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# Kinematic Behavior of AL2024 T3 Aluminium Plate Subjected to Impact of 7.62mm Bullet

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**Abstract:** This study is concern about perforation process of single layer advanced high strength aluminum plate subjected to impact projectile motion. Numerical study had been carried out by using simulation from the ANSYS software to obtain the failure mode and perforation of the single layer Aluminum plate. ANSYS explicit finite element method was used to perform the simulation on the kinematics motion of bullet 7.62mm towards AL2024 T3 target plate at various range of velocity impact. The main focus of this research is concern about the dynamic behaviors response of bullet 7.62mm towards AL2024-T3 target plate at low, medium and high velocity impact. Observation was focused along the simulation process and detailed investigation has been carried out on the deformation and perforation of the single layer AL2024 T3 target plate. From the result obtained, the bullet shape was effectively penetrating target plate at various impact velocity and the failure mode and contour were observed clearly after perforation due to penetration.

**Keywords:** Kinematic, 7.62 Mm Bullet, AL2024-T3, Finite Element

## 1. Introduction

Kinematic is the motion analysis, without mentioning any of the forces that trigger. It is a branch that describes the motion of points, bodies (objects), and bodies (groups of objects), independent of the powers which are driving them as a field of study and is sometimes considered a branch of mathematics [1, 2]. It will be possible to calculate the position, displacement, speed and acceleration of any unknown part of the system using arguments from geometry [3, 4]. AL 2024 T3 is a high strength alloy that is mostly used in the automotive, aerospace and also military application due to high strength to weight ratio and excellent resistance to fatigue [5, 6, 7].

Ballistic impact is a high-speed moving mass effect that can be associated with kinetic energy. It is including the application of 7.62 mm NATO ball bullets which frequently used in military which categories as small caliber ammunition [8]. The high speed impact of 7.62 mm caliber will normally penetrating the metal target plate in many field work of military exercises experimentally.

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Experimental test may provide actual dynamic characteristic of impacted surface of aluminum target plate. Anyhow an alternative way of identifying and evaluating the kinematic behavior in projectile or bullet –target interaction is by using finite element analysis [9, 10, 11, 12, 13] since it may increase visibility on the impact behavior of single layer target plate as well as diversifying the niche area of investigation.

This study focuses on analysis of the kinematic behavior of AL2024 T3 target plate impacted by 7.62 mm bullet at different velocity range using single processor. ANSYS explicit finite element code is used to simulate and study the phenomenon of ballistic impact especially in terms of dynamic response and profile of failure of impacted target plate.

## 2. Materials and Methods

### 2.1 Caliber of 7.62 mm Ammunition

Arms are usually categorized by use, size, and tradition. This varies between military service and military service. The primary difference is the small arms and artillery. Typically, every gun below a 20 mm bore size is known as a small arm [14]. An alternative word that is gaining increasing popularity is to include "small weapons" to support individuals and light. In most nations, the soldier's main weapon is a 5.56 or 7.62 mm assault rifle Single shot grenade launchers and automatic grenade launchers are lightweight support weapons. Machine guns are available in calibers of 5.45, 5.56, 7.62, 12.7 and 14.5 mm. Bullets can be engineered for minimal flight time, minimum dispersion, maximum retained kinetic energy, minimum wind resistance, minimum ballistic fall, maximum penetration and maximum restriction of range.

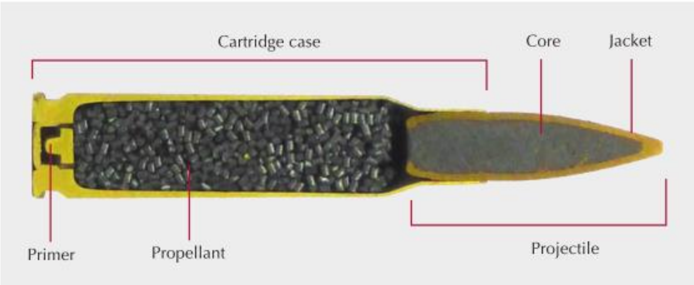



**Figure 1: Caliber 7.62 mm x 51 mm cartridge ( Jenzen-Jones and Schroeder, 2018)**

### 2.2 AL 2024 T3 Aluminum Plate

The AL2024 T3 aluminum ally has good mechanical performances against fatigue crack growth and this type of alloy is widely used in the extrados and fuselage of planes as well as missile parts. Table 1 shows the chemical composition of the AL2024-T3 aluminum alloy [15]. Detailed information on mechanical properties of AL2024-T3 is given in Table 2. This type of material is commonly used in aerospace, automotive and military industry due to corrosion resistance, low weight or a partnership of high strength, proven longevity and tolerance to contact with sun and humidity and reparable and easy to inspect.

