LS-DYNA S-ALE
Recent Progress

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Ansys

S-ALE Setup

A more user-friendly process

Ansys

Step 1: Mesh

*ALE_STRUCTURED_MESH				
MSHID	PID	NBID	EBID	
1	11	100001	100001	
CPIDX	CPIDY	CPIDZ	NID0	LCSID
1001	1002	1003		

*ALE_STRUCTURED_MESH_CONTROL_POINTS			
1001			
1		-107.5	
216		107.5	

*ALE_STRUCTURED_MESH_CONTROL_POINTS			
1003			
1		-15.0	
31		15.0	

*ALE_STRUCTURED_MESH_CONTROL_POINTS			
1002			
1		-30.0	
61		30.0	

MSHID: Mesh ID
PID: Part ID assigned to the mesh
NBID/EBID: Starting Node/Element ID
NID0: Origin Node ID
LCSID: Local Coordinate System ID

Step 2: Multi-materials

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP							
AMMGNM	MID	EOSID					PREF
rod	1	1					0.0
air	3						101325.0
plate	2	2					0.0

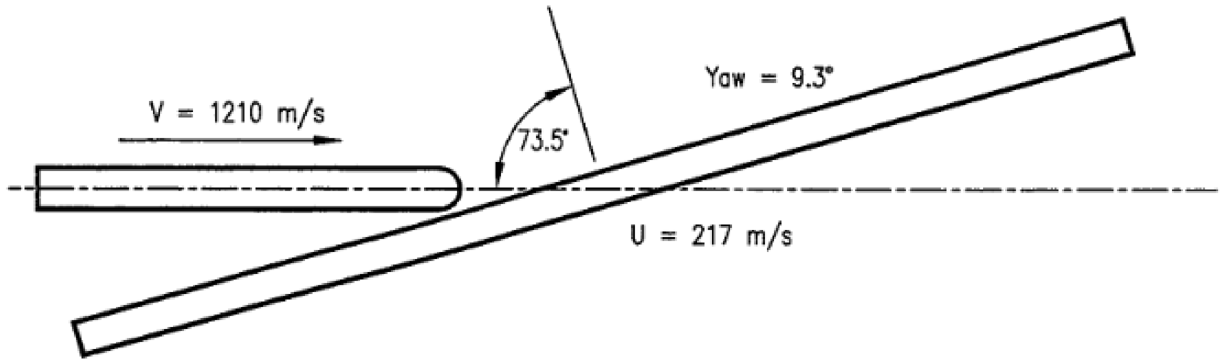

Figure 2. Initial Conditions for Combined Yaw and Obliquity Impact Simulation

PREF: Each multi-material could have its own reference pressure.

Before: PREF in *CONTROL_ALE applied on ALL multi-materials.

Problem: HE starts from 0 while air starts from 1 bar.

Step 3: Fill the mesh

*ALE_STRUCTURED_MESH_VOLUME_FILLING							
MSHID		AMMGTO					
1		air					
GEOM	IN/OUT						
ALL	0						

First, fill all with “air”

*ALE_STRUCTURED_MESH_VOLUME_FILLING							
MSHID		AMMGTO					
1		plate					
GEOM	IN/OUT	BOXID					
BOXCOR	0	1					

Next, fill inside the box with “plate”

*ALE_STRUCTURED_MESH_VOLUME_FILLING							
MSHID		AMMGTO					
1		rod					
GEOM	IN/OUT	NID1	NID2	R1	R2		
CYLINDER	0	1	2	3.835	3.835		

Finally, fill inside the cylinder with “rod”

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S-ALE 2D

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_AXISYM							
AMMGNM	MID	EOSID					PREF
rod	1	1					0.0
air	3						101325.0
plate	2	2					0.0

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_PLNEPS							
AMMGNM	MID	EOSID					PREF
rod	1	1					0.0
air	3						101325.0
plate	2	2					0.0

S-ALE FSI

More stable, faster, less memory usage

Better Leakage Control

Easier to setup

*ALE_STRUCTURED_FSI

*ALE_STRUCTURED_FSI							
StructID	ALEID	SSTYP	ALESTYP				MCOUP
		PFAC			IFLIP		

StuctID: Structure ID
ALE ID: S-ALE mesh PART ID
SSTYP: PARTSET/PART/SEGSET (0/1/2)
MSTYP: PARTSET/PART (0/1)

MCOUP: ALE fluids to be coupled
FLIP: Flip structure normal or not
PFAC: Penalty Stiffness
=-N: Load Curve (recommended)

