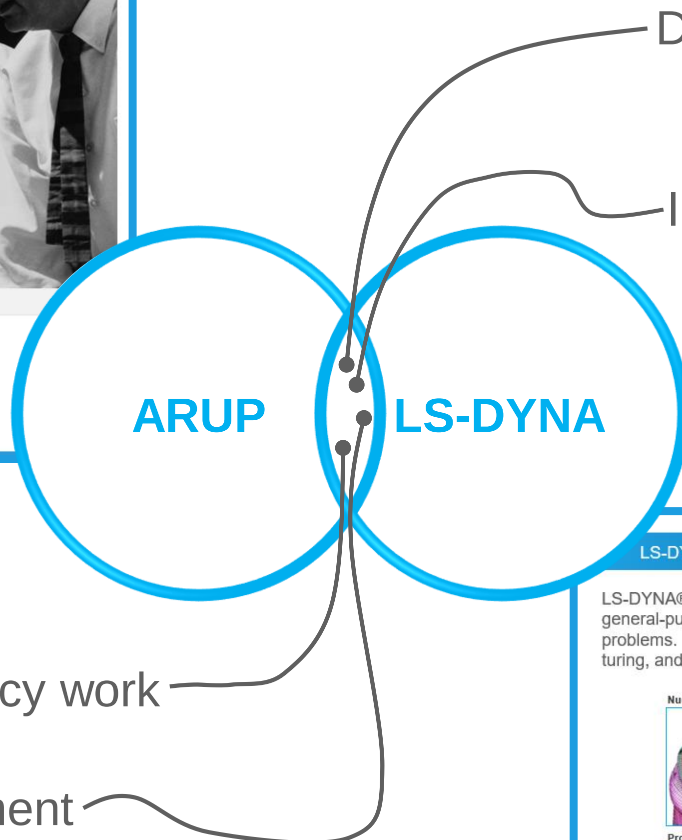
Product Testing

Automotive

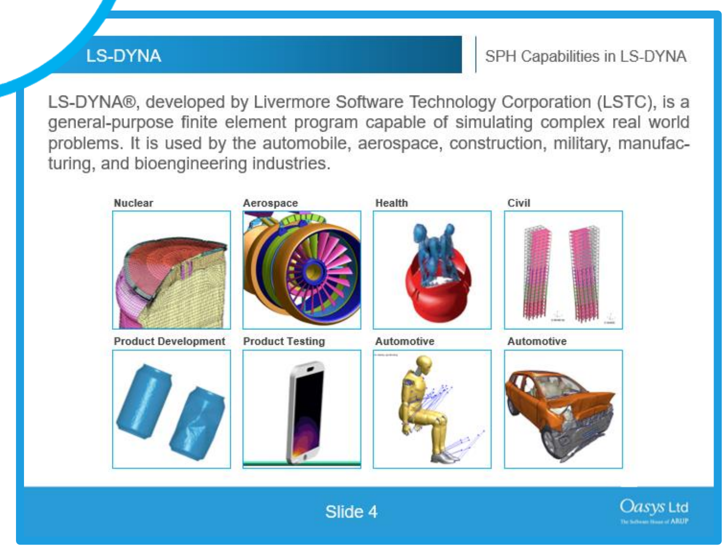


Automotive





Oasys PRIMER | Oasys SHELL | Oasys D3PLOT | Oasys T/HIS | Oasys REPORTER


LS-DYNA

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Slide 4

Oasys Ltd

The code's origins lie in highly **nonlinear**, **transient dynamic** finite element analysis using explicit time integration.

"Nonlinear" means at least one (and sometimes all) of the following complications:

- Changing boundary conditions
- Large deformations
- Nonlinear materials that do not exhibit ideally elastic behaviour

"Transient dynamic" means analysing high speed, short duration events where inertial forces are important. Typical uses include:

- Automotive crash
- Explosions
- Manufacturing.

LS-DYNA® is a multi-purpose explicit and implicit **finite element and multiphysics solver** used to analyse the **nonlinear (and linear) response of structures.**

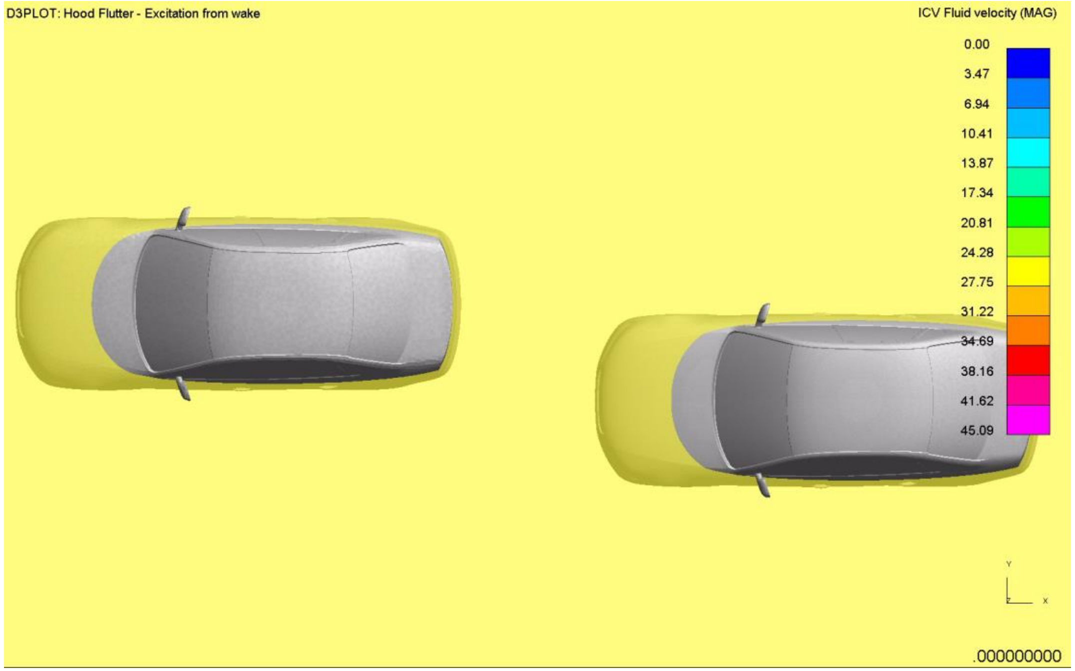
LS-DYNA's analysis capabilities include:

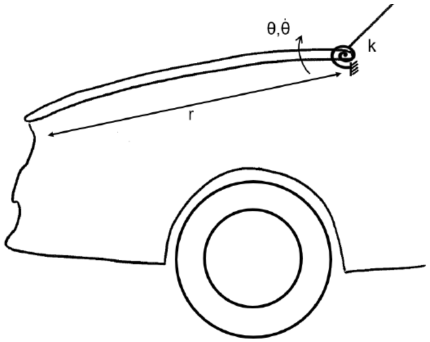
- Full 2D & 3D capabilities
- Nonlinear dynamics
- Linear statics
- Rigid body dynamics
- Quasi-static simulations
- Normal modes
- Thermal analysis
- Eulerian capabilities
- ALE (Arbitrary Lagrangian-Eulerian)
- Fluid analysis
- FSI
- Navier-Stokes fluids
- Compressible fluid solver, CESE
- FEM-rigid multi-body dynamics coupling
- Underwater shock
- Failure analysis
- Crack propagation
- Real-time acoustics
- Implicit springback
- Multi-physics coupling
- Structural-thermal coupling
- Adaptive remeshing
- SPH
- EFG
- Radiation transport
- EM (Electromagnetism)

In a given simulation, any of LS-DYNA's many features can be combined to model a wide range of physical events.

