International Journal of Allied Research in Engineering and Technology (IJARET)
Volume.14, Number 2; Febuary-2023;
ISSN: 2836-5631| Impact Factor: 6.34
https://zapjournals.com/Journals/index.php/ijaret
Published By: Zendo Academic Publishing

UNDERSTANDING BULLET PENETRATION IN GELATIN TERMINAL: A FINITE ELEMENT APPROACH

[1]Rheinmetall Gita, Widyastuti

Article Info

Keywords: Ballistics, Terminal Ballistics, Gelatin Terminal, Finite Element Method, Projectile Behavior, Bullet Design

Abstract

The field of ballistics involves the study of projectile behavior and its effects on surrounding media. Terminal ballistics, a significant aspect of ballistics, focuses on the behavior of projectiles upon impact with dense mediums. Conventionally, terminal ballistics analysis employs gelatin as a surrogate target due to its efficacy in simulating tissue response. In this research, we investigate the ballistic performance of Gelatin terminal, analyzing the influence of diverse bullet designs and initial velocity fluctuations using the finite element method.

Previous studies have identified complications caused by bullets, including backward bounces and splashes. Fragile non-bouncing bullet types tend to resplash, breaking into smaller pieces when encountering challenging targets. This study aims to analyze the efficacy of various bullet designs in penetrating denser mediums, simulating gelatin targets, while studying the simulation outcomes with variations in initial velocity.

The finite element method serves as a powerful tool for examining projectile behavior upon impact. Employing this method, we investigate the effects of different bullet designs and initial velocities on bullet penetration and temporary cavity diameter. The outcomes will facilitate the development of more effective and efficient bullet designs, optimizing target penetration.

Interestingly, previous studies have shown that a two-story bullet design fails to meet total penetration criteria, necessitating a new design that incorporates the projectile's radius of curvature. The projectile's shape coefficient was found to lie within the range of 0.5, indicating the importance of bullet design parameters in achieving desired ballistic performance.

Moreover, the hardness of steel can significantly influence the ballistic properties of the test object. Studies combining steel with various materials have consistently shown steel to be the superior ballistic material. However, it has been observed that increasing steel thickness decreases projectile penetration, although it enhances

[1] Program Study Electrical Engineering, Politeknik Negeri Medan, Almamater Street, no 1, North Sumatera, Indonesia

resistance. To overcome this issue, ongoing research focuses on developing more resilient and lightweight ballistic materials.

This study also delves into coating materials and their impact on steel's ballistic resistance, analyzing fluctuations in ballistic resistance for three-layered materials. Furthermore, alloy combinations of iron and steel are considered for their ballistic properties. The research emphasizes the importance of numerical methods as a cost-effective and time-efficient alternative to experimental approaches.

By employing the finite element method to analyze the ballistic value of Gelatin terminal, this research contributes to the design of more efficient bullets capable of superior target penetration. The investigation of bullet designs and initial velocity variations offers valuable insights into optimizing terminal ballistics performance, advancing the field of ballistics and its applications in various domains.

INTRODUCTION.

The field of ballistics deals with the analysis of the behavior of projectiles and the effects they have on their surroundings. One of the key areas of ballistics is terminal ballistics, which is concerned with the behavior of projectiles upon impact with a denser medium. The target used for analyzing terminal ballistics is usually gelatin, which is better known for its use in ballistics than water. The purpose of this study is to investigate the ballistic value of the Gelatin terminal and analyze the influence of different bullet designs and initial velocity fluctuations on it using the finite element method.

Previous studies have shown that bullets can cause various complications such as backwards bounces and splashes. Fragile non-bouncing type of bullets can result in re-splash, as they tend to separate into smaller pieces when hitting difficult targets. The goal of this study is to analyze the effectiveness of different bullet designs in terms of their ability to penetrate a denser medium, which is simulated by the gelatin target. This can be achieved by analyzing the simulation results obtained by changing the initial velocity.

