Contribution To Target Penetration: Modeling and validation

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Abstract:

Numerical investigation has been undertaken to study the process of target penetration by fragment of high explosive warhead . Finite element modeling of target plates and penetrators using ANSYS LS-DYNA .Fragment simulating projectile (F.S.P) of 1.411 grams and 1.912 grams are used , normally impacting a thin mild steel target plates of 1.25 mm and 2.2 mm thick. Simulating velocities ranged from 450 m/s to 950 m/s .

Comparison of finite element simulation parameters to experimentally available data in literature do show an overall very good *agreement for residual velocities and a satisfactory agreements for plug thickness . Model over estimates plug thickness this might be due to the method of estimating perforation geometry , there are also some discrepancy of residual velocities ,these might be contributed to utilization of static material properties rather than dynamical values or that these velocities are close to ballistic limit velocity.*

KEY WORDS: *high explosive warheads , fragment simulator . penetration .FEM .simulation, LS-DYNA*

1.Introduction.

Targets are defeated by several types of mechanisms that is function of target mechanical integrity , projectile geometry , projectile velocities and incident angle [1] . These mechanisms varies from petal formation (or dishing) , ductile hole enlargement , plug formation and fragmentation (scabbing)[2] . Target failure can occur by combination of two or more mechanisms [3] .

AWERBUCH and BODNER [3] penetration theory indicated that the principle mechanisms of plate perforation process is plug formation and ejection when the thickness of the sheared plug is equal to zero , there is no punching and the mechanism of failure is considered to be ductile type . When the plug thickness is equal to the thickness of target , the plate perforation is completely by plug formation . They also indicated that perforation is usually a combination of two process with transition stage between them .

2- Literature Review:

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). FEM subdivides a large problem into smaller, simpler, parts, called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function [4]. Rajesh et el [5] used ABAQUS/Explicit numerical simulation for the study of the behaviors of both the projectile and the target during impact and penetration . They concluded that numerical simulation help in the optimization of bullet and target in ballistic impact simulation . James O'Daniel et el [6] in modeling of fragment simulating projectile penetration into steel plates using finite element method , they evaluated the damage caused to the projectile and target plates as well as comparison of residual velocity to available literature when the projectile perforated the target .J.Lopez Puente et el [7]. Studied thin carbon /epoxy woven laminates using finite element analysis for normal and oblique impact to determine both the extent damage and morphology .Dan Davis [8] Conducted an experimental and analytical analysis to measure and determine the ballistic performance of fiber glass armor plate .Model created in LSDYNA by adjusting the available material models for the projectile , these models are isotropic and resulted in shear punch out type failure of the plate that poorly replicated the test results . Rade Vignijecic et el [9]. They investigated the capability of hydrocodes to simulate high velocity impact , particular interest is given to the post- penetration debris cloud characterization and the material failure mode identification. Satish Ramavat et el [10]. This study has shown that the predictive capability for penetration of steel core bullet is quiet good , it also helps to get the steel plate behavior under dynamic impact loading . it has been shown that simulation could catch the main features of the experimental work specially the velocity and the kinetic energy of the projectile .

In simulation of ballistic impact in steel plates . Jordi Ambrosini[11] , the analysis considers the influence of adaptive meshing of the plate , interaction and damage of the target plate among others . The final result and discussion can be of interest for the design of an optimized version of the model considered .A study of ballistic response is implemented using simulation of thin material targets in LS-DYNA parametric studies are conducted buy Sikiran Chellum [12] to study the effect of various factors on the damage process. The study demonstrated the effectiveness and accuracy of the finite element simulation of the impact tests on metallic targets with the help of finite element software .

3- Objectives of This Study:

The objective of this study is to use numerical simulation to predict ballistic limit and post

Perforation parameters such as residual velocities and plug characteristics which can be

used to minimize the number of experimental tests .

4- Practical Imoprtance:

The practical importance of the current work conducted is the following :

- Enhancement of fragmentation warhead design through a better design of fragment size , shape and velocity to inflict a maximum damage .
- Better shielding of armor , equipments and personnel to prevent damage by strikers at various velocities.
- Better design for aircraft components and fuselage against penetrators and fragments.
- In non-penetrating impacts , this can be incorporated into better design of helmet

response . protection of satellites , spacecraft and manned space flight against

meteoritic material in space which counts for one of the important environmental

hazards . A similar problem , potentially , is the damage that may be inflected on

a Ballistic missile by high speed particles produced and directed by artificial means.

In industrial processes that involve repeated impacts on components like shot penning and abrasive grit blasting . protection of nuclear facilities and better design of vessels that house hazards materials against impacts .

