INVESTIGATION OF FATIGUE LIFE OF NEW DESIGNED GATLING GUN STRIKER

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ABSTRACT

The Gatling gun is an old war machine that has multiple barrels. These barrels rotate around a central axis and placed on a kind of drum. Since every barrel used for shooting only once per revolution of drum, every single barrel has enough time for cooling off. This cooling operation ensures that time for recycling for barrels can be shorter. A modern Gatling gun has a firing capacity nearly 2000 bullets per minute. This means every barrel and firing mechanism located inside drum are used 670 times per minute. When the working speed of barrel is considered, it is seen that the fatigue life becomes an important issue for every part of this type of gun. Striker is the most critical part of Gatling gun firing mechanism,as every weapon. A striker is used applying force to primer of bullet to ignite propellant. Striker shape is as important as recycling time in terms of bullet primer-striker interaction. Hence, in this study, new designed Gatling gun striker is investigated in terms of fatigue life.Three different striker geometries, which are flat, spherical and chamfered, is used to perform the study. Numerical simulation of the study is fulfilled using ANSYS-Workbench, which is finite element program. Static structural analysis is chosen for analysis system to perform numerical study.Structural steel is assigned for the striker material. Firing load is applied the tip of striker as 100 N. At the end of the study, fatigue life, deformation, and stress values on the Gatling gun striker is obtained.

Key words: Gatling gun, striker, structural analysis, fatigue life, deformation.

1. Introduction

In this study, a summary of literature review which is related to weapon mechanism, and its effect is given. Many studies are investigated and given below about gatling gun.

First rotating weapon was designed by American inventor Richard Jordan Gatling in 1861 and patented in 1862 [1]. The Gatling gun consists of a group of rotating barrels. In single-barreled weapons loading, firing and unloading operations occur at different times. But for the Gatling gun, all these operations are performed simultaneously in different barrels while they rotate. In addition, rotation provide enough time for barrels to cool. Modelling and dynamic simulation of Gatling gun were performed by Li et al. [2]. Virtual prototype and dynamic model were created in SOLIDWORKS and ADAMS respectively. Finite element model of Gatling gun barrel was established by Gao et al. [3]. Five modal frequencies were calculated for different positioned clamping plate. Modal computing method was used to test FEM. Cam curve of Gatling gun was redesigned by Gao et al. [4]. Required driven torque and power consumption were reduced. Yang and Wang studied shooting dynamics of naval guns [5]. They simulated model on ADAMS and compared simulation results with test data. Ahmed et al. [6] discussed dynamic response of gun in firing cycle. They created three-dimensional FEM of large caliber gun and observed design parameters which effect dynamic behavior of weapon. Tuncer and Alli studied hydro pneumatic recoil mechanism [7]. Ni et al. [8] presented dynamic simulation of automatic rifle based on ADAMS. Experimental data was verified with simulation results. Yu et al. [9] carried out geometric element analysis of rifle bolt. They established that cause of failure was high stress concentrations on bolt geometry. Ozmen et al. [10] performed static, dynamic and fatigue analysis of locking block of gun. FEM was used for determining stress values and Morrow Theorem was used to investigate fatigue behavior of locking block. Projectile nose shape effect is investigated in terms of the penetration effect by Doğru [11]. deformation and stress parameters are obtained.

After the literature survey, it seen that striker tip geometry is critical concept in terms of the fatigue life of the striker. Hence, three different striker tip geometryare investigated in this study.

2. Method of Analysis

The geometry of gatling gun striker is modelled in Solidworks program. Ansys structural analysis is used to perform the study (Fig. 1).

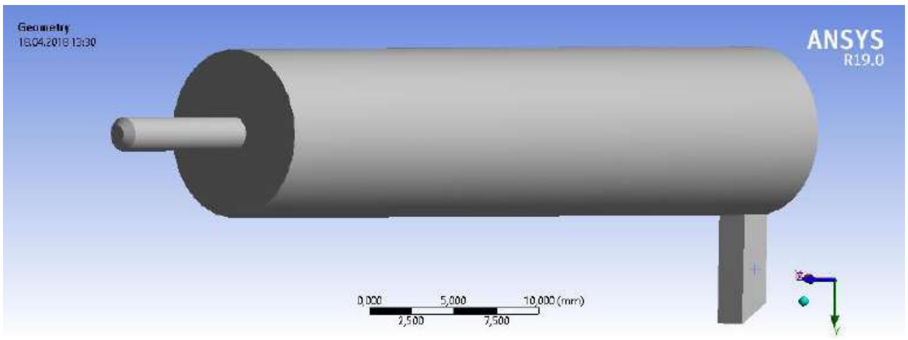

Figure 1. Geometry of striker

Mesh control is done as hex dominant method and mesh sizing, which is include edge and face sizing. Optimum mesh number is found as nearly 50000 elements according to mesh accuracy results. After the meshing operation, fine meshed structure is achieved (Fig. 2).