Finite element method is an effective tool for analyzing the behavior of projectiles upon impact. This method allows for the investigation of the effect of different designs and initial velocities on the penetration and temporary cavity diameter of the bullet. The results obtained from this study will help in the design of more effective and efficient bullets that can better penetrate their targets. It is important to note that a two-story design did not meet the criteria for total penetration, and a new design is required by adding the radius of curvature of the projectile. The coefficient of shape of the projectile is in the range of 0.5.

Steel hardness can also affect the ballistic properties of the test object [2]. other tests combined a steel of different or the same steel material. this is shown by babei et al. in 2011 we tested four types of specimens that incorporate a double layer of steel and aluminum. the best ballistic material is steel. previously, with the upgrade steel thickness, projectile penetration decreased, even in 2001 revealed by borvik et al. [four]. the thicker the ballistic material, the higher the resistance. but in terms of weight. it is so dangerous that research is being done to make it more resilient. it is recommended to reduce the weight of ballistic materials. from these few notes, you can make even more ballistic steel notes. \for this reason this research is an improvement from previous research by examining the effect of numbers. Type of coating material for the ballistic resistance of steel. from a survey of the number and type of layers materials can know that the thickness of the test object affects the results of the ballistic test of metallic materials. this test is carried out using the phenomenon of ballistic resistance fluctuations in three layers.

An alloy of iron and steel. also, i would like to consider the phenomenon of ballistic resistance of the three-layer (three) variation. coating) combination with steel with other target materials. ballistics is an applied science, related to experiments and theories about the shooting projectiles with motion or orbit and phenomena occurs when the projectile hits the target (eddy s. siradj, 2010). determined by performing ballistic tests quality and safety of ballistic objects (buhrle zurich, 1981). ballistics can be divided into three parts: ballistics (inside) ballistics), external ballistics and terminal ballistics (ballistic terminal). phenomena that occur in indoor ballistic influencing the next ballistics (mia, 2017).

Gelatin test part of the ballistic terminal this gelatin is a gelatin target that functions as a tissue human or animal. so far, research on this fragile ball is still ongoing. performed experimentally. learning this way is part of it expensive because you need to provide experimental tools and materials it also takes a long time to reach accuracy true because parameters can change at any time test. this is different from research numerically, this is still very rare. for example there is a numerical method compared to experimental studies financing and the entered parameters are considered constant.

In this study, the ballistic value of the Gelatin terminal will be analyzed using the finite element method. The influence of different designs and initial velocity fluctuations on bullet penetration and temporary cavity diameter will be investigated. The simulations will be carried out by changing the initial velocity, and different bullet designs will be analyzed. The results obtained from this study will contribute to the development of more effective and efficient bullets that can better penetrate their targets

LITERATURE REVIEW.

2.1. Bullet

The bullet consists of a projectile (bullet), cladding (bullet base), gunpowder (propellant), and lighter (rim). A projectile is the part of a bullet or ammunition that flies through the air when fired and moved with no thrust of its own (Mia, 2017). The projectile consists of the tip (nose), jacket, and core (core). (Gita, 2013).

According to Jorma Jussila (2005), the mechanism of action of bullets in the barrel is divided into three stages, namely the first stage, the primer was hit by the lighter which ignited a spark that

then cause the gunpowder to burn. The second stage is, gunpowder explosion causes gas pressure and pushes the projectile to be released from the grip of the cladding. In the third stage i.e. the projectile slides out of the barrel.

Projectiles fired, potentially not hit the target but hit a hard object that others, causing ricochet. The bullet that cause the occurrence of richochet is called a bullet conventional.

Figure 1. Scheme of occurrence of ricochet

This is due to the projectiles coming out of the barrel having a velocity and an angular velocity. High speed This causes the projectile to have high kinetic energy. When a projectile hits an object stronger and harder than the strength and hardness of the projectile, the projectile will be deformed and bounced in any direction. with direction irregular reflection, the projectile has the potential to bounce off the direction of the shooter or is called backsplash (Metrima, 2015).