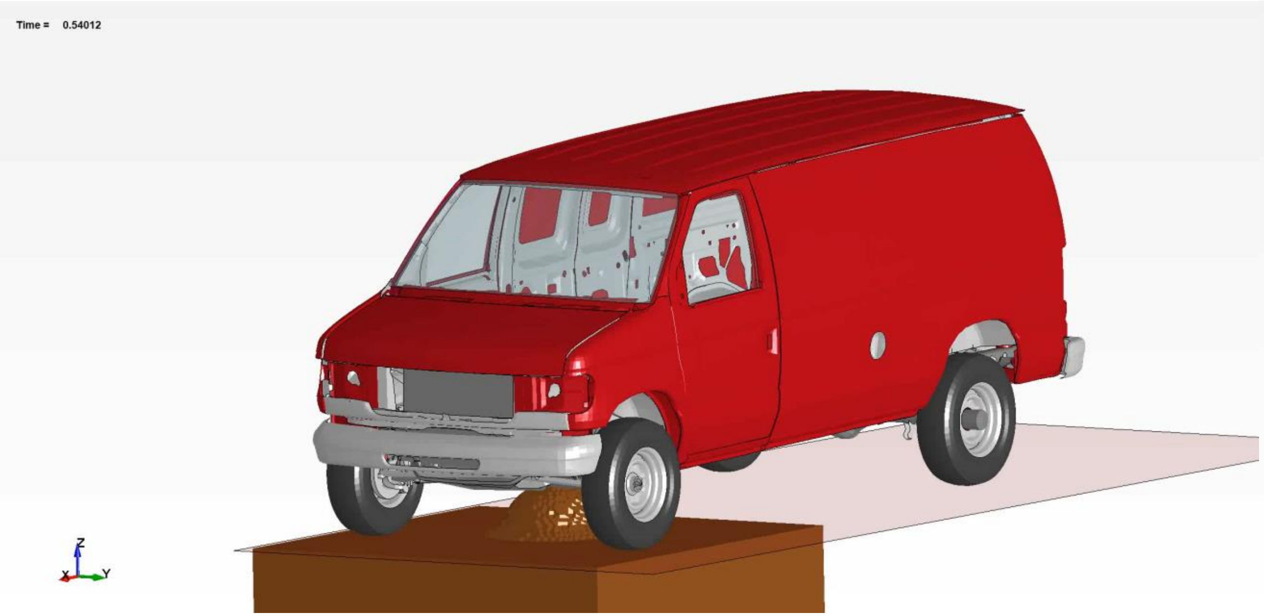
Automate Everything:

- All parameters are internally calculated, automatically chosen.
- PFAC: Penalty stiffness is the only one users need to pick.
- Automated Leakage control
- Eroding option always on
- Edges automatically generated and on

Better Performance:

- Enhanced Leakage Control
- Stable, Faster
- MPP efficiency greatly improved; Nonblocking, Groupable MPP

Ford Econoline Under IED by Eric Piskula



3D : from t=0.54 to 15ms, close effects of explosive & soil; Courtesy: Eric Piskula, Ansys ACE

sequence	Time
2D Axisymmetric T=0 to 0.54ms	31 minutes
3D FSI step T=0.54ms to 15ms	126 hours
3D lifting T=15ms to 100ms	8 hours
Total	135 hours (5 days 15 hours)

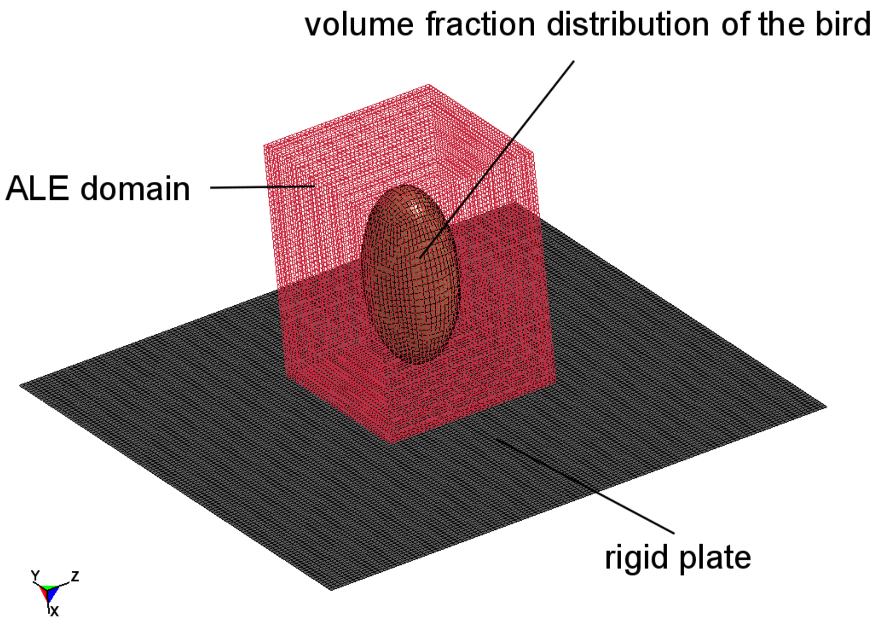
Intel(R) Xeon(R) CPU E5-2687W 0 @3.1GHz, 16 cores 128GB memory

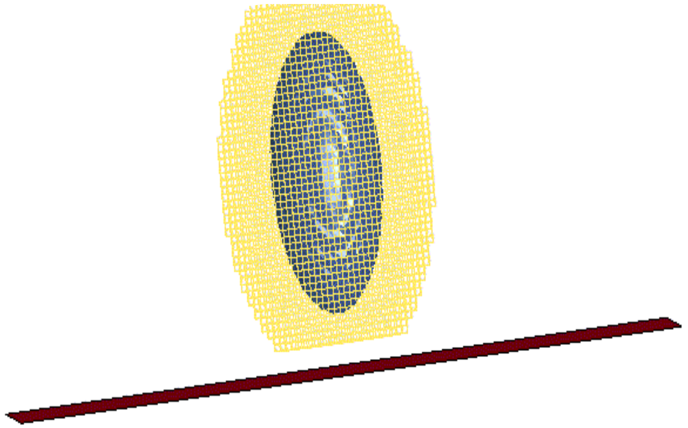
So in conclusion, the new S-ALE features available in R12 are very promising for complex FSI applications and as seen with the buried landmine demo, ***they demonstrate a robustness never seen before***. -- “Explosion with S-ALE & new features”, FEAINFO, Feb 2021, Eric Piskula

Recent Progress

S-ALE Mesh Trimming

- S-ALE mesh needs to be regular, box-shaped.
- Elements far away from our point of interest not needed.
- Solution: Trim the S-ALE mesh at places irrelevant to the simulation to save the cost.
- The cost saving could be significant as the cost is proportional to the number of elements.





