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ADIABATIC EXPANSION OF HIGH EXPLOSIVE DETONATION PRODUCTS

S-ALE 2D axisymmetric Model

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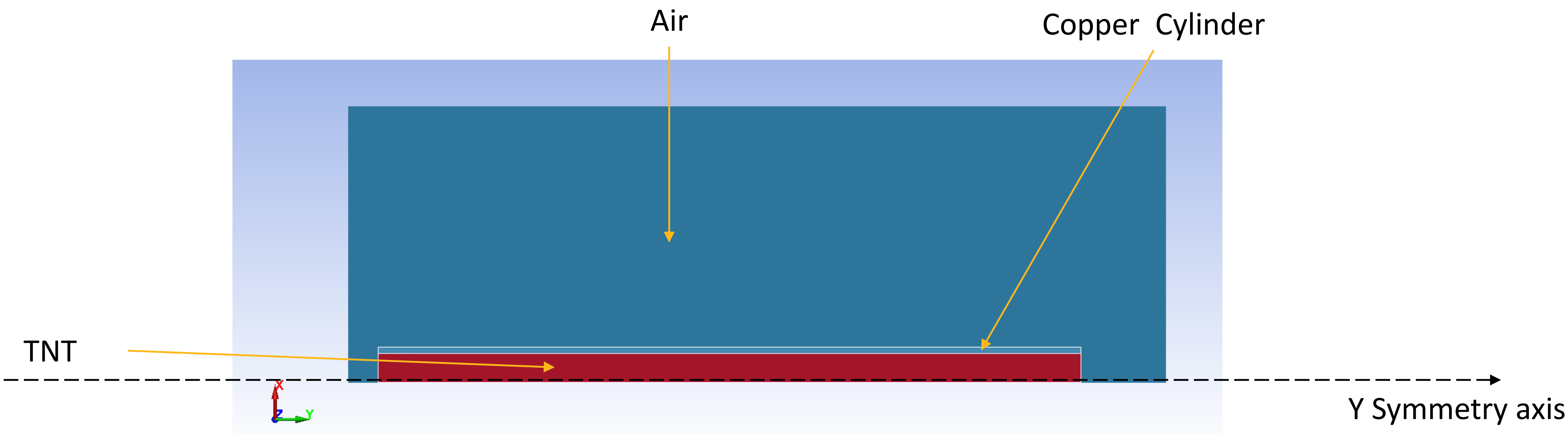
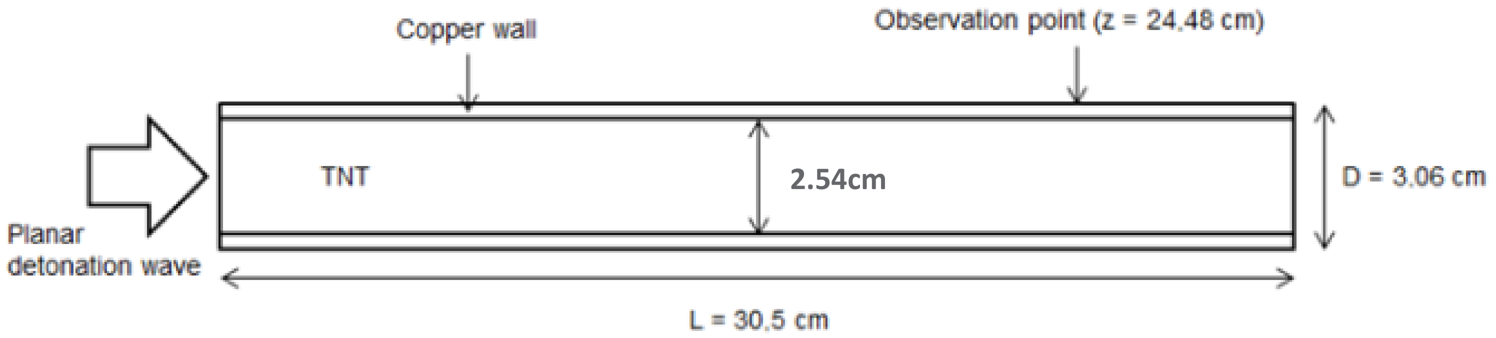
Summary

- The cylinder test was developed at Lawrence Livermore Laboratory (LLNL) with the aim of characterizing the adiabatic expansion of the detonation products, by measuring the motion of the cylinder wall while it is expanded by the detonation products of the explosive charge inside. The cylinder test typically yields an expansion radius history curve that can be associated with the relative expansion volume and the Gurney-type energy density, from which the detonation products energy along its expansion can be obtained. The expansion energy function of the volume is used to derive the detonation products equation of state, of which the JWL (Jones-Wilkins-Lee) is the most widely used.
- Numerical modeling simulations to assess the quality of the JWL parameter sets obtained have been carried out with the LS-DYNA hydrocode. 2D axisymmetric models with Eulerian formulation for the explosive and 2 different modeling techniques for the cylinder wall (Lagrangian, Arbitrary Lagrangian Eulerian) have been used