2.2. Projectile Categorization

In general, projectile materials are made of various materials lead (Pb) alloy. Lead is usually combined with Cu, Zn,Ag, and other materials. The lead was chosen as the material projectiles because they are dense, easy to shape and widely available in nature. However, lead causes problems which is very serious for the environment and human health.

The problem arises because the dust from lead is inhaled by the humans and lead from projectiles that have been fired will accumulate in the soil and dissolve into the surface water and water in the soil (Gita, 2013). Conventional bullets can potentially ricochet and backsplashes. This problem causes the emergence of various studies to find ways to minimize the risk of ricochet and backsplashes as well as looking for lead replacement materials for projectile material. In the development of modern ammunition, Projectiles have been made with various shapes and materials different. This is done to meet the characteristics of projectiles tailored to their needs.

1. According to Brian J. Heard (2008), projectiles grouped into 2 based on the composition of the bullet.

2.3. Jacketed Bullet

A jacketed projectile is a projectile that has a thin to cover the projectile's lead core. Based on the part of the projectile covered by the jacket is divided into 2, namely FMJ (Full Metal jacket) and Partially Jacket. FMJ (Full Metal jacket) is a projectile whose entire covered by a jacket.

In general this type of projectile was developed for applications in the military world. A partially Jacket is a type of projectile that is not entirely part of the projectile is covered by a jacket. The part that is not covered by the jacket is the nose or point of the projectile. The projectile type is very good for hunting. This is because the bullet-type partially jacket kills animals quickly.

Unjacketed projectiles or unjacketed bullets are projectiles that do not have a jacket or all part of uncoated projectiles of copper alloy. This type of projectile will be deformed when hitting a target at risk relatively lower ricochet. This is the type of projectile that cheaper than other types of projectiles with projectile function that prioritizes target shooting. Projectile This type can also be used for self-defense or hunting.

RESEARCH METHODOLOGY

3.1. Materials Used

The steel plate here is a ballistic material used as a shooting target. This steel is mild steel with a thickness of 0.2 mm has a hardness value of 481.7 VHN. The dimensions of this steel plate are 10 cm x 15 cm and can be seen in Figure 1.

Figure1. Steel Plate

3.2. Non Steel Material

This 0.2 mm thick layer of steel plate is combined with mica, ram wire and copper respectively have a thickness of 1 mm, 0.2 mm and 0.1 mm. In all these non-metallic materials the dimensions are 10 cm x 15 cm. However on the type of material with ram wire whose surface is in the form of a hole with a side length of 3 mm. Shape of each type of layer can be seen in Figures 2.

(a) (b) (c)

Figures 2. Non Steel Material

3.3. Test Set Up

This test was carried out using a 4.5 mm caliber ogival-nose projectile fired with a distance of 2 meters using a compressed air rifle that is used to launch bullets in a range of 10 cock as an indication of its speed. The specifications of the air rifle used can be seen in Figure 3.

Figures 3. Air rifle

3.4. Response Variables

The response variable is a variable whose value is influenced by process variables, where the results are obtained after doing simulation and validation. Response variable in this research are:

a. Impact energy of the bullet/kinetic energy when the bullet collide (Ek)

b. The terminal ballistic value of gelatin is indicated by depth of penetration and diameter of the temporary cavity.