METHODS	# of Eles	SMP	Savings	MPP 4 Core	Savings
ALE	84800	1204 s		321 s	
S-ALE	84800	675 s	44%	191 s	40%
S-ALE trim	43219	426 s	65%	112 s	65%

Run time comparison between 3 runs

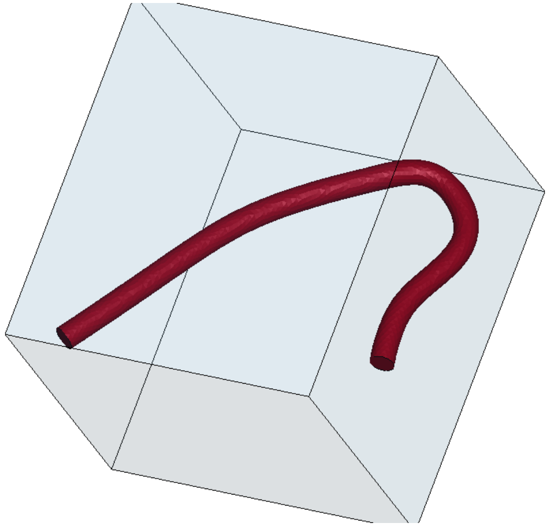
*ALE_STRUCTURED_MESH_TRIM

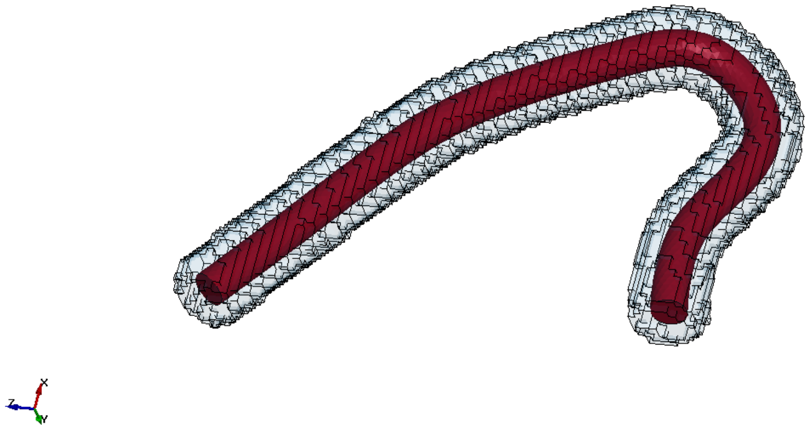
*ALE_STRUCTURED_MESH_TRIM							
MESHID	OPTION	OPER	OUT/IN	SETID	OFFSET		
1	SEGSET			2	10.0		

- Allow for multiple entries; processed in the order of appearance.
- OPTION:
  - Simple geometries like PLANE, CYLINDER, BOX, SPHERE;
  - Geometry is Lagrange Structure (PARTSET or SEGMENT SET)
- OPER: 0 to Trim or 1 to Untrim
- OUT/IN: 0 to trim outside or 1 to trim inside

Original box mesh of 75x63x68 = 321,300 elements; Trimmed at an offset of 10.0 mm; The resultant mesh contains only 14,173 elements; A reduction of 95%.

Glue Compression





https://ftp.lstc.com/anonymous/outgoing/hao/sale/models_R121/trim/

S-ALE Mesh Motion: Symmetric Plane

*ALE_STRUCTURED_MESH_MOTION							
MSHID	COMMAND	AMMGSET	EXPLIM				ISYM
1	FOLLOW_GC	1	2.0				010

ISYM: : Set symmetric plane(s) to control S-ALE mesh motion.

A three digit number, $[XYZ]$, to define symmetry:

$$\text{ISYM} = 100 \times X + 10 \times Y + Z$$

Each digit specifies one direction, X for the local x, Y for local y, and Z for local z (local x, y, and z are defined in *ALE_STRUCTURED_MESH). Each digit can have the following values:

EQ.0: No symmetry

EQ.1: Symmetry plane along the face with a normal vector in the negative direction

