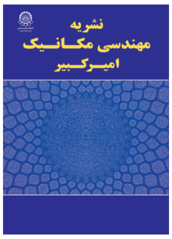

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(5) (2018) 19-22
DOI: 10.22060/mej.2017.12419.5328

Numerical Investigation of the Target Geometry Influence on the Glare Damage Caused By Medium-Caliber AP-Projectile

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Abstract: The medium caliber armor piercing projectiles have high kinetic energy and in practice, it is impossible to prevent these projectiles from penetration through different types of targets, directly. So this is essential to demonstrate a solution to repel these projectiles by studying on behavior of the targets. Air targets, generally made of fiber-metal laminates called GLARE, are one of the most important targets for medium caliber projectiles. In this study, numerical simulation of oblique penetration of medium caliber armor piercing projectile through the flat target of GLARE5 as well as curve targets with 6.3cm and 20cm curvature radius of the same material has been investigated via Abaqus software and consequence damage studied. Simulating failure behavior of the composite, 3D unidirectional composite model has been used and in order to do, a user-defined-subroutine VUMAT written and used with the Abaqus software. Also, because of high kinetic energy of the projectile, projectile damage has been accounted. Method of simulation has been verified by an experimental equation and the influence of target curvature on the penetration investigated. Results have shown that the increasing of the target curvature has not monotonic outcome of decreasing or increasing of the target damage.

Review History:

Received: 18 January 2017
Revised: 14 March 2017
Accepted: 16 April 2017
Available Online: 23 April 2017

Keywords:

Curve geometry
Oblique penetration
GLARE
Medium caliber AP projectile.

1- Introduction

Glare5 as a member of Glare family, has a lot of sufficient properties, needed for the fabrication of flying bodies, such as impact and fatigue properties and no-moisture absorption. So, many studies had been conducted to explore Glare properties (as well as other Fiber Metal Laminates (FMLs)) in many aspects of application [1]. But, there were not any studies on the oblique penetration of a medium caliber AP projectile, which has a high threat to the flying objects, generally made of Glare and other FML composites, through the Glare.

In this paper, oblique penetration of a 25mm AP projectile through the Glare5 with the variety of geometry has been simulated by using ABAQUS, finite element software. Projectile and target, both have not been treated as rigid bodies, because of high kinetic energy of projectile and their massive deformation. As the result, the influence of different geometries on the damage caused by the penetration has been investigated.

2- Methodology

To simulate the problem numerically, it was necessary to use some material models, which define the different materials behavior. So, Isotropic material model has been used to define Aluminum (target metal-layer) [2], Tungsten (projectile core) [3], and Poly-Ethylene (projectile membrane) [3] elastic-plastic behavior and failure criterion of these materials has been set as ultimate stress occurs. Also, 3D unidirectional laminate material model [2] and cohesive element [4] have been used to define failure criterion and delamination of glass fibers (target fibers which have been stuck together by Epoxy), correspondingly.

Three variations of Glare5 target geometries, i.e. flat target, 20cm-curvature-radius curve target, and 6.3cm-curvature-radius curve target (cylindrical target), have been simulated. To focus only on the influence of curvature radius, target dimensions and other problem parameters have been remained constant in all variations. Also, to study the oblique penetration alongside the curvature radius, four impact angles such as zero, 30, 45 and 60 degree have been simulated. In all 12 cases of simulation, impact velocity has been set as 1250m/s.

To verify the method of simulation, an experimental equation [5] which estimate the kinetic energy of the high-velocity projectile absorbed by a Glare flat target when it struck by the projectile with zero-degree impact angle (normal impact), has been used. After verifying the method of simulation and investigating the mesh sensitivity, other cases have been studied.

3- Results and Discussion

Kinetic energy reduction of projectile caused by impacting to the different targets has been compared in Table 1. At the zero-degree impact angle, all targets have shown approximately same behavior. But, as the impact angle increases, the difference between kinetic energy absorbed by the different targets increases. This could be referred to the increasing of the conflict area and also, to the resistant bending moment caused by the curve geometries. Also, a great kinetic energy reduction occurred at the 60-degree impact angle to the cylindrical target because two impacts, to both rear and front sides of the target, happened.

Tables 2 to 4 have shown the length of damaged area of all

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Table 1. Kinetic energy reduction of projectile (J)

Target Geometry	Impact Angle (Degree)			
	0	30	45	60
Flat	268.3	296.6	348.1	461
Curve	268.4	303.5	367.7	550.1
Cylindrical	285	310.4	467.7	1052

Table 2. Length of damaged area of flat target (cm)

layer	0d H	0d V	30d H	30d V	45d H	45d V	60d H	60d V
1	2.9	2.9	3.2	2.8	3.8	3	5.2	3
2	3.2	5	3.6	5	3.8	5.2	4.8	4.6
3	5.2	3.4	5.2	3.6	56	4	6.4	4
4	5.2	4	5.2	4.4	5.6	4.4	6.6	4.4
5	4.2	5.6	4.4	56	4.6	5.8	5.2	5.2
6	3.4	3.4	4	3.4	5.4	4.2	5.6	3.4

layers of flat, curve and cylindrical targets in both horizontal (H) and vertical (V) directions, correspondingly.

