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Numerical Study of the Aerodynamic Behavior of 7.62 x 51 mm Bullet

7.62 x 51 mm Merminin Aerodinamik Davranışı Üzerine Sayısal Çalışma

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ABSTRACT

Firearms play an important role in the defence industry. Various studies have been carried out to increase the range, destructiveness, and stabilization of these weapons. However, one of the important factors affecting these parameters is the design of the projectile core. Aerodynamic improvements in the core design can increase the range without changing the weapon design. In this study, the effect of the 7.62x39 mm bullet core on the aerodynamic flow behaviour around it was investigated. The air flow over the projectile core is analysed in the ANSYS Fluent program.

Keywords: Projectile, Projectile Core, Aerodynamics, ANSYS Fluent, Flow Field

ÖZ

Ateşli silahlar savunma sanayinde önemli bir rol oynamaktadır. Bu silahların menzilini, tahrip gücünü ve stabilizasyonunu arttırmak için çeşitli çalışmalar yapılmıştır. Ancak bu parametreleri etkileyen önemli faktörlerden biri de mermi çekirdeğinin tasarımıdır. Çekirdek tasarımındaki aerodinamik iyileştirmeler, silah tasarımını değiştirmeden menzili artırabilir. Bu çalışmada, 7.62x39 mm mermi çekirdeğinin etrafındaki aerodinamik akış davranışına etkisi araştırılmıştır. Mermi çekirdeği üzerindeki hava akışı ANSYS Fluent programında analiz edilmiştir.

Anahtar kelimeler: Mermi, Mermi Çekirdeği, Aerodinamik, ANSYS Fluent, Akış Alanı

Introduction

In today's wars, firearms are one of the most important means of hitting the target. The bullet used in these weapons is a metallic component that is designed and fired by a mechanism within the weapon. A bullet is a whole consisting of a shell, powder, capsule, and nucleus. The nucleus of a bullet typically has no explosive effect, but when the powder in the shell is ignited by the capsule, the nucleus gains kinetic and impact energy and can damage the target. The development of efficient projectile movement is crucial for the core to reach the target. It is very important in terms of bullet damage that the exit velocity of the nucleus from the gun barrel reaches the target with minimum loss. Therefore, the velocity of the projectile depends on the flight resistance. The design parameters of the projectile are related to the drag and lift forces acting on it. The widespread use of long-range projectiles, worldwide has increased the study of the aerodynamics of projectiles and the analysis of their aerodynamic properties has become an important focus for their improvement.

Aerodynamics is the study of the mass forces of air. In the case of air flowing around a solid body or a solid body moving in still air, the air behaves in accordance with the laws of aerodynamics. In this study, the forces acting on the projectile core at supersonic speeds are analyzed using computer-based numerical analysis. In this context, a literature review was conducted, and proposals for range improvement of projectiles of different geometries supported the subject of the study. Jovanovic et al. (2012) conducted experimental and numerical investigations to understand the hydrodynamics of flow and to model the flow around a hollow sphere and performed numerical investigations at different Reynolds numbers. In their study, they found that the RANS turbulence model gives the best results in the experimental and numerical determination of the velocity field, pressure and friction coefficient, and the length of the reverse flow region. Choi et al. (2006) investigated the flow around objects with pits, such as on a golf ball. They found that pits increase the turbulence intensity in the flow and are an important flow control strategy to reduce friction in the body. Chowdhury et al. (2016) observed that the dimpled surface on a golf ball affects the aerodynamic behavior of the ball. As a result of the study, they evaluated that the dimpled structure significantly changed the surface drag coefficient. In 1995, R.M. Cummings et al. (1995) performed numerical analysis of projectiles in supersonic turbulent flow environments and developed different designs by applying drag optimization to them. Khan and Saha (2013) investigated the aerodynamic behavior of projectile cores with different nose structures using numerical approaches and investigated the effects of velocity and pressure on sharp and rounded edge geometries. In his study, Litz (2016) examined the fluid motions acting on the projectile and stated that the narrowing geometry at the tip of the projectile reduces friction. In 1953, Murphy (1953) investigated the drag coefficient and dynamic stabilization of the projectile by performing experimental measurements on different projectile geometries. Nietubicz and Sturek (1988) conducted numerical and experimental analysis of a projectile at supersonic speed. They compared the results of experiments conducted in a wind tunnel and numerical data with the changes they made in the tail angle of the projectile. Selimli (2020), in his study, investigated the effect of the channel structure and hollow structure formed on the surface of the 9 mm parabellum type light bullet core on the aerodynamic flow behavior around the bullet. The air flow around the projectile core was analyzed with computational fluid dynamics based Fluent software. The compressible airflow is analyzed with the Spalart Allmaras turbulent flow model, taking into account the viscous effects due to Sutherland's law. In the study, he concluded that the channel or hollow surface form created by the projectile geometry can cause an increase in projectile velocity and a decrease in shear stress and drag force. He evaluated that the hollow or channel structure to be formed on the projectile surface will provide positive contributions to the range as well as stabilization in the projectile movement. In 2023, Salunke et al. (2023) examined three bullets of different diameters used in different types of weapons. The first bullet is the NATO 5.56 mm, the second is the 7.62 mm bullet from the APM2 and the third is the 7.82 mm bullet from the AK-47 rifle. For the 2D stationary calculations, the supersonic speed of Mach 2 was adopted to analyze the flow field of all three projectiles. He observed that the 7.82 mm bullet is subjected to maximum buoyancy due to its larger surface area than the other two ammunitions. In 2024, Hao et al. (2024) analyzed the lift and drag coefficients of projectiles with different curves under different angles of attack. When they compared the analysis of the projectile with the logarithmic curve and the projectile with the von Karman curve, they observed that the lift force acting on the projectile with the logarithmic curve was higher.