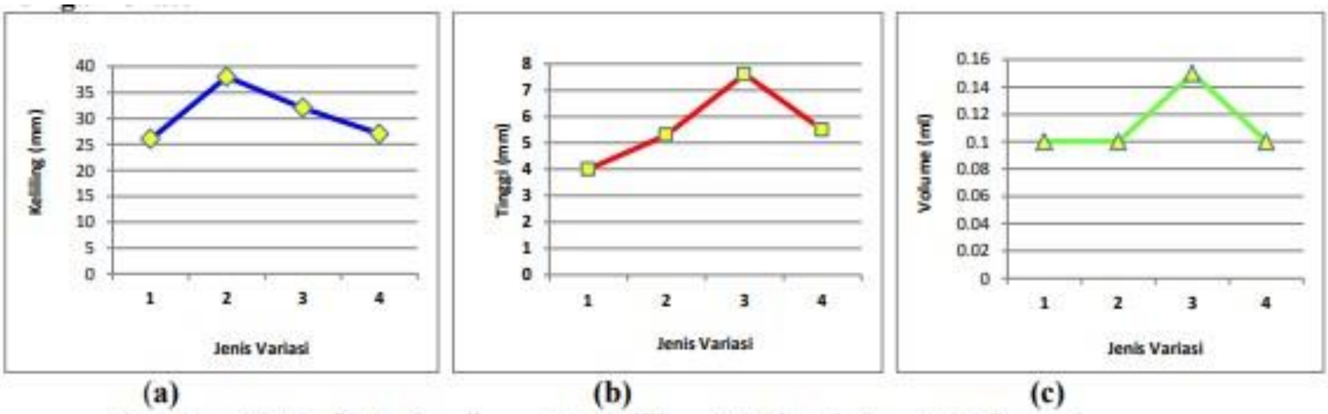
3.5. Process Variables

A process variable is a variable whose value is determined and varied with the aim of obtaining results and analysis about the effect of the process variable on the response variable. The process variables that will be analyzed in this research are muzzle velocity of two different bullet designs.

ANALYZE AND RESULT.

In this study, it is illustrated that the number and type of material layers with variation 2 have a crater circumference the largest when penetration occurs which is shown in figure 4, here it can be seen that the momentum and the kinetic energy given off by the bullet is the same in every variation.

Previously it was known that resilience the best ballistics is in variation 1, because steel is the target material with the best resistance ballistics, so that the area of the crater is also known to be the smallest compared to other materials. however different from variation 3 which combines steel with ram wire has the most crater damage severe, this is because when the bullet penetrates and a perforation occurs by being able to penetrate the material the target does not have a static back force on the ram wire, so in variation 3 the height and volume of the crater are known the largest compared to other variations.



Figures 4. . Comparison Graph (a) Perimeter, (b) Height, and (c) Crater Volume

Initial Velocity Calculation of Interpolation Results Modeling of frangible bullets carried out in

This study has several different parameters. By Therefore, the input data used in the simulation method must be analytically recalculated to ensure the validity of the modeling results. The parameter to be recalculated is initial velocity of the bullet. In this research using two different projectile shape designs. So that to find the initial velocity of the bullet, it is necessary to calculate ballistic coefficient. This is because the velocity of the bullet at a distance x is affected by the ballistic coefficient of the projectile shape design the.

a) Calculating the bullet shape coefficient (i)

Design bullet shape coefficient I

The radius of curvature of the bullet = 16 mm

$$N = \frac{Rk}{d} = \frac{16, mm}{9\ mm} = 1{,}8$$

$$i = \frac{2}{N}\sqrt{\frac{4N-1}{7}}$$

$$i = \frac{2}{1{,}8}\sqrt{\frac{4(1.8)-1}{7}}$$

$$i = 1$$

Design II . bullet shape coefficient To calculate the ballistic coefficient in the II . design using the Siacci calculation method, where the holes made in design II is considered a flow stabilizer. Length of ogive = 14 caliber number n