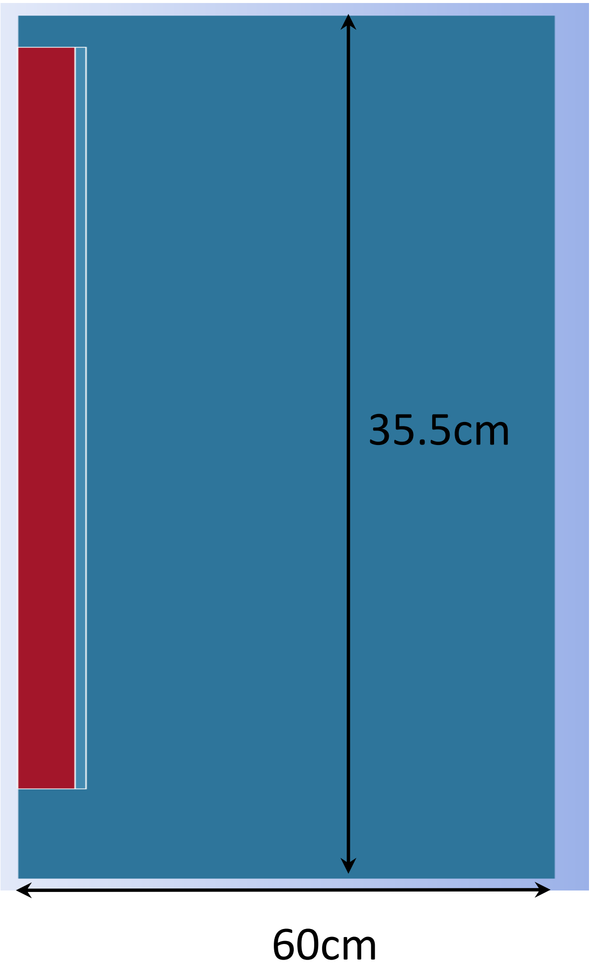
2D axisymmetric

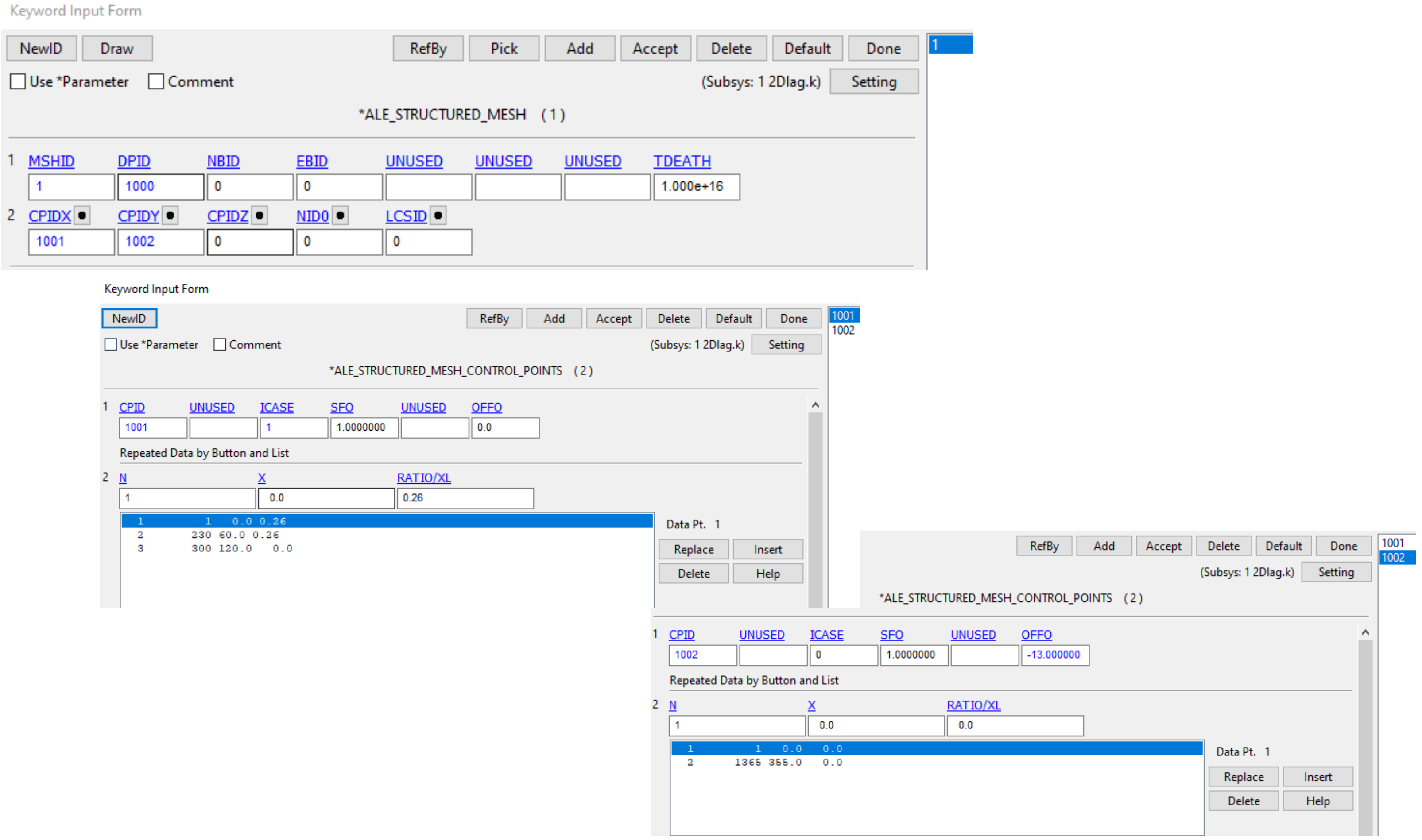




S-ALE domain

- Surrounding air domain enough big to cylinder deformations





Materials

- Copper
  - Johnson Cook (Mat 15) + EOS Gruneisen

*MAT_JOHNSON_COOK_(TITLE) (015) (1)