In this study, the effect of the channel structure formed inside the 7.62x51 projectile core on the aerodynamic behavior of the projectile is evaluated. The compressible flow around the projectile core is analyzed in ANSYS Fluent software using the Spalart Allmaras turbulent flow model, which is used in aerospace and outdoor aerodynamic analysis, considering viscous effects due to Sutherland's law. By examining the flow behavior around the projectile core, the contribution of the design to range and target stabilization is investigated, and it is aimed to contribute to the related field.

Material and Methods

The 7.62-diameter bullet has a bullet diameter of 32.5-mm, a bottom diameter of 6.29-mm and a tip diameter of 1.5-mm. Two-dimensional models of the core were created in Ansys Design Modeler software. The dimensions of the bullet core are 7.62X51 mm. The created bullet core models are visualized in Figure 1.

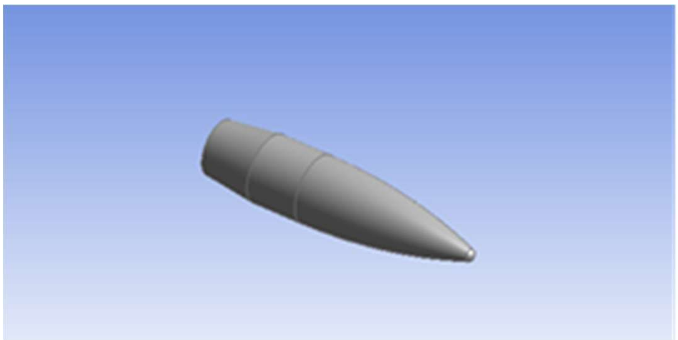

Figure 1.
Bullet core

A wind tunnel is designed around the projectile core in ANSYS program. The flow velocity at the entrance of the tunnel is assumed to be 800 ms^{-1}, the exit velocity of the projectile from the barrel is 800 ms^{-1}, the open air pressure is 101325 Pa, and the ambient temperature is 300 K. The wind tunnel is shown in Figure 2.

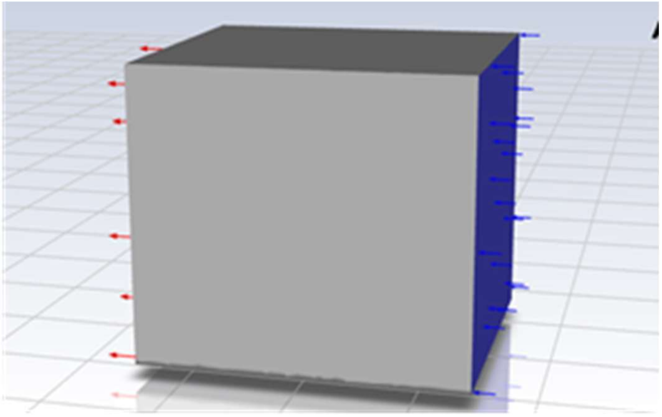

Figure 2.
Wind tunnel

In order to examine the effect of airflow around the projectile core models on aerodynamic behavior, the external flow body model mesh structure was created using Ansys Meshing software. The generated mesh model is visualized in Figure 3.

