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# A Study of Ballistic Resistance on Magnesium Alloy, AZ31B

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**ABSTRACT**

This paper discusses the deformation observation of the AZ31B magnesium alloy associated to the absorption energy criterion under the ballistic impact condition. The ballistic testing on a magnesium alloy plate was performed at the velocity of 435 m/s for the 9 mm × 19 mm Parabellum projectile. The ballistic test was followed by NIJ Standard level IIIA. The 9 mm × 19 mm Parabellum projectile shows that pre-penetration was observed in the magnesium alloy. The depth of penetration on AZ31B was shows 8 mm from 25 mm plate thickness. The magnesium alloy can sustained the ballistic impact from projectile 9 mm × 19 mm Parabellum. However, the properties of magnesium alloy must be improved to sustain at higher level types of projectile.



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## INTRODUCTION

Many technologies require new materials that are lightweight but have high strengths (Mertz, A., 2000), and the magnesium-based alloys are of current interest to the United States military industry because they are the lightest among all structural metal alloys (Jones, T.L., 2007). It was known that the density of magnesium is approximately 35% lower than aluminum, and it is approximately 77% lower than steel (Watari, H., 2004). Magnesium alloy is the lightest metallic material and has a high potential for weight reduction, thereby decreasing the amount of fuel used in automobile and aerospace applications. However, compared with several conventional materials, such as steel, there are less studies has been carried out for observing the relationship between magnesium alloys and impact loading (Yatu, F., 2010), particularly under ballistic condition.

Previous works on magnesium alloy characterisation (Mukai, T., 1998) indicated the determined properties were appropriate for ballistic applications. Hence, this alloy seems suitable to be a part part of an armour plate for reducing the armour weight and simultaneously increase the fuel consumption of and provide ballistic resistance to armour vehicles. Currently, the armour plate used in the rolled homogeneous armour (RHA) is steel-based. Furthermore, replacing RHA with magnesium alloy offers a new alternative that solves the issues in armour weight and fuel consumption while providing the same penetration resistance.

The AZ31B series from the magnesium alloy family was chosen in this study. It is because AZ31B normally used in aerospace and automotive application (Staroselsky, A. and L. Anand, 2003). The AZ31B was a potential material to replace RHA on the armor vehicle because of its impact behaviour. The objective of this study is to investigate the behaviour of magnesium alloy under ballistic impact. The results demonstrated the deformation of magnesium alloy under ballistic. That material can sustained on ballistic with achieved a NIJ standard level IIIA.

### *Experimental Procedure:*

The magnesium-based alloy used in the experiment was AZ31B because this alloy series exhibits high energy absorption, especially for ballistic impact (Jones, T.L., 2007). The composition percentage of AZ31B is shown in TABLE 1 and follows the standard ASTM B 90 (ASTM standard B90).

**Table 1:** Composition percentage element of AZ31B (ASTM standard B90).

| | Composition % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Al | Mn | Zn | Ca | Cu | Fe | Ni | Si | Each | Mg |
| AZ31B | 2.5-3.5 | 0.2-1.0 | 0.6-1.4 | 0.04 | 0.05 | 0.005 | 0.005 | 0.10 | 0.30 | Balance |

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The magnesium alloy sample that is used for the ballistic test is shown in FIGURE 1. The size of the sample was 100 mm in length (*L*), 100 mm in width (*W*), and 25 mm in thickness (*t*). The important factor to be considered is its thickness, as the selected thickness of 25 mm is the standard thickness (Jones, T.L., 2007) of steel RHA used in armour plates.

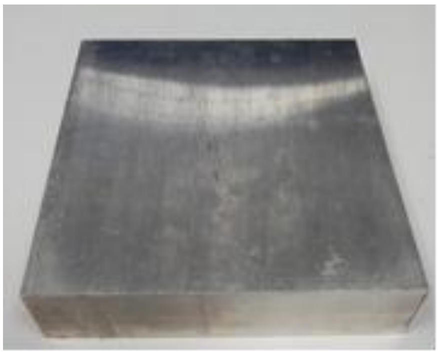


**Fig. 1:** The AZ31B sample used for the experimental ballistic impact.

The projectile was used, namely, a 9 mm × 19 mm Parabellum (used on magnum type firearm). The projectile consists of a jacket made of copper material and lead base filler core. The projectiles were chosen based on the requirement of the National Institute of Justice (NIJ) standard (NIJ Standard-0101.06 2008) to achieve the standard level IIIA. The level IIIA was required a maximum penetration of 44.0 mm of the sample. FIGURE 2 shows both types of projectile that were chosen for the ballistic impact experiment.