**Table 1: Chemical composition (wt.%) of the AL2024 T3 alloy**

| Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.5 | 3.8-4.9 | 0.3-0.9 | 1.2-1.8 | 0.10 | 0.25 | 0.15 | Rest |

**Table 2: Material properties of AL2024 T3 alloy**

| **Physical Properties** | **Metric** |
|---|---|
| Density | 2.78 g/cc |
| **Mechanical Properties** | |
| Ultimate Tensile Strength | 483 MPa |
| Tensile Yield Strength | 345 MPa |
| Elongation at Break | 18 % |
| Modulus of Elasticity | 73.1 GPa |
| Ultimate Bearing Strength | 855 MPa |
| Bearing Yield Strength | 524 MPa |
| Poisson's Ratio | 0.33 |
| Fatigue Strength | 138 MPa |
| Ultimate Bearing Strength | 855 MPa |

2.3 Methodology

The initial geometry model of 7.62 mm caliber and AL2024-T3 aluminum target plate are created using Solidworks software. The projectile is created according to exact shape and dimension of 7.62 mm caliber to ensure that close behavior may be achieved according to actual situation of impact profile. The AL2024 T3 aluminum target plate has the dimension of 100mm x 100mm x 5mm and both of the geometry models are exported, combined and assembly in ANSYS explicit finite element code as shown in Figure 1.

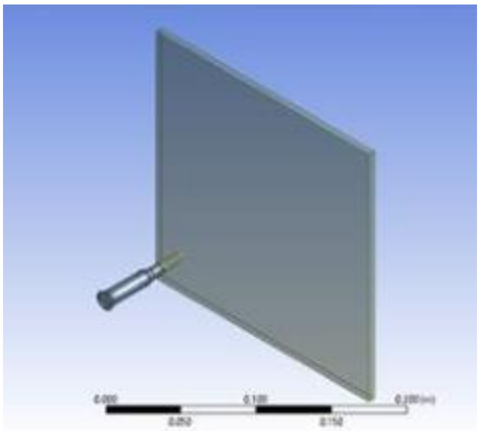


**Figure 2: Geometry model of caliber 7.62 mm and AL2024-T3 target plate**

Dynamic test measures the impact behavior of AL2024 T3 aluminum plate during and after collision. Ansys workbench is used to make the simulation of dynamic test on both projectile and target plate. To ensure that the dynamic impact simulation work effectively, the data and modal analysis is used to make the simulation. Modal analysis is a technique used to study the dynamic characteristic of a structure under a stress and strain option. By using explicit dynamic analysis, the behavior of dynamic can be determined. Explicit dynamic analysis also gives the idea on how the design will respond to different range of velocity. The range of impact velocity of projectile towards target plate is between 800 m/s to 1000 m/s.

## 3. Results and Discussion

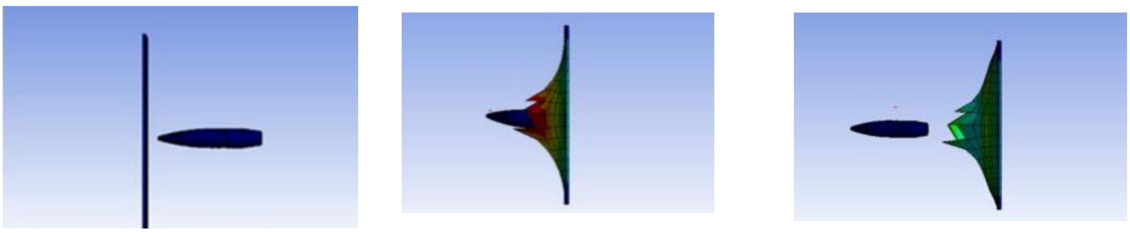
### 3.1 Numerical Results

Figure 3(a) shows a sharp cone bullet-nose shape positioned near the impact zone at the centre of target plate at t = 0 ms. . When the projectile hit the target plate at the speed of 800 m/s an early deformation in geometry of the model on impacted plate will continue until it reaches the stage of plastic strain deformation and initial crack on the contact surface occurred. At the maximum deformation the crack propagation around the sharp edge shape of the bullet will expend as the projectile keep moving forward and eventually perforation takes place at t = 0.2 ms. The change in geometry of the impacted target plate will remain after reach the permanent plastic deformation where projectile has already fully penetrated at t = 0.3 ms as shown in figure 3(c). It is shown that the perforated surface of AL2024 T3 aluminum plate indicating the formation of petals and it has a good agreement with the numerical and experimental study done by Borvik et al (2009, 2011).