The network structure was created with 1640938 cells and an average quality of 77%. While creating the network structure, the inflation command was used for better results of pressure, velocity, and density changes in the boundary layers on the projectile.

The airflow around the projectile core was analyzed using Fluent software based on computational fluid dynamics. The compressible airflow is analyzed with the Spalart Allmaras turbulent flow model used in aerospace and outdoor aerodynamic analysis, taking into account the viscous effects due to Sutherland's law.

Convergence criteria have been identified in Fig. 4 to show the problem solving process in 500 iterations. In this figure, variations of the continuity, velocity, and energy residuals has been presented respectively.

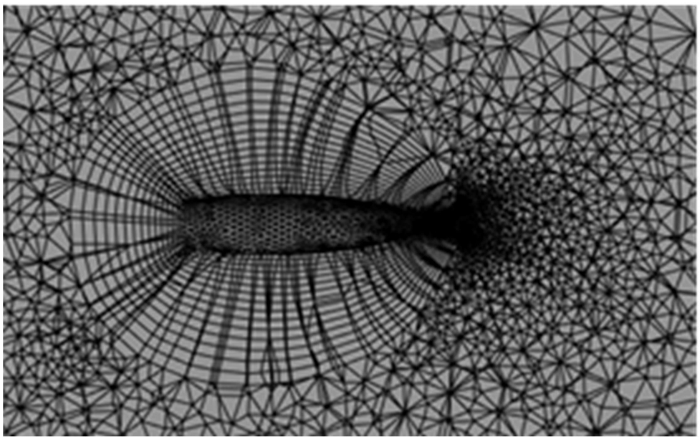

Figure 3.
Mesh model

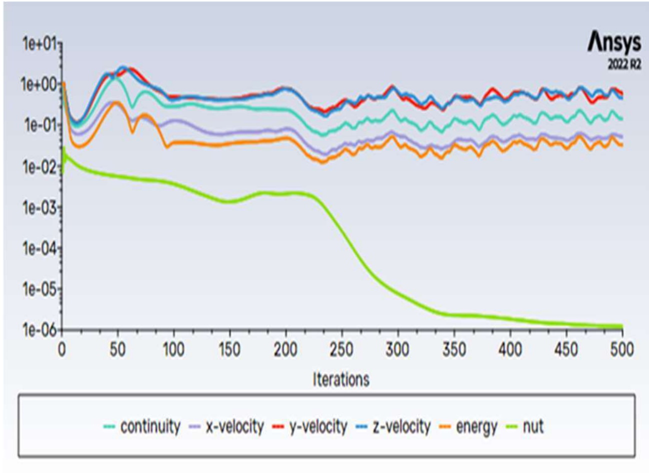

Figure 4.
Residual variations versus iteration number

Results

In this study, the aerodynamic parameters velocity, pressure, and density values obtained as a result of the analyses performed for the 7.62x51 bullet core model are analyzed. As a result of the analysis, it was observed that the flow velocity around the projectile, which has an exit velocity of 800 $m^{-}s^{-1}$, decreases to 44 ms^{-1} in the rear region of the projectile. The reason for this is the edginess of the projectile geometry. When the average flow velocity around the projectile core is evaluated, it is seen that there is a decrease in the flow velocity around the core and a 94.5% decrease in the rear part of the projectile. In this context, the velocity distributions around the projectile core are visualized in Figure 5 for Mach number 2.3. The results obtained here are in agreement with scientific studies (Doğru, 2017)

In an environment where the atmospheric pressure is assumed to be 101325 Pa, it is seen that the pressure increases to 1300000 Pa at the tip of the projectile, while it decreases to -30000 Pa at the back of the projectile. This decrease in pressure was calculated to be 130%. The pressure distributions around the projectile core are visualized graphically in Figure 6 for Mach number 2.3. The results obtained here are in agreement with scientific studies (Doğru, 2017)