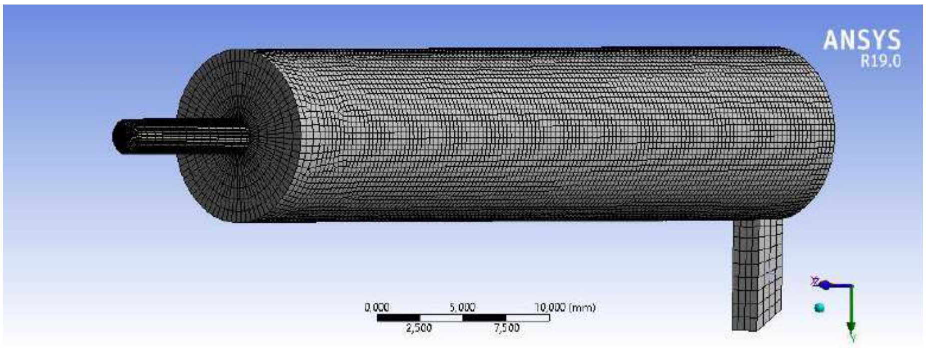

Figure 2. Mesh view

Fixed support is utilized as boundary condition (Fig. 3).

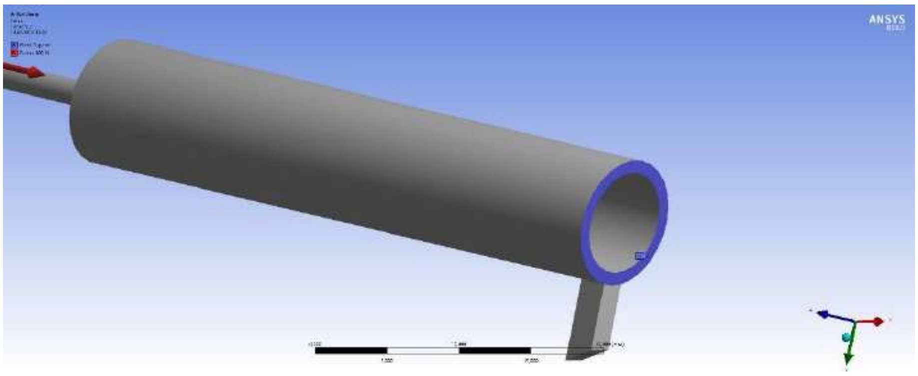

Figure 3. Fixed support position view

View of position and direction is given for the applied force to the gatling gun striker (Fig. 4). Applied force is accepted as 100N.

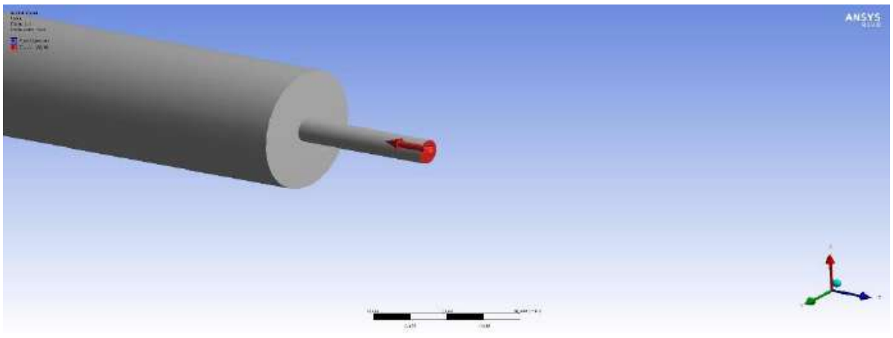

Figure 4. Applied force position and direction

3. Case Study

In this study, structural analysis of Gatling gun striker is investigated to obtain stress and deformation values. Also, fatigue life and safety factor are investigated as analysis parameters. Three different striker geometries, which are flat, chamfered, and spherical shape, are analysed according to aim of study. Striker material is selected as structural steel. 100N force is applied to the tip of striker. ANSYS workbench structural analysis tool is utilized to execute this work. At the end of the study, deformation and stress values are obtained for each case and fatigue life and factor of safety are determined.

