Recent Developments and Roadmap Part 5: ALE, DEM, SPH, Particle

12th International LS-DYNA User's Conference

June 5, 2012

LSTC
Livermore Software Technology Corp.

Outline

- Introduction
- Recent developments

LS-PrePost	Mr. Philip Ho
Dummies	Dr. Christoph Maurath
Incompressible CFD	Dr. Facundo Del Pin
Electromagnetics	Dr. Pierre L'Eplattenier
ALE, DEM, SPH, Particle	Dr. Jason Wang

- Conclusions

SPH, ALE, DEM, Airbag Particle

Dr. Jason Wang

SPH Thermal Solver

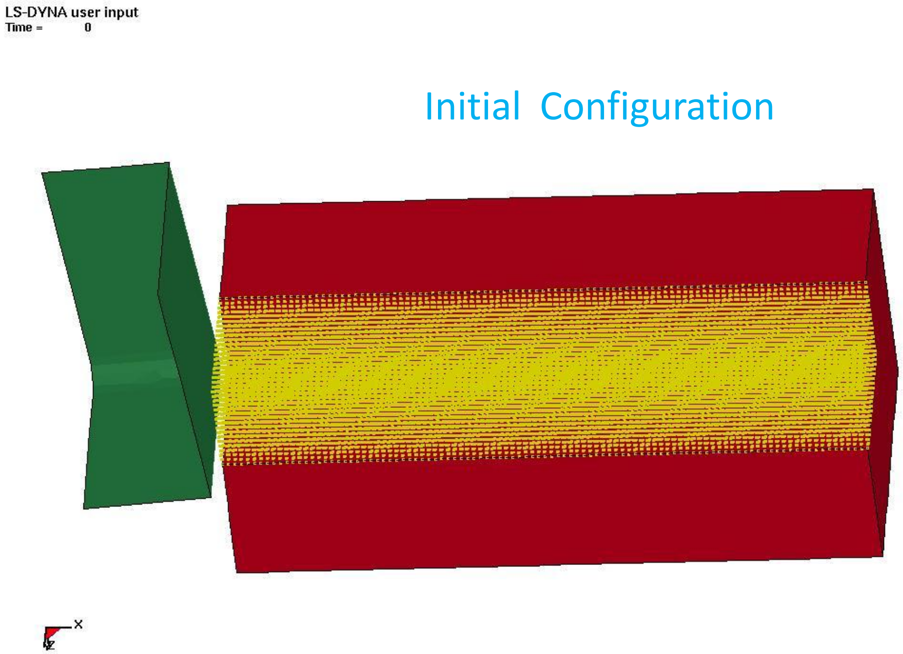
- An explicit thermal conduction solver is implemented for SPH analysis
- Following keywords and materials are supported

*INITIAL_TEMPERATURE_OPTION
*BOUNDARY_TEMPERATURE_OPTION
*BOUNDARY_FLUX_OPTION

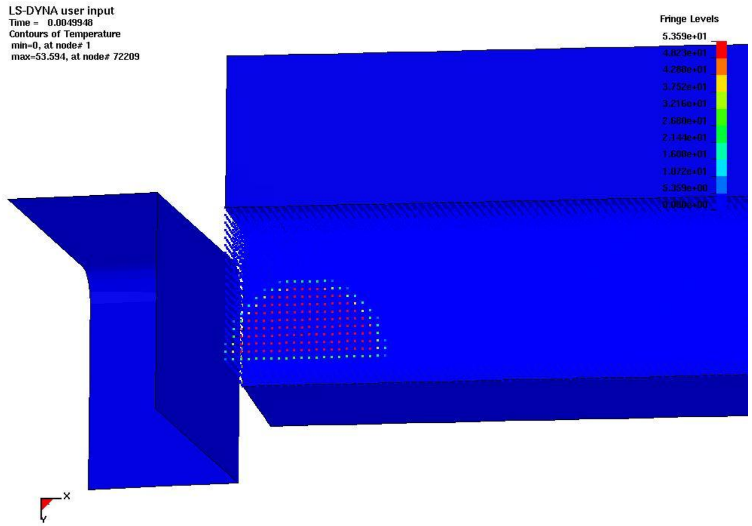
*MAT_THERMAL_ISOTROPIC
*MAT_ADD_THERMAL_EXPANSION
*MAT_VISCOELASTIC_THERMAL
*MAT_ELASTIC_VISCOPLASTIC_THERMAL
*MAT_ELASTIC_PLASTIC_THERMAL

