ON THE NUMERICAL METHODS AND PHYSICS OF PERFORATION IN THE HIGH-VELOCITY IMPACT MECHANICS

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1. Introduction

An objective of this paper is a mutual comparison of few selected numerical approaches with respect to reproducing the fundamental physical phenomena in the perforation process, observed experimentally, Fig. 1. The main task was to obtain a plug formation after impact of a cylindrical projectile in computer simulation.

a)

b)

Fig. 1. High-speed camera images of an experimental tests of: (a) Armox 500T steel, (b) aluminum alloy (PA11), plates perforated by a 7.62x54R B32 Armor Piercing projectile.

2. Problem description

The analysis was carried out for a normal impact of a cylindrical projectile in 6.5mm thick disc made of Armox 500T steel, Fig.1.

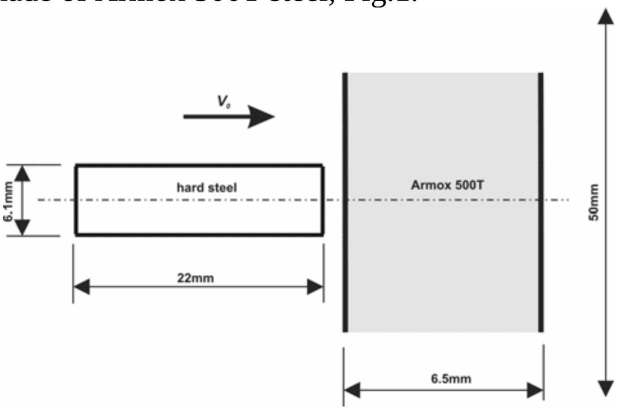
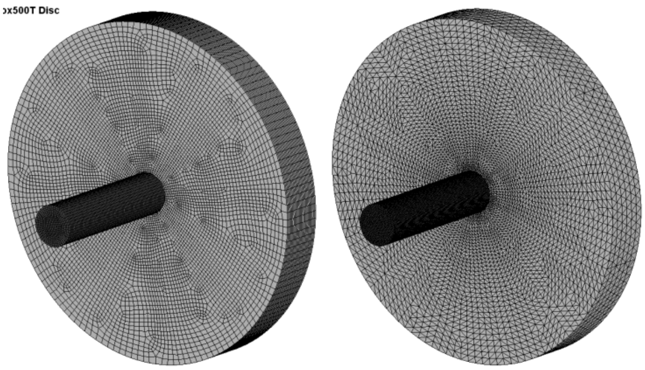


Fig. 2. Dimensions of the target disc and the cylindrical impactor.

3. Description of the numerical model

The Finite Element Method (FEM) and Element Free Galerkin (EFG) [4,6], implemented in the LS-DYNA code were applied. The full 3D models of the projectile and target were developed with strain rate and temperature dependent material constitutive relations. The Johnson-Cook constitutive model with Gruneisen Equation of State (EOS) was used to describe a behavior of the metallic parts: Armox500 disc and High-Hard Steel impactor. Appropriate values of material constants were presented in Table 1. The Boundary Conditions (BC) were defined by supporting the target plate at its back edges. In Fig. 3 a 3D view of the model meshes is showed with cubic (a) and tetrahedral (b) topology.



a) b)

Fig. 3. The impactor and target mesh overview for hex (a), and tetra (b), mesh topology.

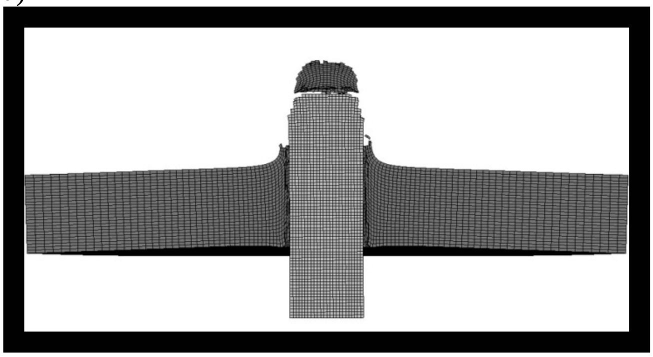
Table. 1. Johnson–Cook constitutive model, failure model and Gruneisen Equation of State data for hard steel and Armox 500T [1,6]

