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An Investigation on Dynamic Response of Collision by Multiple Projectiles Towards Multi-Layer Al2024 T3 Aluminium Plate

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Abstract: Multilayer structure has been widely used in many engineering applications in order to increase durability, performance and safety of its structure. Numerical investigations were carried out on 15 mm thick multilayer aluminium Al 2024 T3 target plates impacted by multiple hemispherical and blunt nose shape of projectiles with a diameter of 10 mm. Three-dimensional numerical simulations were carried out using IMPACT finite element code. The present studies are concerned about the failure process of a deformable multilayer aluminium target plate perforated by multiple projectiles of hemispherical and blunt nose shape as a rigid body. The failure modes of projectiles with different nose shapes have been compared and analysed. The research covered several perforated multilayer aluminium Al 2024 T3 plate failure mode profiles based on impact velocity levels ranging from 20 m/s to 100 m/s. During the perforation by multiple blunt nose shape projectiles, no plugging formation occurs. The petals formation of blunt nose shape of projectile is almost the same as hemispherical nose shape of projectiles at velocities of 20 m/s and 60 m/s. The petal formation size grows larger as the impact velocity increases especially for hemispherical nose shape projectiles. The obvious petal formation size increase can be seen at a velocity of 100 m/s due to an increase in impact velocity. The petal formation size, bulge formation and hole enlargement increase as the impact velocity increases.

Keywords: Al 2024 T3, Multiple Collusion, IMPACT Finite Element

1. Introduction

Multilayer aluminium plate has always been used as a defence material in military applications. Researchers have been considering this topic because of its military and non-military applications. Military applications such as the design of structures resistant to projectile penetration, anti-bullet armours, and missile and rocket design, as well as non-military applications such as the manufacturing of machines for transporting dangerous materials and protecting spacecraft, are among the most important applications of this subjects. Impact loads resulting from the

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stroke of external items such as missiles and rockets, as well as internal factors such as raising the applied pressure, are critical in the abovementioned applications [1]–[4].

Multi-layered plate layouts have become popular in recent years because of the fact that steel materials are not always fabricated to the requisite thickness, necessitating numerous layers to build shields that match design standards [5]–[9]. In addition to experimental and computational research, numerous analytical models for estimating the ballistic resistance of multi-layered shields have been created to explore the performance of multi-layered targets [10]–[13]. The similarity and inconsistency conclusions drawn from previous studies suggest that multi-layered shields' ballistic resistance is still a point of contention.

This research is focus in the investigation on dynamic response of multilayer AL2024 T3 aluminium target plate when subjected to collision by multiple projectiles impact with different nose shape at different velocities. The dynamic properties of AL2024 T3 analysed based on the impact on projectile. The dynamic behaviour of aluminium studied based on the thickness of the aluminium, resulting in deformation and perforation when subjected to multiple impacts. The dynamic behaviour of multilayer aluminium plate is defined by using IMPACT finite element code. The results accurately predict the impact failure mode depending on projectile nose shape and impact velocity.

2. Materials and Methods

The main objective of this work is to discover the relationship between the multiple collision of projectile and the effect on the target by multilayer of Aluminium AL2024 T3 plate as well as to analyse on failure mode of multiple Al2024 T3 plate when subjected to normal direction of impact. The impact penetration simulations were carried out using the hemispherical and blunt nose shape projectile. Multiple projectiles launch at the same time towards the target. The projectiles impacted the targets perpendicularly with various velocities every each of simulation which was 20 m/s, 60 m/s and 100 m/s. The diameter, the length and the mass of the projectile are shown in Table 1.

Table 1: Parameter of projectile and target plate

Type	Description
Bullet/Projectile	Nose Shape: Hemispherical and Blunt Diameter :10mm Length: 45mm Mass: 3.56 gram Classification: Rigid Body
Target Plate	Dimension: 100mm x 100mm x 5mm Types: Al2024 T3 Tensile Strength: 483 MPa Classification: Deformable body

2.1 Aluminium Al2024 T3 Target Plate

The alloy Al 2024 T3 is a high-strength metal composed of aluminium, copper, and magnesium. It is the most prevalent and well-known of the high-strength aluminium alloys [14]. It is commonly used in automotive, aerospace and military industry due to high strength-to-weight ratio, corrosion resistance, easily repairable and inspectable.