TITLE

1	MID	RO	G	E	PR	DTF	VP	RATEOP
	3	8.960e-06	45.925999	0.0	0.3500000	0.0	0.0	0.0
2	A	B	N	C	M	TM	TR	EPSO
	0.0900000	0.2920000	0.3100000	0.0250000	1.0900000	1656.0000	293.00000	1.0000000
3	CP	PC	SPALL	IT	D1	D2	D3	D4
	383.00000	0.0	2.0000000	0.0	0.0	0.0	0.0	0.0
4	D5	C2/P/XNP/D	EROD	EFMIN	NUMINT	K	EPS1	
	0.0	0.0	0.0	1.000e-06	0.0	0.0	0.0	

Plot Raise New Padd

*EOS_GRUNEISEN_(TITLE) (1)

TITLE

1	EOSID	C	S1	S2	S3	GAMMA0	A	E0
	2	3940.0000	1.4890000	0.0	0.0	1.9700000	0.4700000	0.0
2	V0	UNUSED	LCID					
	1.0000000		0					

Materials

- TNT
  - High Explosive Burn(Mat 08) + EOS JWL

*MAT_HIGH_EXPLOSIVE_BURN_(TITLE) (008) (1)

TITLE

MID	RO	D	PCJ	BETA	K	G	SIGY
1	1.630e-06	6930.0000	21.000000	0.0	0.0	0.0	0.0

*EOS_JWL_(TITLE) (1)

TITLE

	EOSID	A	B	R1	R2	OMEG	E0	VO
1	1	371.20999	3.7230000	4.1500001	0.9500000	0.3000000	7.0000000	0.0

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_AXISYM (2)

AMMGNM	MID	EOSID	UNUSED	UNUSED	UNUSED	UNUSED	PREF
TNT	1	1					0.0

- Air
  - Null (Mat 09) + EOS Linear Polynomial

*MAT_NULL_(TITLE) (009) (1)

TITLE

	MID	RO	PC	MU	TEROD	CEROD	YM	PR
1	4	1.000e-09	0.0	0.0	0.0	0.0	0.0	0.0

*EOS_LINEAR_POLYNOMIAL_(TITLE) (1)

TITLE

	EOSID	C0	C1	C2	C3	C4	C5	C6
1	3	0.0	0.0	0.0	0.0	0.4000000	0.4000000	0.0

	E0	V0
2	2.500e-04	0.0

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_AXISYM (4)

	AMMGNM	MID	EOSID	UNUSED	UNUSED	UNUSED	UNUSED	PREF
1	Air	4	3					0.0

S-ALE Filling for Air & TNT

- Initialization by a full filling with Air

*ALE_STRUCTURED_MESH_VOLUME_FILLING (2)

MSHID	UNUSED	AMMGTO	UNUSED	NSAMPLE	UNUSED	UNUSED-	VID
1		1		3			0
GEOM	**IN/OUT**	**E1**	**E2**	**E3**	**E4**	**E5**	
ALL	0	0.0	0.0	0.0	0.0	0.0	

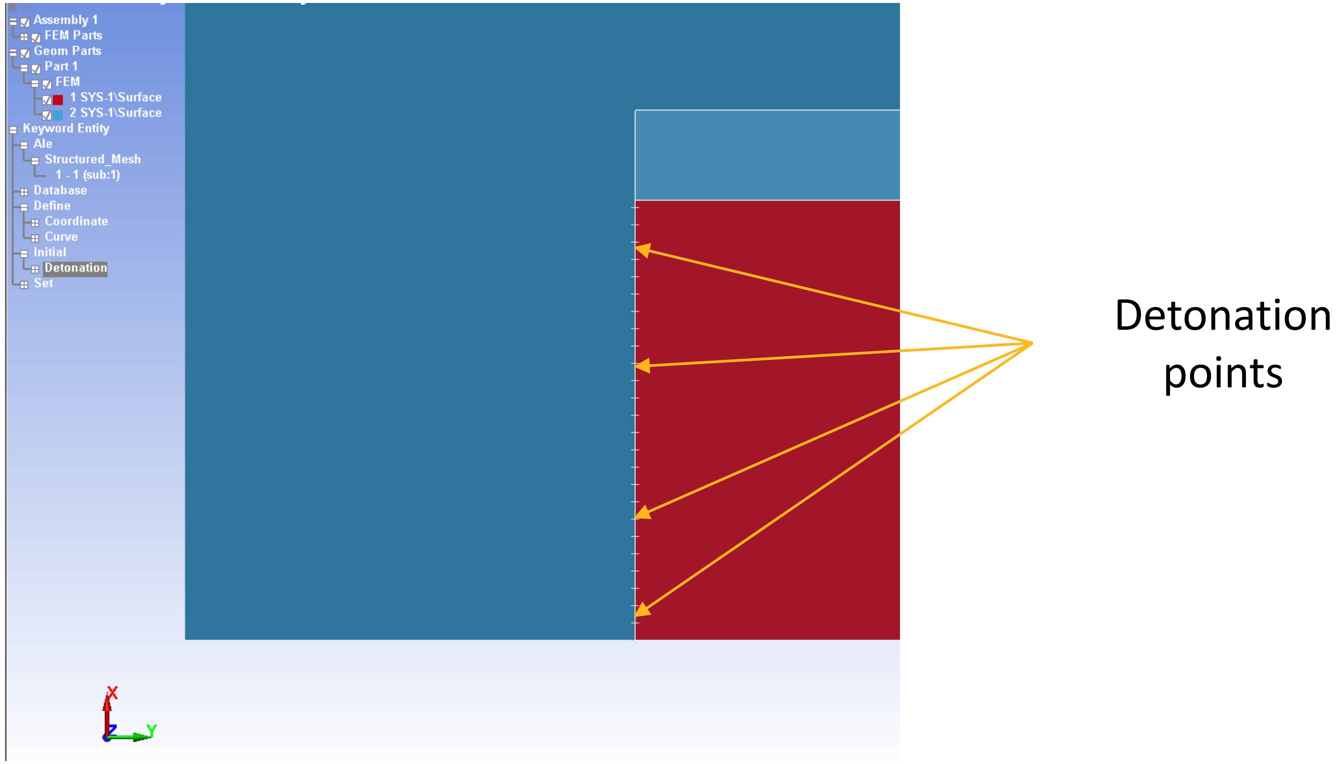
- Filling Explosive in using a dummy Lagrangian part (rigid)