5- Numerical Simulation:

LS-DYNA, a hydrodynamic finite element computer code, was used to simulate the impact of FSPs onto the steel plates to determine the ballistic limit and post perforation characteristics.

5.1- Numerical Mesh:

To model the impact, penetration and deformation processes occurring when the projectile impacts the steel plates, and the subsequent deformation of the plate, it is necessary to divide the plates and the projectile into a finite number of regions called elements. The network of elements obtained is called a mesh. The computations are then performed, by solving the constitutive equations that describe the relationship between the forces and the displacements in the materials.

Figure 1 shows an example of the initial global finite element mesh that was used for the simulations. This mesh was considered as the initial state just as the projectile impacts the target.

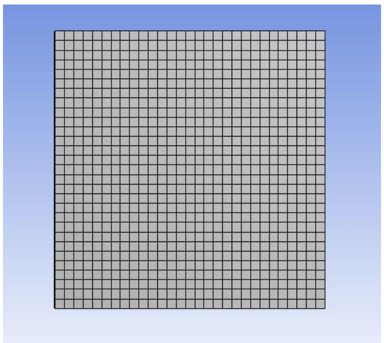


Figure 1 A target plate mesh

Figure 1 B projectile mesh

Table I below shows the element/node distribution for the different projectile/target systems that were considered in this study:

Table 1 target /projectile element and node number

Mesh	Target thickness (mm) Element type/ quadratic		FSP (gram) Element type/ triangle	
	1.25	**2.2**	**1.411**	**1.912**
Node	1800	1682	1261	1120
Element	841	784	1008	910

5.2 - projectile and target characteristics:

Table 2 projectile data

Projectile Type	Projectile material	Projectile Hardness BHN	Projectile Diameter Mm	Projectile Velocity (m/s)	Projectile Weight grams
Flat head	C 1731	243	5.56	400 - 950	1.411&1.912

Table 3 Mechanical properties of target material

Material Type	Material Thickness Mm	Density Kg/m^3	Yield stress Mpa	Ultimate stress MPa	Hardness BHN
C0146	1.25&2.2	7800	280	330	80

6- Computational Results and Discussion :

A review of literature obtained experiential data and model predicted residual velocities and plug thickness for both target plates used indicates a very good overall correspondence between the sets of results As shown in tables 4 and 5

Table 4 FEM model predicted results for striker 1.411 gram

	Model Prediction (FEM)					experimental (13)	
Target thickness (mm)	Impact velocity (m/s)	Exit velocity (m/s)	Plug mass (g)	Plug thickness (mm)	V50	Exit Velocity (m/s)	Plug Thickness (mm)
1.25	535	335	0.588	2.4	350	335	1.8
	608	390	0.668	3.5	350	389	1.85
	736	525	0.809	3.9	350	472	1.89
	761	507	0.836	4.2	350	561	2
	943	690	1.036	5	350	750	2.4
2.2	535	280	0.642	3	400	273	1.9
	608	305	0.729	3.8	400	342	2.7
	736	460	0.883	5.1	400	410	3.6
	761	490	0.912	5.6	400	554	4
	943	590	1.130	6	400	630	4.7

Table 5 FEM model predicted results for striker 1.912 gram

Model Prediction (FEM)						Experimental (13)	
Target thickness (mm)	Impact velocity (m/s)	Exit velocity (m/s)	Plug mass (g)	Plug thickness (mm)	V50 (m/s)	Exit velocity (m/s)	Plug thickness (mm)
1.25	535	290	0.823	2	380	336	1.1
	608	360	0.936	2.6	435	444	1.8
	736	520	1.133	3.6	380	561	1.9
	761	550	1.170	4.1	380	620	2.1
	943	670	1.450	4.8	380	742	2.6
2.2	535	235	0.856	2.2	410	172	1
	608	320	0.972	3.1	410	262	1.2
	736	440	1.177	4.7	410	409	1.2
	761	475	1.216	5	410	527	3
	943	615	1.507	5.8	410	626	3.7

