


TNO innovation for life

Comparison between IM fragment and EFP impact

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Overview

- Introduction
- Literature on EFP's
- Fragment impact Experiment
- Model/ FI Simulation
- EFP simulation results
- First comparison
- Worst case scenario
- Summary

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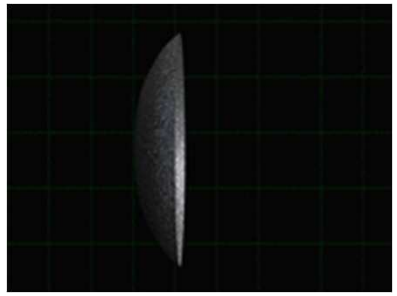
Introduction

- One of the most common threats in the military Out of Area Operations is the IED-EFP
  - Direct danger to the personnel
  - Hit in a vehicle's munition bunker →catastrophic event with many casualties

  - The development of IM munitions is already a major step towards increased munition safety
  - Question at "IM technology workshop" held at "Instituut Defensie Leergangen", The Hague, The Netherlands in June 2011: Is IED-EFP a bigger/different threat than the IM fragment (STANAG 4496) ??



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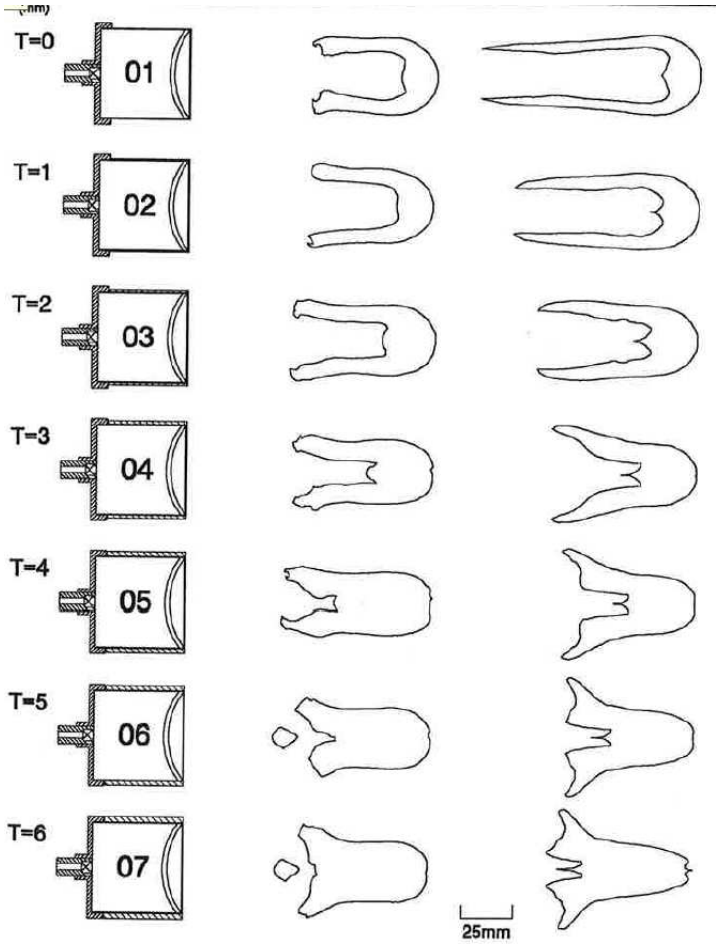
Literature on EFP (C. Weickert and P. Gallagher; K. Weimann)



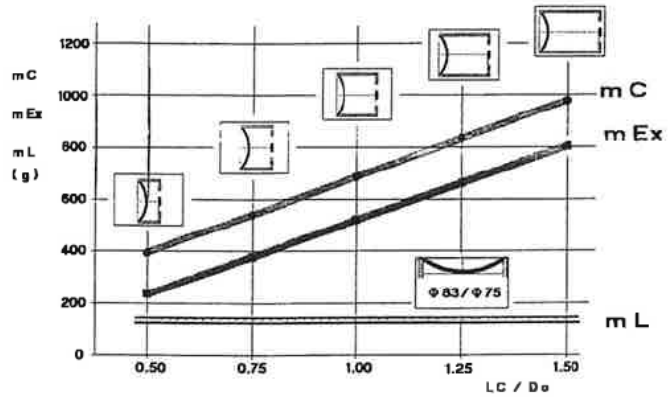


Figure 2. Mass of casing (mC) and explosive (mEx) as function of charge length (LC).

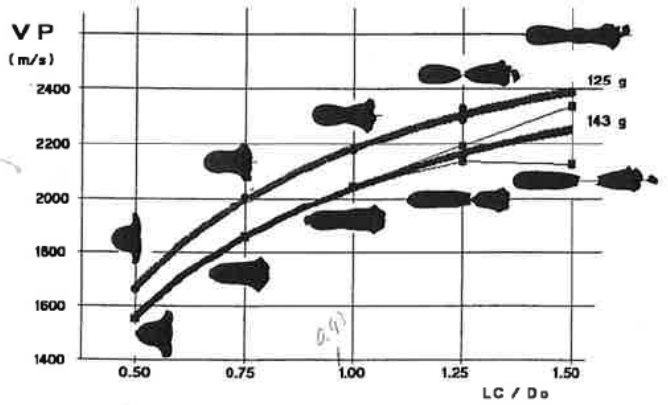
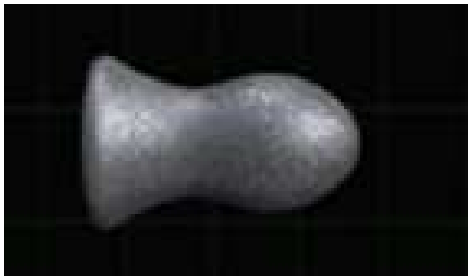
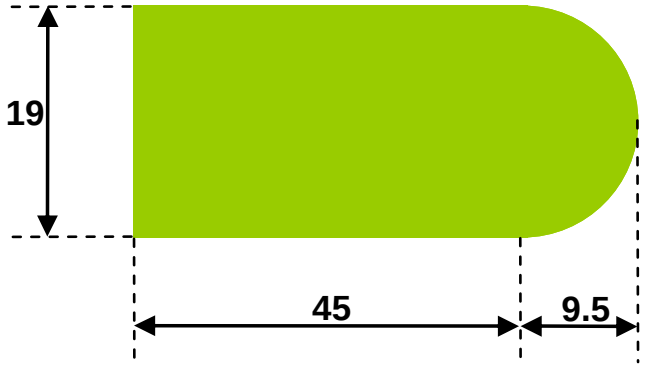


Figure 3. Projectile velocity (VP) and projectile form at different charge lengths (LC).

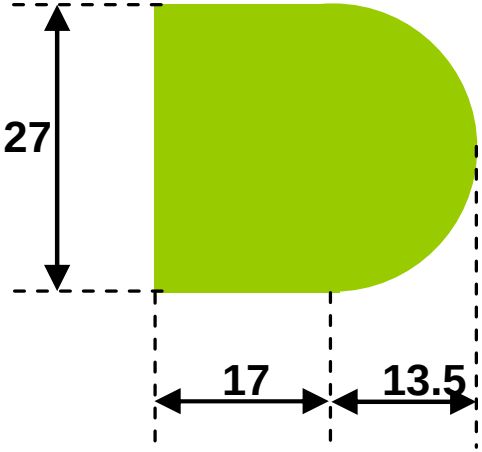
Arbitrary chosen EFP; 2 types, velocity of 2100 m/s

Type A: m= 130 grams, copper





Type B: m= 133 grams, copper



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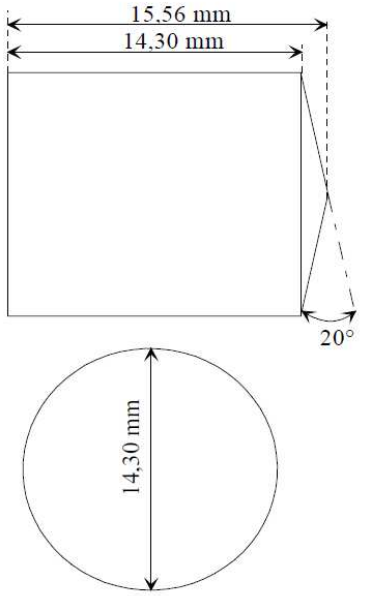
Fragment impact experiment

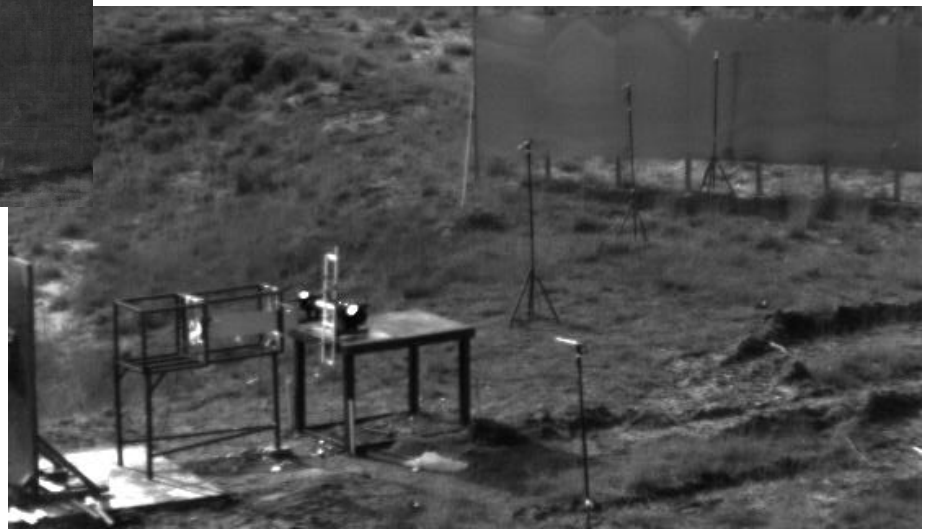
- STANAG IM test Fragment: cylinder of 14.3 mm diameter, 15.6 mm long and 18.6 grams at velocity of 2530 +/- 90 m/s
- Munition: 100 mm/ 90mm warhead Shaped charge with composite casing, High solid loading HMX based explosive
- Aluminium casing of warhead and copper liner



TNO IM Fragment impact 50 mm gun (STANAG 4496)

At velocity of 2700 m/s deceleration of ~17 m/s per meter (7m distance to target → ~ 120 m/s)