*ALE_STRUCTURED_MESH_VOLUME_FILLING (2)

MSHID	UNUSED	AMMGTO	UNUSED	NSAMPLE	UNUSED	UNUSED-	VID
1		3		3			0
GEOM	**IN/OUT**	**PID**	**E2**	**E3**	**E4**	**E5**	
PART	0	1	0.0	0	0	0	

Initialization of explosive

- TNT explosive is detonated with a booster explosive generating a planar shockwave hitting the TNT
  - For simplification, detonation points are defined enough close to generate a planar detonation wave



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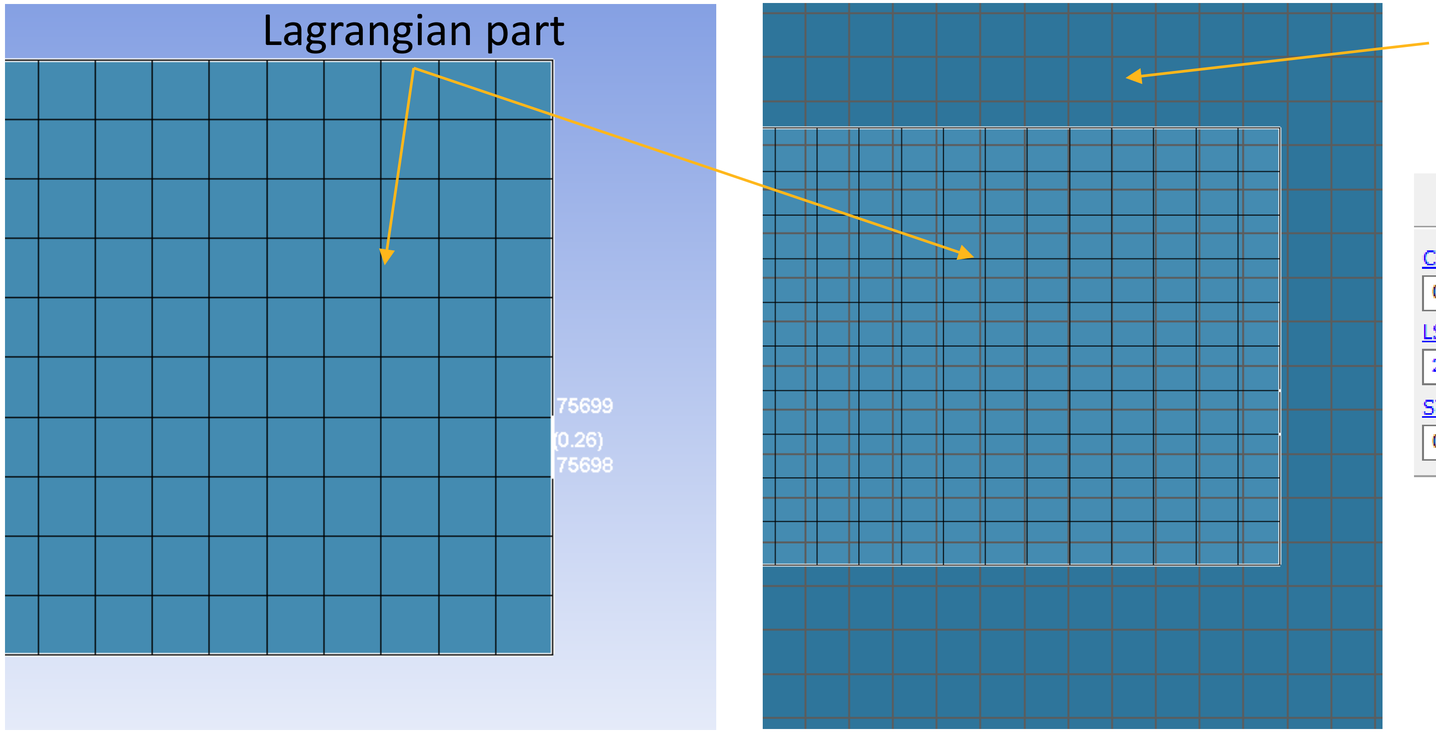
Case with Cylinder Wall / Lagrangian Approach

