Smoothed Particle Hydrodynamics Method in LS-DYNA

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3rd LS-DYNA Forum
14-15 Oktober 2004
Bamberg, Germany

Outline

• Aspects of Smoothed Particle Hydrodynamics
• The SPH method in LS-DYNA
• LS-PRE/POST
I.

ASPECTS OF
SMOOTHED PARTICLE HYDRODYNAMICS

Smooth Particle Hydrodynamics in LS-DYNA

- A lagrangian collocative method - explicit
- Solve
  1. Conservation of mass
  2. Conservation of momentum
  3. Conservation of energy if necessary
- Apply for Impact/Penetration, Incompressible Flow
- Difficult to handle boundary conditions
- Accuracy is low compare to F.E. or EFG Methods
• No connectivity between the particles (meshfree method)

• Can handle high deformations in a lagrangian frame

• Particles = interpolation points \(\Rightarrow\) simple
II.

The SPH Method in LS-DYNA
PARTICLE MODEL

Typical lengths

- Mass $m$
- Distance $d$ between particles
- Smoothing length $h$

2 parameters of discretization: $h$ and $d \neq$ classical methods

SMOOTHING FUNCTION

$$W(d, h) = \frac{1}{h^\alpha (x, y)} \theta\left(\frac{d}{h(x, y)}\right)$$

$$\theta(d) = C \times \begin{cases} 
1 - \frac{3}{2}d^2 + \frac{3}{4}d^3 & \text{si } 0 \leq |d| \leq 1 \\
\frac{1}{4}(2 - d)^3 & \text{si } 1 \leq |d| \leq 2 \\
0 & \text{elsewhere}
\end{cases}$$
SPH APPROXIMATIONS

Particle approximation of a function:

\[ \Pi'U(x_i) = \sum \frac{m_j}{\rho_j} u(x_j)W(x_i - x_j, h) \]

Particle approximation of the Gradient:

\[ \Pi'h\nabla u(x_i) = \sum \frac{m_j}{\rho_j} [u(x_j)A_{ij} - u(x_i)A_{ji}] \]

ONE CYCLE LOOP IN LS-DYNA

START

Accelerations

Velocity / Position

Compute \( h \)

Contact, Boundary C.

Sorting

Density, strain rates

Particle forces

Pressure, energy, stress
• Global keyword on SPH. Deals with all the SPH parts of the model

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<th>NCBS</th>
<th>BOXID</th>
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<th>IDIM</th>
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• 2nd card (optional)

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**CONTROL_SPH in LS970_5434 (aug’04)**

- **IFORM**: Particle approximation theory

- Gives which formulation is used for the approximation
  - 0: standard formulation (default)
  - 1: renormalized formulation
  - 2: symmetric formulation
  - 3: symmetric formulation with renormalization
  - 4: elliptical formulation (not to be defined here)
  - 5: fluid formulation
  - 6: fluid formulation with renormalization

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**SUMMARY OF IFORM VARIABLE**

- **Conservation of momentum**

\[
\frac{dv_i}{dt} = - \sum_{j \in p} m_j \left( \frac{\sigma_i}{\rho_j} A_{ij} - \frac{\sigma_j}{\rho_j} A_{ji} \right) \quad \text{IFORM} = 0
\]

\[
\frac{dv_j}{dt} = - \sum_{j \in p} m_j \left( \frac{\sigma_i}{\rho_j} + \frac{\sigma_j}{\rho_j^2} \right) \nabla W_{ij} \quad \text{IFORM} = 2
\]

\[
\frac{dv_i}{dt} = - \sum_{j \in p} m_j \left( \sigma_{ij} - \sigma_{ji} \right) \quad \text{IFORM} = 5
\]
SUMMARY OF IFORM VARIABLE

* Conservation of momentum

\[
\frac{dv_i}{dt} = -\sum_{j \in P} m_j \left( \frac{\sigma_i}{\rho_i^2} A_{ij} - \frac{\sigma_j}{\rho_j^2} A_{ji} \right) : B_{ij} \quad IFORM = 1
\]

\[
\frac{dv_i}{dt} = -\sum_{j \in P} m_j \left( \frac{\sigma_i}{\rho_i^2} + \frac{\sigma_j}{\rho_j^2} \nabla W_{ij} \right) : B_{ij} \quad IFORM = 3
\]

\[
\frac{dv_i}{dt} = -\sum_{j \in P} m_j \left( \sigma_i A_{ij} - \sigma_j A_{ji} \right) : B_{ij} \quad IFORM = 6
\]
*BOUNDARY_SPH_SYMMETRY_PLANE* 

- Allows the definition of a symmetry plane.
- Creates ghost particles

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Ghost SPH

SPH particles

Symmetry plane

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**SECTION_SPH_USER**

- Allows the user to define his own variation for the smoothing length
- Have to define the variables of the first card of *SECTION_SPH*
- Subroutine \textit{hdot} is defined in \textit{dyn21.f} and is called by the code.
- Available only in Is971
III.

LS-PRE/POST
• Regular mesh => correct

• Irregular mesh => not correct

Try to avoid situations like:

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CREATE A CUBE

SWITCH FROM HEXAHEDRON
Axis of Revolution

3. LS-DYNA Anwenderforum, Bamberg 2004
Netzfreie Verfahren

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