- Thermal coupling with SPH is implemented

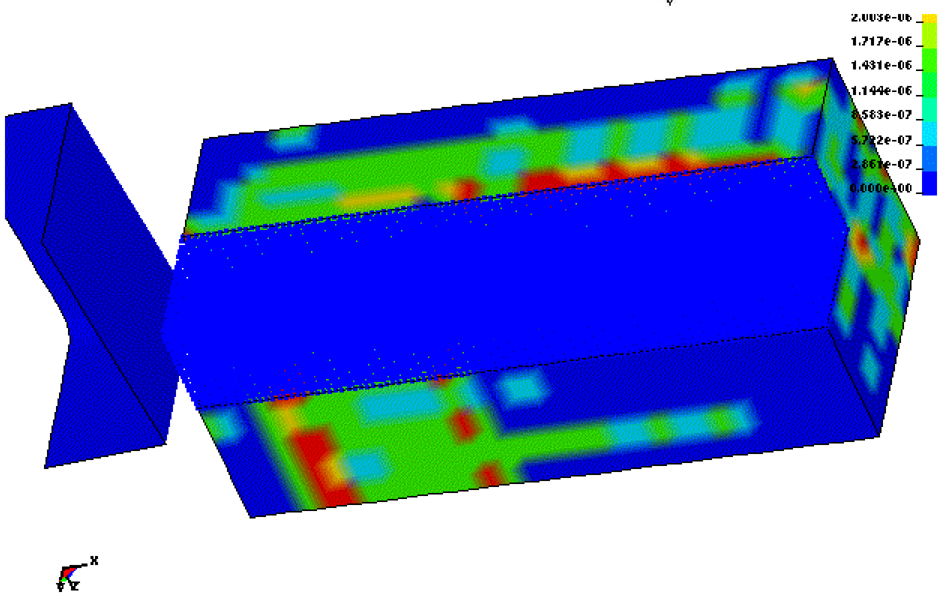
Metal Cutting with Heat



Initial Configuration



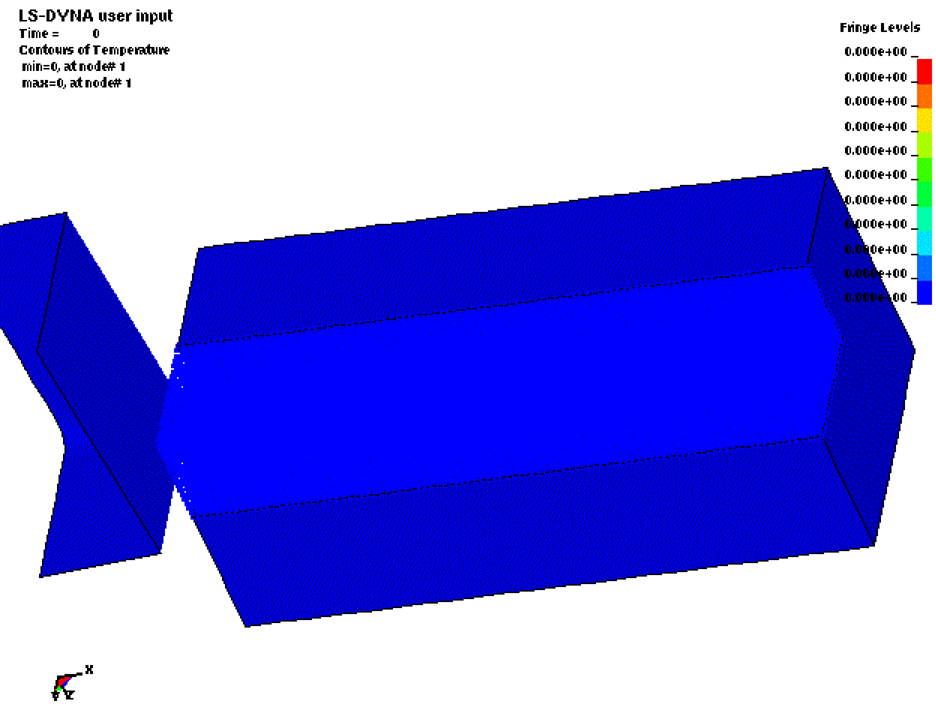
Initial Temperature



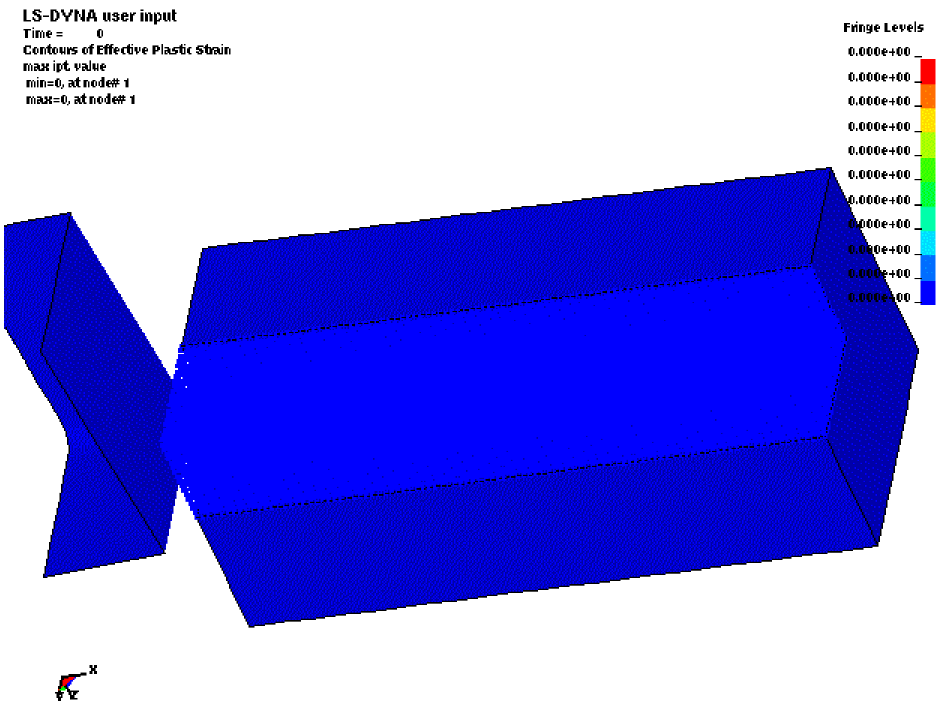
Von-Mises Stress

Metal Cutting with Heat

Heat source: *BOUNDARY_FLUX
*MAT_JOHNSON_COOK (stress flow depends on the temperature)