High speed recording bullet vs fragment impact



Fragment impact experiment

- Test 1: velocity 2510 m/s, off-centre hit → burning of SC

- Fragment impact 2 at 2570 m/s: in centre→ detonation

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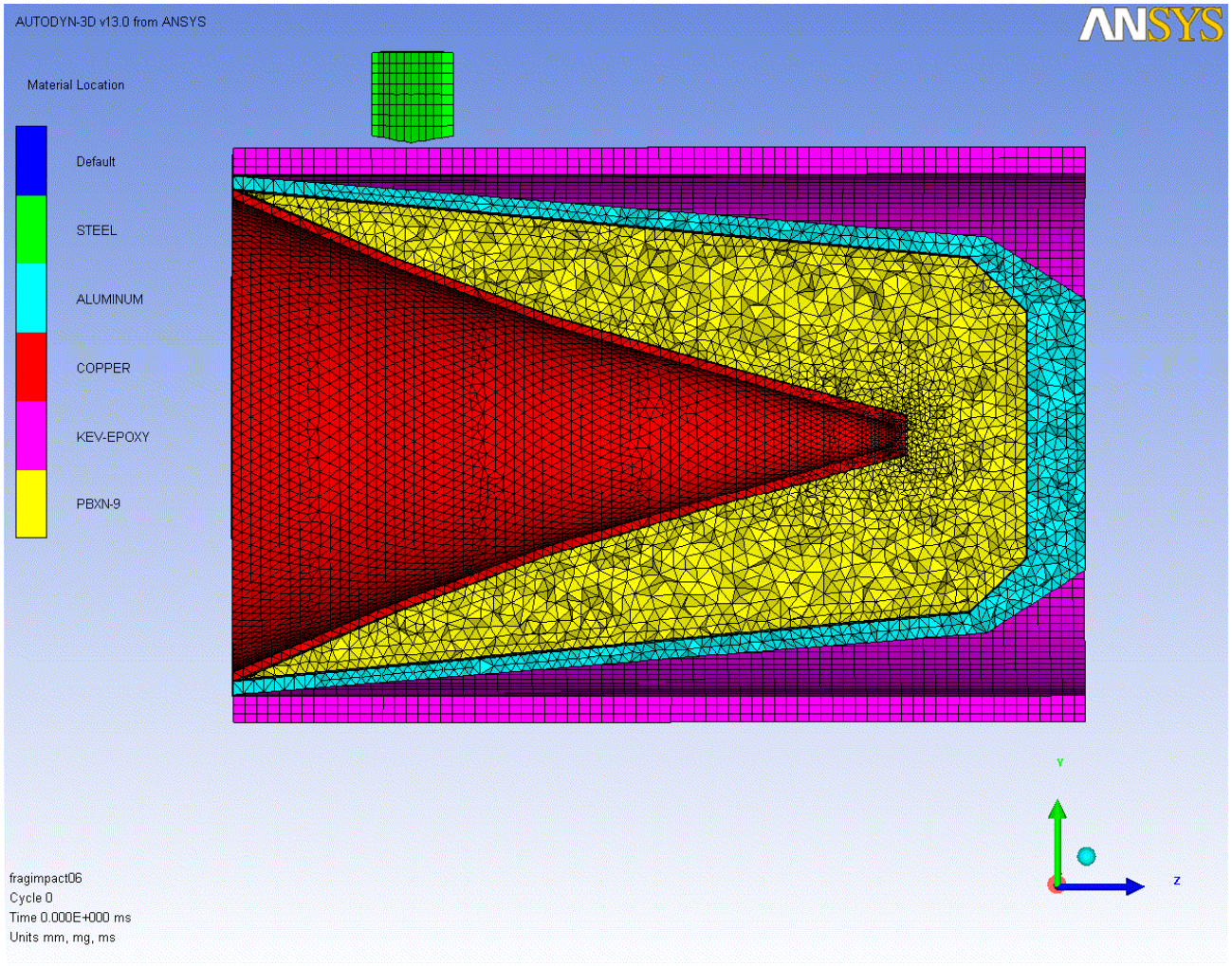
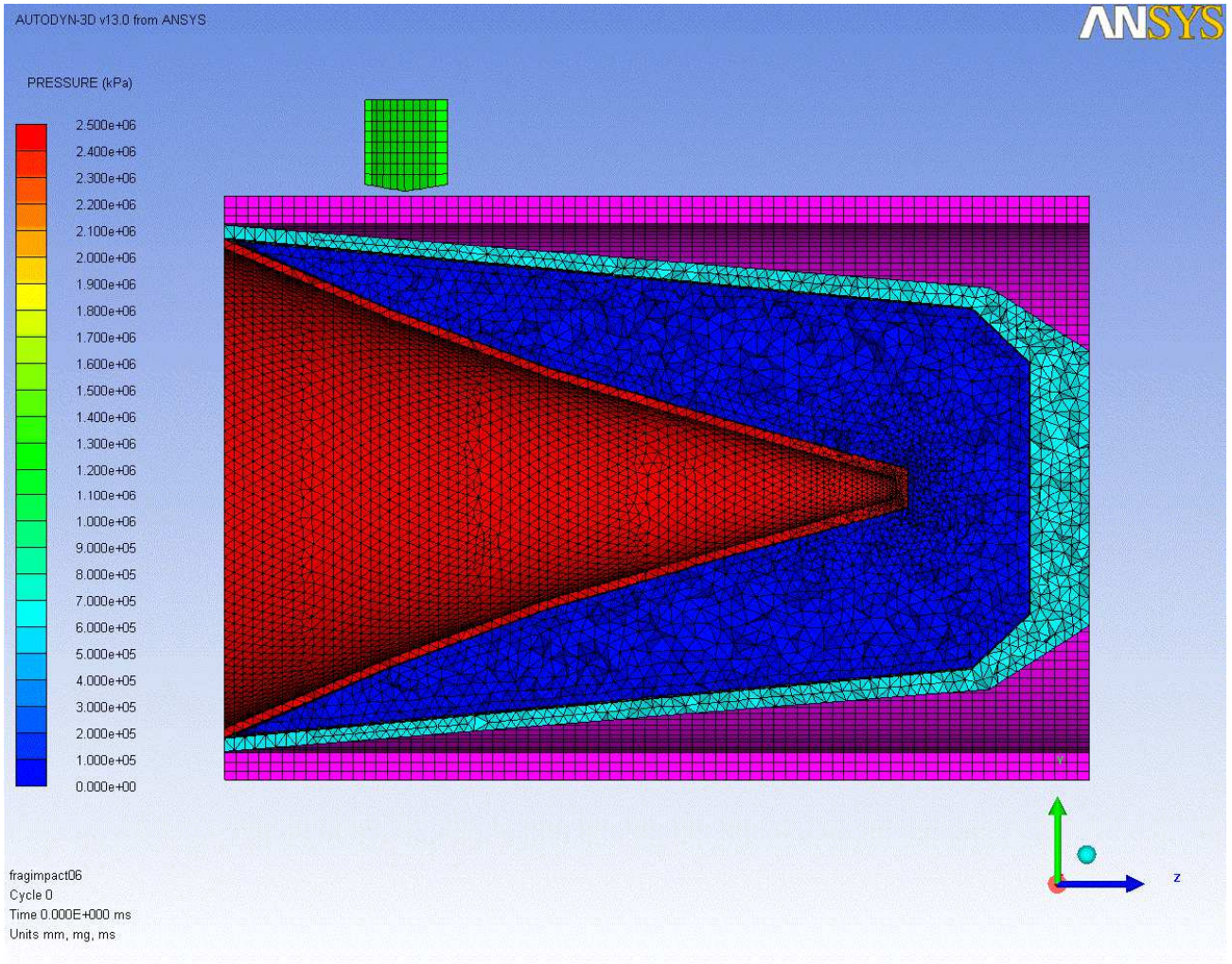
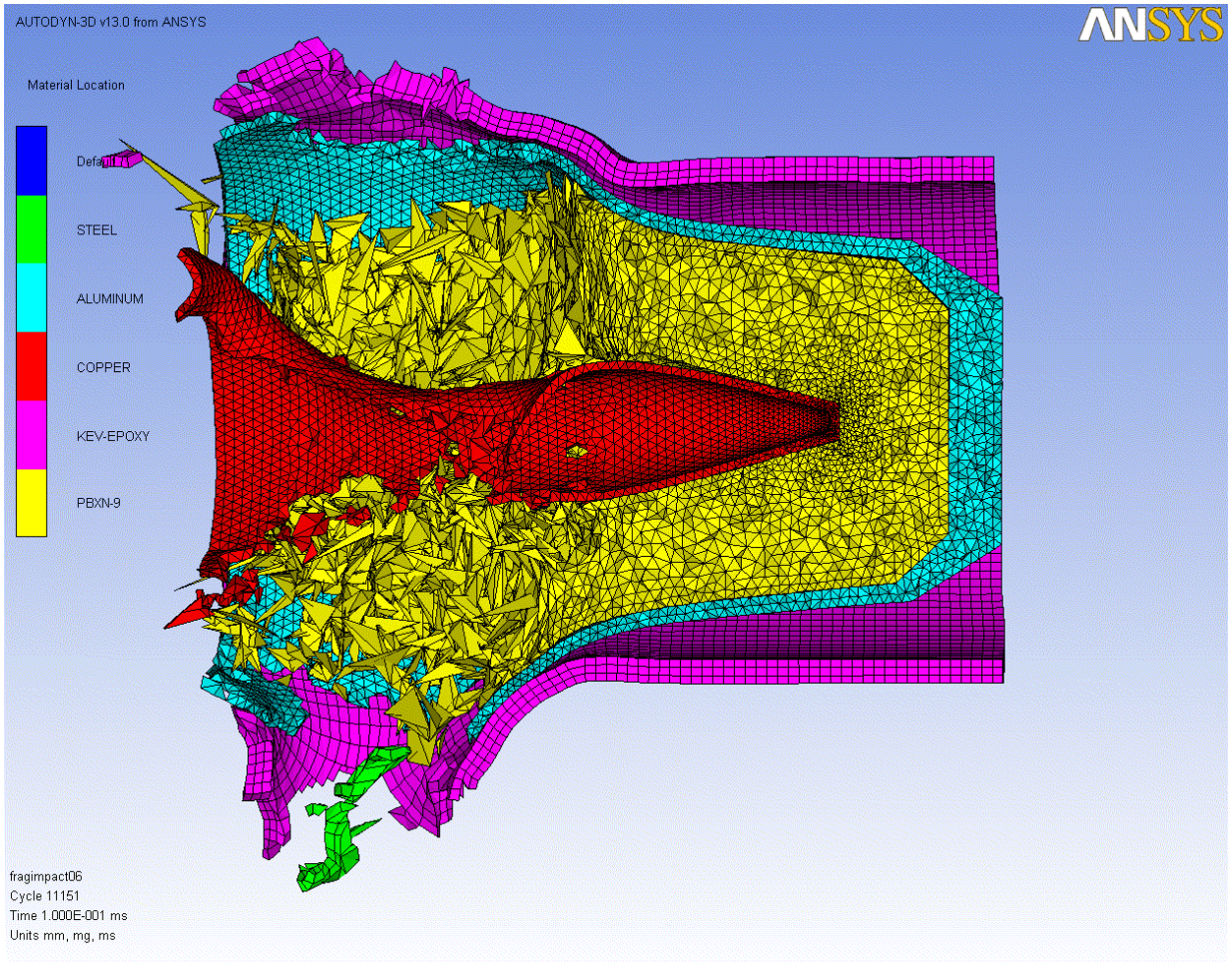
Grid and materials in Ansys-Autodyn



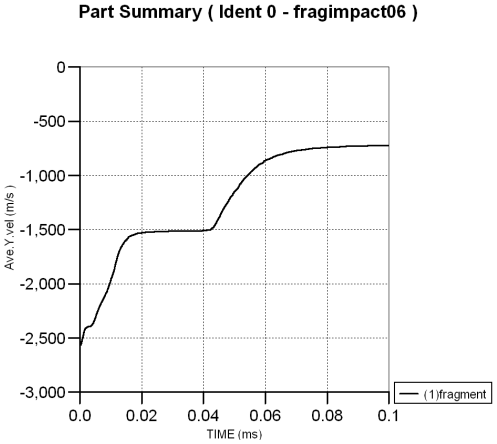
Simulation of fragment impact (center)

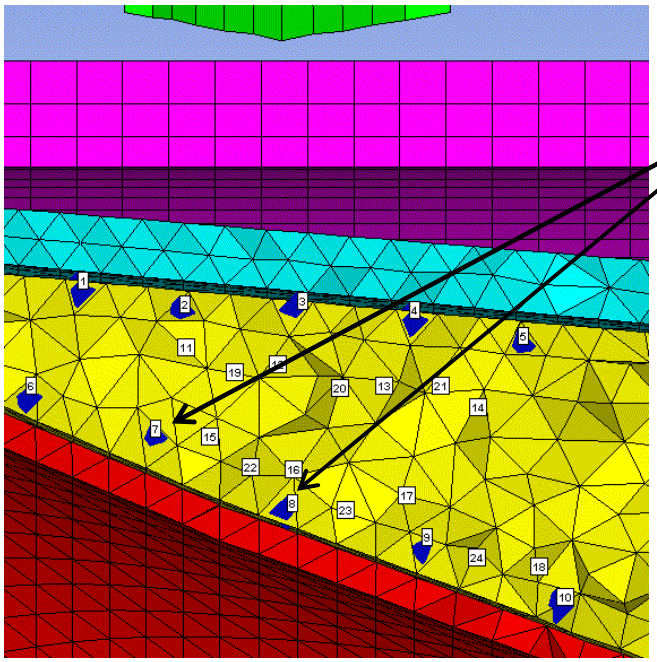


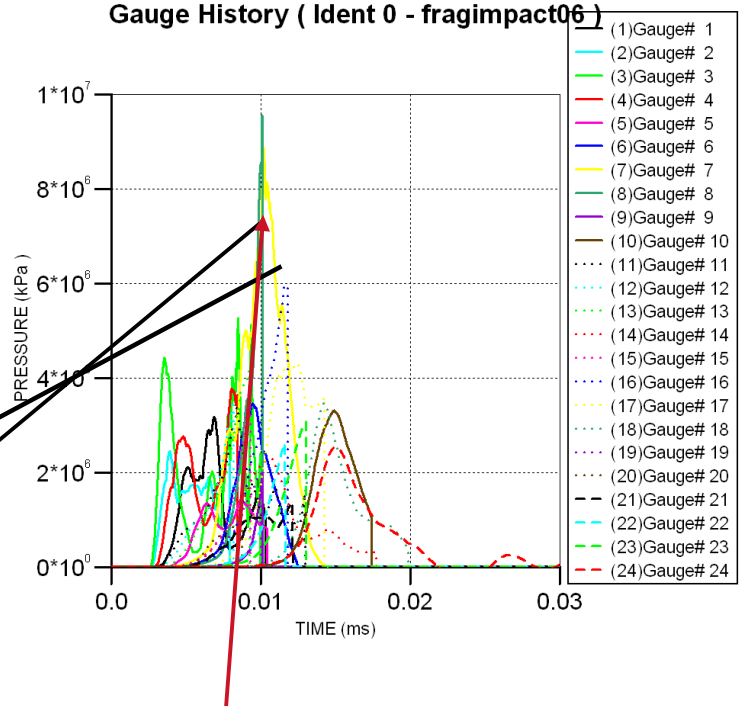
After penetration of fragment (no reaction of explosive simulated)