3.1. Flat Striker

Flat striker geometry is given in figure 5. When the figure is investigated, it is seen that clearly tip of the striker is fully flat plane. In addition, force is applied the flat plane as distributed.

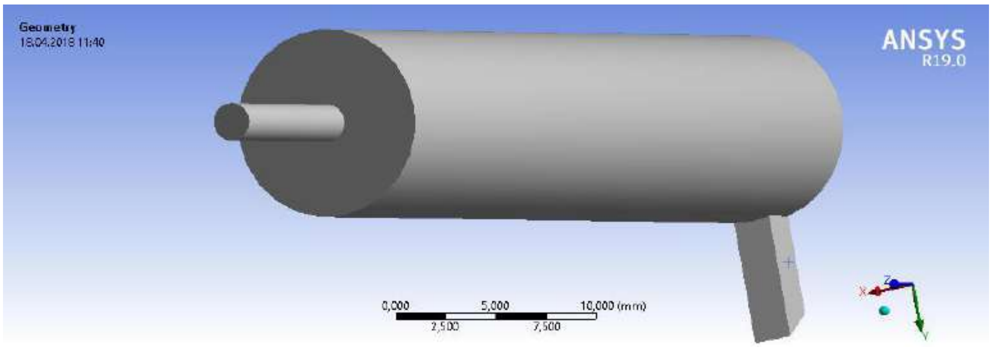

Figure 5. Flat striker geometry isometric view

Mesh structure of flat striker view is given in figure 6. Mesh element number, which is 48000 elements, is obtained due to tip of the flat striker geometry is plane.

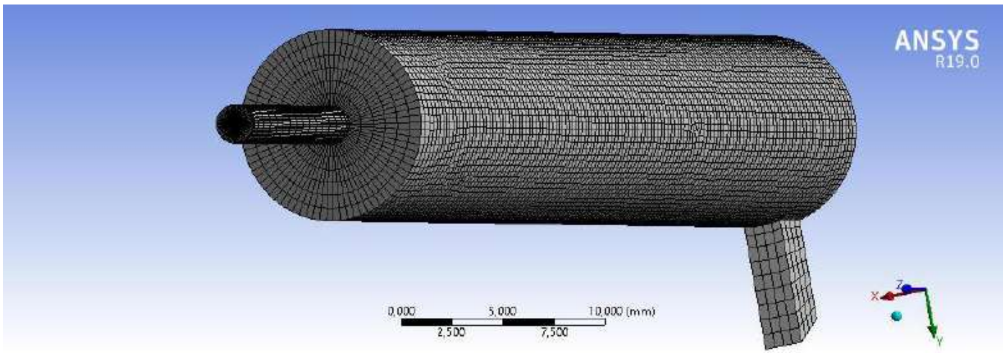

Figure 6. Mesh view of flat striker

Analytical results of von-mises stress distribution of flat strikeris given in figure 7. When the figure 7 is investigated, it is clearly seen that maximum stress value occurs at the root of the striker tip.

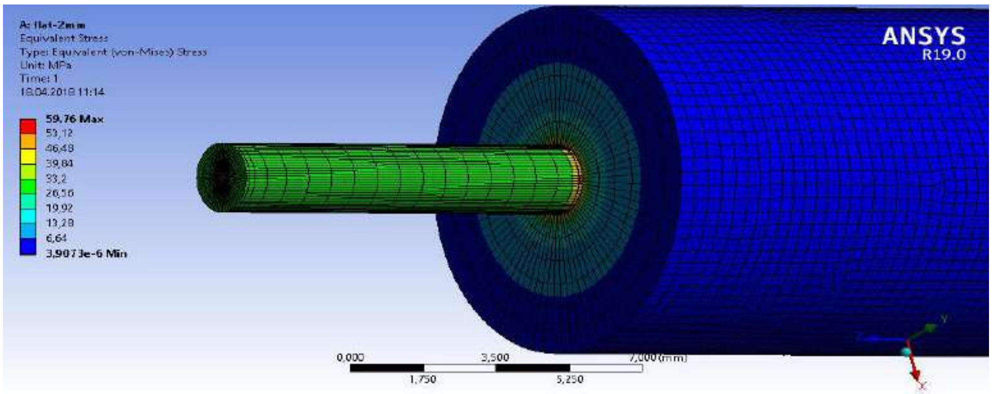

Figure 7. Von-Mises stress distribution of flat striker

Maximum deformation value is obtained at the tip of the flat striker (Fig. 8)