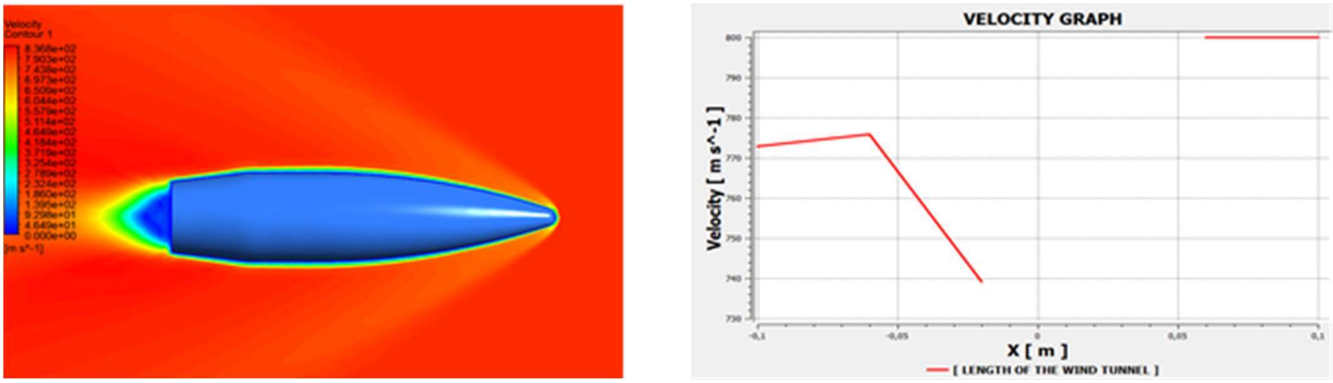

Figure 5.
Velocity analysis

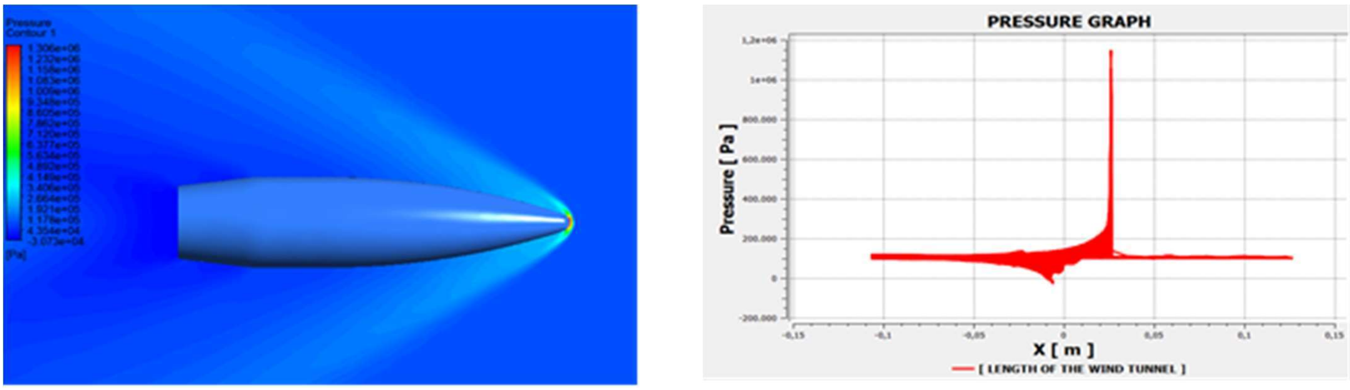

Figure 6.
Pressure analysis

Conclusions

In this study, in order to contribute to the related field, the contribution of the aerodynamic behavior of the projectile geometry to the projectile range is investigated. For this purpose, after the necessary literature review, computerized analyses were performed. The 7.62x51 mm bullet core was designed in SolidWorks and analyzed in ANSYS Fluent software.

- As a result of the analysis, it was seen that the flow velocity around the projectile, which has an exit velocity of 800 ms^{-1}, decreases to 44 ms^{-1} in the rear region of the projectile.
- When the average flow velocity around the projectile core was evaluated, it was observed that there was a decrease in the flow velocity around the core. There was a 94.5% reduction in the rear part of the bullet.
- At the tip of the projectile, the pressure increased to 1300000 Pa, while at the rear of the projectile, it dropped to -30000 Pa.
- The drop behind the bullet is calculated at 130%.

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O.Yıldırım : Supervision, conceptualization
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