Velocity and pressures; speed drop of 1000 m/s

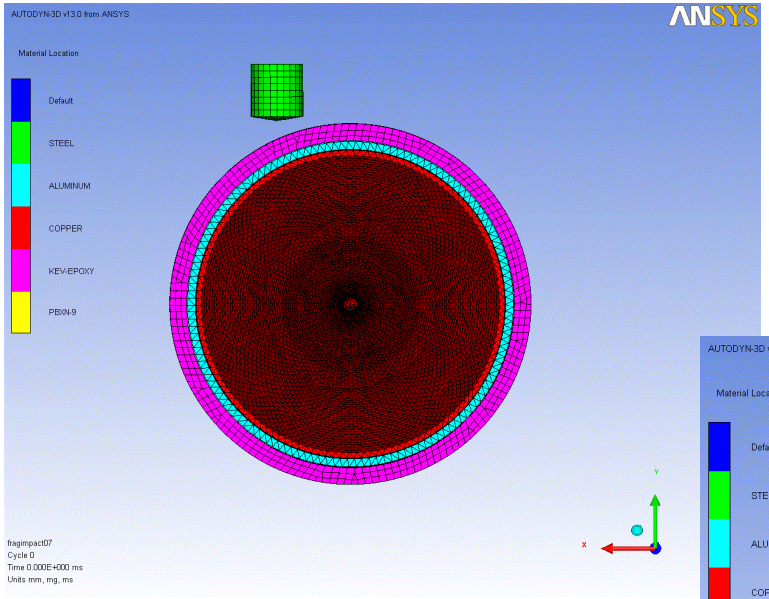


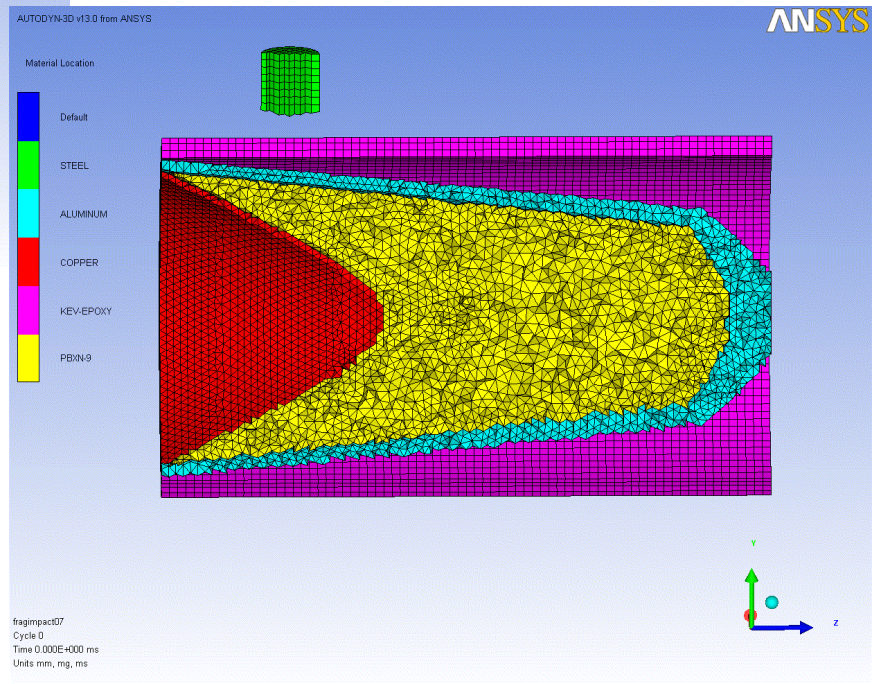


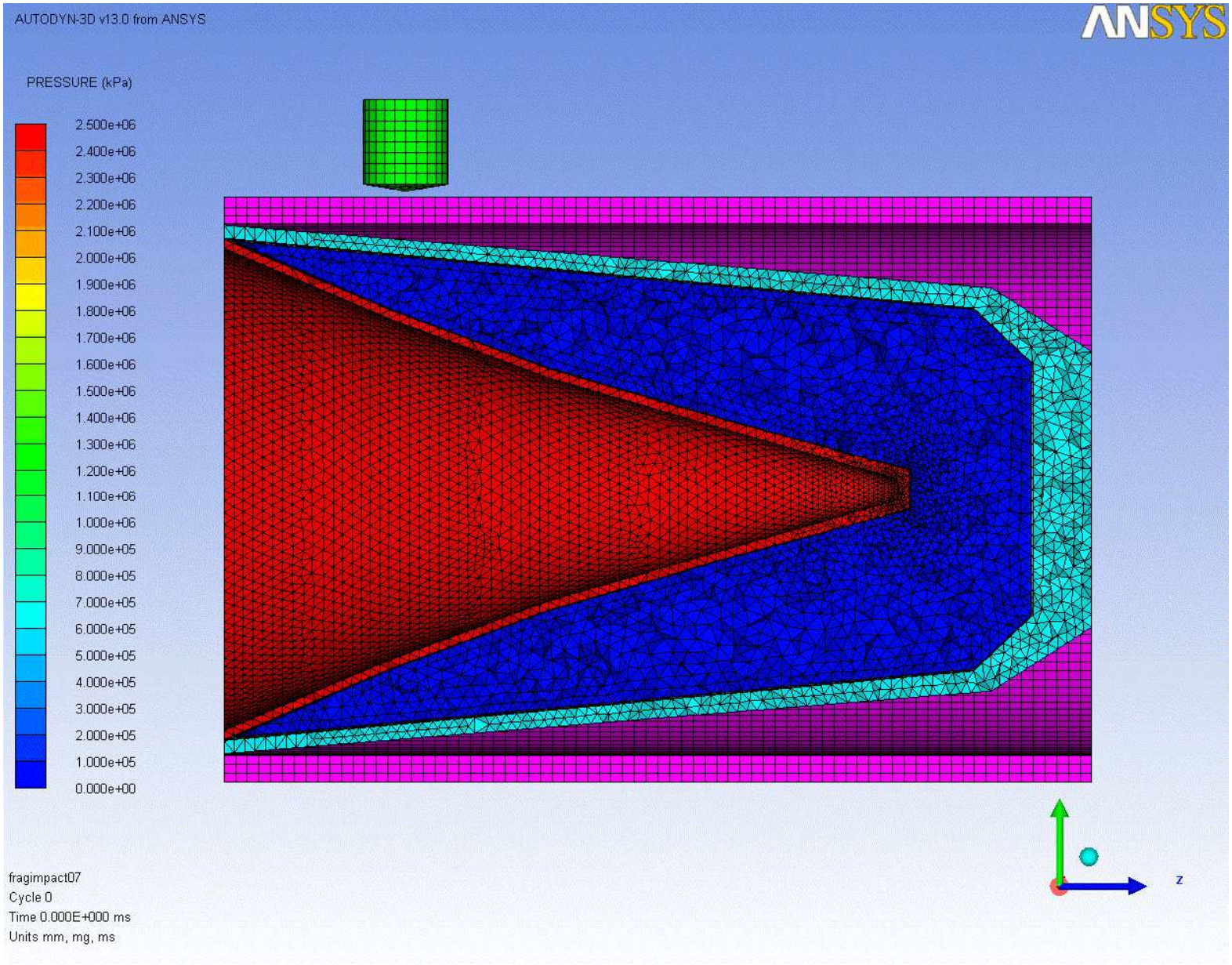


Reflection of copper liner→ P increase

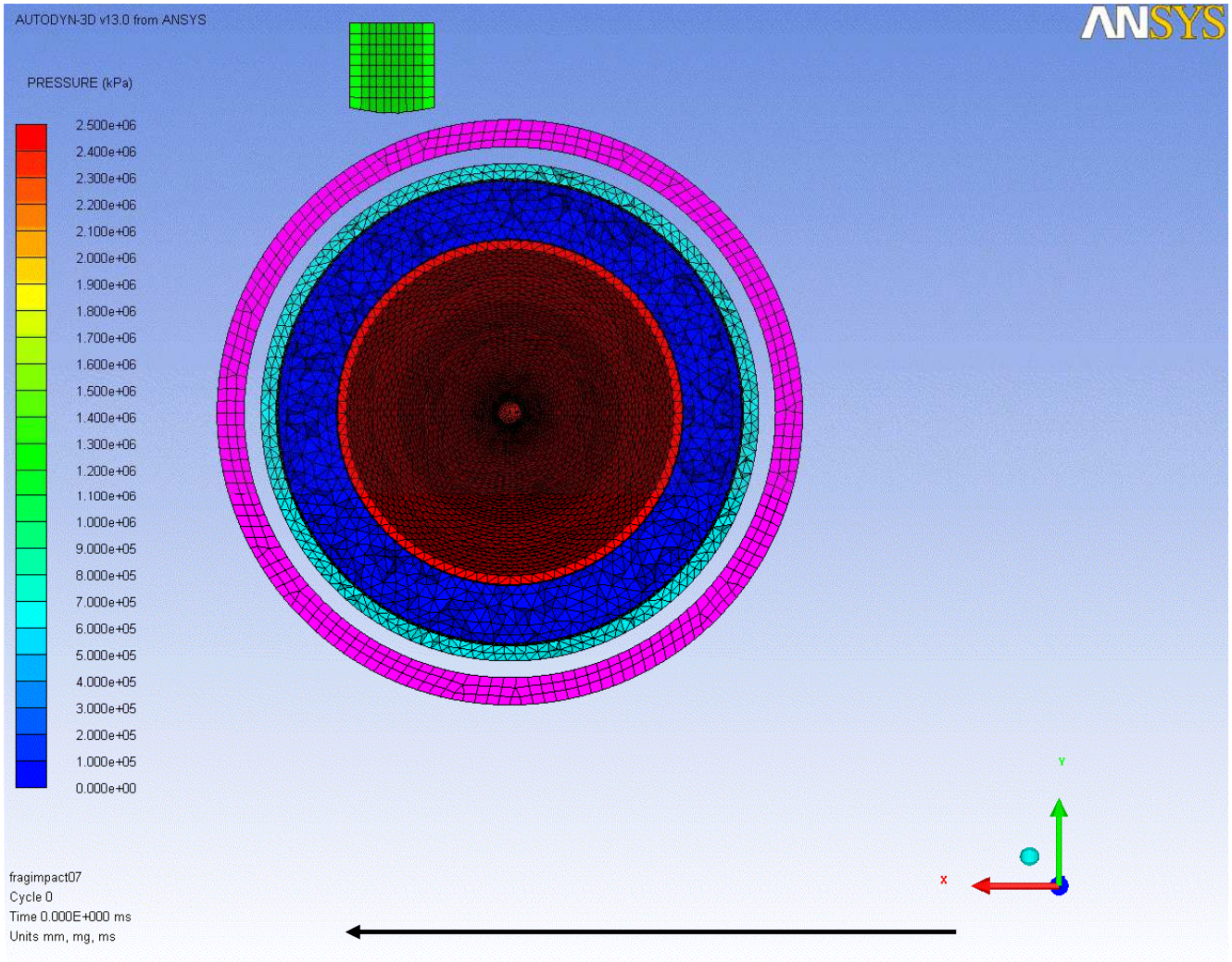
Fragment impact (off-center impact)