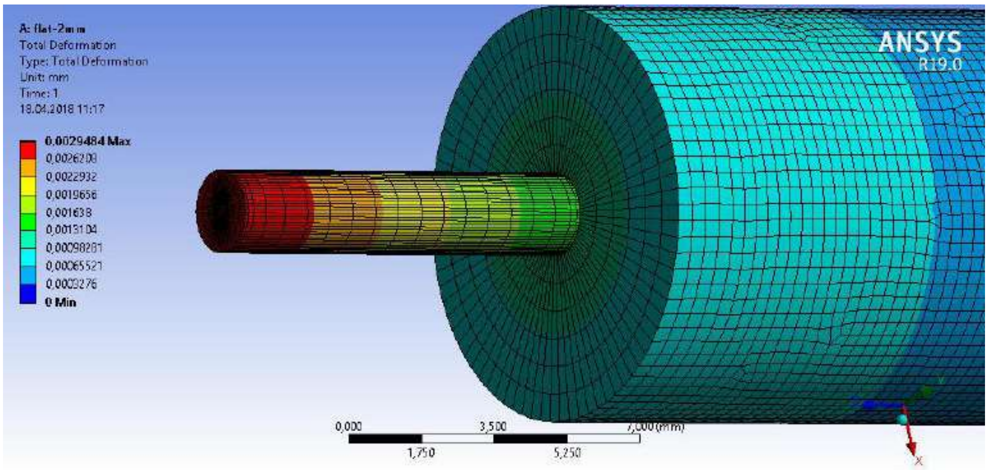

Figure 8. Deformation values of flat striker

Fatigue life is determined for the flat type striker by using structural analysis (Fig 9). Critical point is found at the root of the flat striker.

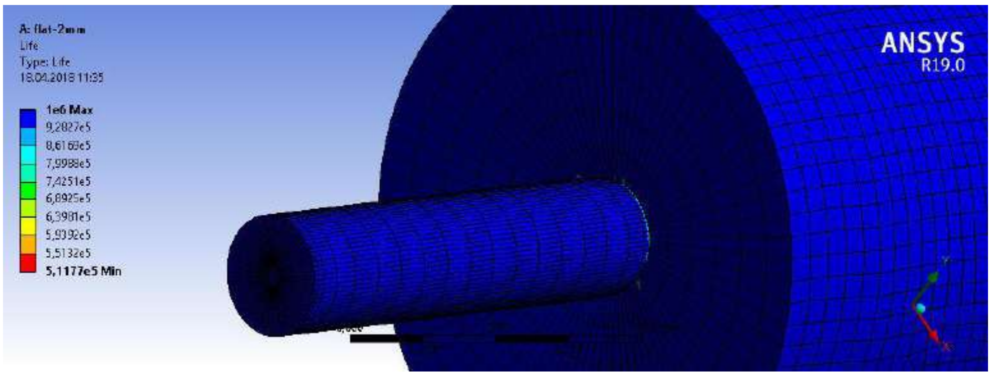

Figure 9. Fatigue life of flat striker

Factor of safety for the flat striker is obtained at the end of the study (Fig. 10). Safety factor value is found under the one. Also, critical region is seen at the root of the flat striker in terms of the safety factor concept.