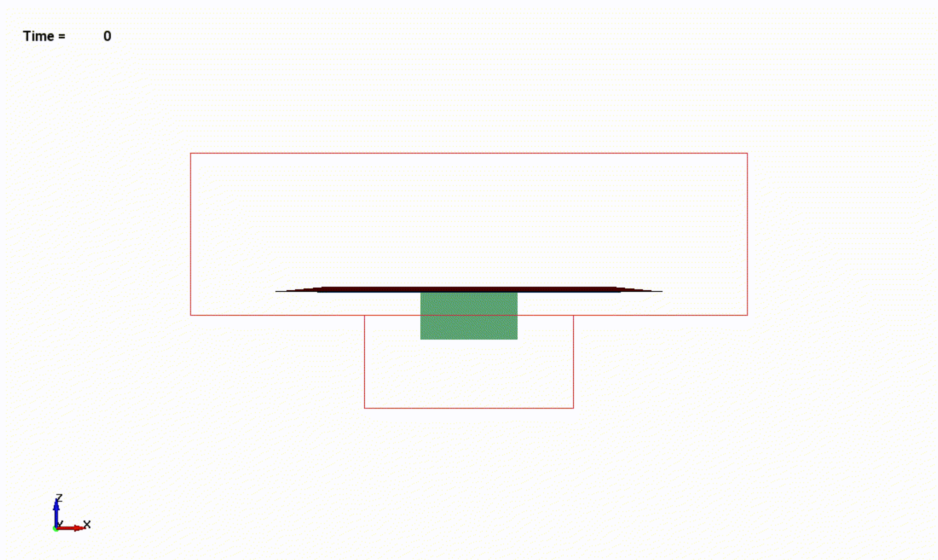
EQ.2: Symmetry plane along the face with a normal vector in the positive direction

For example, ISYM = 201 means quarter symmetry with symmetry planes at the faces with normal vectors +x and -z. 111 means 1/8 symmetry with symmetry planes at the faces with normal vectors -x, -y and -z.

*ALE_STRUCTURED_MESH_MOTION: COVER_LAG

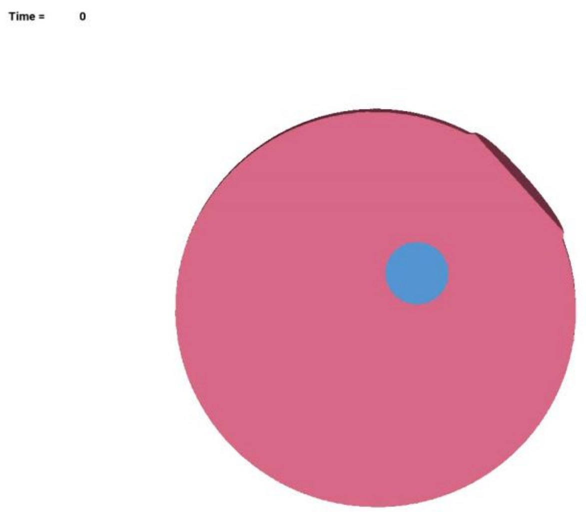
*ALE_STRUCTURED_MESH_MOTION						
MSHID	OPTION	SID	SIDTYPE	NODCEN		FRCPAD
1	COVER_LAG	101	0			

COVER_LAG: : to make the mesh follow the motion of a Lagrangian structure and expand/contract so that the Lagrangian structure is fully covered in the S-ALE mesh. It is most useful to model airbag deployment.



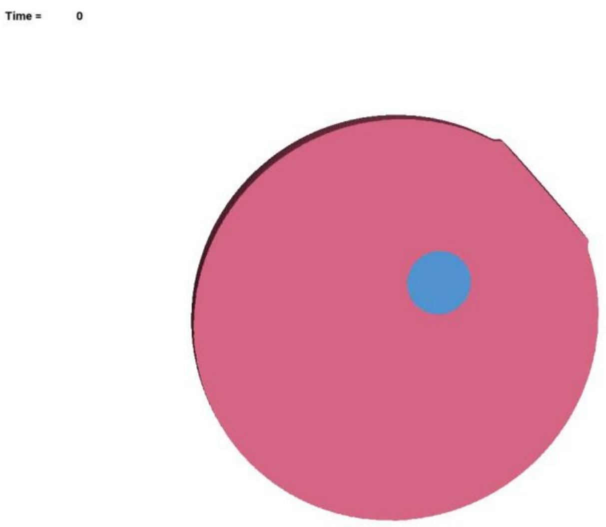
https://ftp.lstc.com/anonymous/outgoing/hao/sale/models/meshmotion/airbag1/

*ALE_STRUCTURED_FSI: Leakage Prevention



***ALE_STRUCTURED_FSI:** came with a much better leakage prevention

- Much more accurate at capturing fluid interface
- Not only process structure segments, but also edges, nodes.
- Enhanced leakage control algorithm
  - Better estimation of spring stretch
  - Innovative algorithm to achieve energy balance
  - New algorithm is order-free → more stable
- New MPP implementation (order-free calculation) ➔ more stable



However, at times, still, leakages do occur, mostly

- Highly pressurized + Light material (gas, air) → Blast, detonation
- A little unbalanced penalty spring forces would cause high pressure gradient at places → Air always manages to find the low-pressure place and goes there.

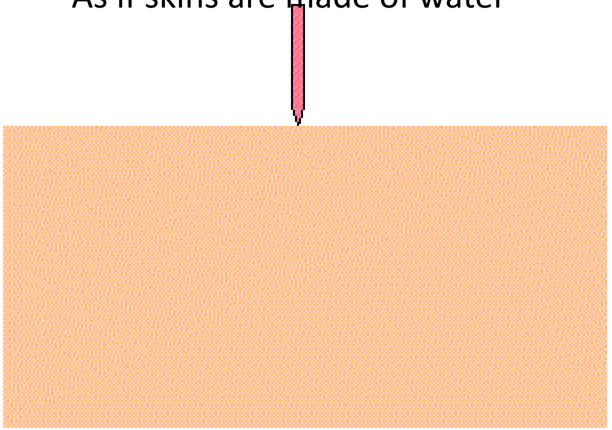
A recent algorithm enhancement → big improvement