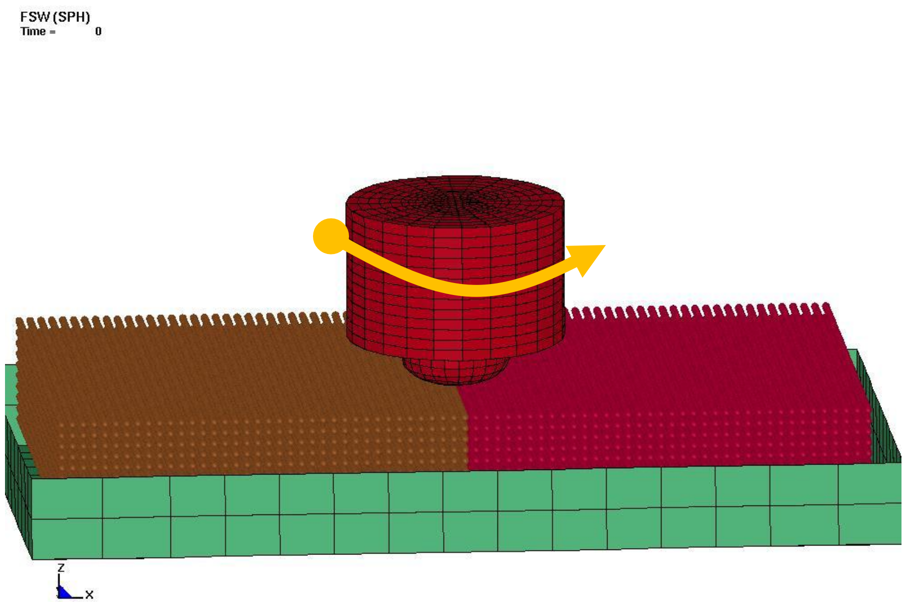
Temperature



Plastic Strain

Friction Stir Welding with SPH

Courtesy of Kirk A Frazer at ROCHE



Rigid body tools

Johnson cook Material with Viscoplasticity

Heat Capacity = 875, Thermal Conductivity = 175

EQHEAT = 1.0, FWORK=1.0 for heat source

ADD_THERMAL_EXPANSION for work-pieces

Friction Stir Welding with SPH

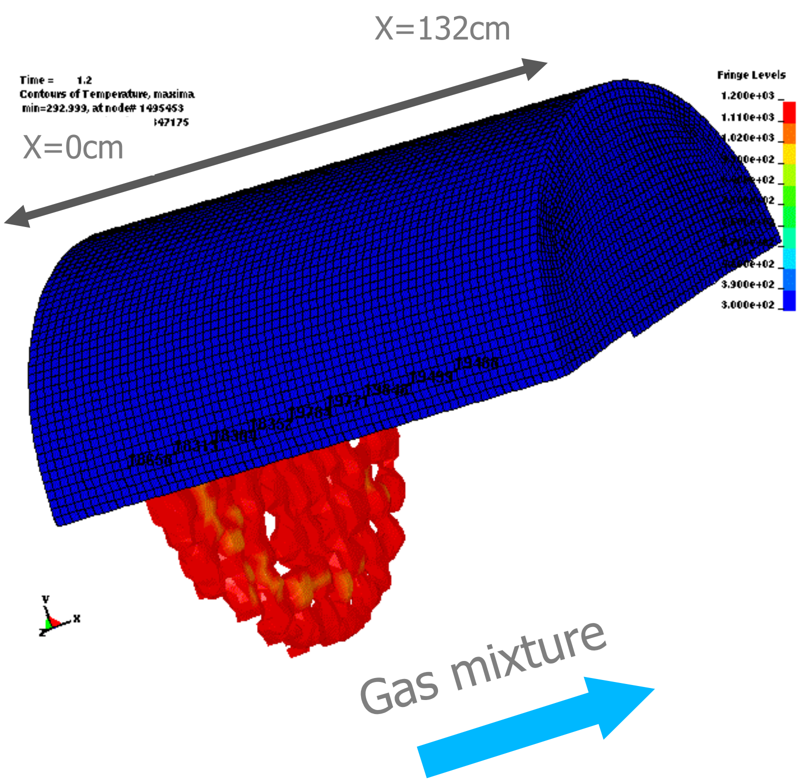
Courtesy of Kirk A. Fraser at ROCHE

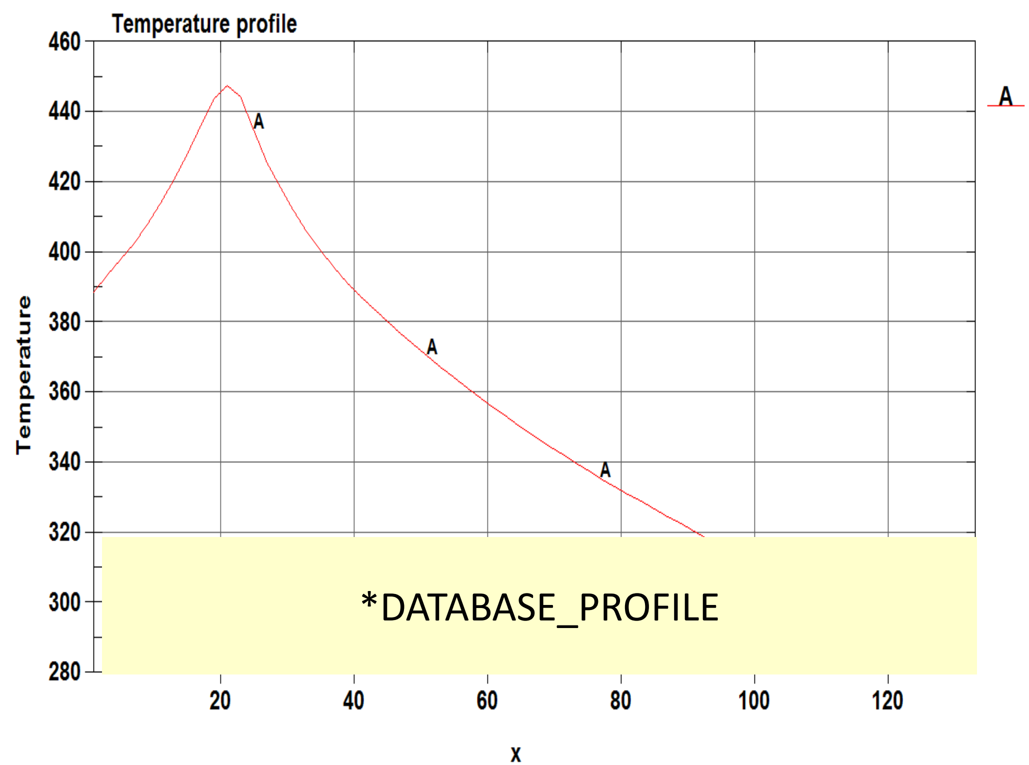
Deformation

Temperature

ALE and Thermal Coupling

ALE *MAT_GAS_MIXTURE coupled with shell structure using
*CONSTRAINED_LAGRANGE_IN_SOLID



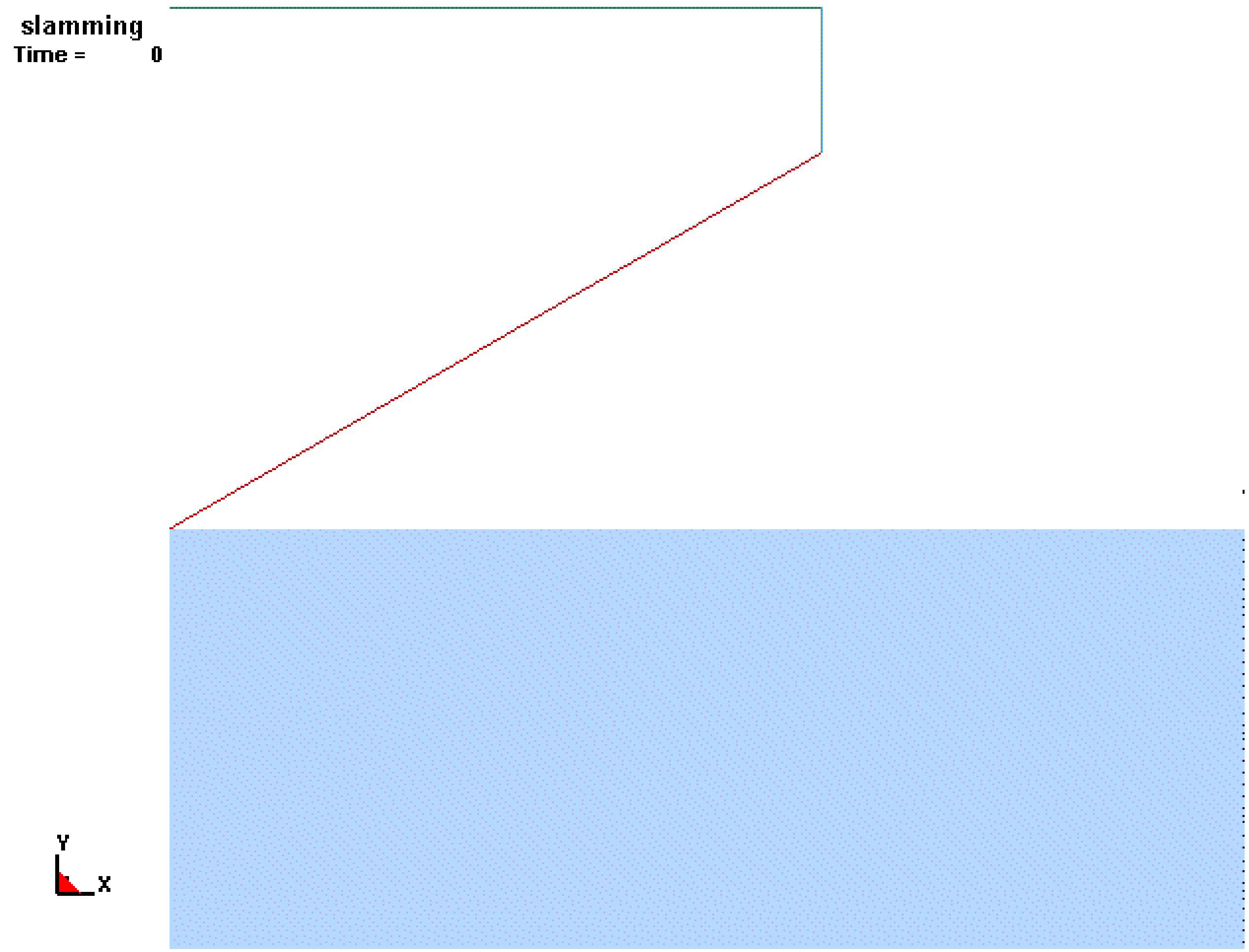


Energy is removed from gas and deposited to shell via heat convection
The energy is used as source term for thermal analysis