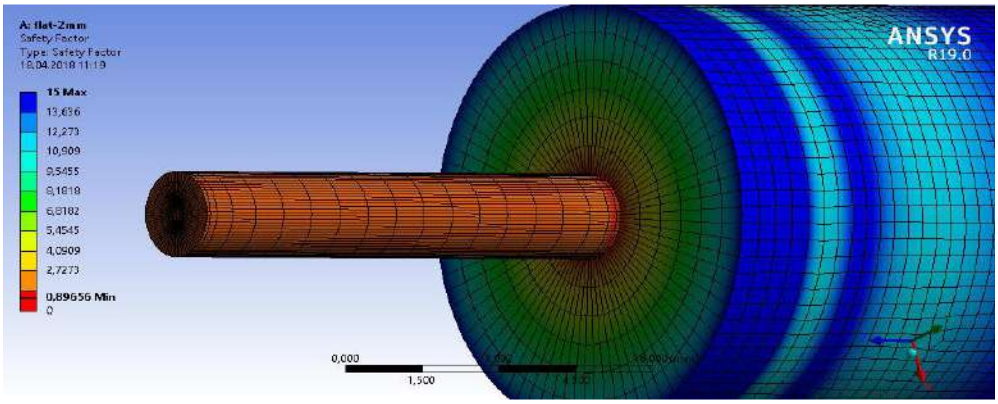

Figure 10. Safety factor of flat striker

3.2. Spherical Striker

Geometryof the sphericalstriker is shown in figure 11. When the figure is investigated, it is seen that tip of the striker is designed as spherical shape. In addition, force is applied the spherical plane as distributed.

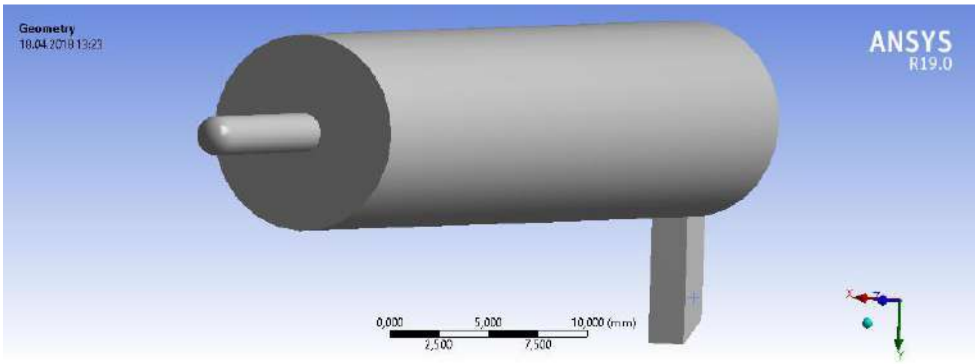

Figure 11. Spherical striker geometry isometric view

Meshed geometry is given for thesphericalstriker in figure 12. Mesh element number, which is 55000 elements is found. Mesh number of spherical striker is the most according to others, due to tip of the spherical striker geometry is created as rounded body.

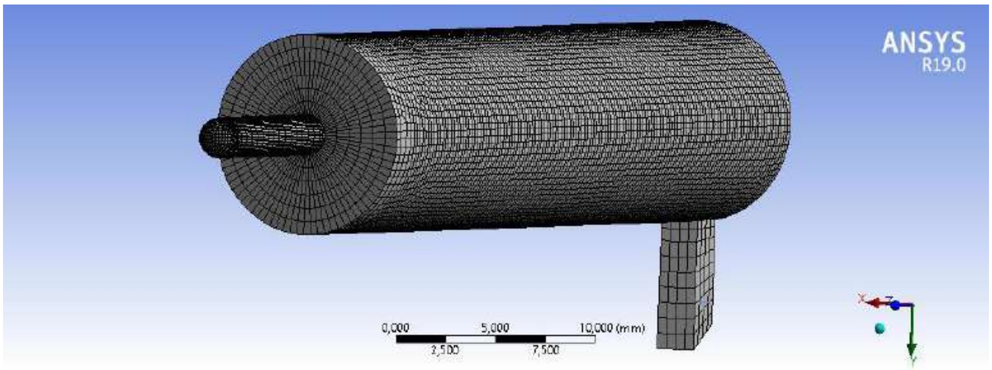

Figure 12. Mesh view of spherical striker

Analytical results of von-mises stress distribution of spherical striker is given in figure 13. When the figure 13 is examined, it is seen that maximum stress value occurs at the root of the striker tip. But, the stress value is large enough not to be underestimated on the edges of the tip.