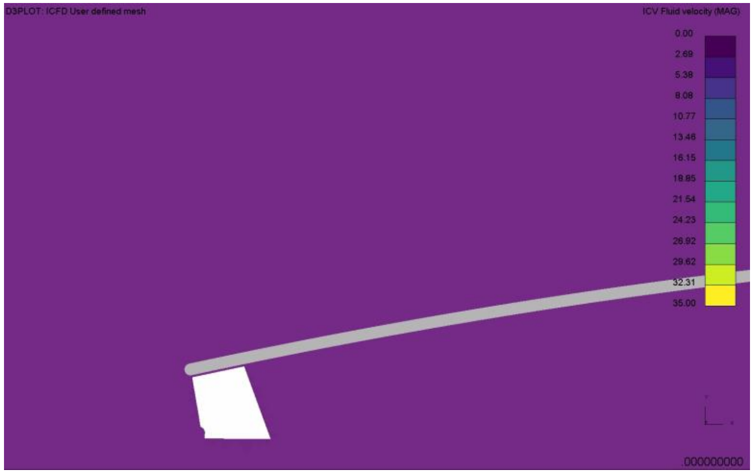
LS-DYNA's potential applications are numerous and can be tailored to many fields.

CFD Solver - Time-varying loads from wake of preceding vehicle





FSI – Hood Flutter Analysis



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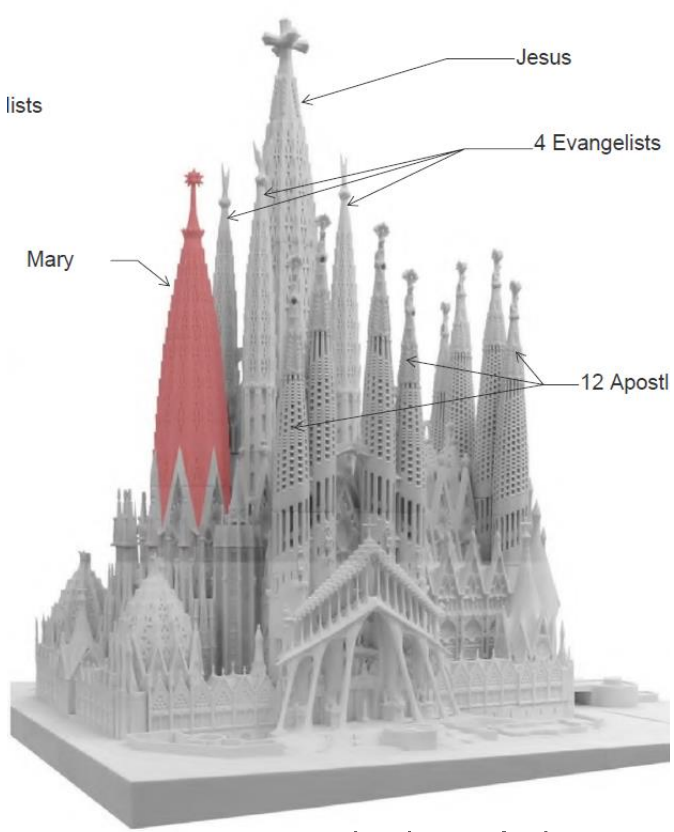

FEA, Seismic Analysis – La Sagrada Familia, Mary Tower

In a given simulation, any of LS-DYNA's many features can be combined to model a wide range of physical events.

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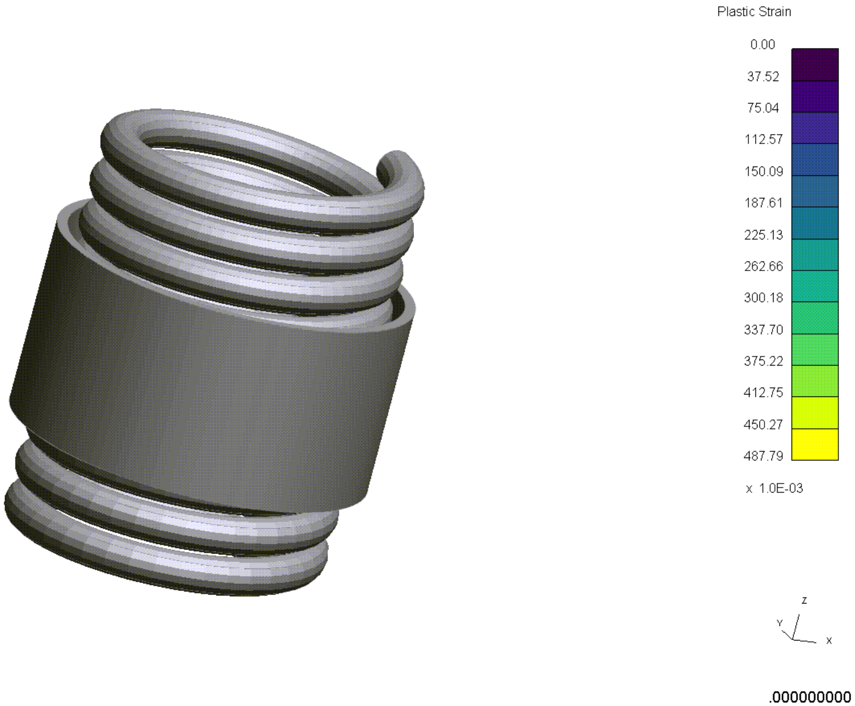