ALE Dynamic Adaptive

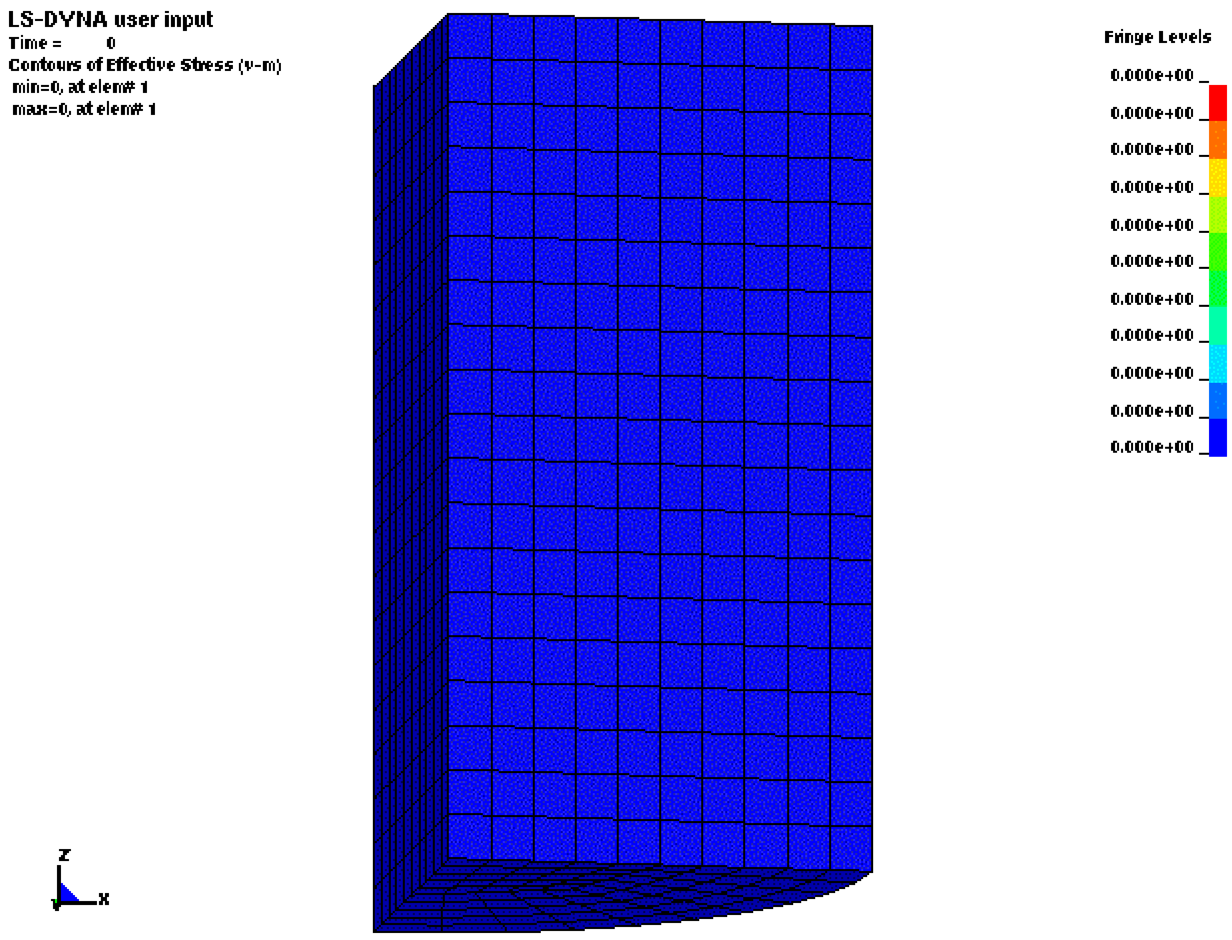
*REFINE_ALE

slamrfn.layrf3.avi



Dynamic Adaptive FEM Solid Mesh

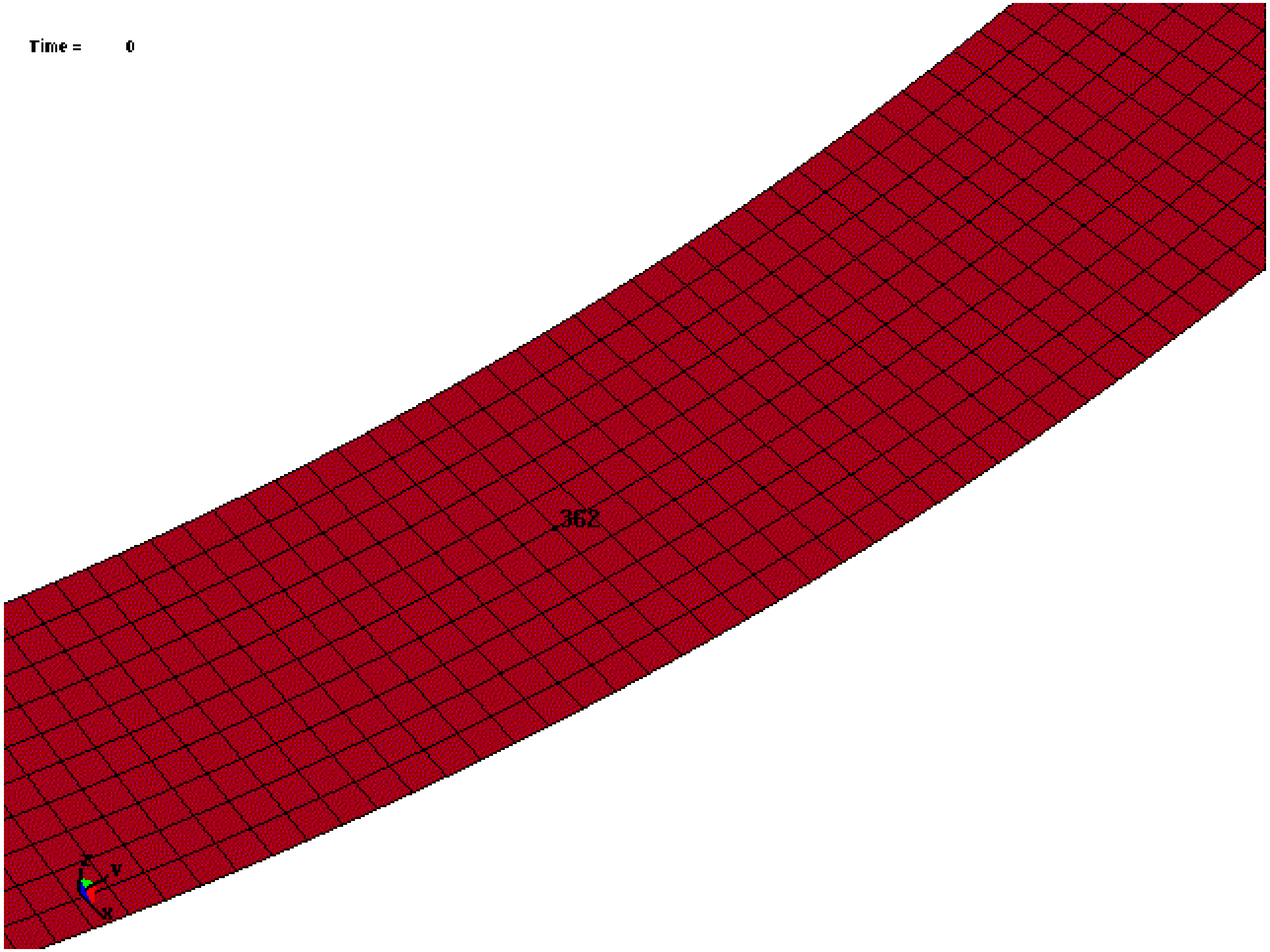
*REFINE_SOLID



sldrfn.taylor.avi

Dynamic Adaptive FEM Shell Mesh

*REFINE_SHELL



shlrfn.avi

Particle based Blast Loading

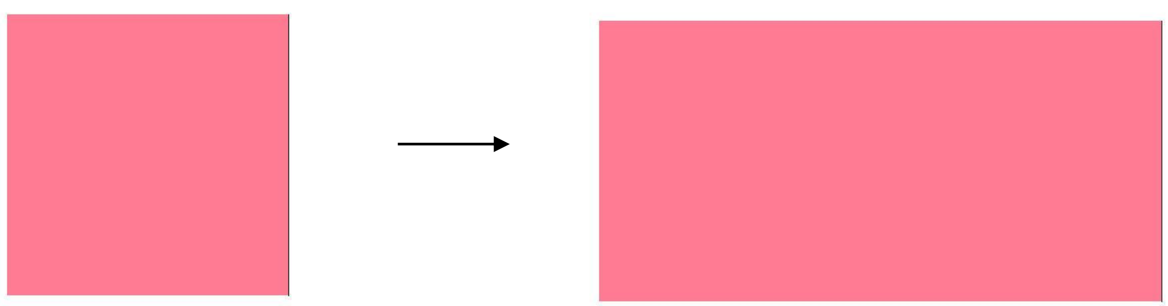
Real Gas Model of High Explosive Particle

- Air Particle
  - Modeled by ideal gas law: $pV=nRT$
  - The volume of molecules is neglected
  - Works for low pressure and moderate temperature
- High Explosive Particles
  - Modeled by real gases: $p(V-b)=nRT$
  - The co-volume effect is included
  - Works for high pressure and high temperature
  - Pressure drops sharply during adiabatic expansion