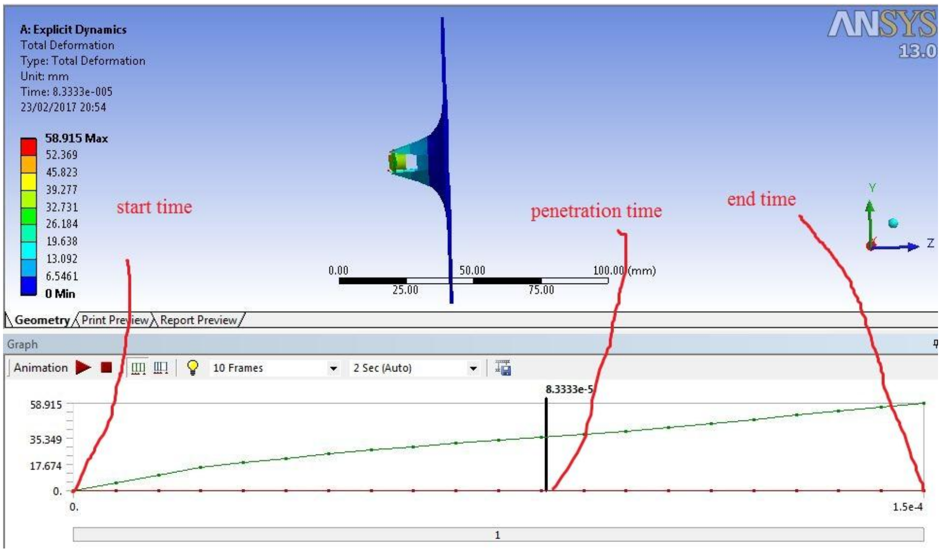
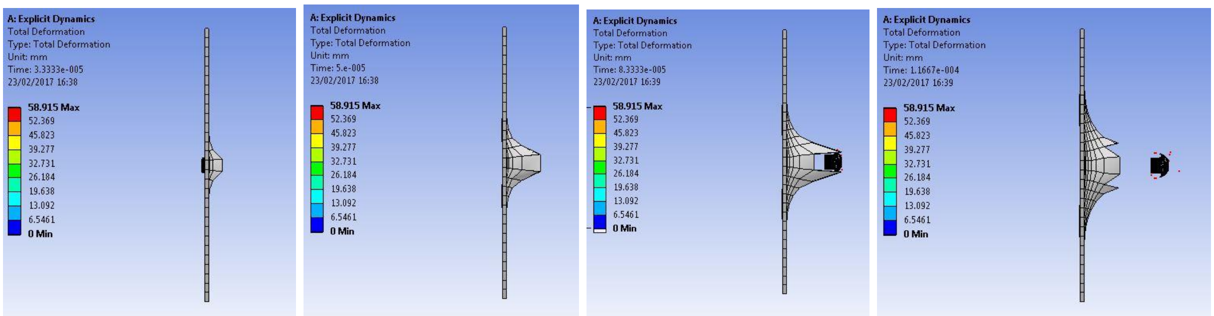


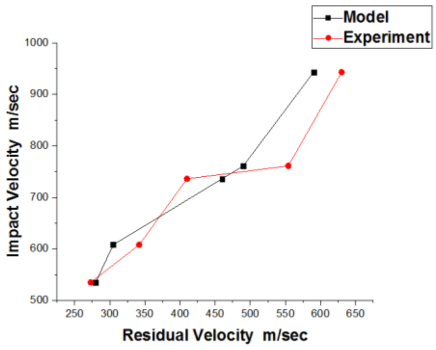
Figure 2 indicates penetration time for target plate 2.2 mm



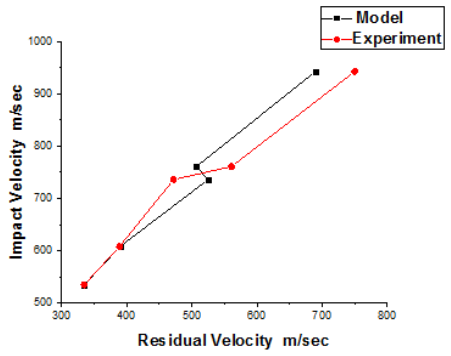
a- pre impact b- plate bending c- plug forming and moving d- plug ejection

Figure 3. various stages of F.S.P penetrating target plate

comparison of projectile residual velocity with experimental data for striker mass 1.411gram impacting target thickness of 1.25mm shown in figure (4) do show an excellent agreement .where in the case of target 2.2 mm with the same striker shown in figure (5) there are some discrepancy at lower velocity range .model over estimates the final velocity ,these might be contributed to utilization of static material properties rather than dynamical values or that these velocities are close to ballistic limit velocity.

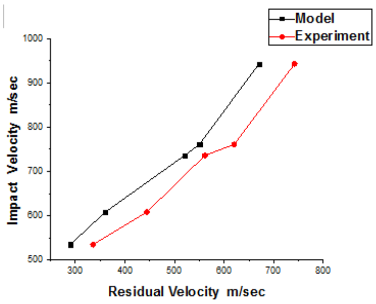


Figure(4) Residual velocity function of impact for1.25mm target plate and 1.411gram striker

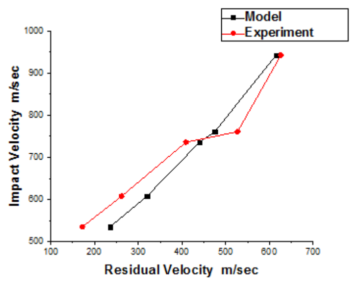


Figure(5) Residual velocity function of impact velocity velocity for 2.2 mm target plate and 1.411 gram striker

figure(6) and figure(7) show the impact velocity vs residual velocity for striker mass 1.912 gram and target plots 1.25mm and 2.2 mm respectively.