2.2 Finite Element Method Analysis

The process of using software to solve problems is divided into three stages. To begin, a model is created using a Pre-Processor. Following that, a solution using the IMPACT software, and finally, a Post Processor-based display of the results and the solution's output files. The geometry model of both types of nose shape and multilayer Aluminium AL2024 T3 plate were created using finite element pre-processor GiD with IMPACT interface module. Next, the condition of the plate was created. The plate was constrained at all the edges and subjected to multiple impact projectile with two different nose shapes at different velocity. Both types of nose shapes projectile have a diameter of 10 mm. Each square target plate has a dimension of 100 mm × 100 mm x 5 mm as shown in Figure 1.

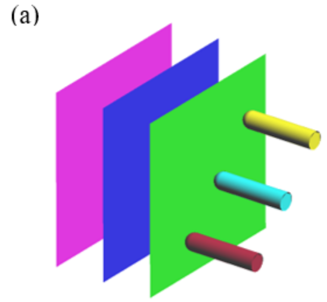

Figure 1: Finite element model of projectiles and multilayer plate (a) Hemispherical nose shape (b) Blunt nope shape

3. Results and Discussion

The main focus and outcome of this study is the dynamic responses of multilayer Al2024 T3 plates when impacted in the normal direction by multiple projectiles. The projectile motion simulation occurs at different velocity. The parameters involve including impact velocity, failure mode contour, nose shape of projectile and properties of target plate.

3.1 Analysis of Petalling Process

The back surface of the target plates bulges close by the impact zone. The combination of the bulge formation of each impacted area by all three projectiles creates a larger bulging at the back surface of the multilayer aluminium plate. The bulged area is categorised into petal zone and the cracks zone. High circumferential tensile strains in the bulge induce petals to develop [15].

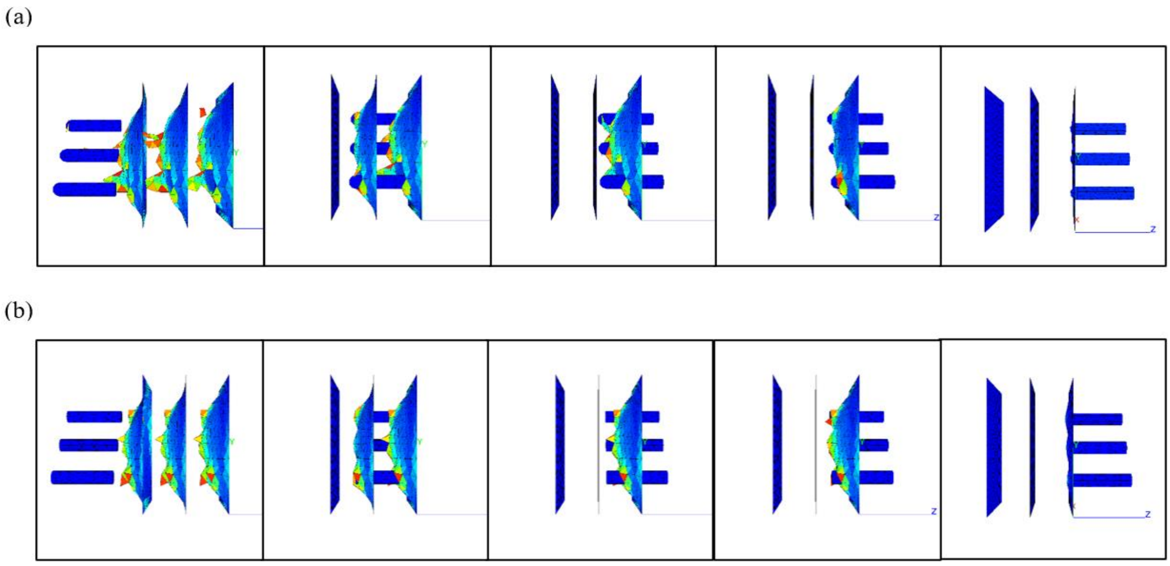

Figure 2: Simulation result of multiple projectiles (a) Hemispherical nose shape (b) Blunt nose shape perforated the multilayer of Al 2024 T3 target plate at velocity, v = 100 m/s.