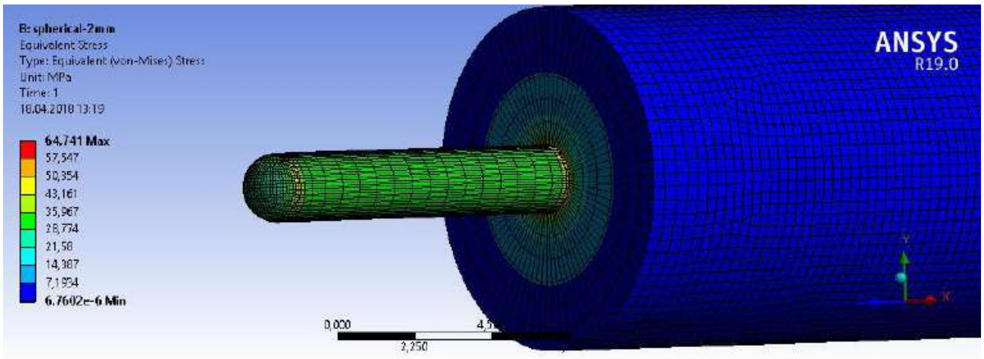

Figure 13. Von-Mises stress distribution of spherical striker

Maximum deformation value is obtained at the tip of the spherical striker (Fig. 14).

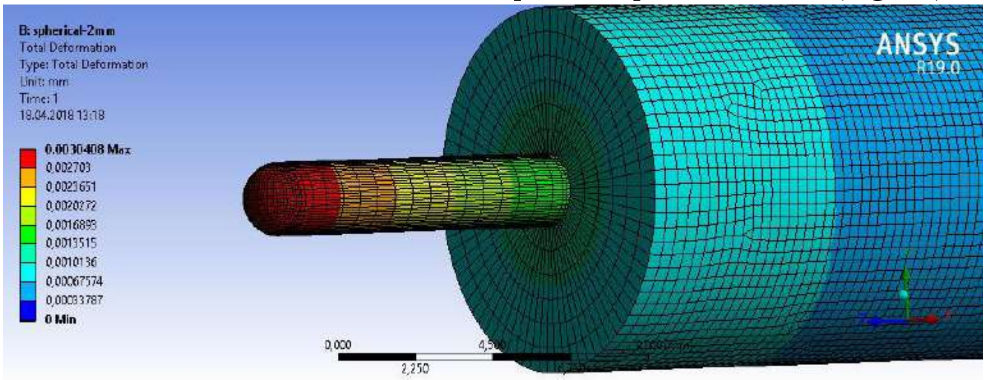

Figure 14. Deformation values of spherical striker

Fatigue life is determined for the sphericaltype striker by using structural analysis (Fig 15). Critical point is found at the root of the sphericalstriker.

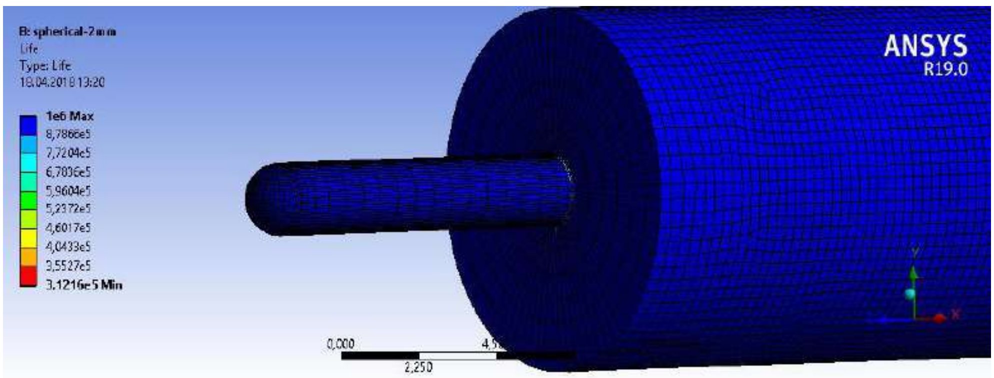

Figure 15. Fatigue life of spherical striker

Factor of safety for the spherical striker is obtained at the end of the study (Fig. 16). Safety factor value is found under the one. Also, critical region is seen at the root of the spherical striker in terms of the safety factor concept.