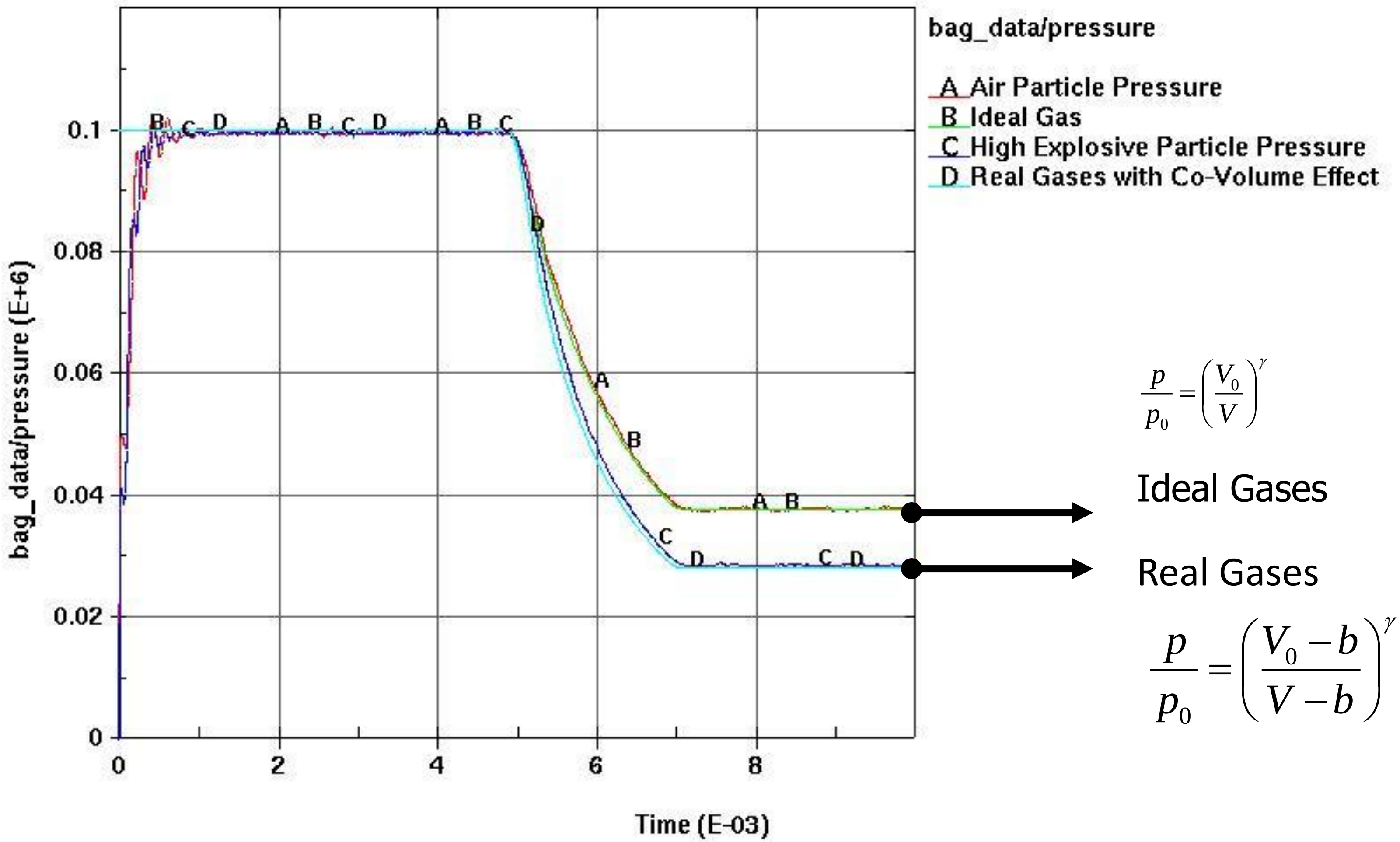
Adiabatic Expansion

- An 8 liter box filled up with air particles, the box is expanded to 16 liter
- Ratio of heat capacities $\gamma = 1.4$
- The same procedure is repeated with high explosive particles with

$$b = 0.32V_0$$



Adiabatic Expansion



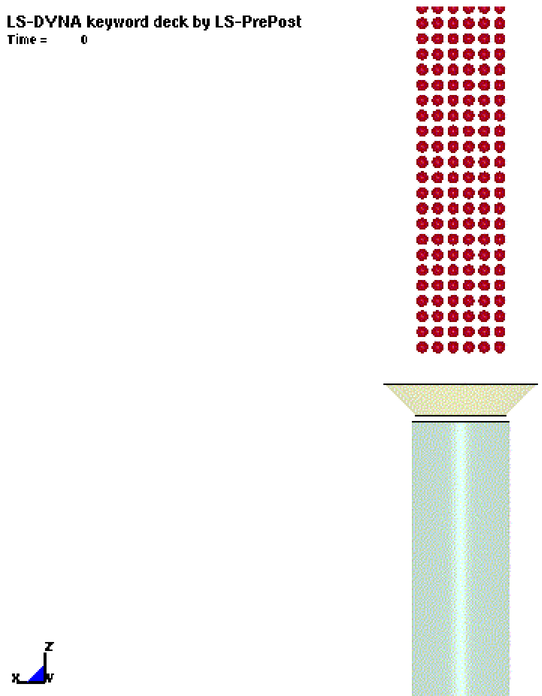
$$\frac{p}{p_0} = \left(\frac{V_0}{V}\right)^{\gamma}$$

Ideal Gases

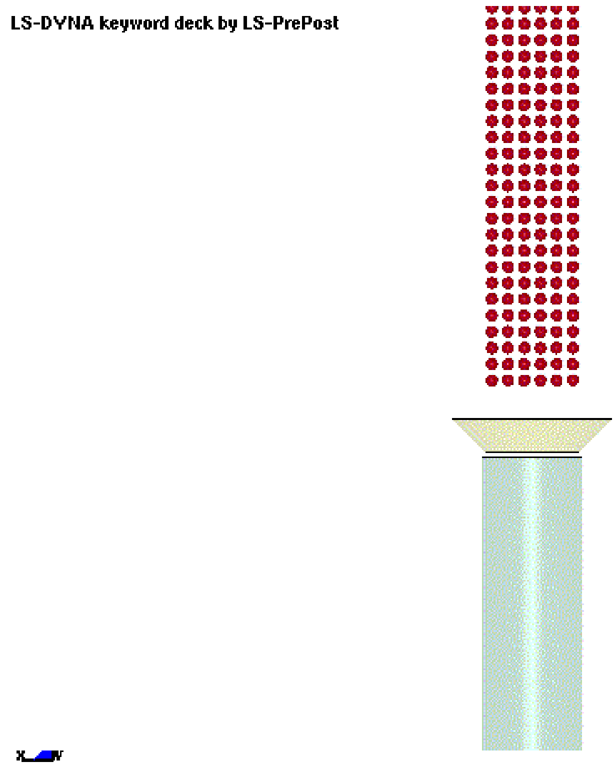
Real Gases

$$\frac{p}{p_0} = \left(\frac{V_0 - b}{V - b}\right)^{\gamma}$$

Discrete Element Sphere (DES)