$$n = \frac{(4.l^2+1)}{4} = \frac{785}{4} = 196{,}25$$

$$i = \frac{2}{n}\sqrt{\frac{4n-1}{n}}$$

$$i = \frac{2}{196{,}25}\sqrt{\frac{4\ (196{,}25)-1}{196{,}25}}$$

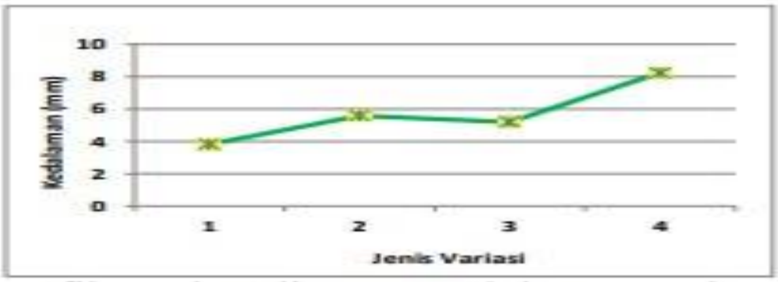
$$i = 0{,}02$$

This design II frangible bullet has a radius value small curvature of. Based on equation 2.2 shown that the value of curvature greatly affects the value of ballistic coefficient, so the value of the radius of curvature which small causes the projectile shape coefficient value (i) to be big and vice versa. Projectile shape coefficient value (i) is a form function factor according to the intended use determine the bullet's ability to penetrate the media and target.

b) Calculating air density

Deceleration concerning the velocity of the bullet, other than determined by the form of a bullet that has a high penetrating ability different, is also determined by the density (specific gravity) of the air as bullet velocity media which is calculated by equation 2.3. The more The greater the density of the air, the lower the bullet velocity too more and more.

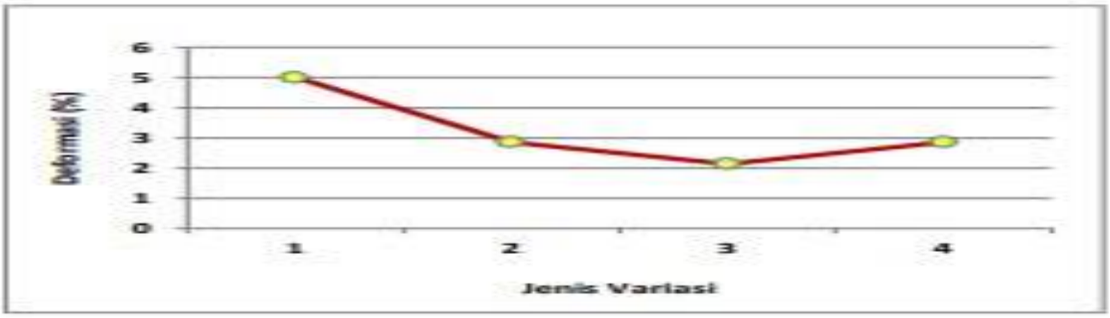
The air density value in the Malang district is 1.17265 3 . Air density values that are close to normal does not affect the value of the ballistic coefficient. The shape, mass of the bullet, and the density of air determine the value of ballistic coefficient frangible bulletin design I,



Figures 5. Bullet Depth Comparison Chart

In Figure 5. it can be seen that in the variation of the 4 bullets that entered the deepest beam because the material was copper the thickness used is very small so that the bullet easily penetrates the plate and the remaining speed of the bullet when it penetrates the beam is still large. In variation 1, the depth of the bullet entering the beam is the smallest compared to variation 3, but not as big as variation 2.

And it can also be seen in Figure 5. that the graph shows ballistic resistance with steel material better than other materials, namely the depth value the smallest bullet entered the beam at variation 1 of 3.82 mm. So it shows the velocity and residual energy the bullet after penetrating the armor layer is also the smallest because the depth of the bullet enters the beam indicates the velocity and residual energy of the bullet.



Figures 6. Bullet Deformation Comparison Chart

In Figure 6 it can be seen that variation 1 has the largest deformation because all layers are made of steel material so that it has a high level of hardness in all layers of the target material. While variation 2 and variation 4 have the same bullet deformation. But in the variation of 3 the bullet deformation is the smallest among the number and types of layers of other materials, because in the variation of 3 layers of steel combined with ram wire which is known that the coating sheet used on the surface of the plate is not uniform but consists of a rectangular hole and made of wire arranged continuously with side lengths 3mm hole. From this, it can be analyzed that when the bullet penetrates, the surface of the bullet's nose is not all hit a part of the surface of the ram wire, so it can be seen if the deformation of the bullet is obtained in variations 3 is not the maximum and the smallest compared to the other variations. From the statements above, it can be known that the better the ballistic resistance, the number, and type of material layers, the more energy the bullet absorbs
by the target material is getting bigger. This affects the deformation of the bullet which is getting bigger too. because the deformation of the bullet is an indication of the energy of the bullet absorbed by the target material.