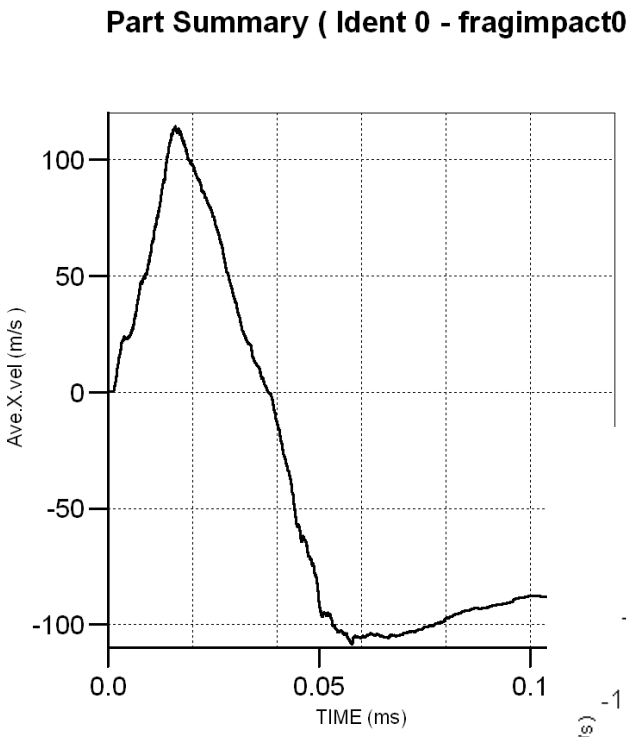

AUTODYN-3D v13.0 from ANSYS
ANSYS
PRESSURE (kPa)
2.500e+06
2.400e+06
2.300e+06
2.200e+06
2.100e+06
2.000e+06
1.900e+06
1.800e+06
1.700e+06
1.600e+06
1.500e+06
1.400e+06
1.300e+06
1.200e+06
1.100e+06
1.000e+06
9.000e+05
8.000e+05
7.000e+05
6.000e+05
5.000e+05
4.000e+05
3.000e+05
2.000e+05
1.000e+05
0.000e+00
Z
fragimpact07
Cycle 0
Time 0.000E+000 ms
Units mm, mg, ms

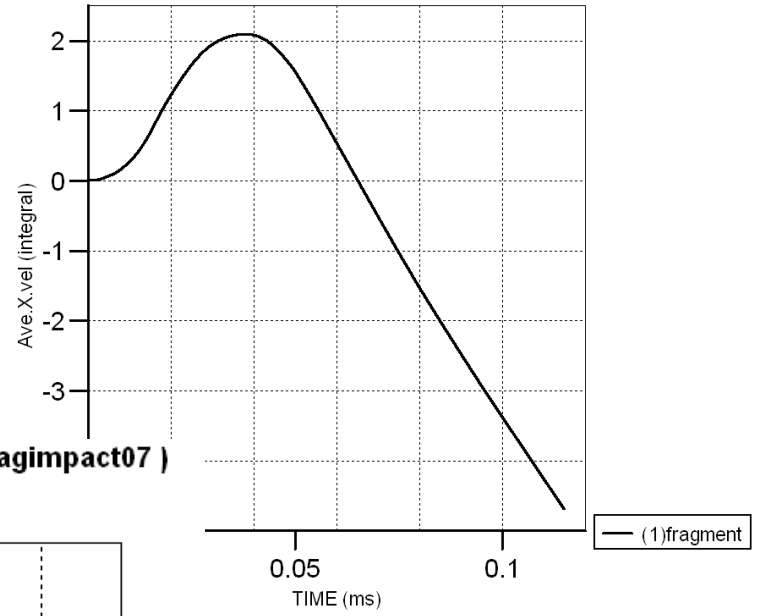
Simulation of off-center impact

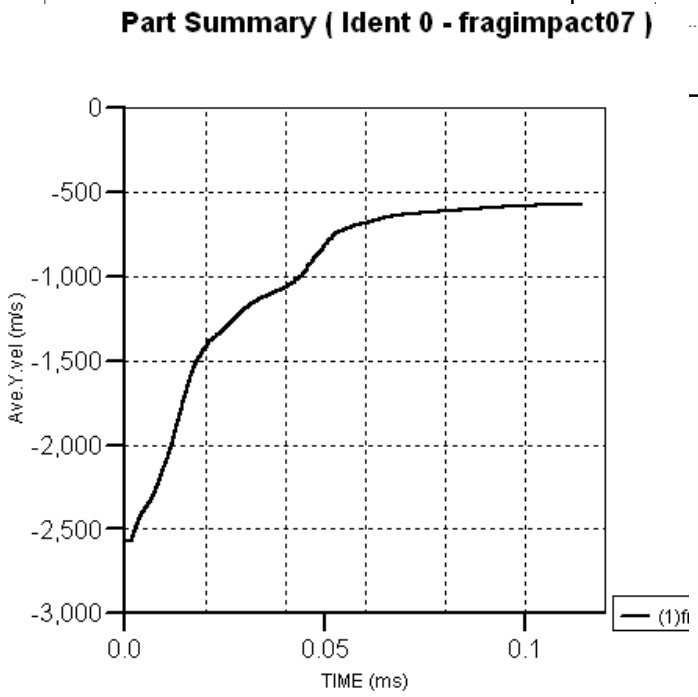


X-direction

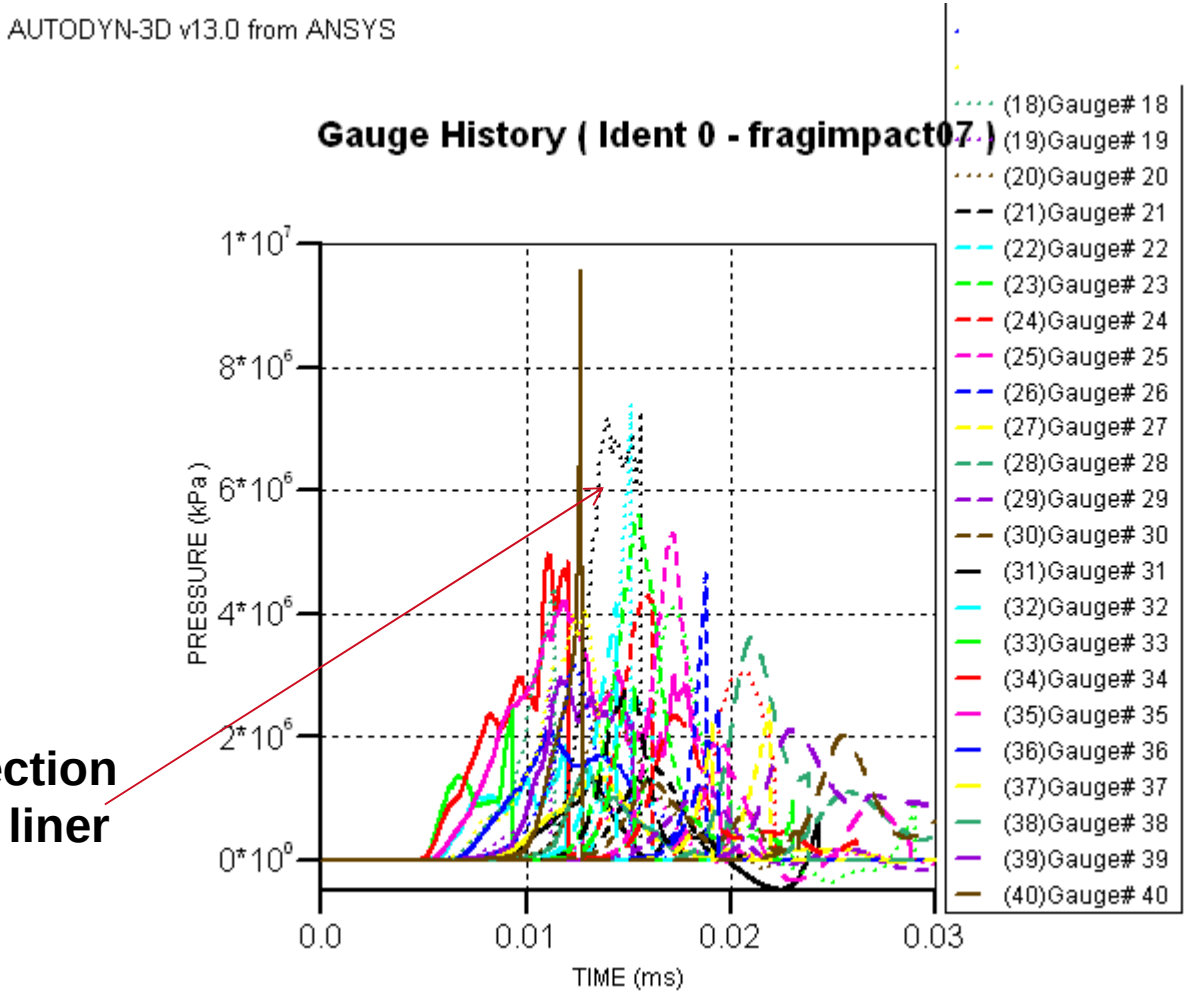
X velocity, displacement of projectile







Presssure (off-center)



After reflection of copper liner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Summary Fragment impact

- Very high pressures with long duration
  - Central impact: 0.8 µsec at 8 MPa and 3.7 µsec at 5 MPa; some over 8 GPa
  - Off Central impact: 1.2 µsec at 6.5MPa

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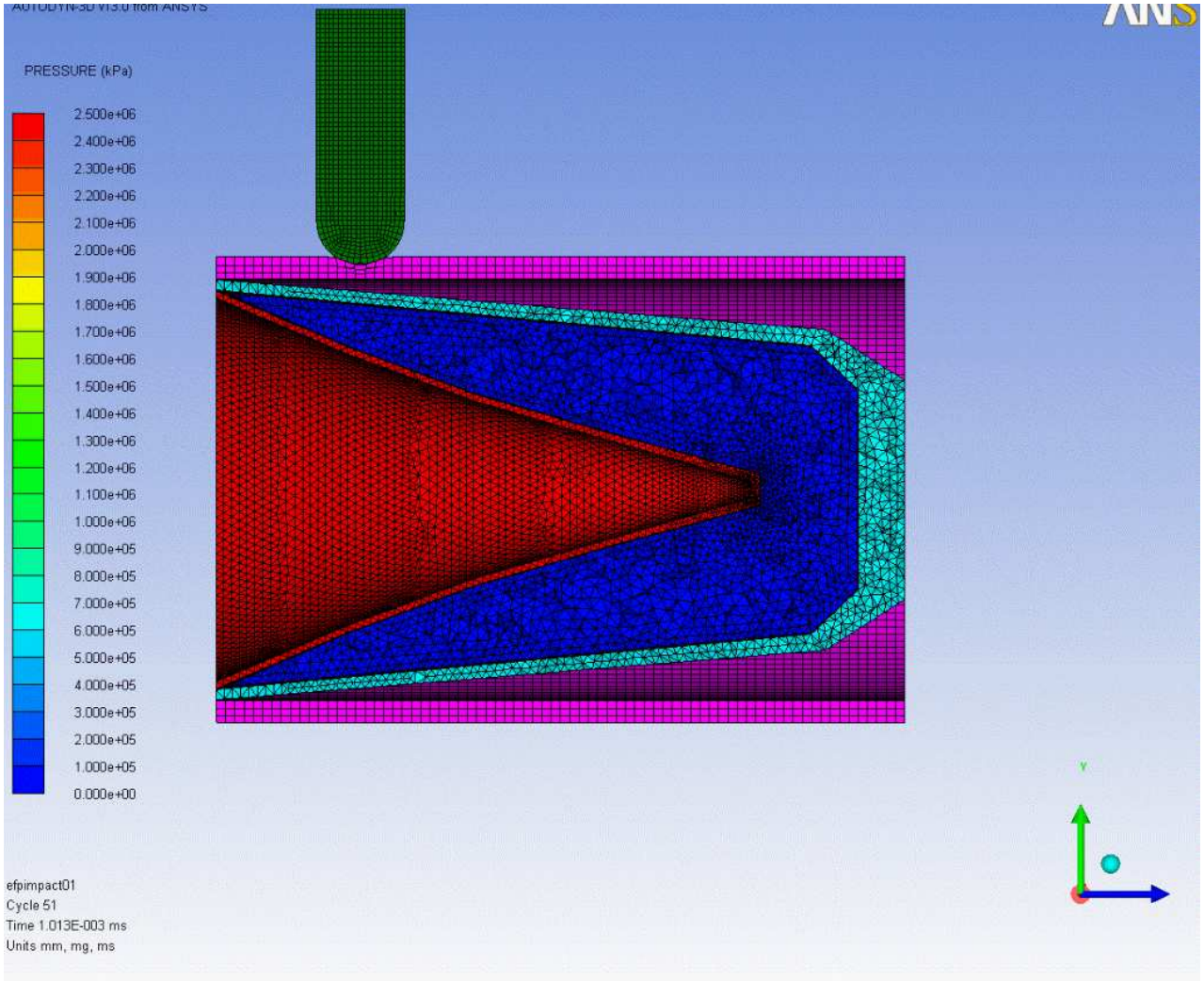
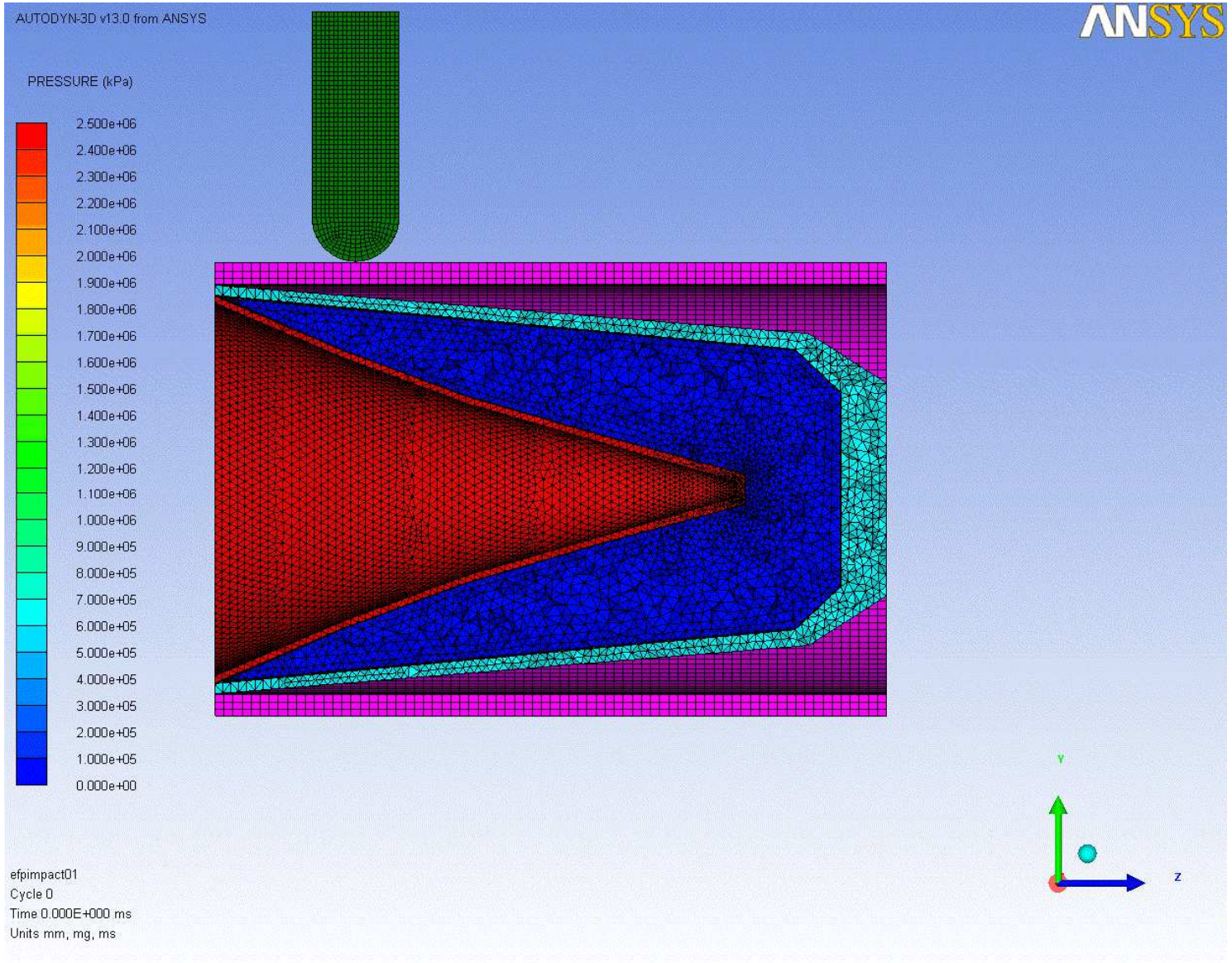
Impact of 19 mm EFP (2100 m/s)