- The mesh part overlaps the Eulerian domain and FSI is required to interact Eulerian domain with the Lagrangian part



Eulerian domain

*ALE_STRUCTURED_FSI (1)

COUPID	TITLE						
0							
LSTRSID	ALESID	LSTRSTYP	ALESTYP	-	-	-	MCOUP
2	1000	1	1				-1
START	END	PFAC	FRIC	-	FLIP		
0.0	1.000e+10	1.0	0.0		0		

Mesh size for Lagrangian & Eulerian domain is 0.26mm

Case with Cylinder Wall / Eulerian Approach

- the Eulerian domain is just fill with dummy part (rigide) like the TNT - no FSI is required

*ALE_STRUCTURED_MESH_VOLUME_FILLING (3)

MSHID	UNUSED	AMMGTO	UNUSED	NSAMPLE	UNUSED	UNUSED-	VID
1		2		3			0
GEOM	**IN/OUT**	**PID**	**E2**	**E3**	**E4**	**E5**	
PART	0	2	0.0	0	0	0	

- Copper material must be defined like a multi-material

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_AXISYM (4)

	AMMGNM	MID	EOSID	UNUSED	UNUSED	UNUSED	UNUSED	PREF
1	COPPER	3	2					0.0

- As MAT Johnson-Cook (015) allows failure -> a Vacuum material must be defined

*ALE_STRUCTURED_MULTI-MATERIAL_GROUP_AXISYM (4)

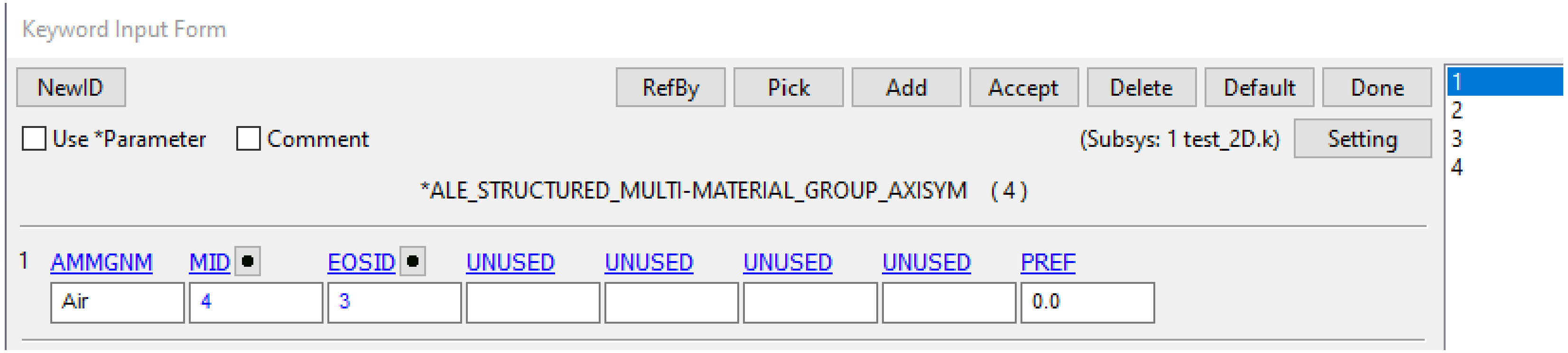
	AMMGNM	MID	EOSID	UNUSED	UNUSED	UNUSED	UNUSED	PREF
1	vaccum	5	0					0.0

*MAT_VACUUM_(TITLE) (140) (1)