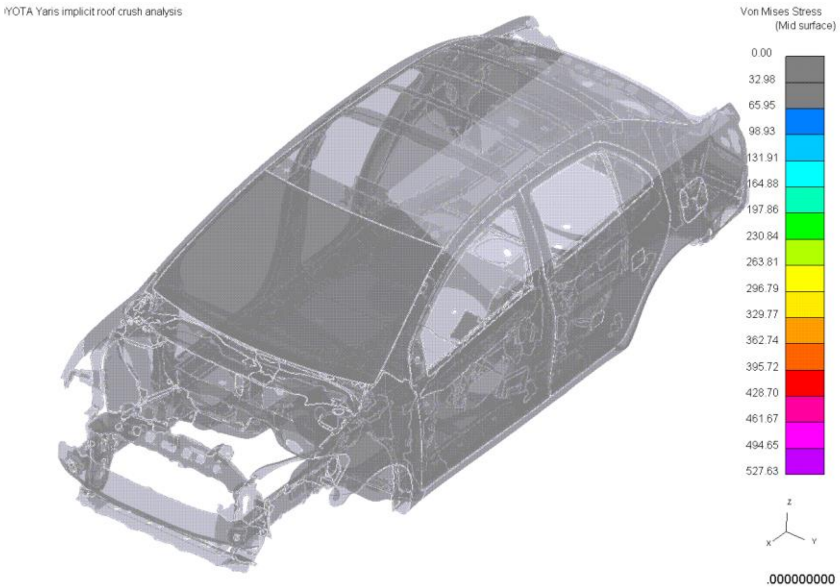

EM – Tube Expansion due to induced currents

FEA, Implicit – Roof Crush

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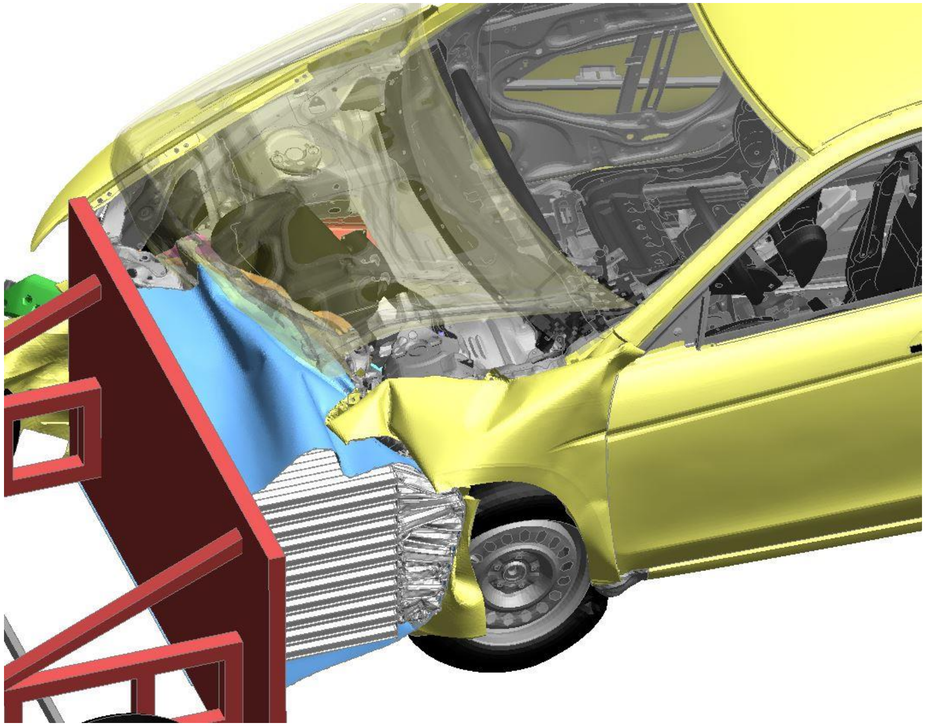
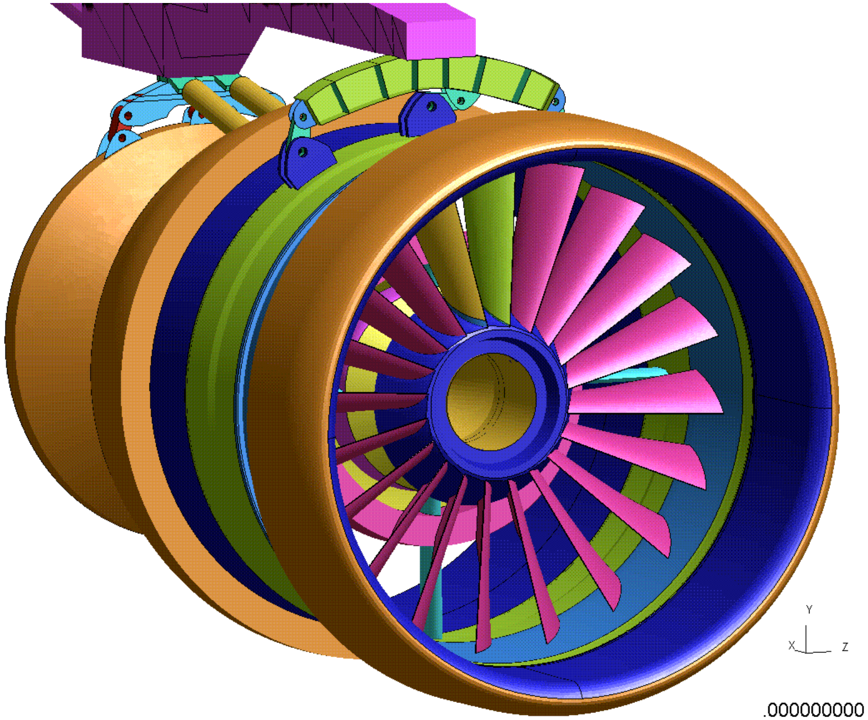


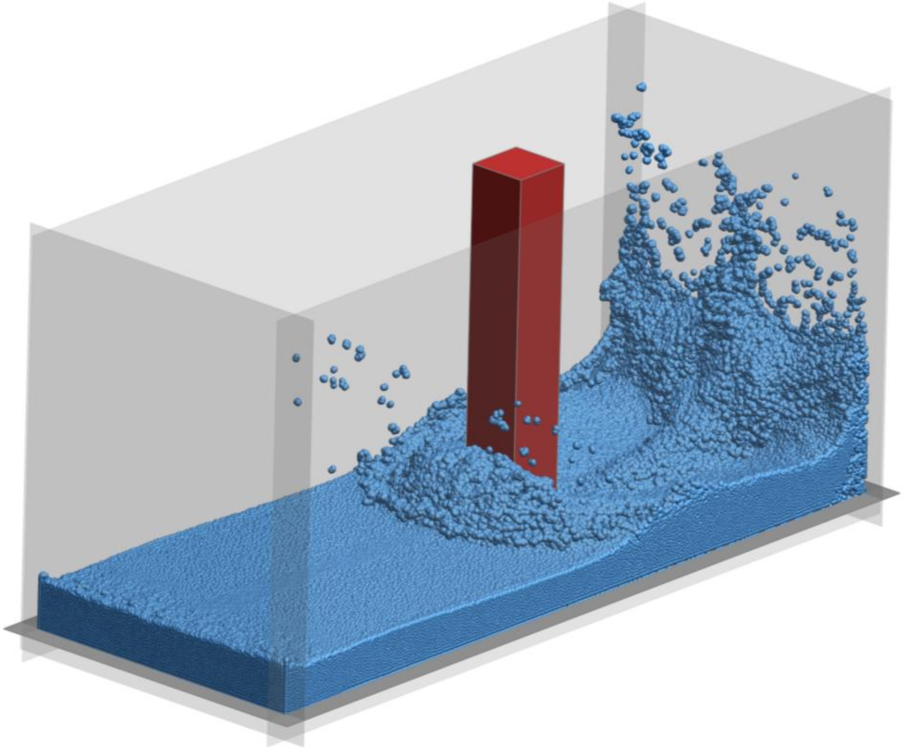
FEA, Crashworthiness – EuroNCAP testing



FEA, Impact Analysis – Fan Blade Off

The SPH module in LS-DYNA is integrated with the full range of LS-DYNA's powerful analysis tools.