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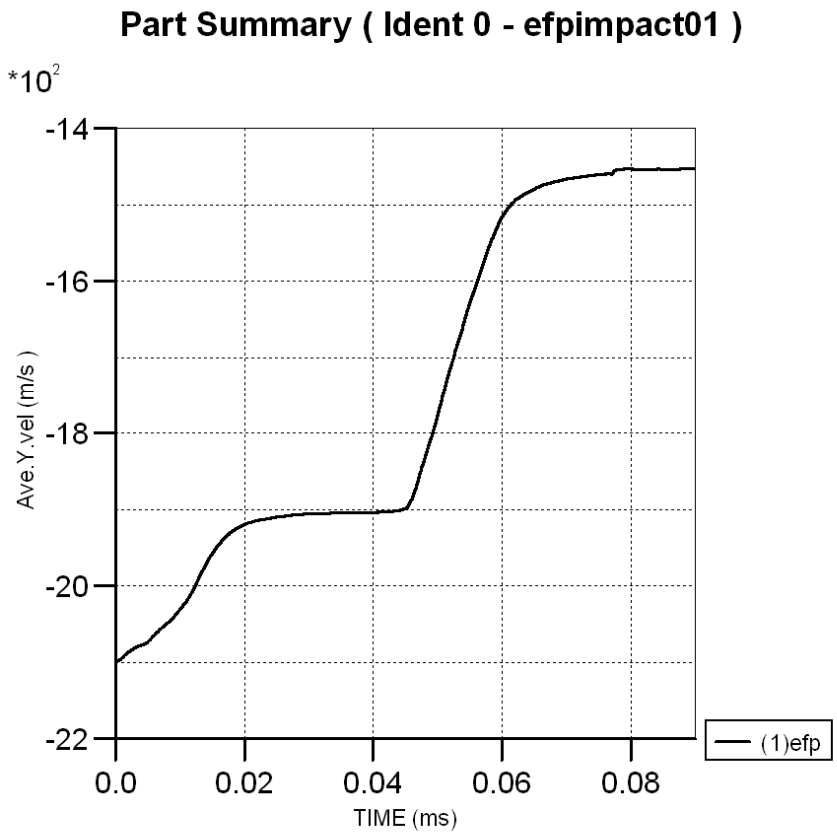
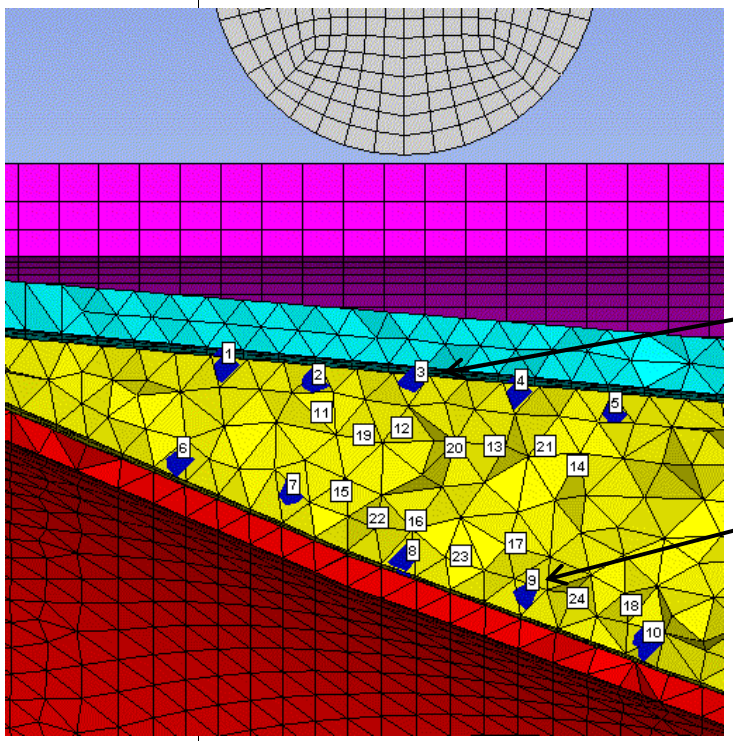
1.600e+06
1.500e+06
1.400e+06
1.300e+06
1.200e+06
1.100e+06
1.000e+06
9.000e+05
8.000e+05
7.000e+05
6.000e+05
5.000e+05
4.000e+05
3.000e+05
2.000e+05
1.000e+05
0.000e+00
Y
Z
efpimpact01
Cycle 0
Time 0.000E+000 ms
Units mm, mg, ms