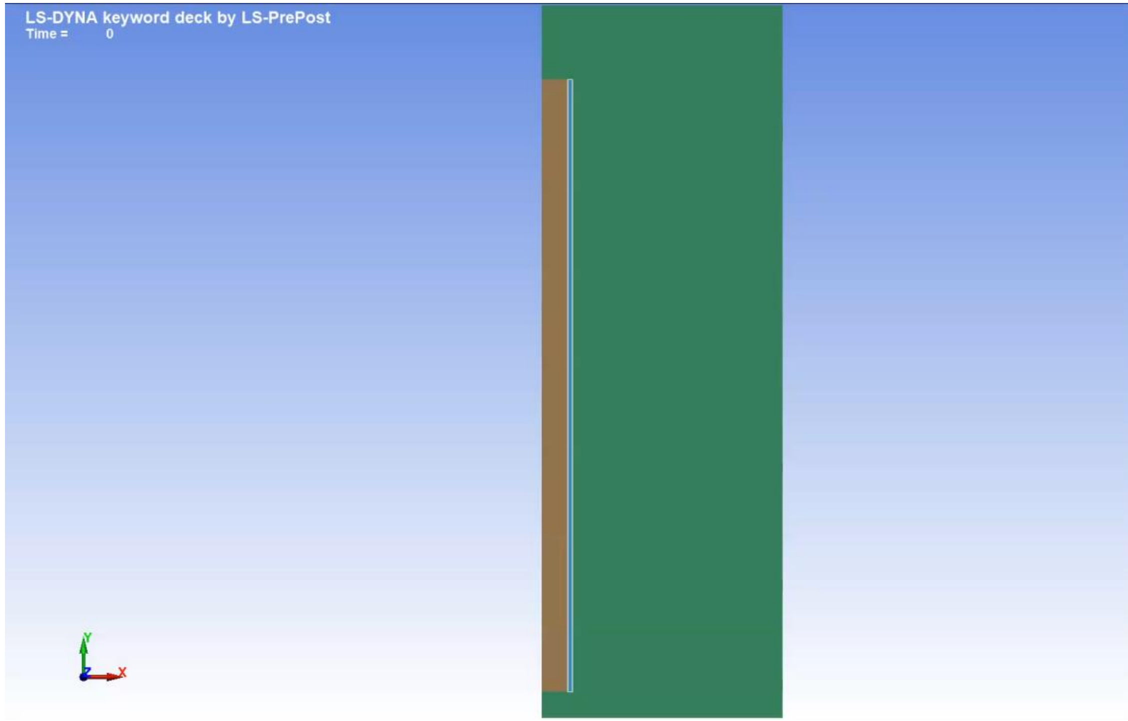
TITLE	
MID	**RHO**
5	1.000e-09

Case with Cylinder Wall / Eulerian Approach

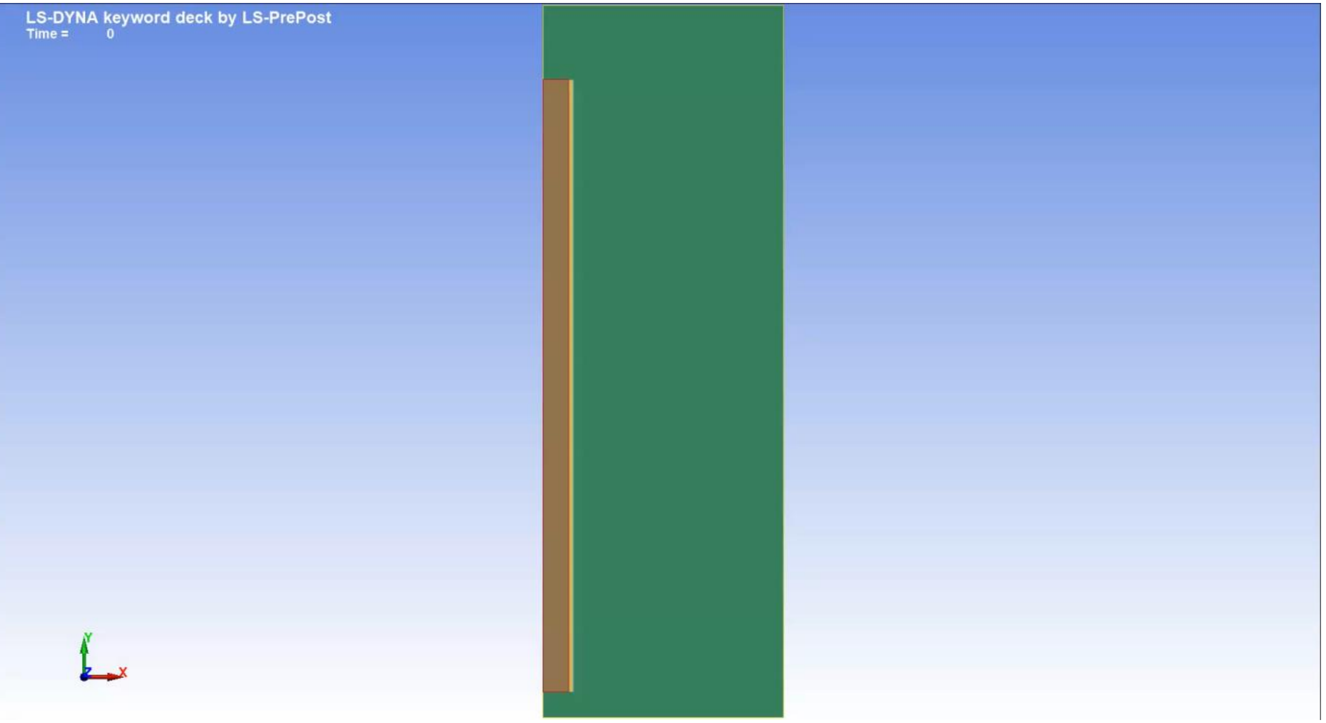
- 4 ALE multi materials are defined :
  - Air - 1
  - Copper - 2
  - TNT - 3
  - Vacuum - 4