This enables you to understand and explore the reaction of the structure as well as the flow within one code and one analysis.



SPH definition follows same structure as any other feature in LS-DYNA:

***ELEMENT_SPH** ***ELEMENT**

ELEMENT_SPH_*{OPTION}

Card	1	2	3	4	5	6	7	8	9	10
Variable	NID	PID	MASS							
Type	I	I	F							
Default	none	none	0.							
Remarks			1							

VARIABLE	DESCRIPTION
NID	Node ID and Element ID are the same for the SPH option.
PID	Part ID to which this node (element) belongs.
MASS	GT.0: Mass value LT.0: Volume. The absolute value will be used as volume. The density ρ will be retrieved from the material card defined in PID. SPH element mass is calculated by $\lvert MASS \rvert \times \rho$.

***SECTION** ***SECTION_SPH**

SECTION_SPH_*{OPTION}

Card 1	1	2	3	4	5	6	7	8
Variable	SECID	CSLH	HMIN	HMAX	SPHINI	DEATH	START	SPHKERN
Type	I/A	F	F	F	F	F	F	I
Default	none	1.2	0.2	2.0	0.0	1.e20	0.0	0

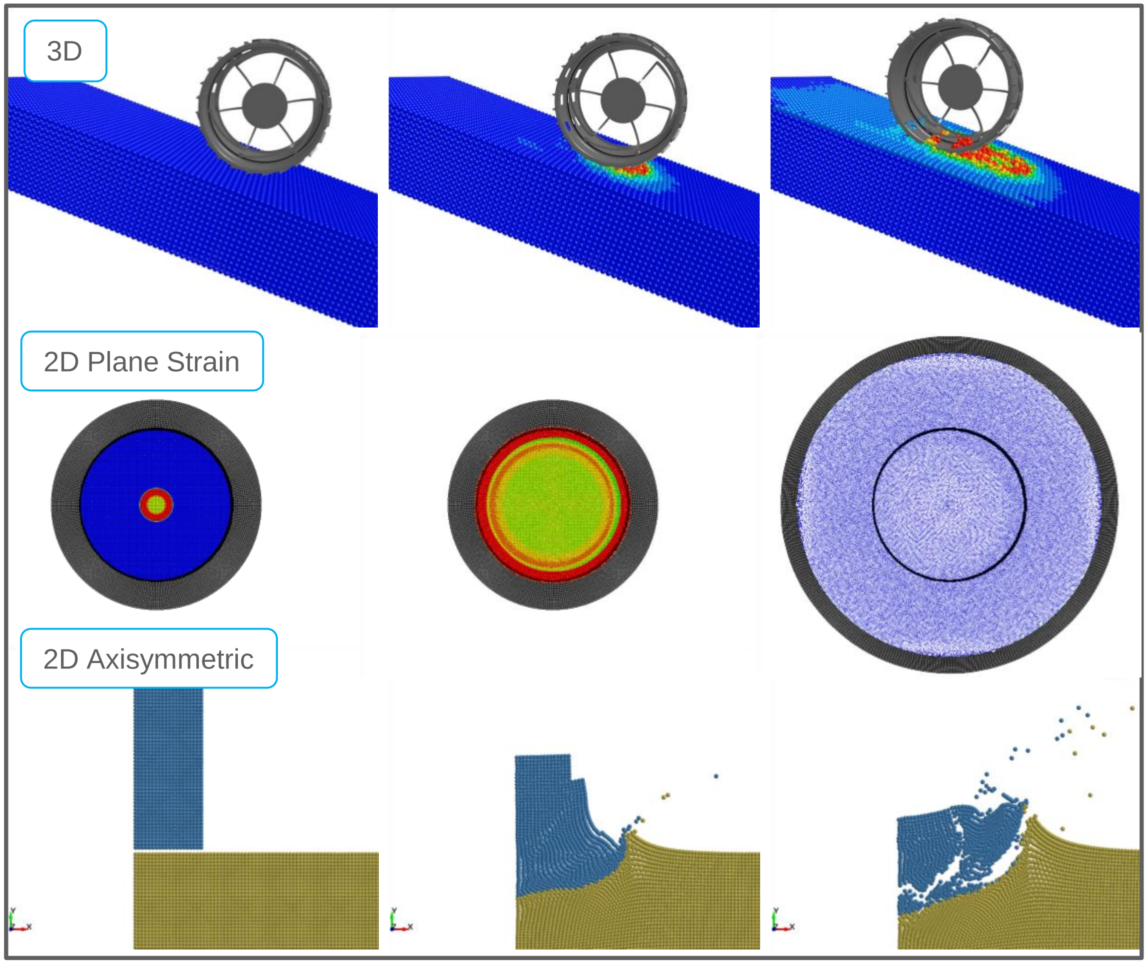
VARIABLE	DESCRIPTION
SECID	Section ID. SECID is referenced on the *PART card. A unique number or label must be specified.
CSLH	Constant used to calculate the initial smoothing length of the particles. The default value works for most problems. Values between 1.05 and 1.3 are acceptable. Taking a value less than 1 is inadmissible. Values larger than 1.3 will increase the computational time. The default value is recommended. See Remark 1.
HMIN	Scale factor for the minimum smoothing length. See Remark 1.
HMAX	Scale factor for the maximum smoothing length. See Remark 1.
SPHINI	Optional initial smoothing length (overrides true smoothing length). With this option LS-DYNA will not calculate the smoothing length during initialization, and the field CSLH is ignored.
DEATH	Time imposed SPH approximation is stopped.
START	Time imposed SPH approximation is activated.
SPHKERN	Option for SPH kernel functions (smoothing functions): EQ.0: Cubic spline kernel function (default). EQ.1: Quintic spline kernel function: higher order smoothing function with bigger support size (recommend to use HMAX = 3.0 or bigger value, only available for FORM = 0, 1, 9 and 10).

Define mass or volume of the particle

Parameters to stablish smoothing length

LS-DYNA SPH Capabilities

SPH is implemented in 3D, 2D plane strain and 2D axisymmetric formulations.



SPH Capabilities in LS-DYNA

***CONTROL** ***CONTROL_SPH**

***CONTROL_SPH**

Purpose: Provide controls relating to SPH (Smooth Particle Hydrodynamics).