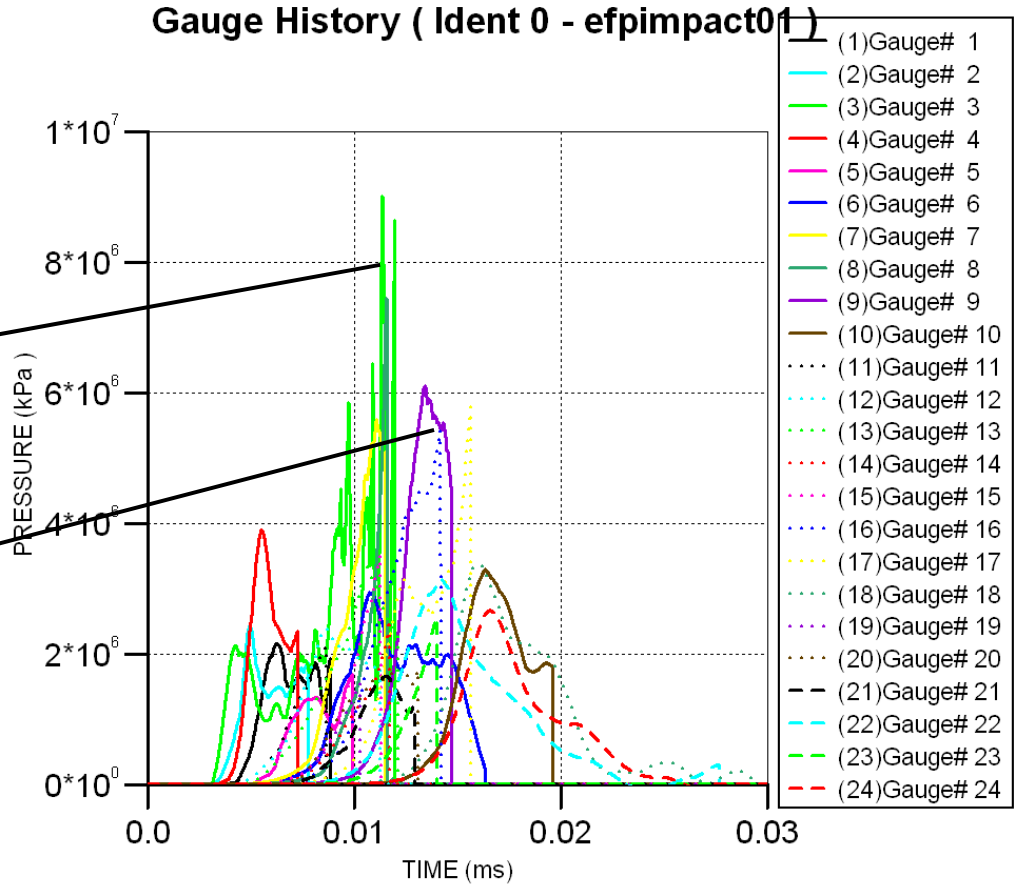
EFP velocity decrease (19 mm) ~200 m/s

AUTODYN-3D v13.0 from ANSYS

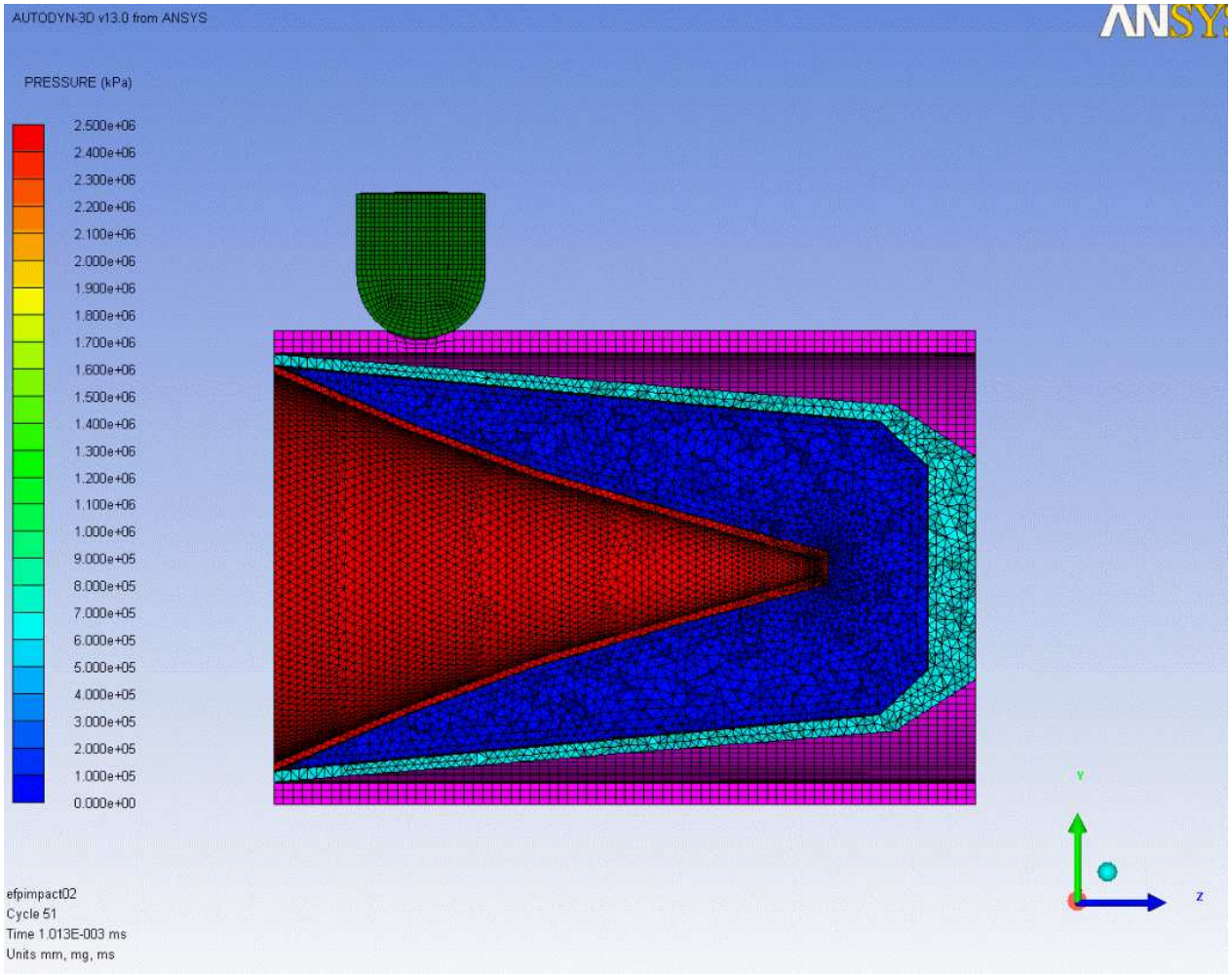


Shock pressure (19 mm)

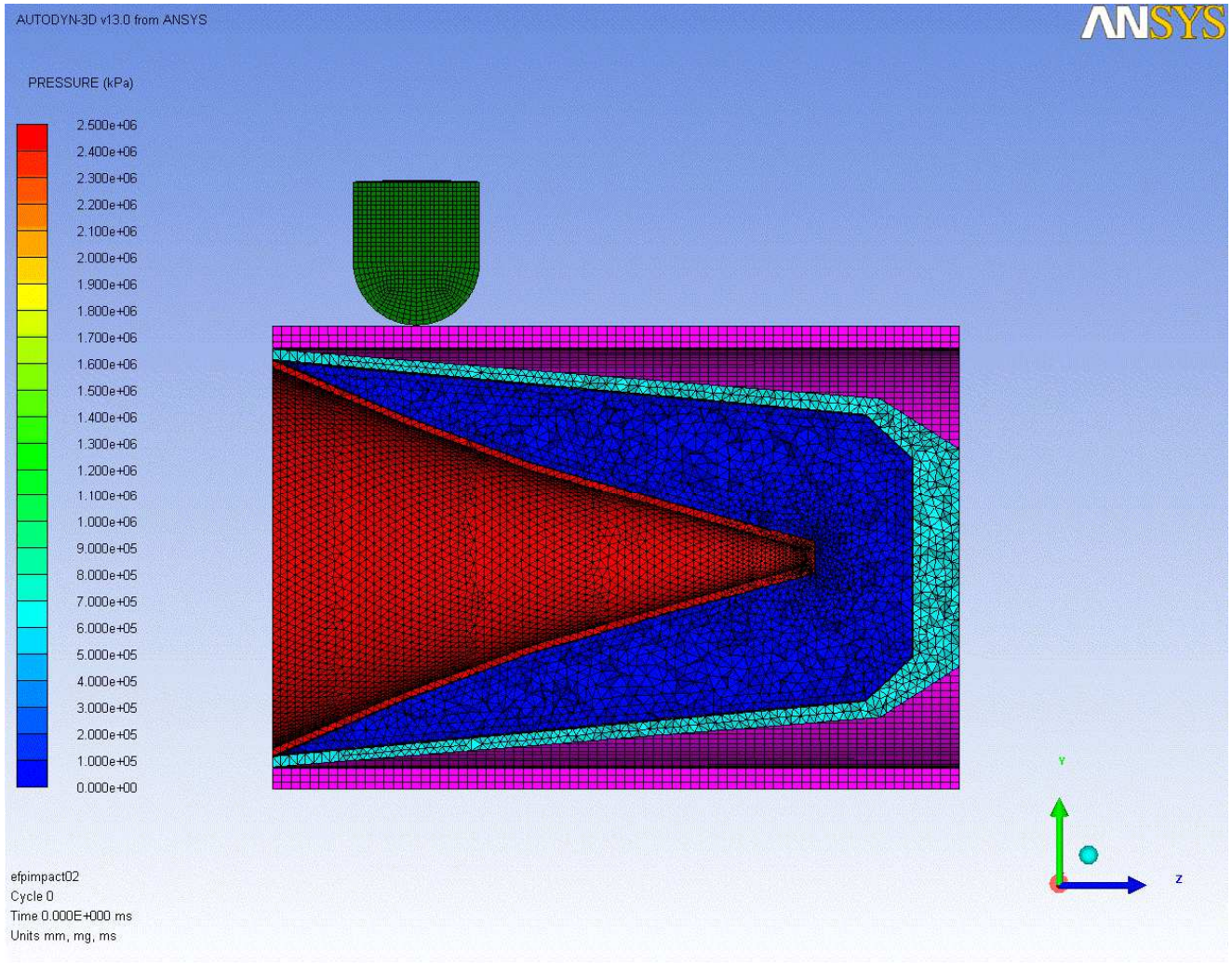




27 mm EFP impact

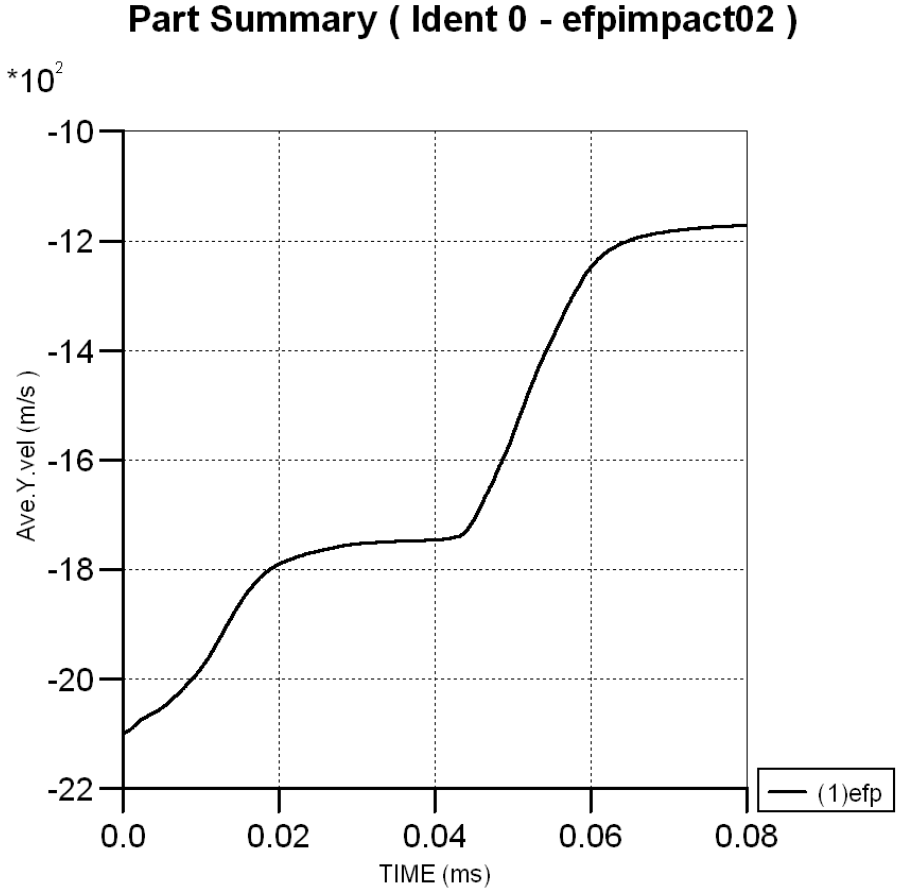


Simulation of 27 mm EFP at 2100 m/s

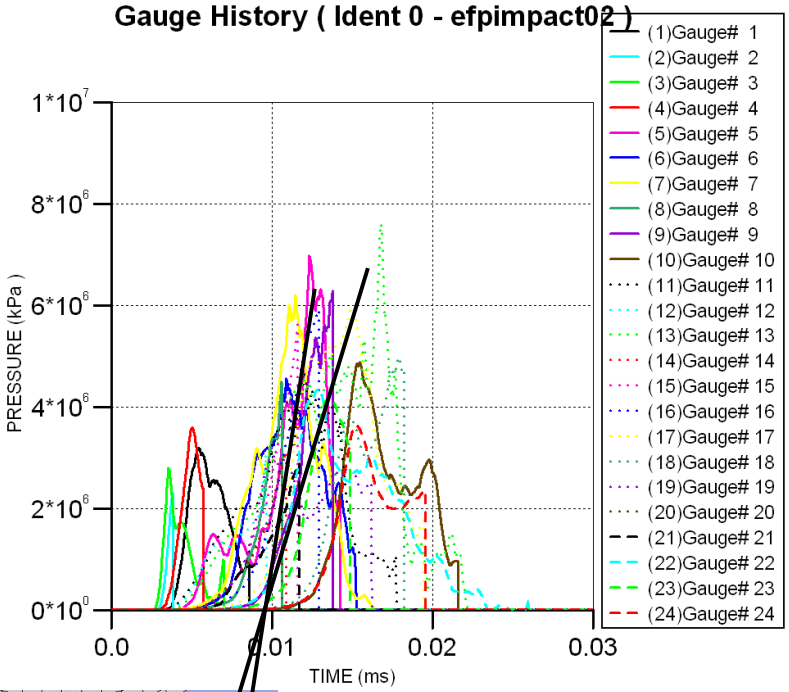


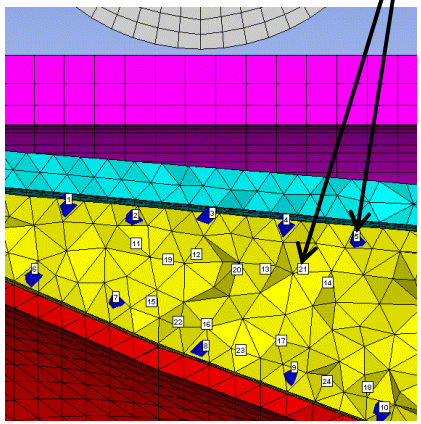
Velocity decrease of EFP (27 mm) ~ 350 m/s

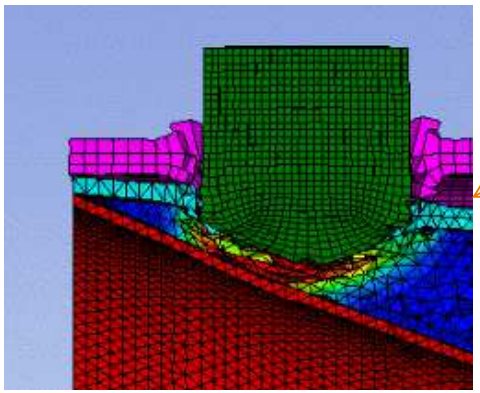
Effect. surface 5.7 cm² (twice the value of 19 mm EFP = 2.8 cm²)