Dry

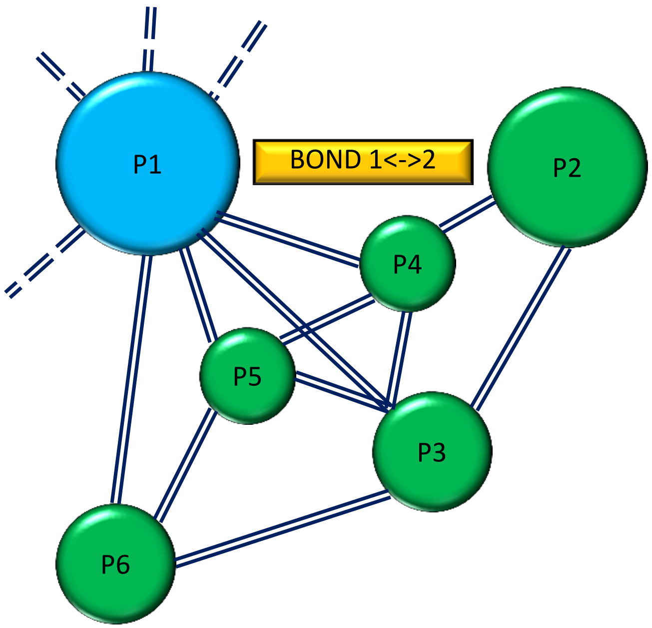


Wet

LSTC DES Bond Model

Emerge into Continuum Mechanics

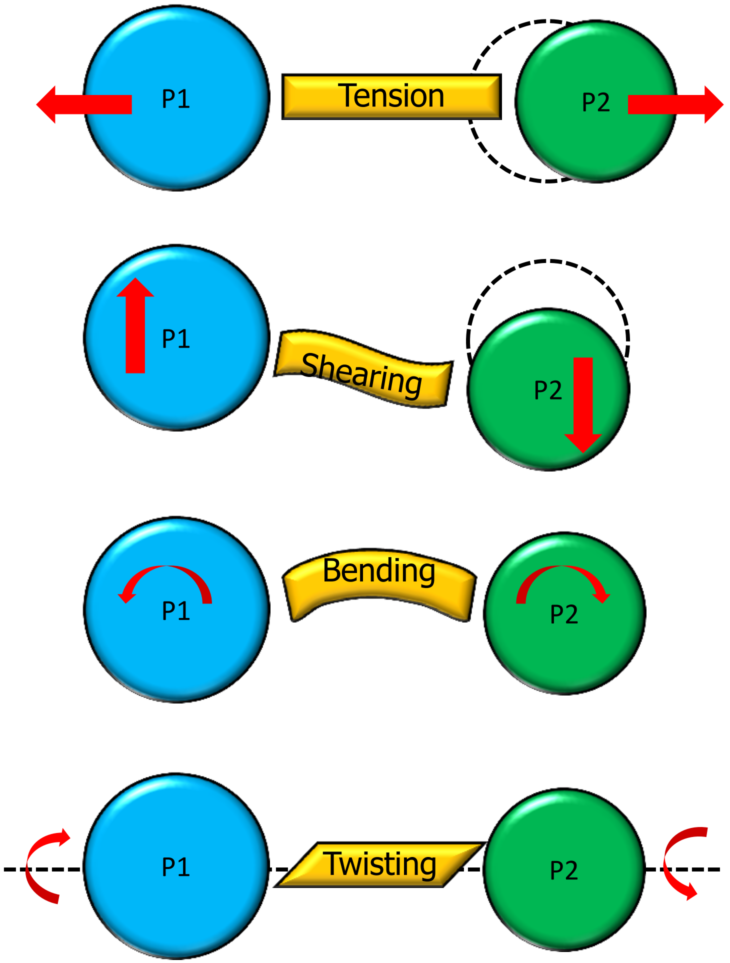
- All particles are linked to their neighboring particles through Bonds.
- The properties of the bonds represent the complete mechanical behavior of Solid Mechanics.
- The bonds are independent from the DES model.
- They are calculated from Bulk Modulus and Shear Modulus of materials.



Mechanical Behaviors

LSTC Bond Model

- Every bond is subjected to:
  - *Stretching*
  - *Shearing*
  - *Bending*
  - *Twisting*
- The breakage of a bond results in Micro-Damage which is controlled by the critical fracture energy value J_{IC}.

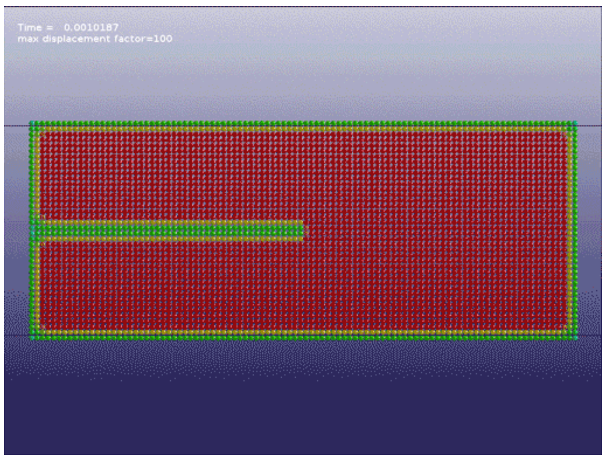


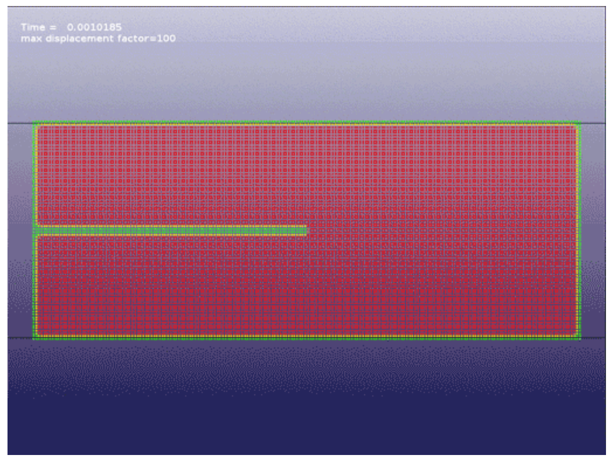
Fracture Analysis

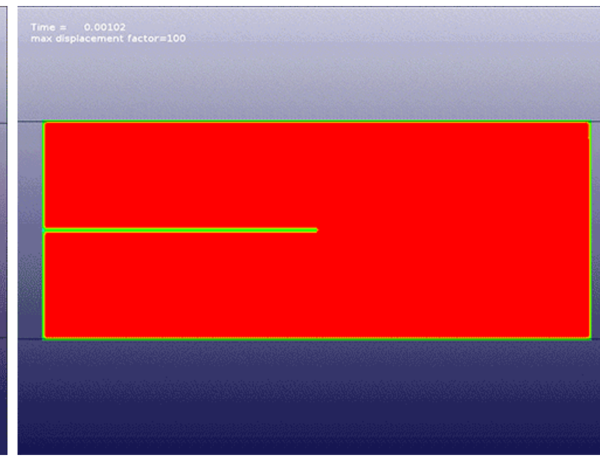
Pre-notched plate under tension

Quasi-static Loading | Material: Duran 50 Glass | Density: 2235kg/m^3

Young's Modulus: 65GPa | Poisson Ratio: 0.2 | Fracture Energy Release Rate: 204 J/m^2







Case 1:
Sphere Radius: 0.5 mm
N. of spheres: 4000

Crk Growth Spd: 2012 m/s
Fracture Energy: 10.2 mJ

Case 2:
Sphere Radius: 0.25 mm
N. of spheres: 16000

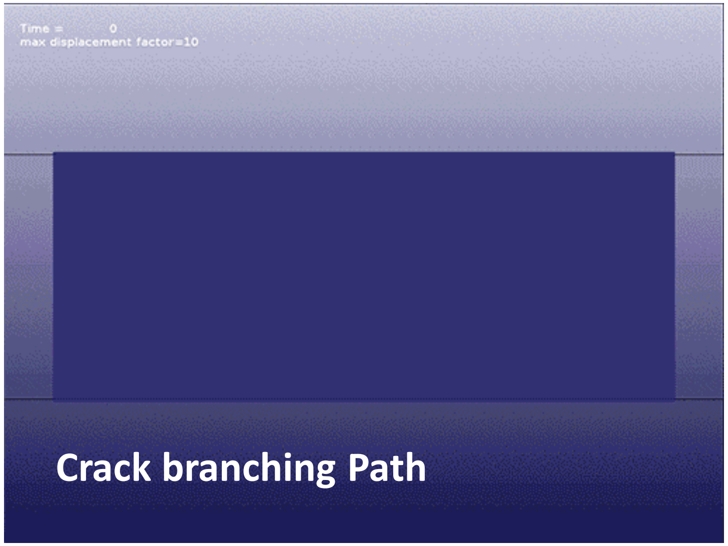
Crk Growth Spd: 2058 m/s
Fracture Energy: 10.7 mJ

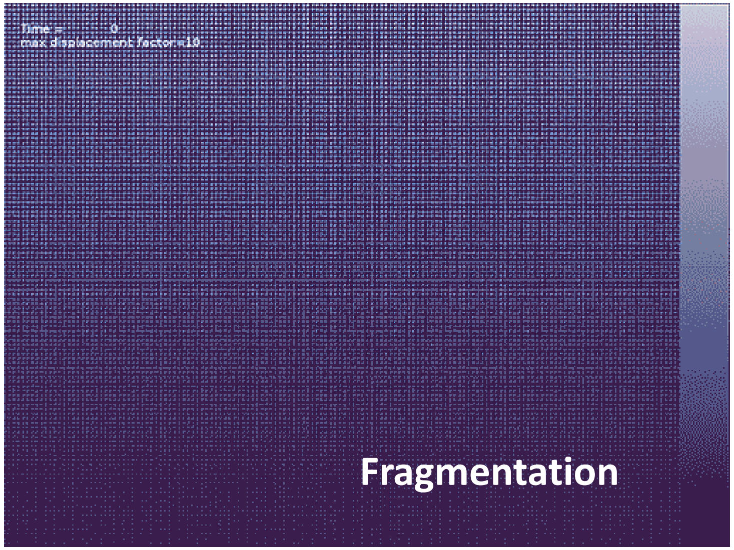
Case 3:
Sphere Radius: 0.125 mm
N. of spheres: 64000