*ALE_STRUCTURED_FSI: Variable Friction in FSI

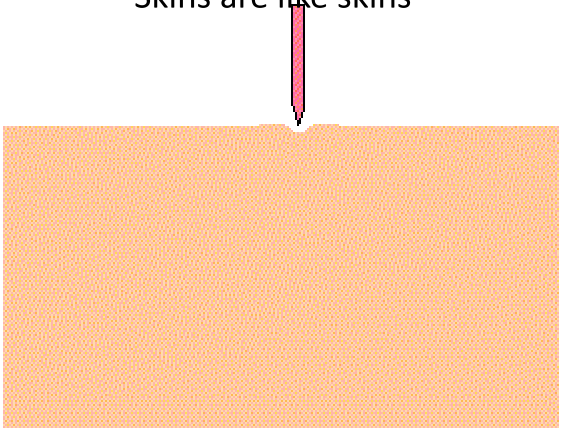
*ALE_STRUCTURED_MESH_FSI							
SLAVE	MASTER	SSTYP	MSTYP				MCOUP
START	END	PFAC	FRIC			FLIP	

FSI quadrature
Time = 0

Without friction
As if skins are made of water



With friction
Skins are like skins



Needle Insertion

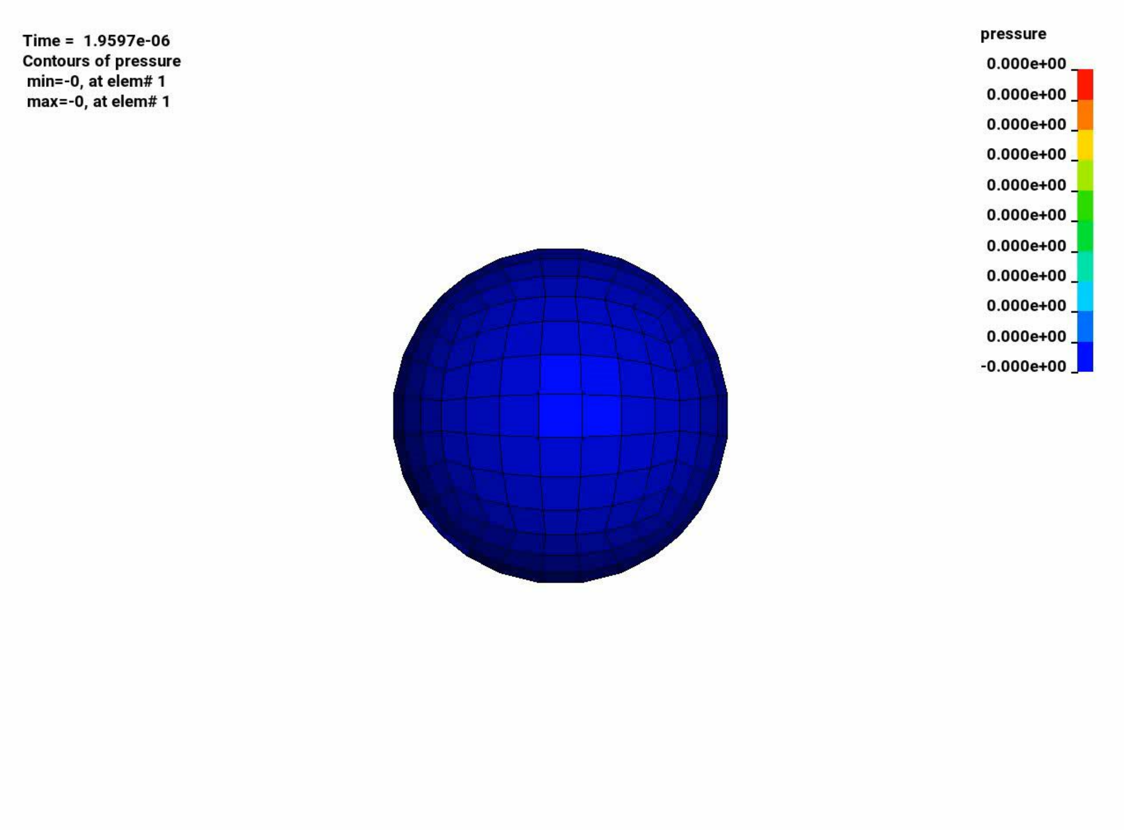
FRIC:
= “0.1” (constant friction coeff)
= “-N” (variable friction, N table ID)

Table:
Coupling pressure versus load curve

Load Curve:
Relative velocity versus fric coeff

```
*DEFINE_TABLE
       2
          0.00          3
        1.00e2          4
        1.00e3          5
        1.00e4          6
*DEFINE_CURVE
       3
         0.000        0.600
         1.0e9        0.600
*DEFINE_CURVE
       4
         0.000        0.500
         1.0e9        0.500
*DEFINE_CURVE
       5
         0.000        0.300
         1.0e9        0.300
*DEFINE_CURVE
       6
         0.000        0.100
         1.0e9        0.100
```

*ALE_STRUCTURED_FSI: Interface Force File



lsdyna i=input.key h=fsifor

To show FSI segment pressure, force, etc. on each segment

- LAG structure segments geometries shown;
- And pressure/forces data could be fringed out
- ALE elements/nodes not shown.