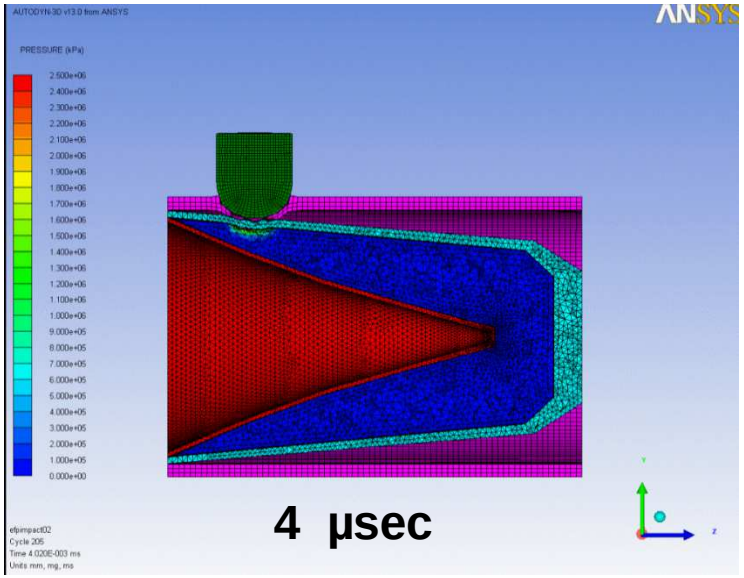


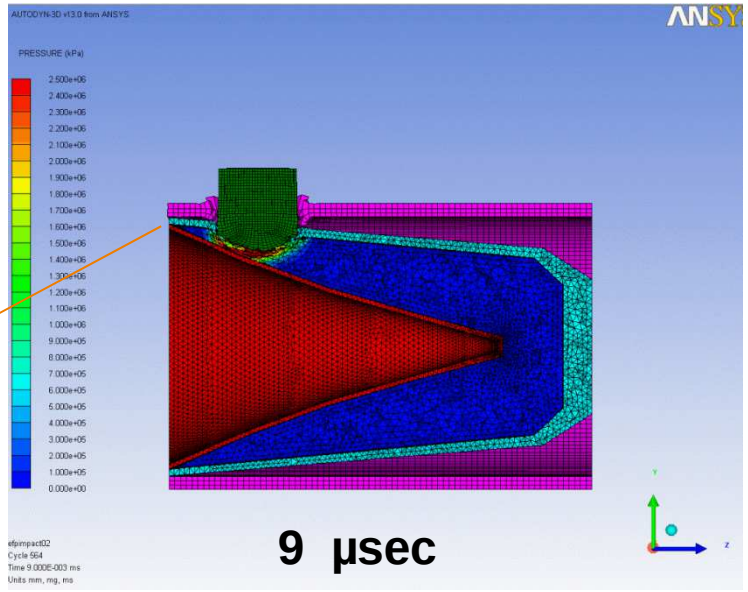
Shock pressure EFP









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EFP summary

- EFP 19 mm:
  - large area with long shock pulses over 3 MPa,
  - several peaks 1-2 µsec up to 6 Mpa

- EFP 27 mm:
  - Large area with long shock pulses up to 5- 6 Mpa (1-2 µsec)

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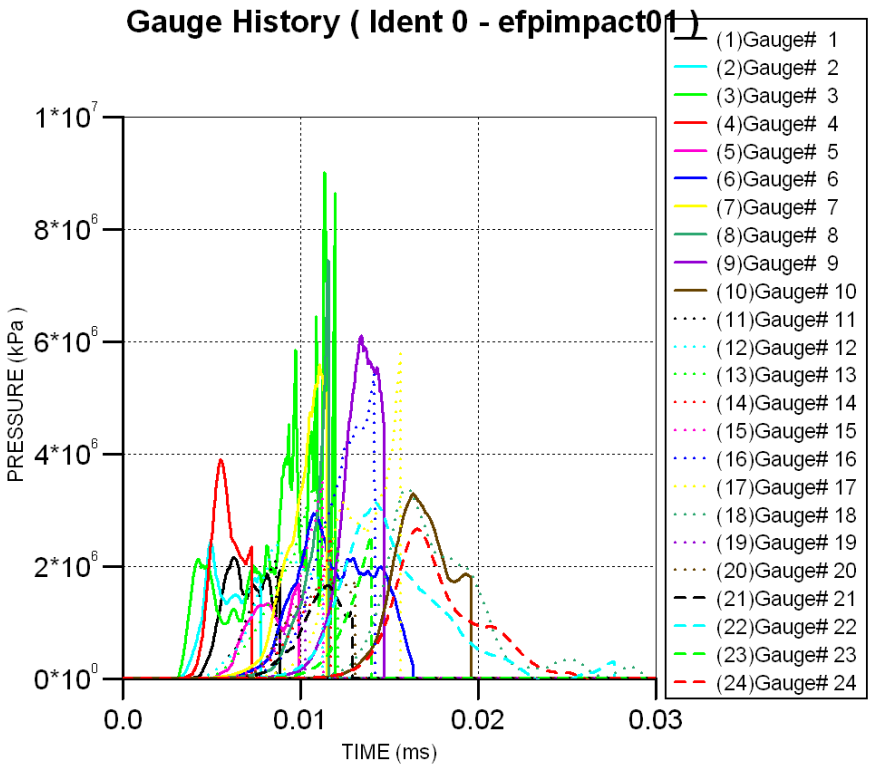
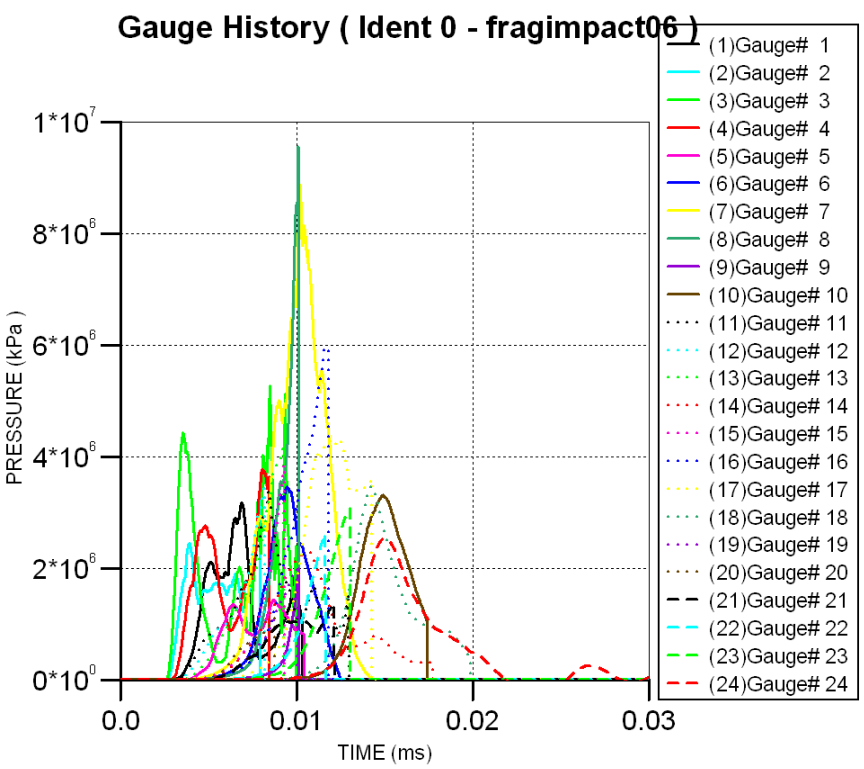
Fragment - 19 mm EFP comparison
More high pulses for fragment impact