CONCLUSION.

Based on data analysis and discussion on research this, it can be concluded that:

1. From the simulation results that have been carried out with variations of muzzle velocity and different designs get the value the gelatin ballistic terminal expressed by the total penetration on the I bullet design sequentially, namely by 175 mm, 190 mm and 193 mm. While the total penetration obtained from the simulation results of the bullet design II respectively 200 mm, 220 and 230 mm. Bullet design I diameter temporary cavity in a row are 19 mm, 23 mm and 30 mm. Whereas for bullet design II diameter temporary cavity respectively are 21 mm, 24 mm and 11 mm
2. Of the two existing bullet designs, the total penetration is produced not in accordance with existing standards.

3. New design required by adding radius the curvature of the projectile so that the shape coefficient projectile is in the range of 0.5 < i < 1 for design bullet I so that the resulting penetration meets the standard which exists.

REFERENCES.

Benini, Joseph. 2000. Frangible Metal Bullets, Amunition and Method of Making Such Articles. USA : United States Patent.

Benini, Joseph. 2001. Frangible Metal Bullets, Amunition and Method of Making Such Articles. USA : United States Patent.

Buyuk, Murat. 2008. Moving Beyond the Finite Elements, a Comparison the Finite Element Methods amd Meshless Methods for a Ballistic Impact Simulation. Washington : george Washingtong University.

Choi, dkk. 2011. Numerical Study on Properties of Interior Balistic According to Solid Propellant Position in Chamber. Korea : Inha University Datoc,

Danielle. 2010. Finite Element Analysis and Modelling of A.38 Lead Round Nose Ballistics Gelatin Test. San Luis Obispo. Faculty of California Polytechnic State University.

Firmansyah, K. M. (2015). Pengaruh Temperatur Sintering Metode Metalurgi Serbuk

Terhadap Frangibility dan Performa Balistik Peluru Frangible Komposit Cu10%wtSn. Jurnal Teknik ITS, 1-6. Germerhaussen, R. 1982. Handbook on Weapony. Dusseldorf :

Rheinmetall Gita, Widyastuti. 2013. Pengaruh Komposisi Cu dan Variasi Tekanan Kompaksi Terhhadap Densitas dan Kekerasan.

Heard, J. Briand. 2008. Handbook of Firearms and Ballistics Second Edition. WileyBlackwell. UK

Hornady. 2015. Ammunition Test Report and Application Guide. Hornady Manufacturing Company.

J. Komenda, 2012. Analysis of Ballistic Characteristics of Pistol Cartridge. Vol. 7, No 1.

J. Komenda, 2017. Evaluation Method of Frangible Bullets Frangibility. Vol. 12, No 2.

Jonas, G H. 2015. Mechanics and Penetrations : Analysis and Expertiment. USA : Perganon Press Ltd.

Joseph. 2015. Development of Ballistic Impact Device for Measuring the Impact Energy of Powder-Metal Bullets. Dubois. Pennsylvania State University.

Kamil. 2017. Analisa Numerik Balistik Impak Peluru Frangible Bullet Dengan Metode Elemen Hingga. Surabaya. ITS Kreyszig, Erwin. 2006. Advanced Engineering Mathematics Tenth Edition. New York, University Columbus.

Lang, David. 1998. Frangible Amunition. USA : United States Patent. Leasure, John. 2008. Lead Free Reduced Ricochet Limited Penetration Projectile. USA : United States Patent.

Narayanamurthy, V., Rao, C. L., & Rao, B. (2014). Numerical Simulation of Ballistic Impact on Armour Plate with a Simple Plasticity Model. Defence Science Journal Vol 64, 5561.