The petal formation generates around each plate has almost the same pattern for the first, second and third layers of the plate as the constant velocity are used in this study. The petal generated in the form of a triangular shape. The second layer plate shows the largest crack propagation followed by the first plate and third plate when hemispherical projectiles are used. Perforation on multilayer plates using a blunt nose shape create a petal formation around it and no plugging occurs as shown in Figure 2. It is due to the critical impact energy of a projectile being determined by the projectile's nose radius and when the energy reached its peak, the failure mode changed from shear plugging to tensile stretching [16].

3.2 The Effect of Impact Velocity

Figure 3 show the failure mode of multiple hemispherical and blunt projectiles nose shape hit the multilayer target plate at impact velocities of 20 m/s, 60 m/s and 100 m/s respectively. A larger size of bulging occurs for the impact velocity of 60 m/s and 100 m/s respectively for both nose shapes. A visible deformation and failure mode may be recognized during the third stage of perforation when the projectiles exit, especially for hemispherical nose shape projectile. It is due to the higher impact engagement that creates a larger opening of petals.

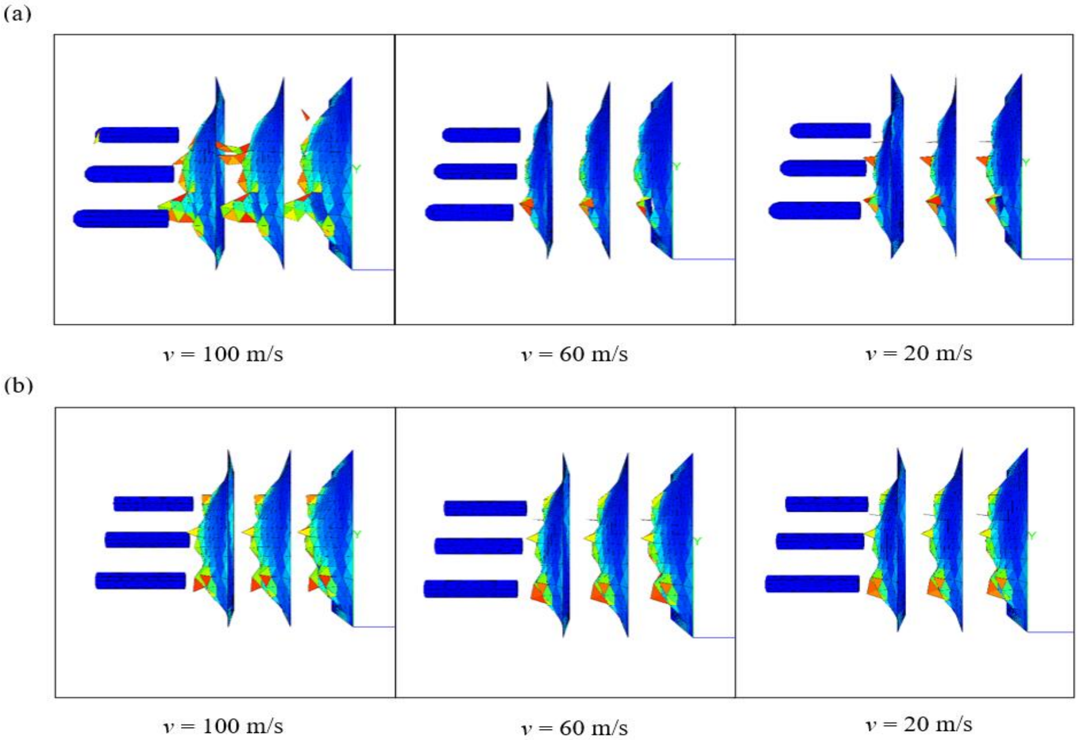

Figure 3: Different velocity impacts of the multiple projectiles (a) Hemispherical nose shape (b) Blunt nose shape

3.3 Hole Enlargement

The velocity of impact increases, the expansion of the hole continues to expand. The hole created during perforation on the aluminium multilayer plate has the same size for each target plate and increases in size when the velocity increase. The size of the holes grows larger at a velocity of 100 m/s especially for hemispherical nose shape projectiles as shown in Figure 4. Several cracks perforation occur, and the size of the petals get larger.