Card 1	1	2	3	4	5	6	7	8
Variable	NCBS	BOXID	DT	IDIM	MEMORY	FORM	START	MAXV
Type	I	I	F	I	I	I	F	F
Default	1	0	10^{20}	none	150	0	0.0	10^{15}

VARIABLE	DESCRIPTION
NCBS	Number of time steps between particle sorting.
BOXID	SPH approximations are computed inside a specified BOX. When a particle has gone outside the BOX, it is deactivated. This will save computational time by eliminating particles that no longer interact with the structure.
DT	Death time. Determines when the SPH calculations are stopped.
IDIM	Space dimension for SPH particles: EQ.3: for 3D problems EQ.2: for 2D plane strain problems EQ.-2: for 2D axisymmetric problems (see Remark 2)
MEMORY	Defines the initial number of neighbors per particle (see Remark 1 below).
FORM	Particle approximation theory (Remark 2): EQ.0: default formulation EQ.1: renormalization approximation EQ.2: symmetric formulation EQ.3: symmetric renormalized approximation EQ.4: tensor formulation EQ.5: fluid particle approximation EQ.6: fluid particle with renormalization approximation EQ.7: total Lagrangian formulation EQ.8: total Lagrangian formulation with renormalization EQ.9: adaptive SPH formulation (ASPH) with anisotropic smoothing tensor (Remark 2, (g)) EQ.10: renormalization approximation for adaptive SPH formulation (ASPH) with anisotropic smoothing tensor EQ.12: moving least-squares based formulation (Remark 2, (e)) EQ.15: enhanced fluid formulation EQ.16: enhanced fluid formulation with renormalization
START	Start time for particle approximation. Particle approximations will be computed when time of the analysis has reached the value defined in START.
MAXV	Maximum value for velocity for the SPH particles. Particles with a velocity greater than MAXV are deactivated. A negative MAXV will turn off the velocity checking.

LS-DYNA SPH Capabilities

Many **different particle approximation theories** available, to pick depending on the application:

- For most solid structure applications, FORM=1 is recommended (more accurate results around BC).
- For fluid material applications, use FORM=15/16 is. These include a smoothing of the pressure field and are not recommended for materials with failure or with important strain localizations.
- For large or extremely large deformation applications, FORM=0-6,15 and 16 (Eulerian kernel) can be used.
- Lagrangian kernel formulation (FORM = 7 or 8) can be used to avoid tensile instability issue but they cannot endure very large deformations.
- For improved accuracy and tensile stability, FORM=12 is available, based on moving least-squares. It handles extremely large deformations, but entails large computational cost.
- Only formulations 0, 1, 15 and 16 are implemented for 2D axisymmetric problems (IDIM = -2).
- FORM = 9, 10 are adaptive smoothed particle hydrodynamics formulation.

SPH Capabilities in LS-DYNA

***CONTROL** — *CONTROL_SPH

***CONTROL_SPH**

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Card 1	1	2	3	4	5	6	7	8
Variable	NCBS	BOXID	DT	IDIM	MEMORY	FORM	START	MAXV
Type	I	I	F	I	I	I	F	F
Default	1	0	10^{20}	none	150	0	0.0	10^{15}

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START	Start time for particle approximation. Particle approximations will be computed when time of the analysis has reached the value defined in START.
MAXV	Maximum value for velocity for the SPH particles. Particles with a velocity greater than MAXV are deactivated. A negative MAXV will turn off the velocity checking.

LS-DYNA SPH Applications

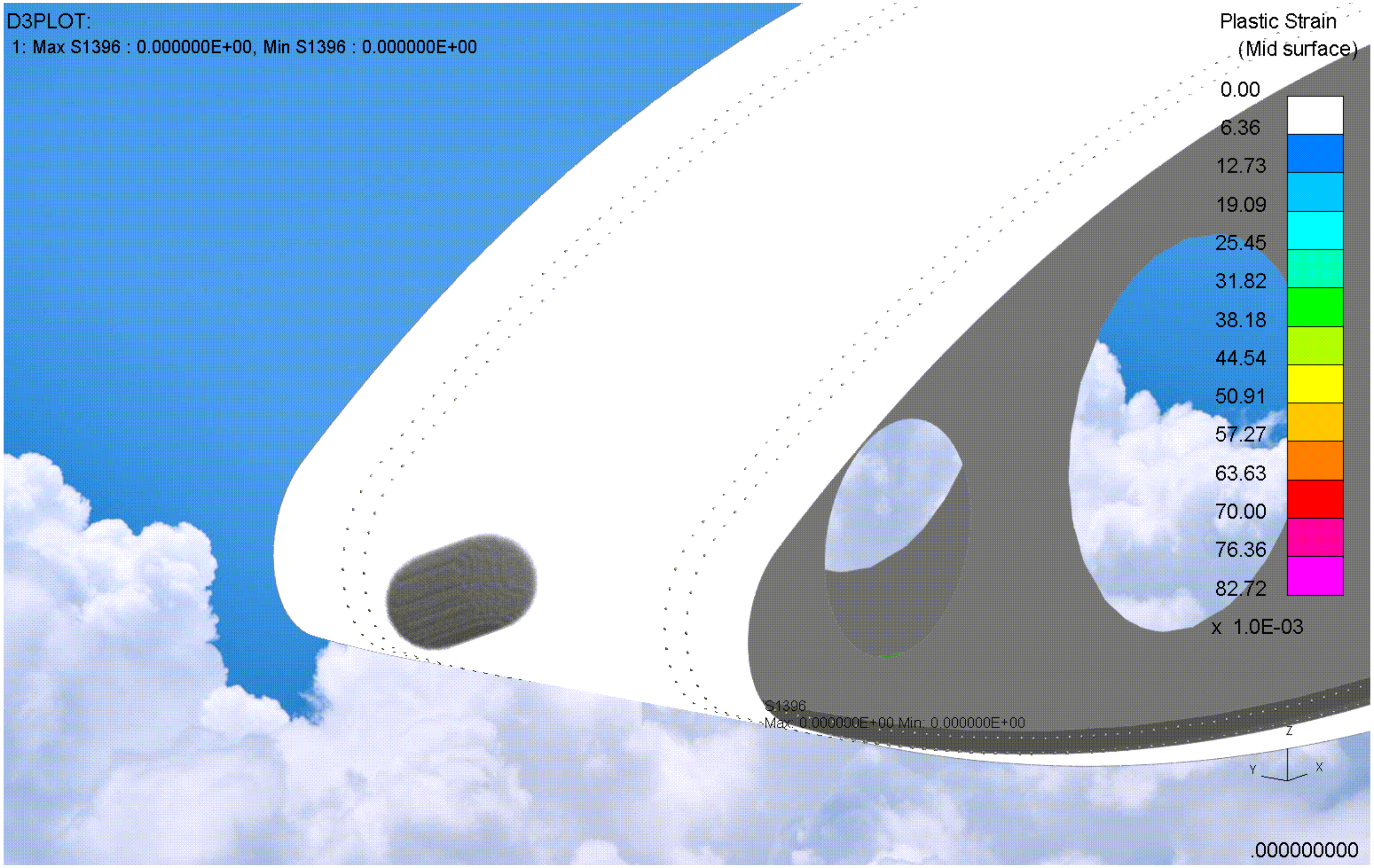
In LS-DYNA, SPH is usually used for:

- Applications with large material distortion
- Modelling material that decomposes into many small fragments
- Moving boundaries and free surfaces

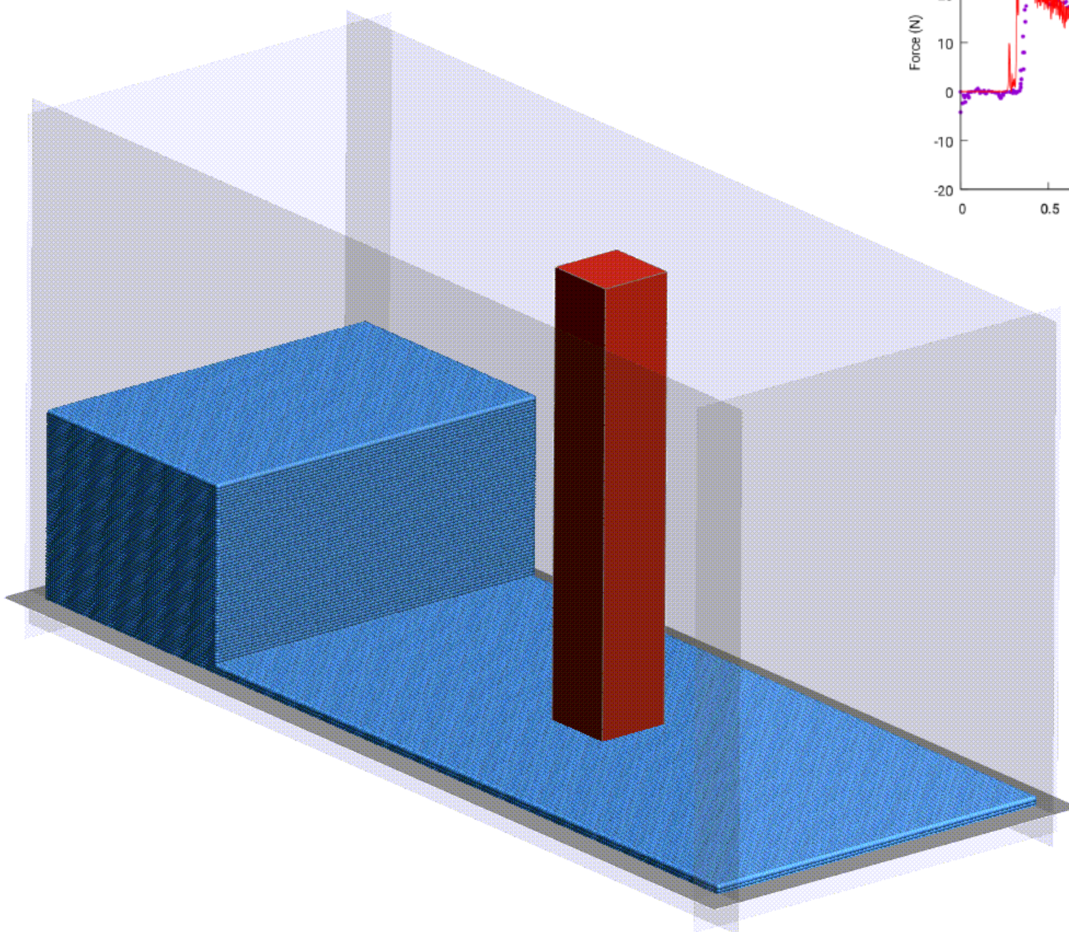
Common Applications:

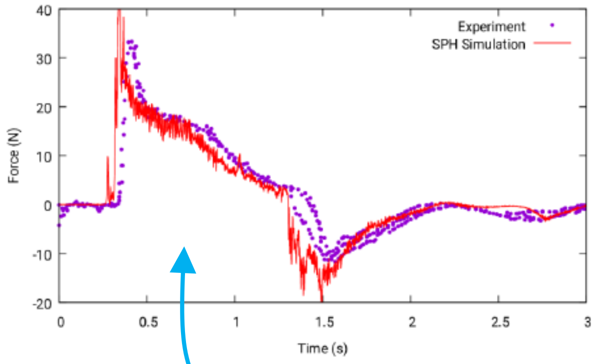
- Bird strike
- Sloshing and splashing
- Material testing analysis
- Fluid / structure interaction
- Fragmentation and spalling
- Forging and extrusion
- Metal cutting and forming
- Soil penetration
- High velocity impacts
- Wave impact studies
- Incompressible flows
- Underwater impacts
- Automotive including:
  - Fuel tank sloshing
  - Sand dune impact
  - Soil-tyre interaction
  - Wheel aquaplaning

Bird Strike into aircraft wing:

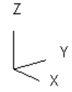


Wave-Structure Interaction:





Total contact forces compared to experimental data.