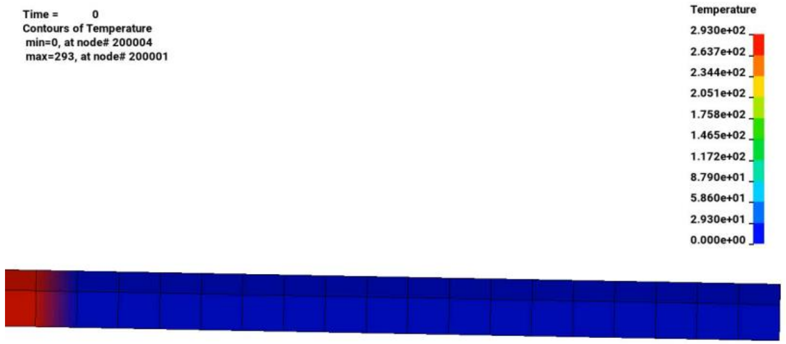
Enhancement: skip S-ALE mesh and nodal info.

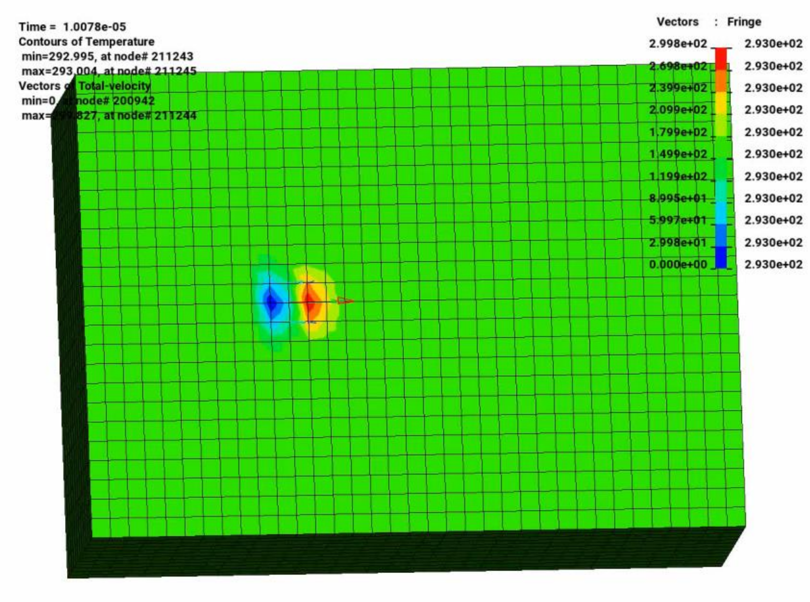
- Element connectivity (state 0)
- External nodal user IDs (state 0)
- Coordinates, velocities (per state)
- Big reduction in file sizes, especially for models with huge numbers of S-ALE elements (tens of millions)

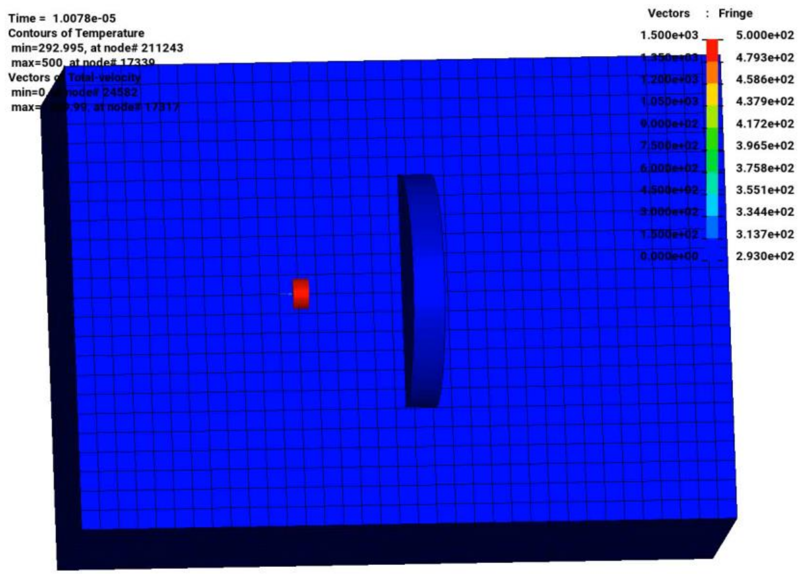
The example shown was with ~10k S-ALE nodes;
File Size Reduction: 22M→1M (11134 nodes → 486 nodes)

S-ALE: Thermal Support

A penetrator hitting a target, flying in S-ALE air. Temperature and Velocity Shown.