**Fig. 2:** The projectile 9 mm × 19 mm Parabellum.

The distance between the test barrel and the plate was 5 m. That distance was choosing because NIJ standard requirement based on an experiment using the handgun rounds. The angle of attack was normal or at the value of 90° to the target. That angle will produce the maximum energy absorption of penetration. FIGURE 3 shows the schematic diagram and image of the experimental setup. The velocity of the projectile was detected using a high-speed velocity sensor. The actual velocities obtained during the tests were used as the input for the simulation procedure.

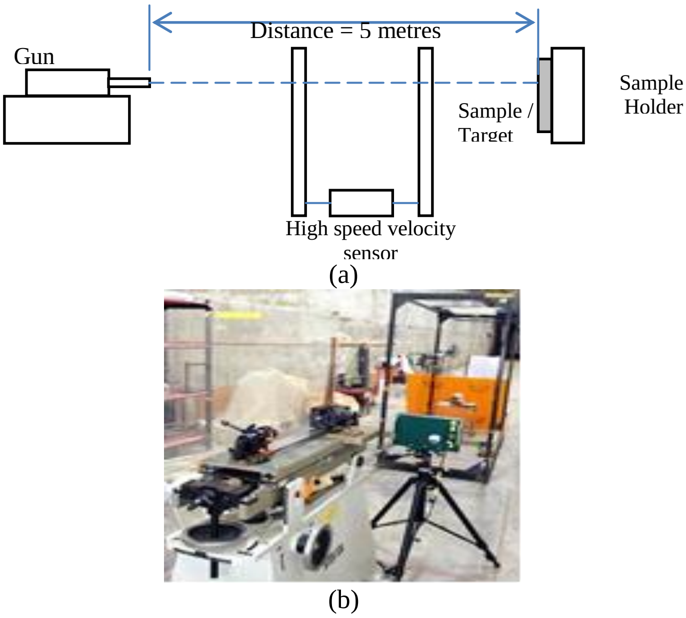
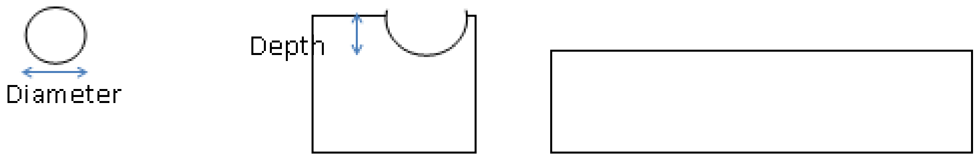



**Fig. 3:** (a) The schematic diagram of the experimental setup according to the relevant guideline (NIJ Standard, 2008), (b) The arrangement of the ballistic equipment during the test.

## RESULTS AND DISCUSSION

Figure 4 shows the schematic diagram of an indicator that was used to measure the effect of the ballistic impact, which is important for determining the shape of the penetration on the plate. The diameter and depth was importance to measure because it will present the behaviour of material on absorption energy. TABLE 2 shows the results of the penetration using the indicator measurement shown in FIGURE 4.




(a) (b)

**Fig. 4:** Schematic diagram of (a) diameter and (b) depth of projectile penetration.

**Table 2:** Projectile penetration results.

| Sample | 9×19mm Parabellum | | |
|---|---|---|---|
| | Diameter (mm) | Depth (mm) | Complete Penetration |
| AZ31B | 17 | 8 | No |

Figure 5 shows the effects of ballistic impact on the specified magnesium alloy when the 9 mm × 19 mm Parabellum projectile was used. However, there is no complete penetration was observed on the sample. The result shows the depth of penetration effect was 8 mm from 25 mm plate thickness. That shows the magnesium alloy, AZ31B can sustain on ballistic impact. From the calculation of kinetic energy, the projectile was produced the 704.86 J. That energy give the 32% of depth penetration, it will be considered that magnesium alloy can be sustained about three times greater than current energy. But it must be a same shape of projectile.

**Fig. 5:** View of the front side of the target plate after projectile penetration: 9 mm × 19 mm Parabellum at AZ31B.

***Conclusion:***

The effect of the behaviour of AZ31B alloy was investigated. The deformation occurred at 1/3 of the material thickness when the 9 mm × 19 mm Parabellum projectile was used. The kinetic energy on projectile was produced is 704.86 J and it can sustain up to three times of current energy produced with same shape and size of projectile. According to the finding this research, the magnesium alloy seems to be a suitable material for ballistic and military applications.

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