**(a)** **(b)** **(c)**

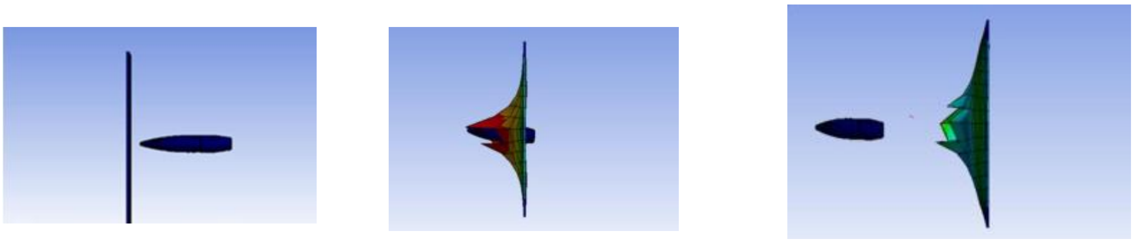
**Figure 3: Pre and Post Perforation of bullet impacted single layer of target plate at v = 800 m/s; (a). Before impact, (b). During impact at t= 0.2 ms, (c). After impact at t= 0.3 ms**

The same scenario also occurs to the projectile impact towards target plate at the velocity of 900 m/s and 1000 m/s as shown in Figure 4 and 5 respectively. The velocity of the bullet, bullet shape, direction of impact and type of material of target plate will affect significantly on the contour of failures. High velocity will generate higher impulsive force to the target plates and the deformation of the target plates influenced by the velocity and the contact area between the plates and the bullet.



**(a)** **(b)** **(c)**

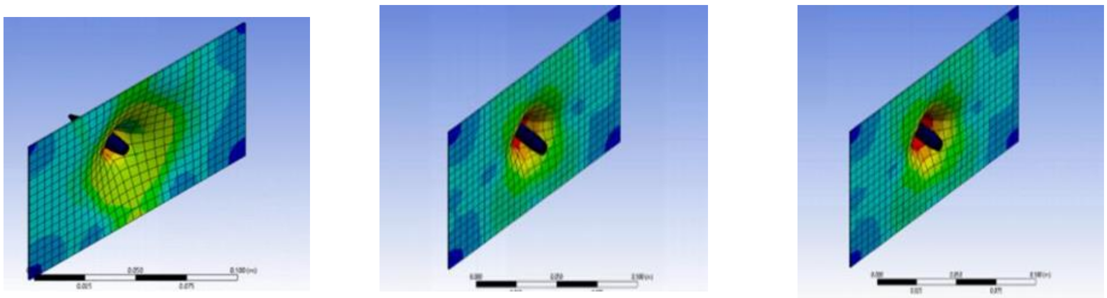
**Figure 4: Pre and Post Perforation of bullet impacted single layer of target plate at v = 900 m/s; (a). Before impact, (b). During impact at t= 0.2 ms, (c). After impact at t= 0.3 ms**



(a) (b) (c)

**Figure 5: Pre and Post Perforation of bullet impacted single layer of target plate at v = 1000 m/s; (a). Before impact, (b). During impact at t= 0.2 ms, (c). After impact at t= 0.3 ms**

The failure mode that has been obtained for the single plate impacted by projectile has different crack propagation, petalling shape and size of penetration hole. The crack propagation increases as projectile keep moving forward to perforate the target plate and basically the holes enlargement is proportional with the increment of velocity impact. Figure 6 shows the failure mode of model impacted by normal impact of 7.62 mm projectile in which it can be seen clearly that the deformation and perforation contour plot of various velocity range of impact observed on the surface area of contact. On the high impact velocity which is 1000m/s, there is increase in crack propagation on the surface area due to high collision of 7.62 mm bullet towards target plate. The petalling also increases and the others effect is the hole enlargement of perforated surface.



(a) (b) (c)

**Figure 6: Failure mode of model impacted by 7.62mm bullet with velocity of; (a). 800 m/s, (b). 900 m/s, (c). 1000 m/s**

## 4. Conclusion

Normal impact of small arms bullet of 7.62 mm on 5 mm thickness of single layered AL2024 T3 aluminum target plate has been studied numerically where the simulation was carried out by using ANSYS explicit finite element code. The single plate of target plate was impacted by the 7.62mm bullet at three range of velocity which is 800 m/s, 900 m/s, and 1000 m/s respectively. Based on the study which has been implemented it is shown that the mode and contour of failure found on the impacted target plate has tremendously influenced by the projectile nose shape and the range of velocity. The impacted target plate by different range of impact velocities were leads to the formation of petals and enlargement of hole around the perforated surface and this has a good agreement with the study done by other researchers numerically and experimentally.

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