Parameter	Units	Hard Steel (62HRC)	Armox 500T steel
Johnson -Cook		[2,3]	[2]
A	GPa	2.7	0.849
B	GPa	0.211	1.34
C	-	0.005	0.0054
m	-	1.17	0.87
n	-	0.065	0.092
Gruneisen Equation of State		[5]	
c	m/s	4570	
S_1	-	1.49	
S_2	-	0.0	
S_3	-	0.0	
Γ_0	-	1.93	
a	-	0.5	
Johnson-Cook failure			
D_1	-	0.4	0.001
D_2	-	0.0	0.747
D_3	-	0.0	0.201
D_4	-	0.0	0.0
D_5	-	0.0	0.0

4. Analysis of the results

The selected results of simulation for analyzed cases were depicted in Fig. 4 with cross-section view. It is perceivable that any plug was not formed in case of FEM with tetrahedral mesh topology. The comparison of two other cases shows equivalent results, but the EFG with tetra mesh brings to appearance a smaller plug.

a)



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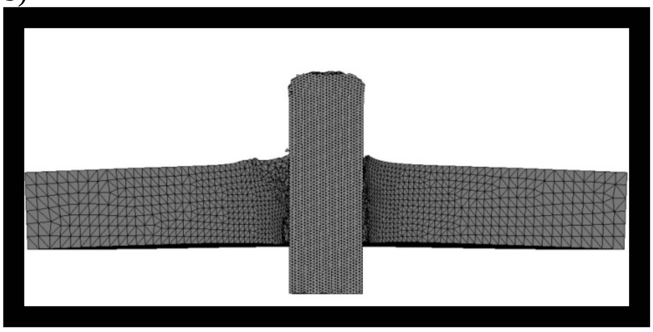

c)

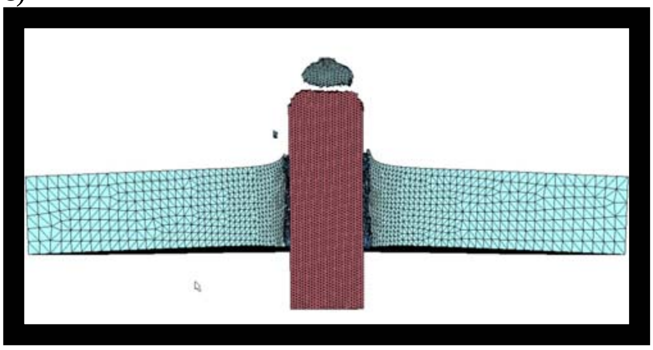

Fig. 4. A comparison of the computer simulation results for three cases at 30th microsecond after impact: (a) FEM method with hex mesh topology, (b) FEM with tetra mesh, (c) EFG method with tetra mesh.

The effects of simulations presented as the time histories of the projectile's kinetic energy, Fig. 5, and free surface velocity of the target at symmetry axis, Fig. 6, confirm that FEM and tetrahedral mesh lead to improper results, essentially different from others.

Fig. 5. The time histories of the projectile kinetic energy for studied cases.

Fig. 6. The time histories of the plug velocity for studied cases.

Table. 2. The residual projectile's length at 30th microsecond after impact (22 mm the initial value).

Case:	**Residual projectile's length [mm]**
FEM-hex	18.5
FEM-tet	18.5
EFG-tet	18.0

5. Conclusions

The performed analysis confirmed that the special care must be undertaken if the numerical modeling has to reconstruct the primary physical phenomena, even if some simply measured parameters, e.g. residual projectile's length, stay similar, Table. 2.

Acknowledgement

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References

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