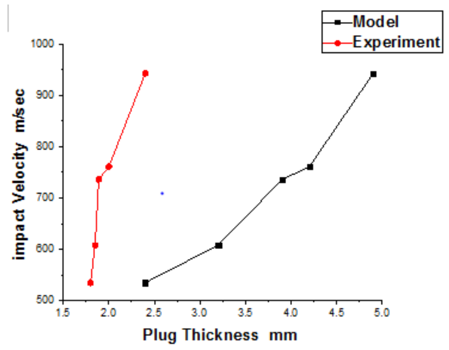
Figure(6) Residual velocity function of impact for1.25mm target plate and 1.911gram



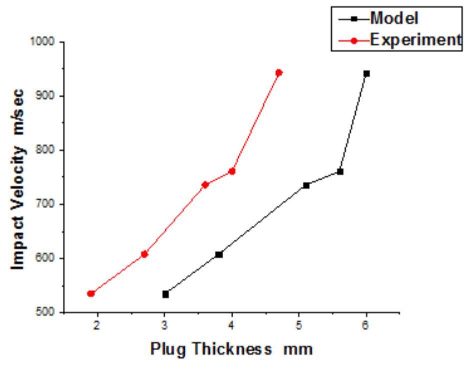
Figure(7) Residual velocity function of impact velocity velocity for 2.2 mm target plate and 1.911 gram striker

General trend and agreement are achieved to an acceptable level .striker mass play an important role in the mechanics of penetration of target. Plat thickness and mass represents a secondary fragments therefore its important to assess it. The generated secondary fragments can carry enough energy to be very lethal .

For striker 1.411 gram and target thickness 1.25mm figure(8) presents plug thickness vs impact velocity .as can be seen there are big disagreement with experimental values this is due to the method of estimating the thickness for penetration geometry .



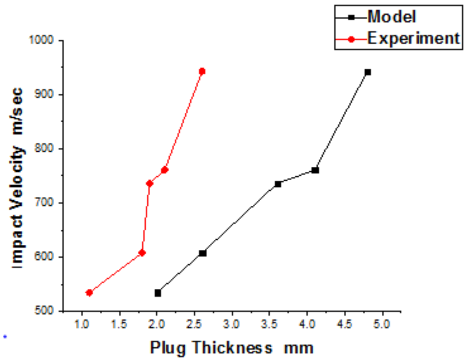
Figure(8) Impact velocity function of plug thickness for1.25mm target plate and 1.411gram striker



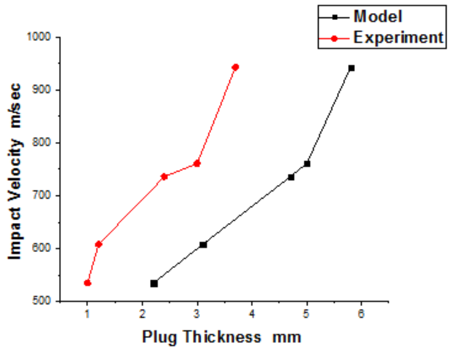
Figure(9) Impact velocity function of plug thickness for 2.2 mm target plate and 1.411 gram striker

For target 2.2mm with striker 1.411gram plug thickness vs impact velocity is shown in figure(9) do show a good agreement in this case less target bending is occurred shear is dominant.

Figure(10) and figure (11) show impact velocity vs plug thickness for striker 1.912 gram and plat thickness1.25mm and 2.2 mm respectively general trend is achieved at higher velocities .



Figure(10) Impact velocity function of plug thickness for1.25mm target plate and 1.912gram



Figure(11) Impact velocity function of plug thickness for 2.2 mm target plate and 1.912 gram striker

Conclusion :.

Fragment simulator projectile are widely used to simulate fragment shape, mass and velocity. Contemporary warheads give exploding fragment velocities between 1000 and 2000 m/s . Striking velocities on targets are usually less than 1000 m/s.

In modeling of penetration phenomena there is a great diversity among the approaches used to simulate penetration, which range in sophistication from a simple description of test results to intricate mechanical theories. Numerical simulations can provide detailed information that is not otherwise obtainable, there data can be used to supplement experimental data and the use of both may lead to a more comprehensive understanding of the physical process.

Simulation modes have emerged as an important design tool in the field of warhead engineering . Their use is most effective when integrated to design iteration cycle.

Residual velocities are well predicted by the model while plug thickness are overestimated .

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