These results have shown the fact that changing in the target curvature, won't result in same outcome. By decreasing the curvature radius from unlimited (flat) to 20cm (curve), damaged area dimension in horizontal direction have been decreased. By further decreasing the curvature radius from 20cm (curve) to 6.3cm (cylindrical), damaged area dimension in horizontal direction have been greatly increased. This non-monotonic pattern could be referred to the increasing of the projectile-target conflict area which appears when curvature increases. Also, curve fibers have shown more strength than straight ones which affect damaged area dimensions in fiber layers.

Table 3. Length of damaged area of curve target (cm)

layer	0d H	0d V	30d H	30d V	45d H	45d V	60d H	60d V
1	2.5	2.8	2.8	2.8	3.3	2.8	5.4	3.2
2	2.8	4.6	2.8	4.6	3.2	4.4	5	3.8
3	3.4	5.2	3.2	4.8	3.2	4.8	4.7	3.8
4	3.4	5.2	3.3	5.2	3.4	4.6	5.1	4.6
5	3.4	5.2	3.1	5.2	3.6	5	5.8	4.6
6	2.5	3	3.7	3.4	4.6	3.4	6.3	3.4

Table 4. Length of damaged area of cylindrical target (cm)

layer	0d H	0d V	30d H	30d V	45d H	45d V	60d H	60d V
1	3.4	3	3.8	3	5.6	3	11.9	4.2
2	3.5	3.6	4.2	3.4	5.6	3.4	11.9	4.4
3	4.2	3.6	4.4	3.6	5.6	3.4	12.9	4.4
4	4.2	4	4.3	3.4	6.5	3.4	12.9	3.8
5	5	4	4.8	3.6	6.5	3	11.9	3.8
6	4	3.6	5	3.4	6	3	14	4.2

Layers 1 and 6 (Aluminum layers) are similar in penetration progress and material. But, layer 6 damaged area is larger than that of layer 1. This fact could be referred to a specific phenomenon called asymmetric petalling which happens at the oblique impact cases in layer 6 (Fig. 1).

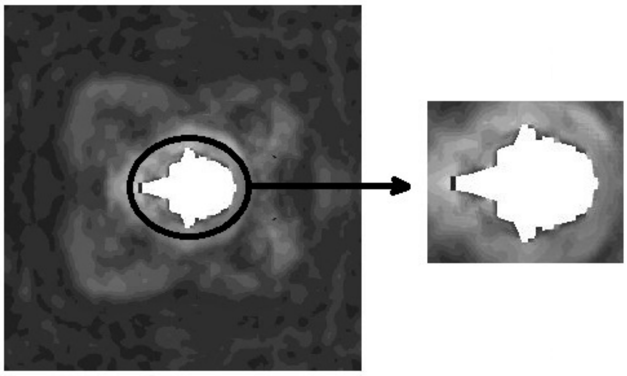

Fig. 1. Asymmetric Petalling

In addition to the increased conflict area, asymmetric petalling, and curve fibers, in the vertical direction, another specific phenomenon called small-cracks formation at high impact angles, governs damaged area dimension. At high impact angles, projectile slides on the surface of the target. So, instead of formation of one large vertical crack, small vertical cracks appear (Fig. 2).

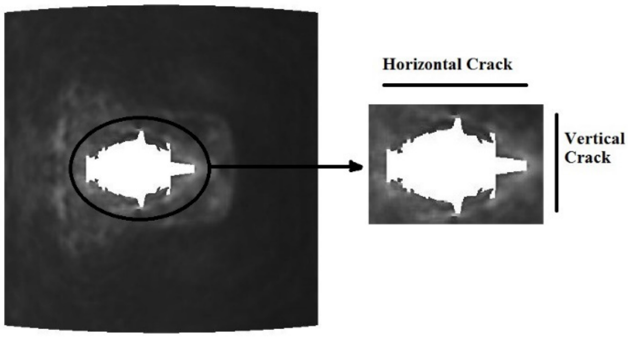

Fig. 2. Vertical small-cracks formation

4- Conclusion

In this paper, oblique penetration of a 25mm AP projectile through the Glare 5 2/1 targets with flat, curve and cylindrical geometries has been studied by using ABAQUS, and consequence damaged area has been investigated. It has been shown that the increasing of the target curvature, as a solution to overcome the threat of the high kinetic energy medium caliber AP projectiles, has not always conduced desirable outcome and by inordinately increasing the curvature radius, damaged area (in cylindrical target) is even larger than that of flat target. Also, curve target has caused the decreasing of the damaged area dimensions, only under 45 degree impact angles, and at the higher impact angles, inversely has conduced larger damaged area.

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Please cite this article using:

P. Pirali, M. Ghadami, Numerical Investigation of the Target Geometry Influence on the Glare Damage Caused By Medium-Caliber AP-Projectile, *Amirkabir J. Mech. Eng.*, 50(5) (2018) 19-22.

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