Results

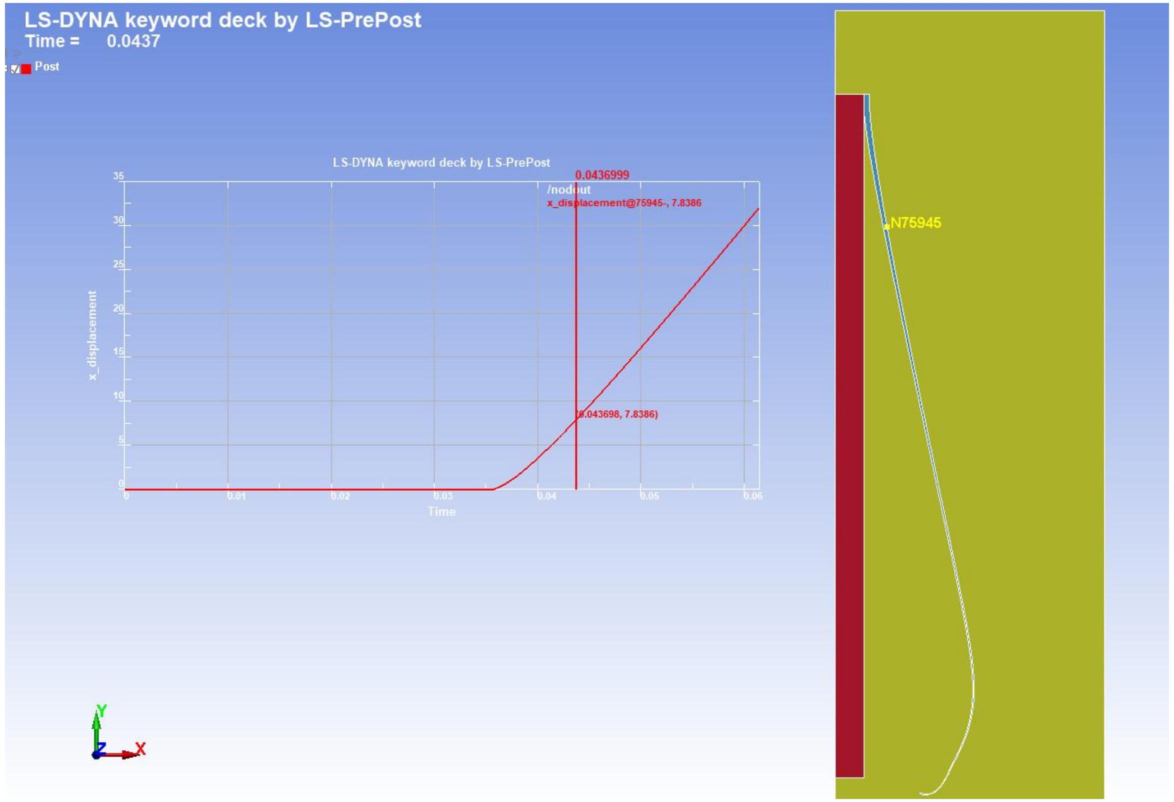


Lagrangian

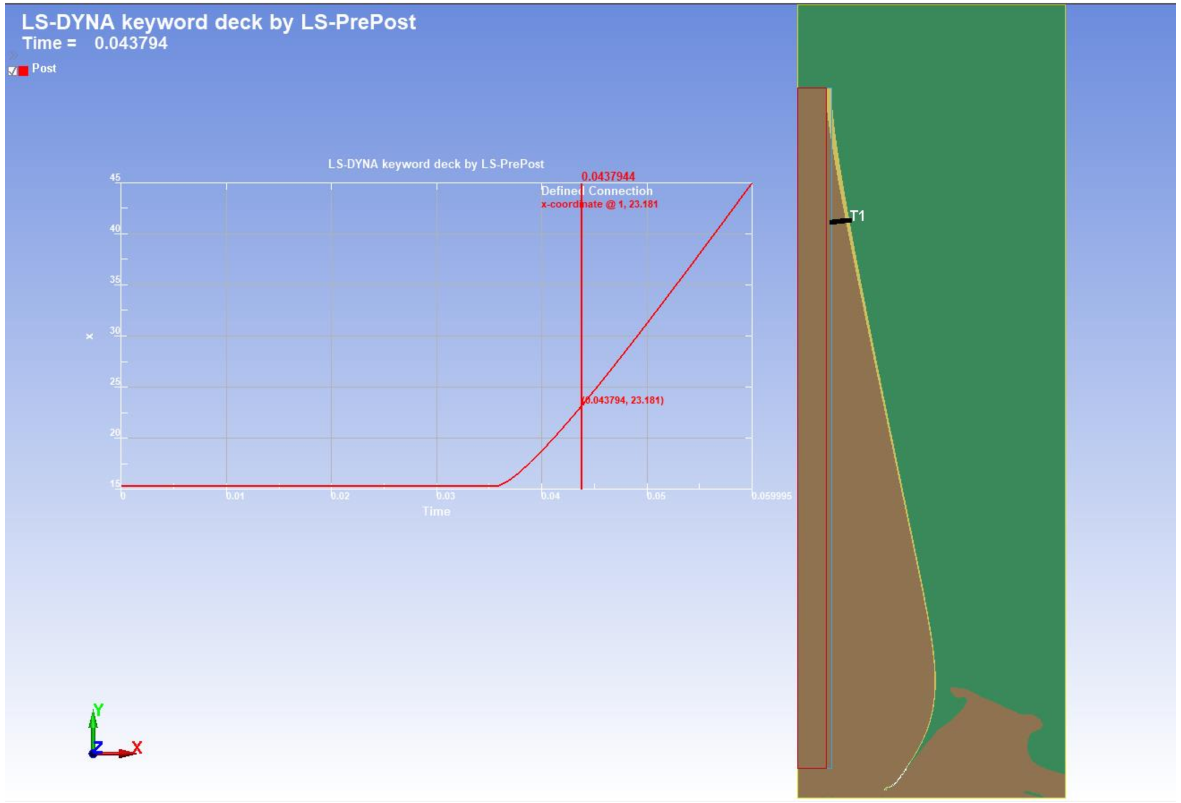


Eulerian

Results



Lagrangian



Eulerian

Comparison with real test

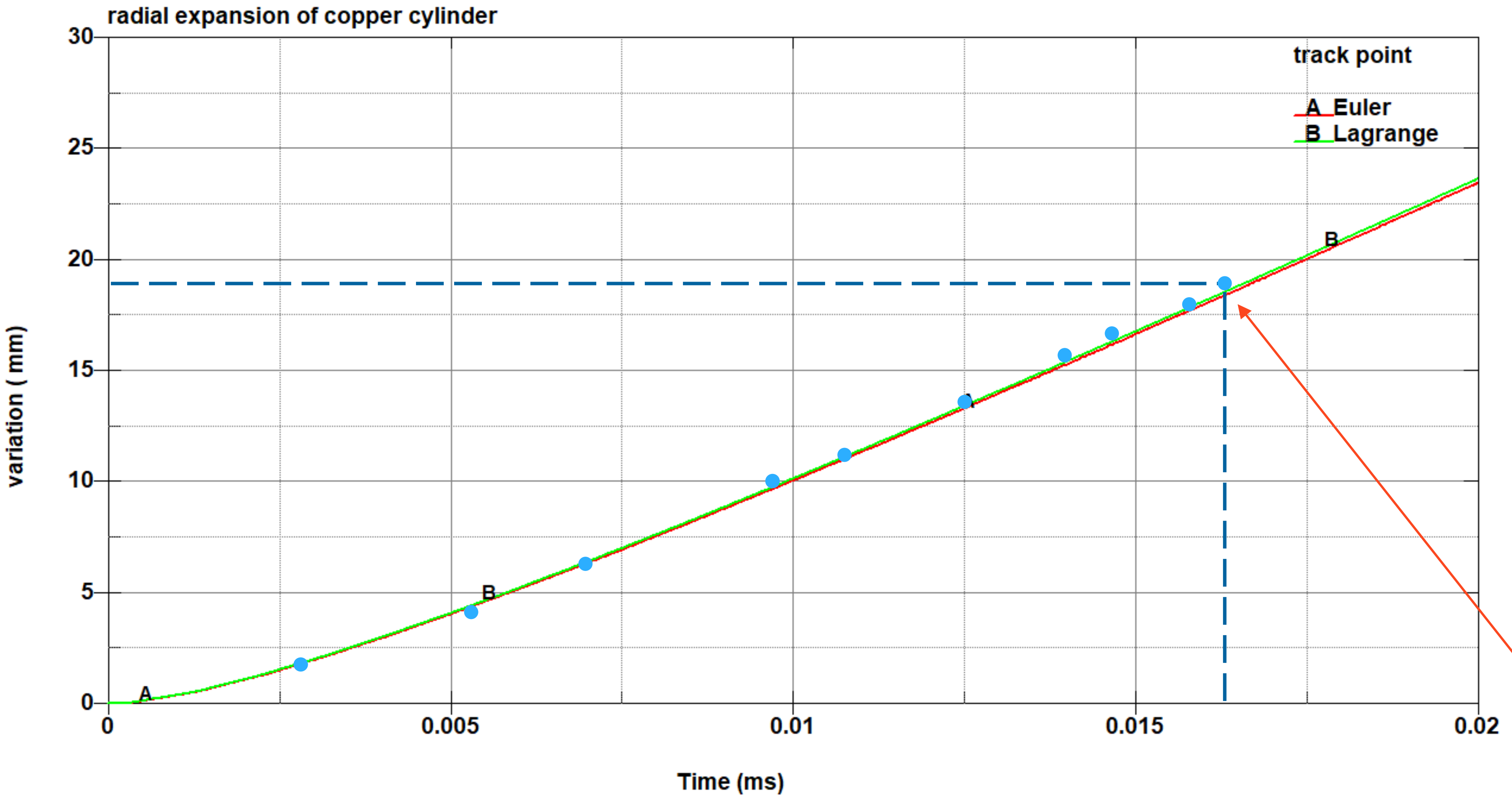


Table IVb. Cylinder test data for 1-in., 2-in., and 4-in. scaled TNT.

$R - R_0$ (cm)	2.54 cm diam TNT 0.2606 cm copper wall t/1 at $(R - R_0)/1$ (μsec)	5.08 cm diam TNT 0.521 cm copper wall t/2 at $(R - R_0)/2$ (μsec)	10.17 cm diam TNT 1.04 cm copper wall t/4 at $(R - R_0)/4$ (μsec)
0			
0.1	1.545	(1.52)	1.62
0.2	2.64	2.69	2.78
0.3	3.615	3.67	3.72
0.4	4.53	4.56	4.61
0.5	5.41	5.42	5.48
0.6	6.25	6.26	6.31
0.7	7.06	7.08	7.12
0.8	7.85	7.88	7.92
0.9	8.63	8.65	8.70
1.0	9.41	9.42	9.47
1.1	10.18	10.17	10.23
1.2	10.94	10.91	10.98
1.3	11.69	11.65	11.72
1.4	12.44	12.38	12.45
1.5	13.17	13.11	13.18
1.6	13.90	13.83	13.90
1.7	14.62	14.56	14.62
1.8	15.34	15.28	15.34
1.9	16.05	16.00	16.05
2.0	16.76		16.76
2.1	17.47		17.46
2.2	18.18		18.16