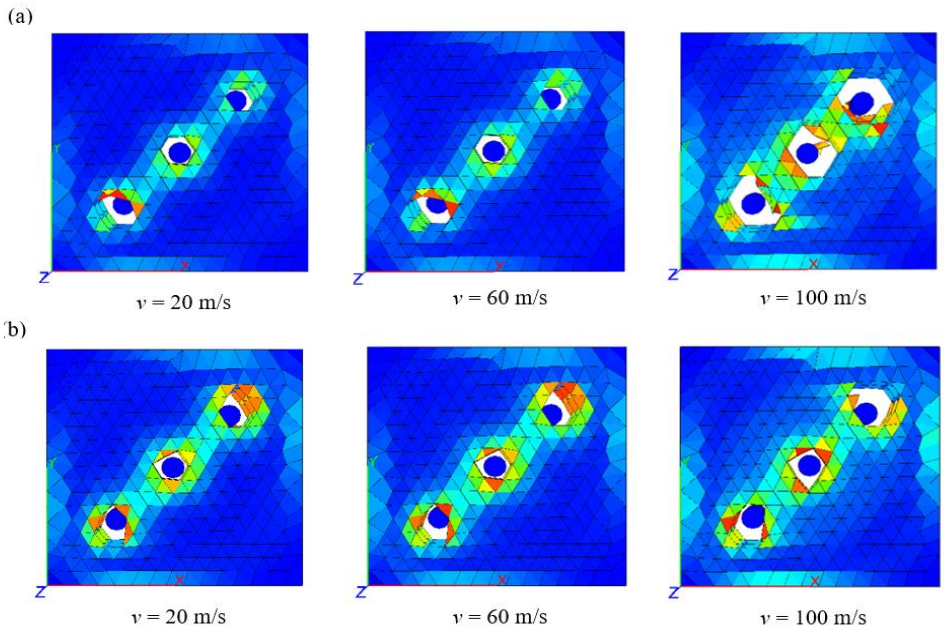

Figure 4: Hole enlargement during impact at a different velocity (a) Hemispherical nose shape (b) Blunt nose shape

3.4 Strain Rate Analysis

The different tones of strain-level occur at the perforated target area. Figure 5 show the colour tone indicated the strain level, as the strain increases the colour tone will increase. The maximum strain is labelled with red colour. The back surface of the multilayer target bulge when the multiple projectiles start to penetrate and petals formation occur after the initial crack propagation take place. Thus, the deformation occurs when the initial crack propagation takes place and plastic deformation occurs at the highest strain. The maximum level of local strain for hemispherical projectiles is 0.4992 while the maximum local strain reach for blunt projectiles is 0.4996.

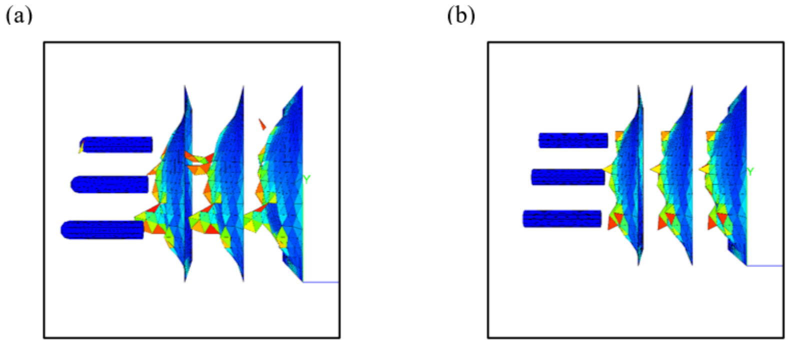

Figure 5: Failure mode profile for multilayer aluminium Al 2023 T3 subjected to impact towards multiple collusion of projectiles (a) Hemispherical nose shape (b) Blunt nose shape

4. Conclusion

The failure mode of multilayer aluminium target plate impacted by multiple collusion of hemispherical and blunt nose shape projectiles was the petals and bulging formation size around the area of perforated surface. The failure profile of multilayer target has almost the same petals formation between the first, second and third layer when subjected to both nose shape projectile. The formation of the petals that occur during perforation for each of the multiple projectiles is different. There is no plugging formation occur during the perforation by multiple blunt nose shape projectiles. The petals formation of blunt nose shape projectiles is almost the same as hemispherical nose shape projectiles at velocity of 20 m/s and 60 m/s. The petal formation size, bulge formation and hole enlargement increase as the impact velocity increases.

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