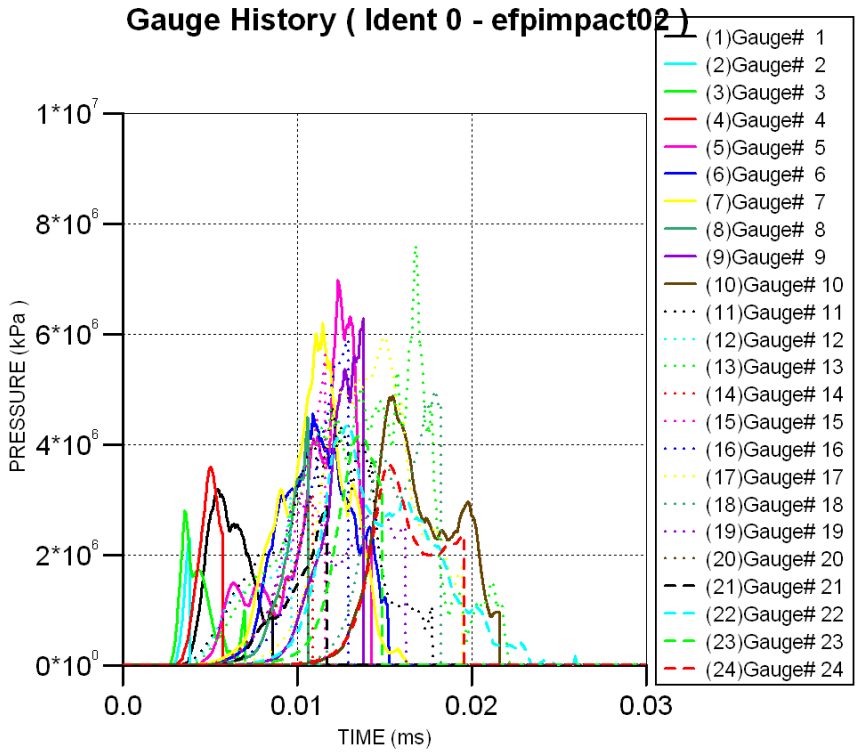
19 mm EFP



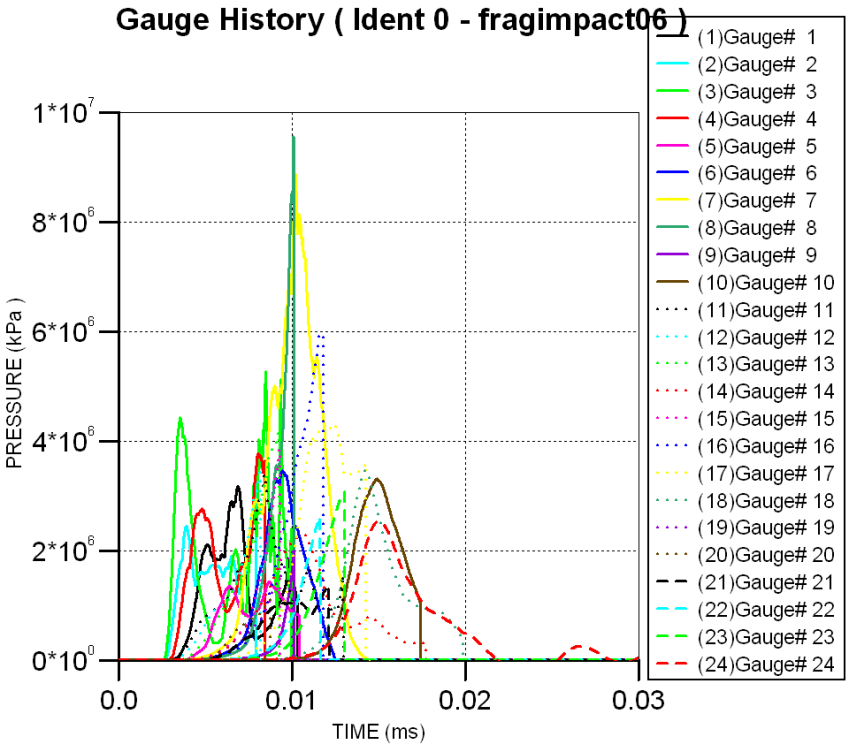
Fragment

Fragment - 27 mm EFP comparison
More pulses around 6 MPa for EFP

YS



27 mm EFP



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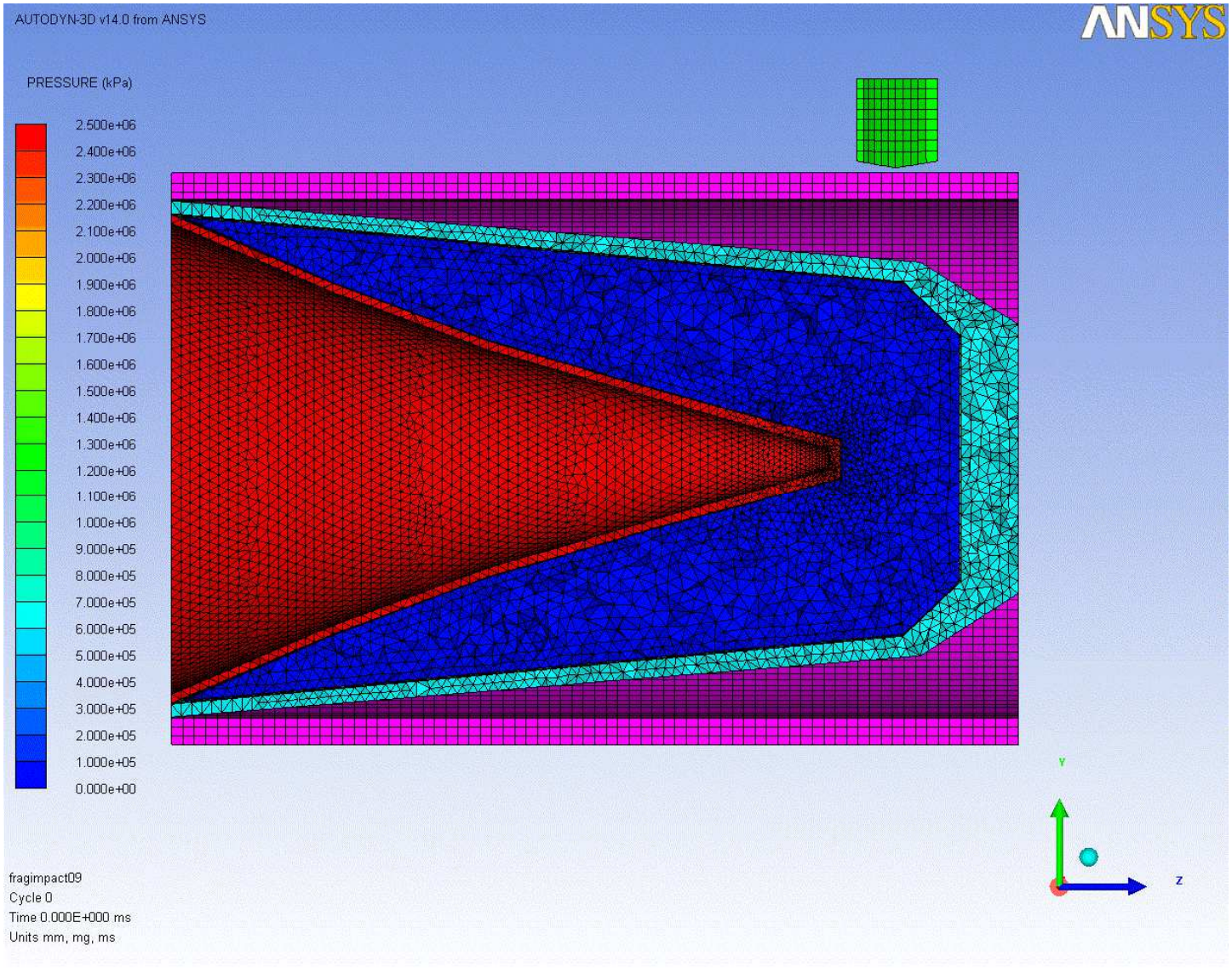
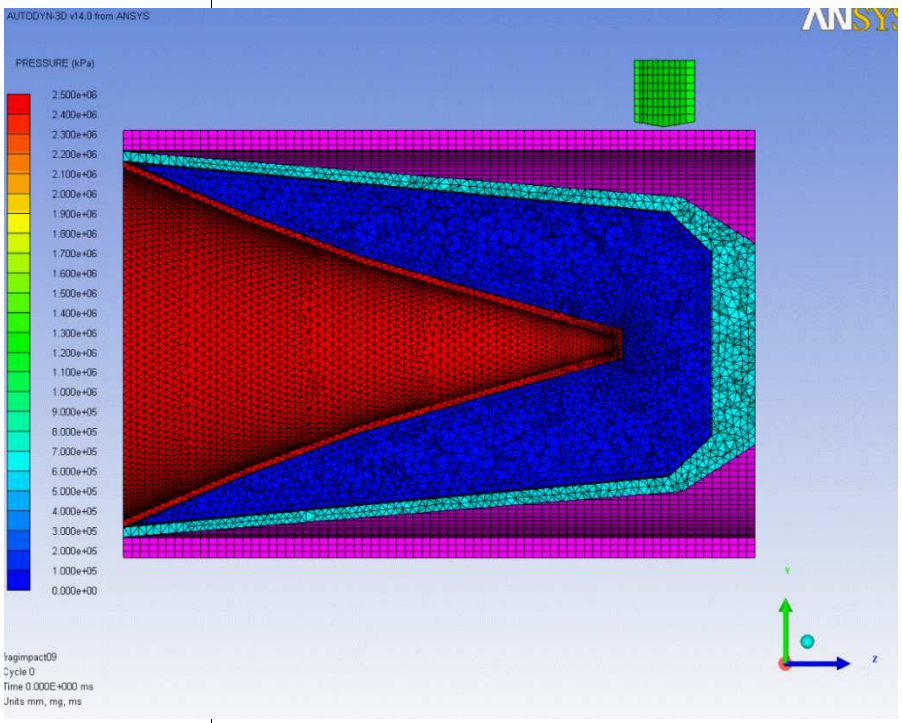
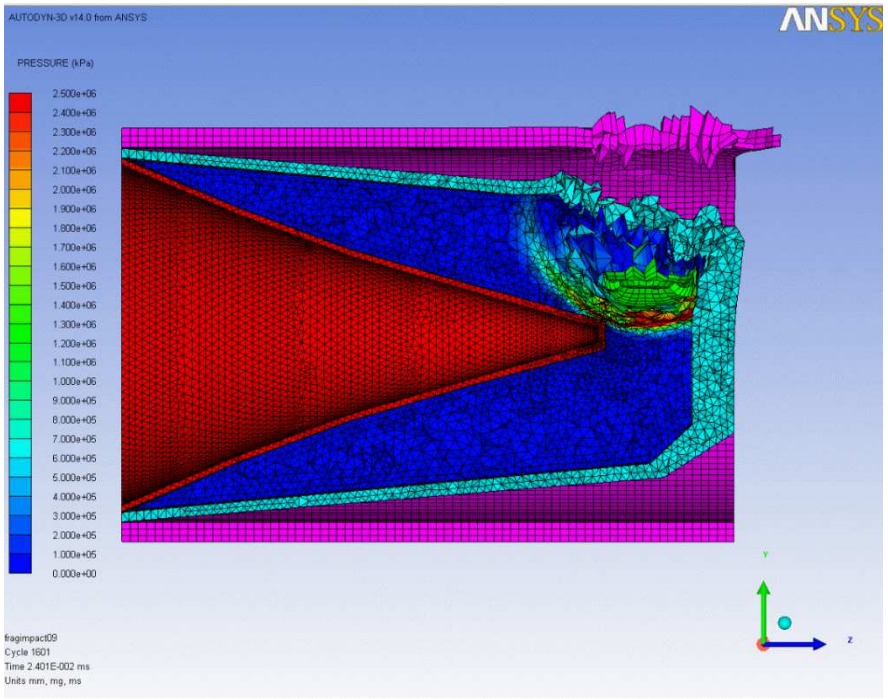
Simulation of FI near end of warhead

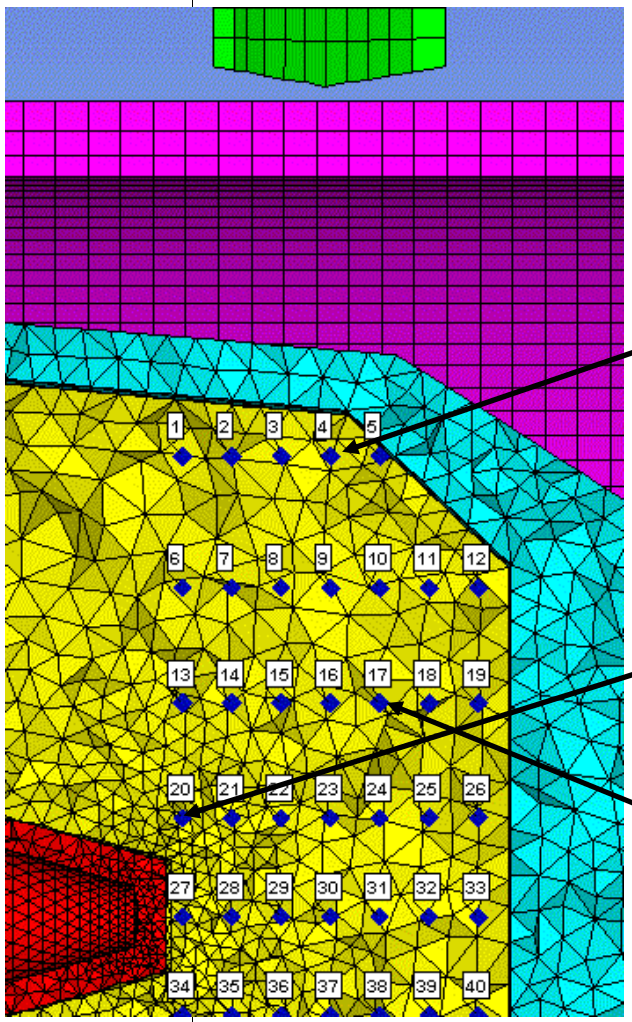


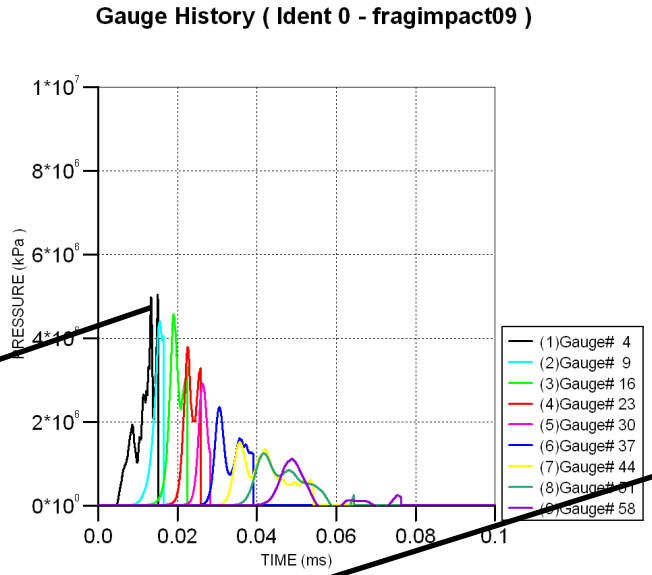
Fragment impact near the end of the warhead

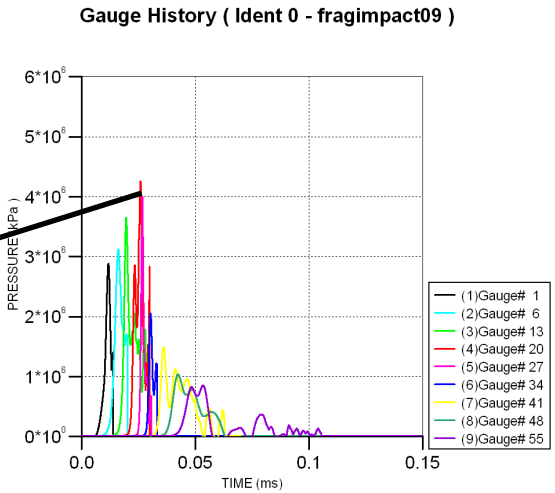


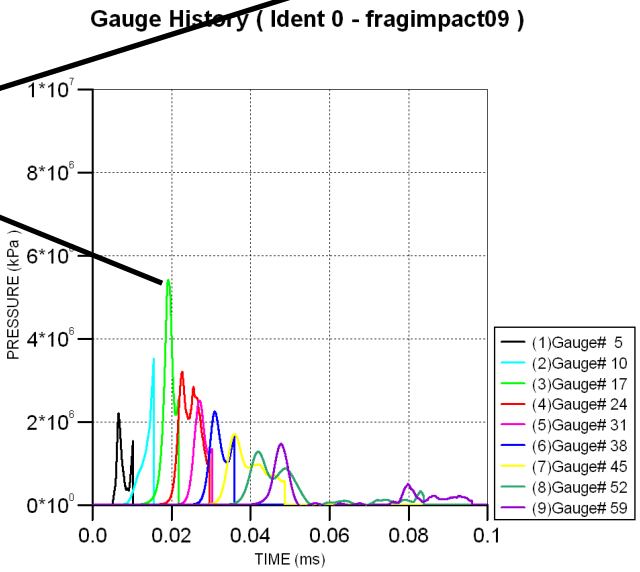


Pressure waves







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Summary

- Comparison IM fragment at around 2530 m/s and EFP's at 2100 m/s
- Experiment:
    - Fragment impact in centre → Detonation
    - Off centre impact burning i.s.o. detonation
- Simulation:
- EFP impact at 2100 m/s quite comparable to IM fragment impact for thin-walled warheads
- But
    - In case of barrier (protection) probably EFP is in favour due to higher velocity after penetration
    - Thick walled warhead: rarefaction wave is important
    - Confirmation is needed
- Strong dependency on configuration (barriers of walls and reflection waves): Worst case is not in the area with large amounts of explosives!