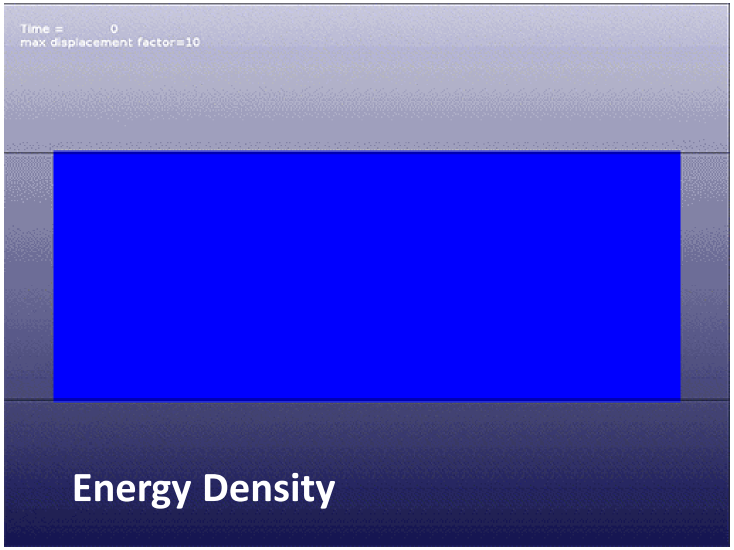
Crk Growth Spd: 2028 m/s
Fracture Energy: 11.1 mJ