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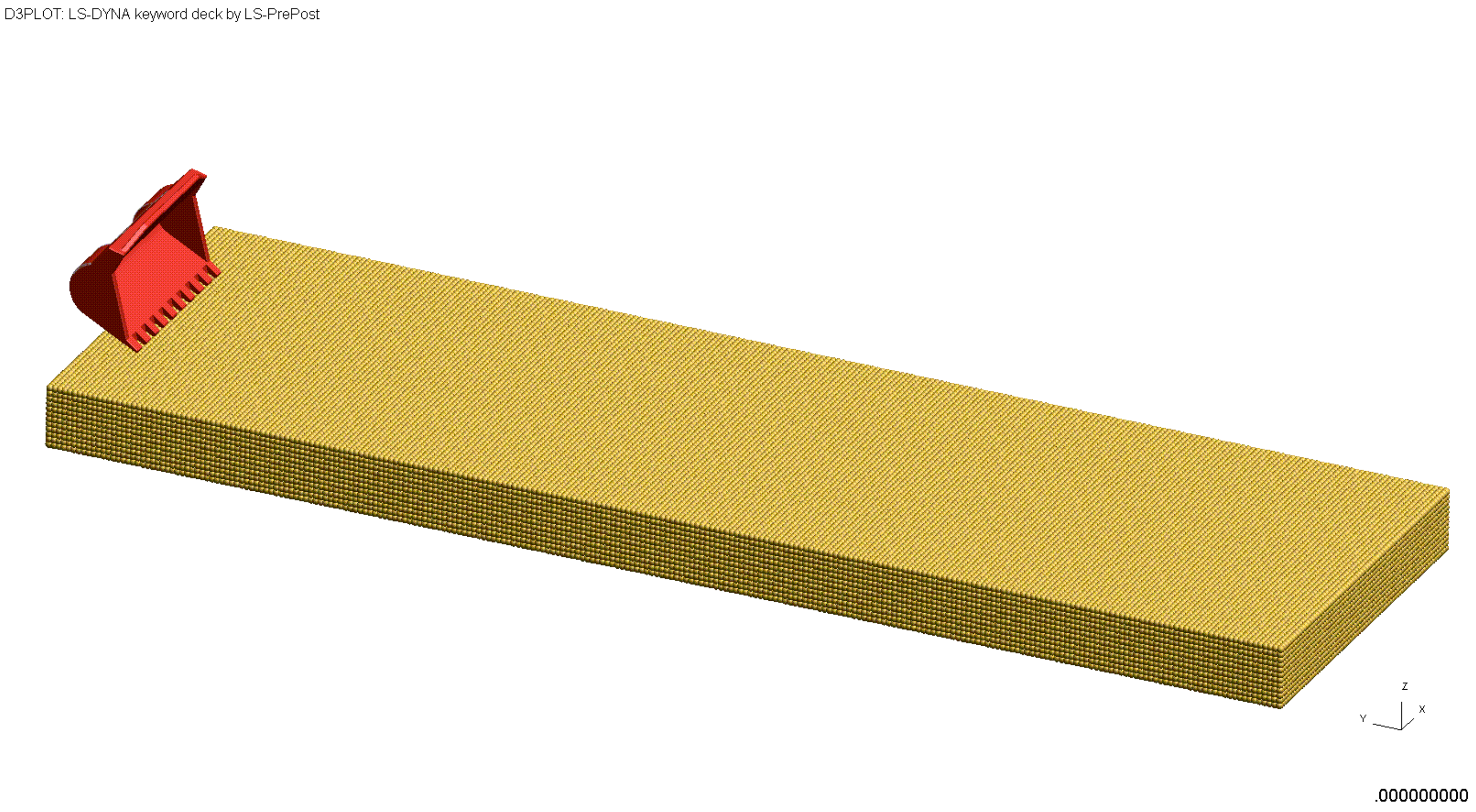
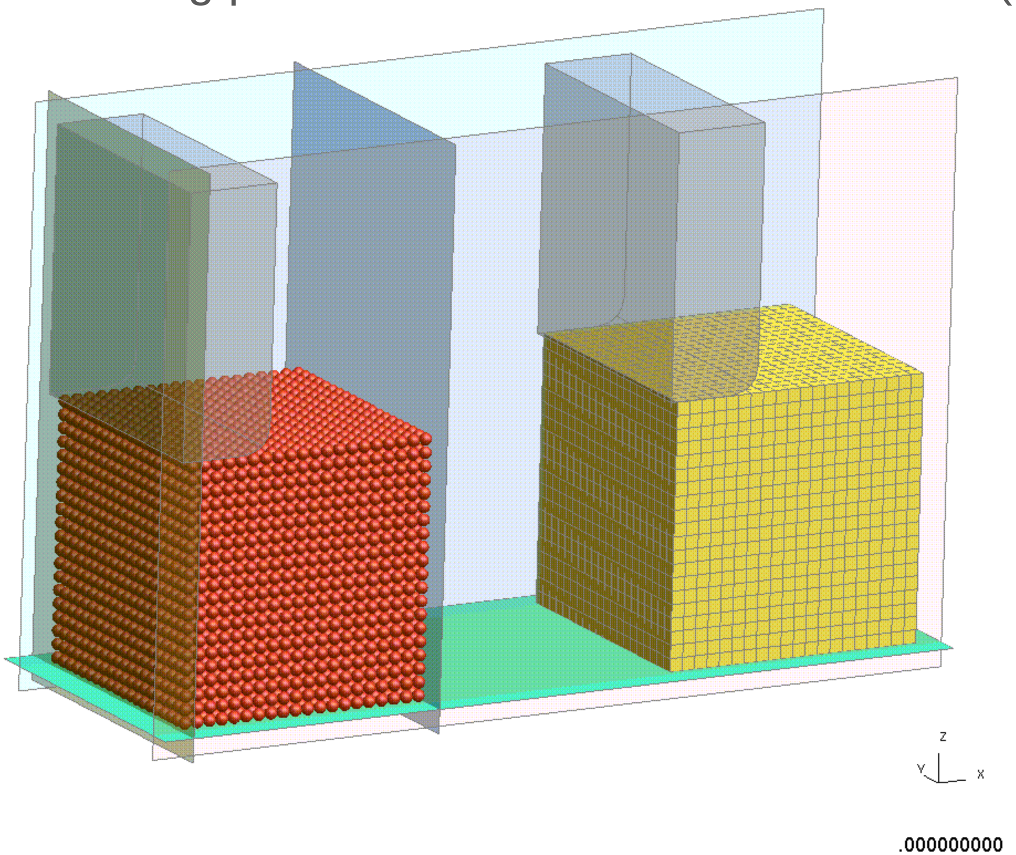
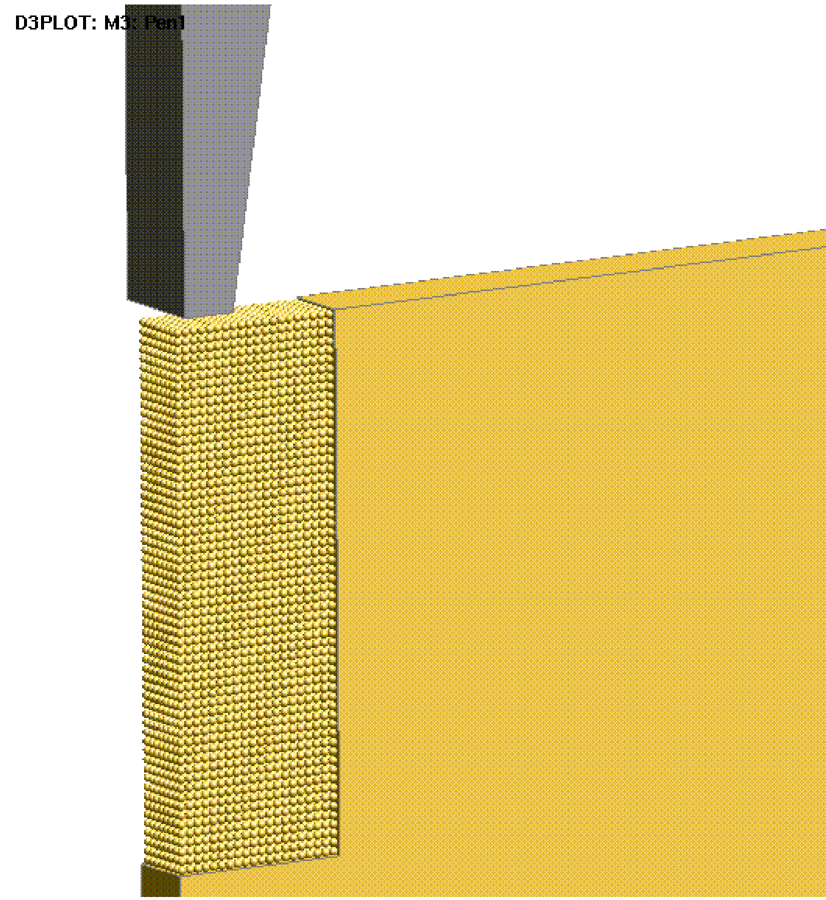
Earth Moving - Excavator:

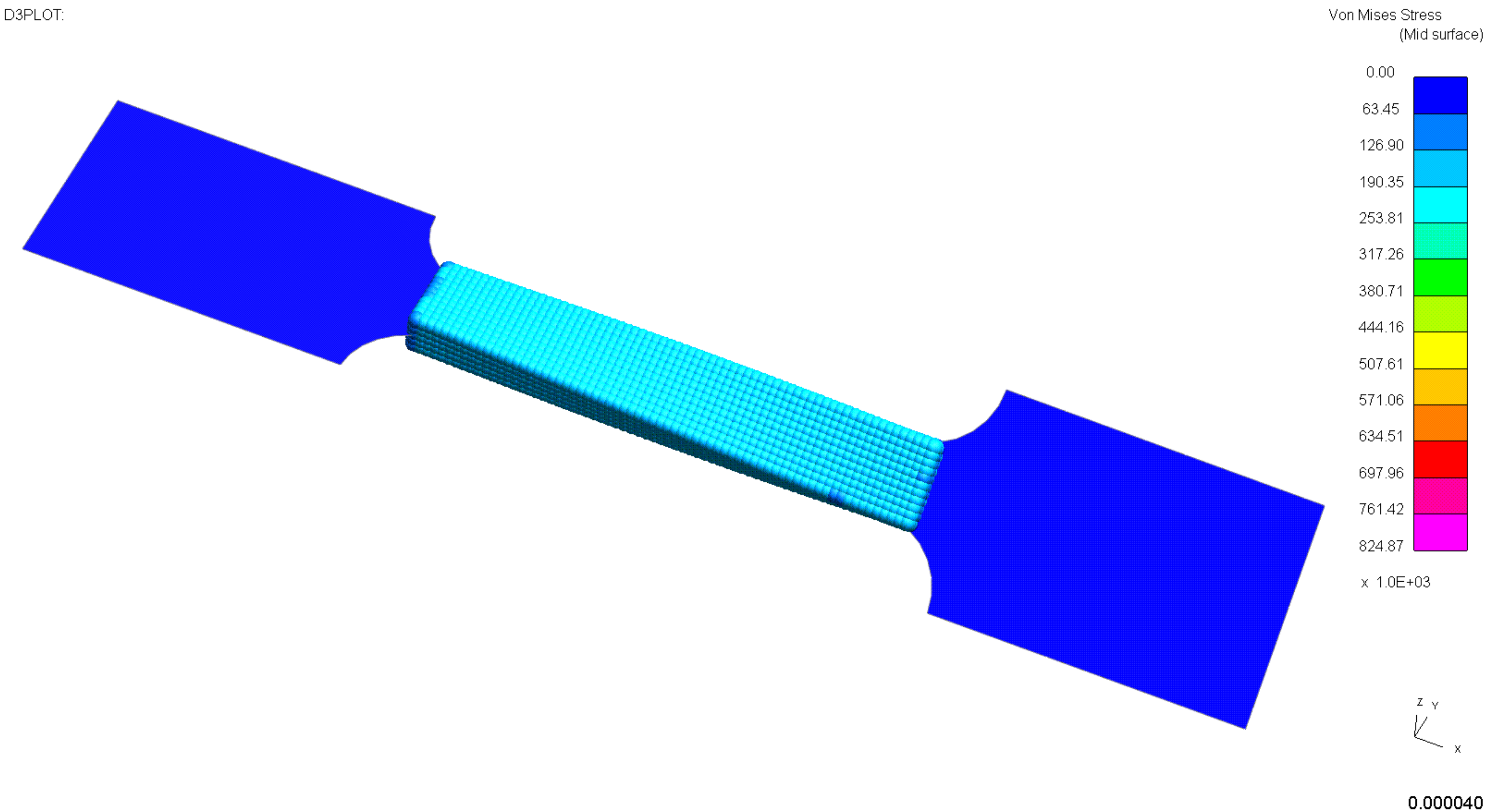


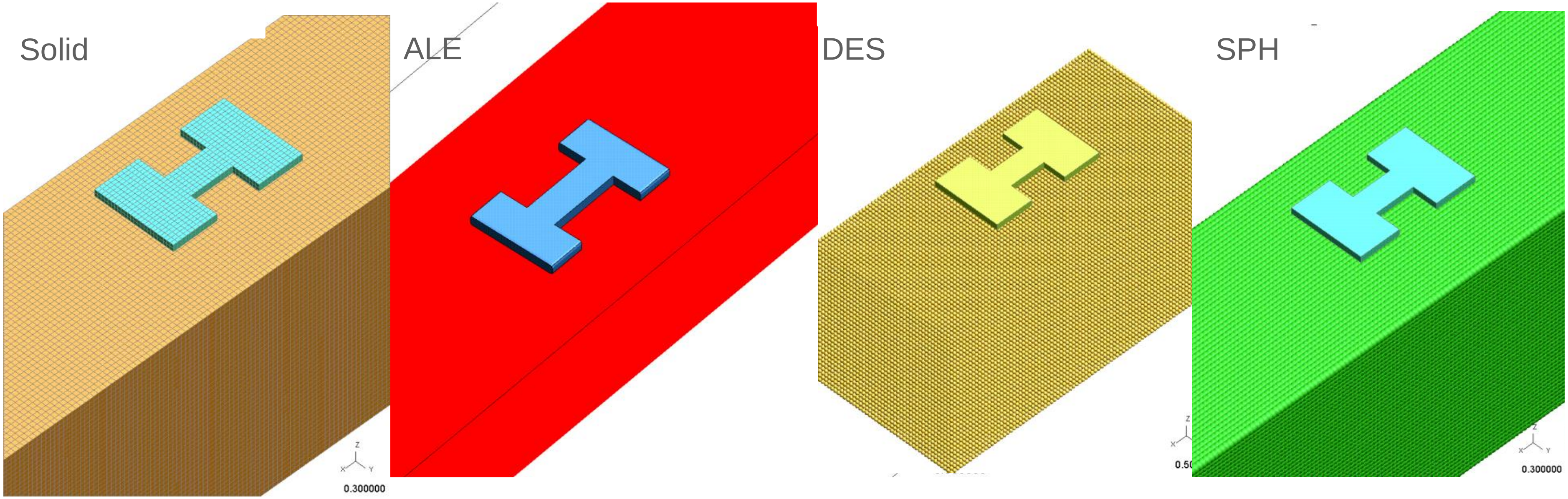
Modelling penetration of foundation structures (buildings) into soil:



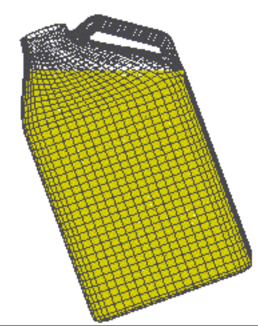


Torsion Test:





Methods of Modelling Sand



Drop Test: Bottle Filled with Water

ARUP

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