Temperature plot: 20 elements; half air, half vacuum.
Under constant flow

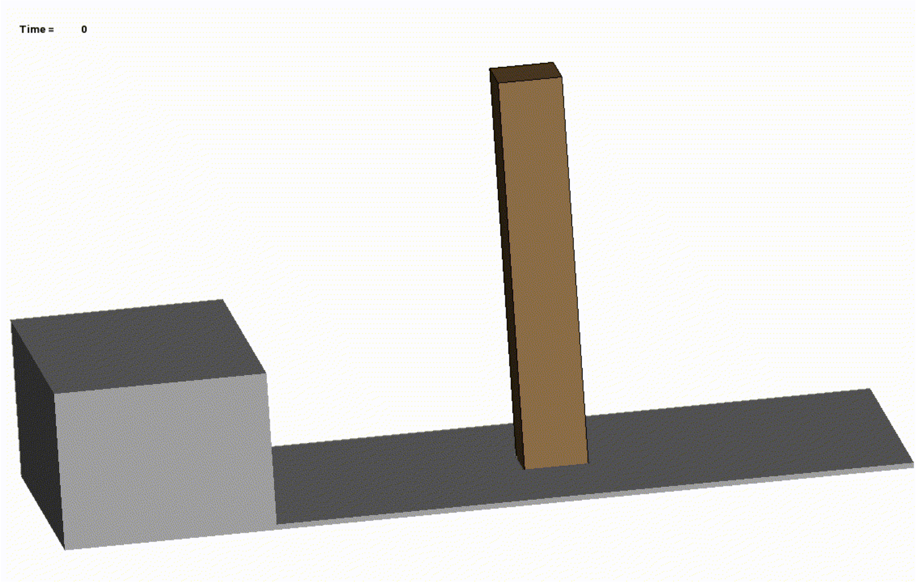
***Courtesy: Jenson Chen, DFE Tech**
https://ftp.lstc.com/anonymous/outgoing/hao/sale/models/thermal/

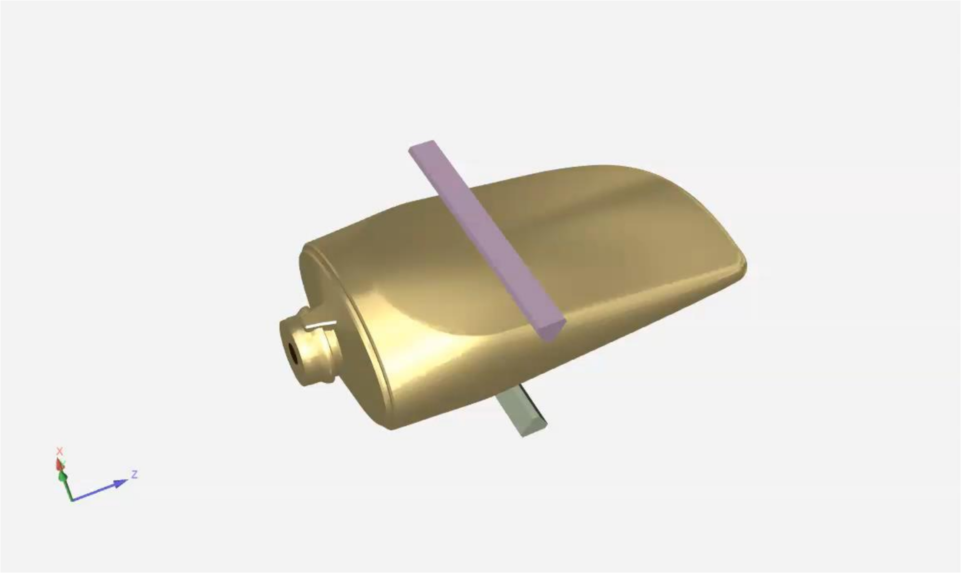
- TOPAZ only supported ELFORM 5 and ELFORM 12 (single material with void)
- Heat capacity and thermal conductivity matrices: Each element only allows for 1 material
- Additional inner loop. Loops through each ALE multi-material
- FSI thermal support to allow heat exchanges between fluids and structure (*CLIS, for now)
- Other special treatments throughout the code

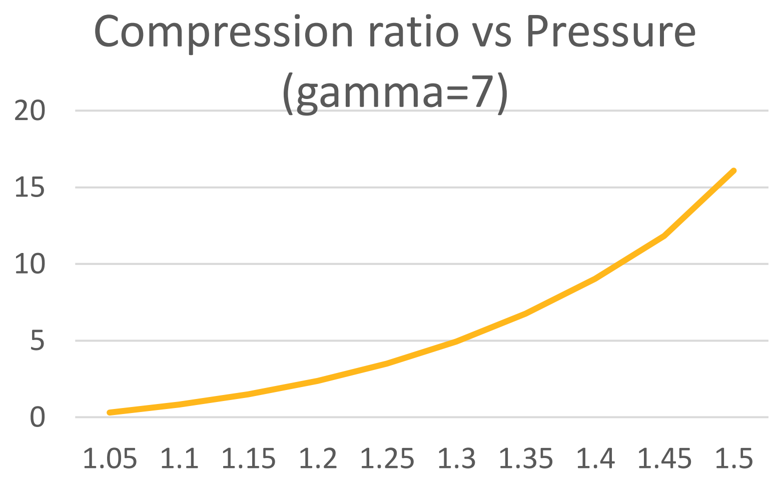
*EOS_MURNAGHAN: ALE support added -- long duration process

*EOS_MURNAGHAN:

Long duration, low speed flow. We scale up the timestep by reducing the sound speed. This approach is physically sound as long as the reduced sound speed is still 10 times larger than the flow speed.