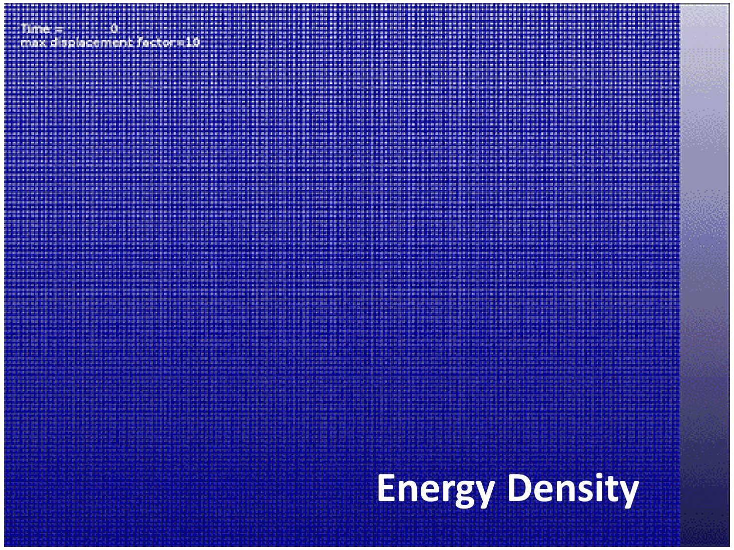
Fragmentation Analysis

Dynamic Loading









LS-DYNA Multi-Physics Solvers

	ALE	SPH	DES	PGas
ALE		▲	▲	
SPH			■	
DES				●
Pgas				

△ *ALE_COUPLING_NODAL

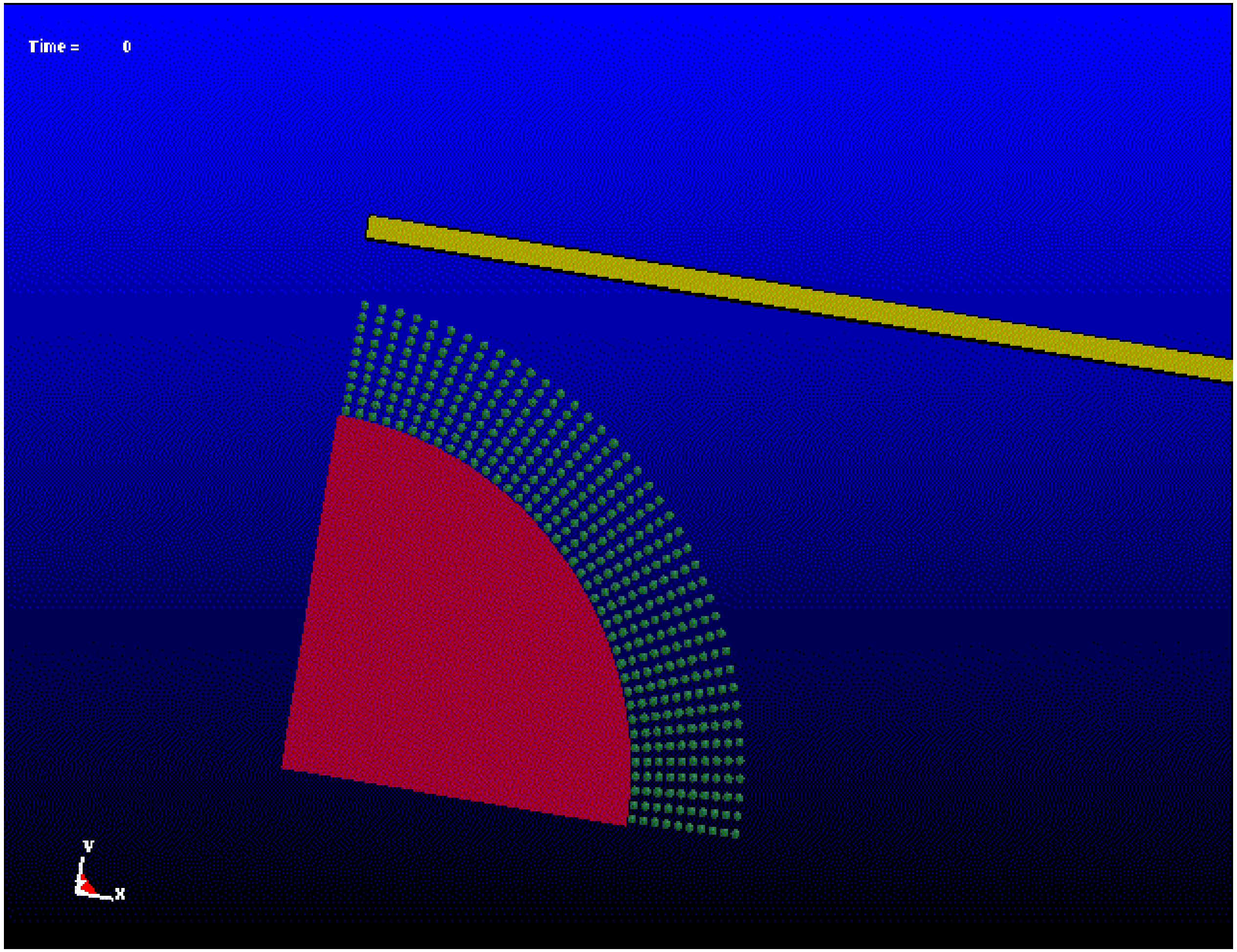
□ *DEFINE_SPH_TO_SPH_COUPLING

○ *PARTICLE_BLAST

● testing ● developing

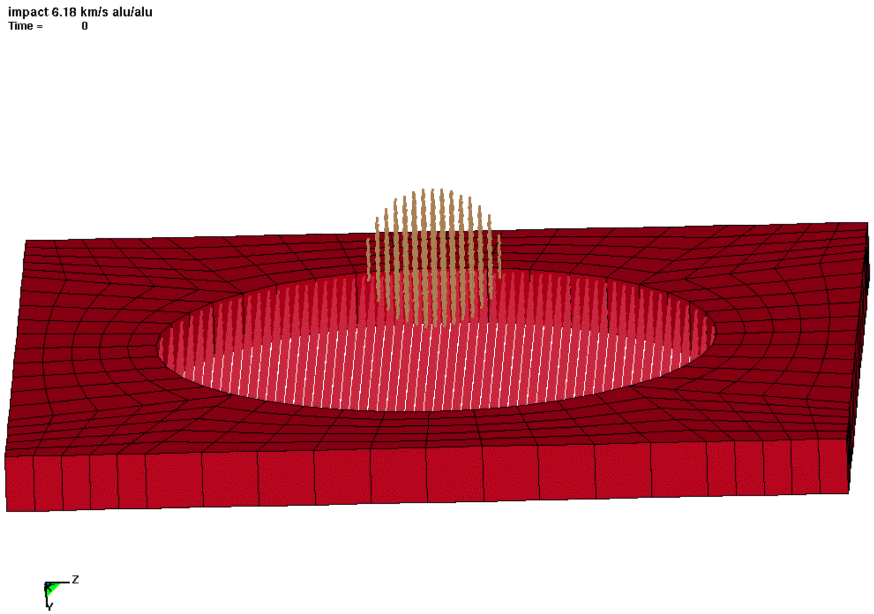
*ALE_COUPLING_NODAL

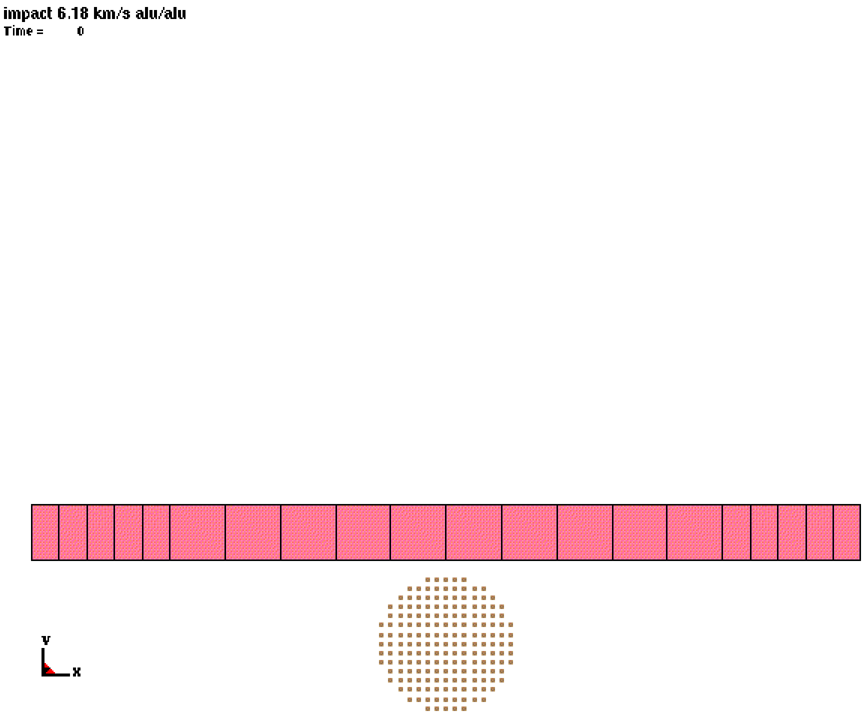
A simple test case modeling explosion driven sand grains hitting on a plate



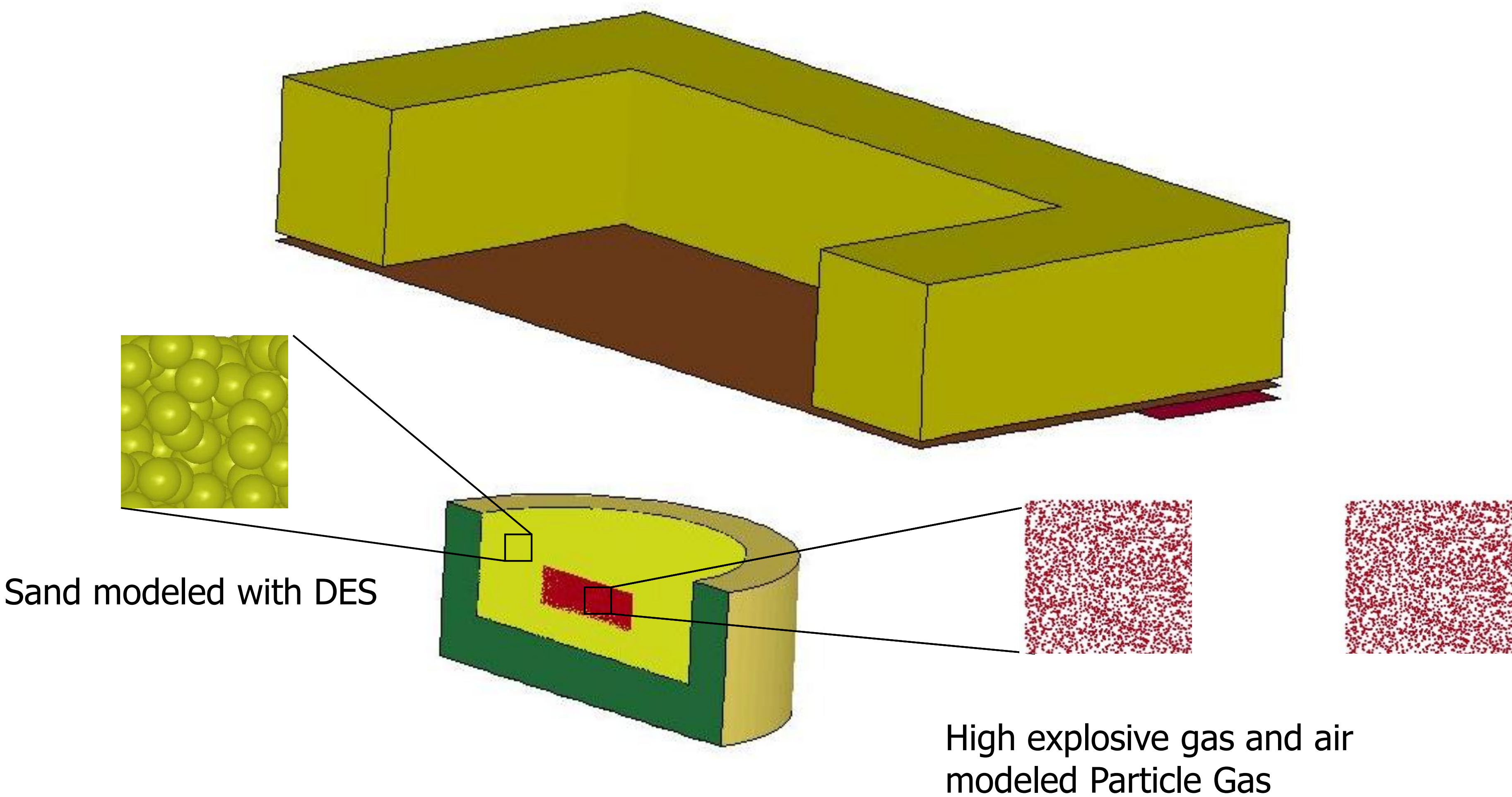
*DEFINE_SPH_TO_SPH_COUPLING

- Penalty based SPH to SPH particle contact
- Will be extended to SPH and DES coupling



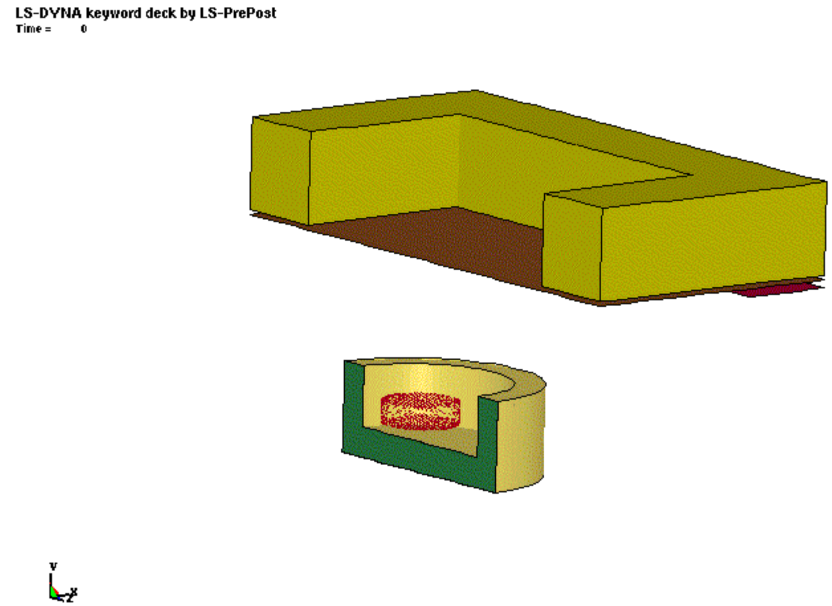


*PARTICLE_BLAST



*PARTICLE_BLAST

Blast simulation with sand



Blast simulation without sand

Thank You !