SPH Capabilities in LS-DYNA

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SPH and Industry Event
LS-DYNA®

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.

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.
Our aims and values underpin everything we do

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LS-DYNA Consultancy work

Oasys Suite Development

distribution

Internal Projects

SPH Capabilities in LS-DYNA
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

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- 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)
LS-DYNA Applications

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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EM – Tube Expansion due to induced currents

FEA, Implicit – Roof Crush
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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 the same structure as any other feature in LS-DYNA:

Define mass or volume of the particle

Parameters to establish smoothing length

**ELEMENT**

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<th>Variable</th>
<th>Type</th>
<th>Default</th>
<th>Remarks</th>
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**SECTION**

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**VARIABLE**

- **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.
    - **SPHI**
      - Optional initial smoothing length (overrides true smoothing length). With this option LS-DYNA will not calulate 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):
        - **EQ0**: Cubic spline kernel function (default).
        - **EQ1**: Quintic spline kernel function: higher order smoothing function with bigger support size (recommended to use HMAX = 3.0 or bigger value, only available for FORM = 0, 1, 9 and 10).
SPH is implemented in 3D, 2D plane strain and 2D axisymmetric formulations.

<table>
<thead>
<tr>
<th>VARIABLE</th>
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<tr>
<td>NCBS</td>
<td>Number of time steps between particle sorting.</td>
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<tr>
<td>BOXID</td>
<td>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.</td>
</tr>
<tr>
<td>DT</td>
<td>Death time. Determines when the SPH calculations are stopped.</td>
</tr>
<tr>
<td>IDIM</td>
<td>Space dimension for SPH particles: EQ.2 for 3D problems, EQ.2 for 2D plane strain problems, EQ.2 for 2D axisymmetric problems (see Remark 2).</td>
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<td>MEMORY</td>
<td>Defines the initial number of neighbors per particle (see Remark 1 below).</td>
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<td>START</td>
<td>Start time for particle approximation. Particle approximations will be computed when time of the analysis has reached the value defined in START.</td>
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<tr>
<td>MAXV</td>
<td>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.</td>
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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. 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.
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.
Earth Moving - Excavator:

D3PLOT LS-DYNA keyword deck by LS-PrePost
Modelling penetration of foundation structures (buildings) into soil:
Torsion Test:

[Image of a torsion test simulation with stress distribution shown]
LS-DYNA SPH Applications

Methods of Modelling Sand

- Solid
- ALE
- DES
- SPH

SPH Capabilities in LS-DYNA

Drop Test: Bottle Filled with Water
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