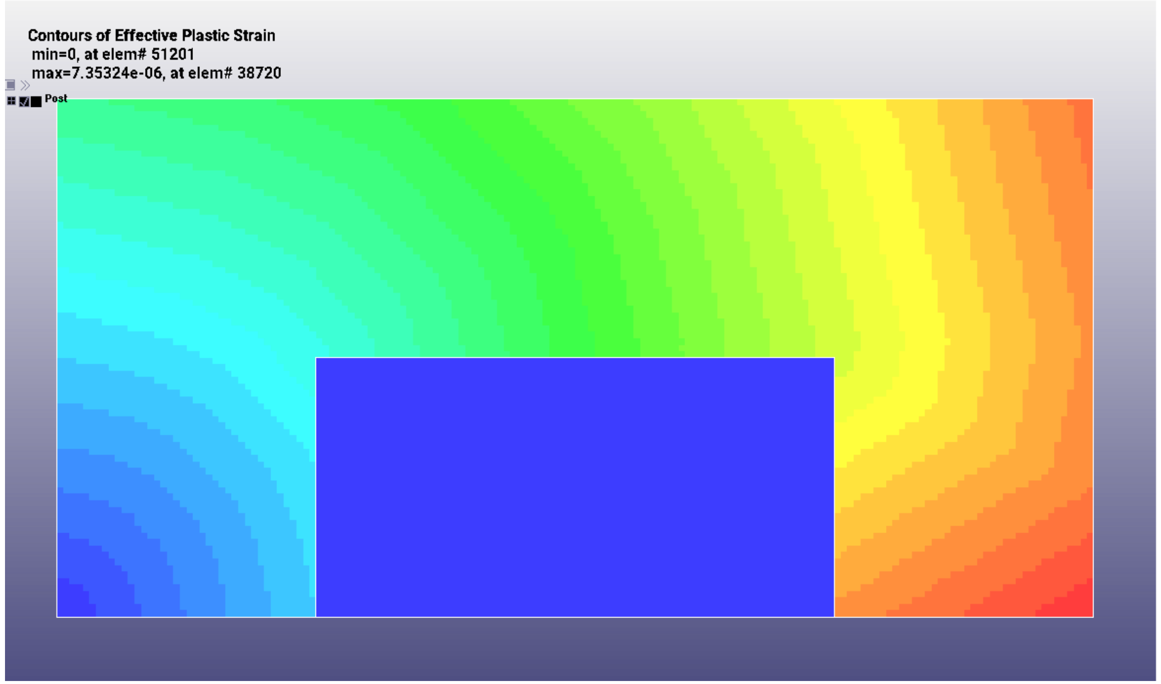




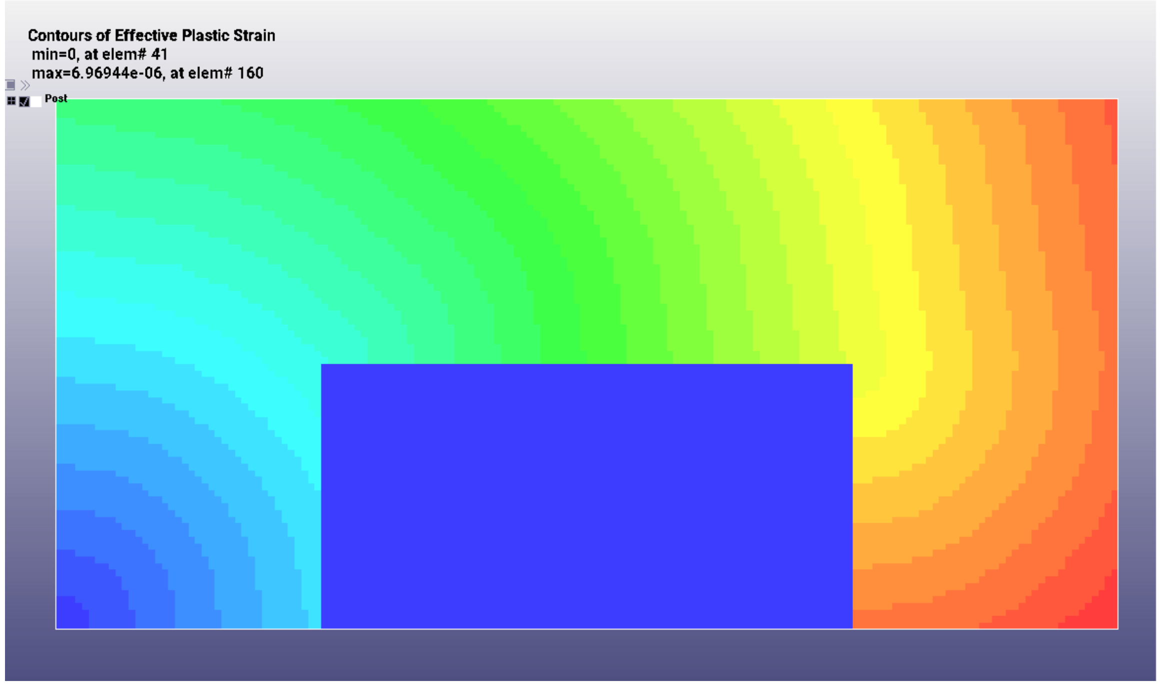
Fast: 2.5 million ALE elements; 4s simulation time finished in 3hrs with 48 cores

*CONTROL_EXPLOSIVE_SHADOW reimplemented for S-ALE

Previous



New



https://ftp.lstc.com/anonymous/outgoing/hao/sale/models_R121/HE_shadow/

Detonation time (e-6)	Theoretical	Old	Error	New	Error	LVL=2	Error
Upper-right Corner	6.58108	6.7573	2.68%	6.58746	0.09%	6.68485	1.57%
Lower-right Corner	6.94192	7.3298	5.58%	6.95685	0.21%	6.95685	0.21%

Ansys