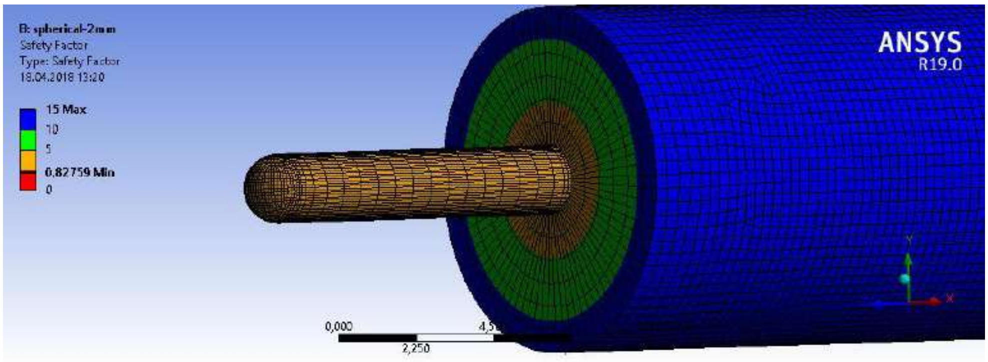

Figure 16. Safety factor of spherical striker

3.3. ChamferedStriker

Chamfered striker geometry is given in figure 17. When the figure is investigated, it is observed that tip of the striker is chamfer specification.Force is applied the chamfered horizontal plane as distributed.

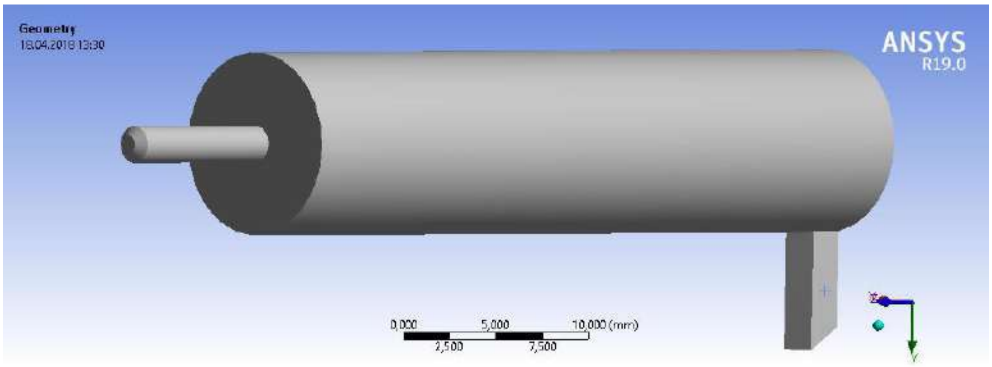

Figure 17. Chamfered striker geometry isometric view

Mesh structure of chamferedstriker view is given in figure 18. Mesh element number, which is 51000 elements. The mesh number of the chamfered striker is found in the middle in terms of the executed analysis.

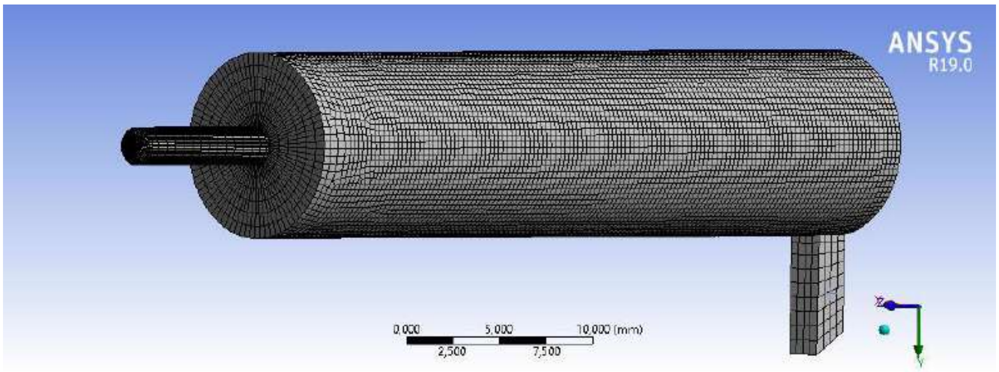

Figure 18. Mesh view of chamfered striker

Analytical results of von-mises stress distribution of chamferedstriker is given in figure 19. When the figure 19 is investigated, it is viewed that maximum stress value obtains at the root of the striker tip.

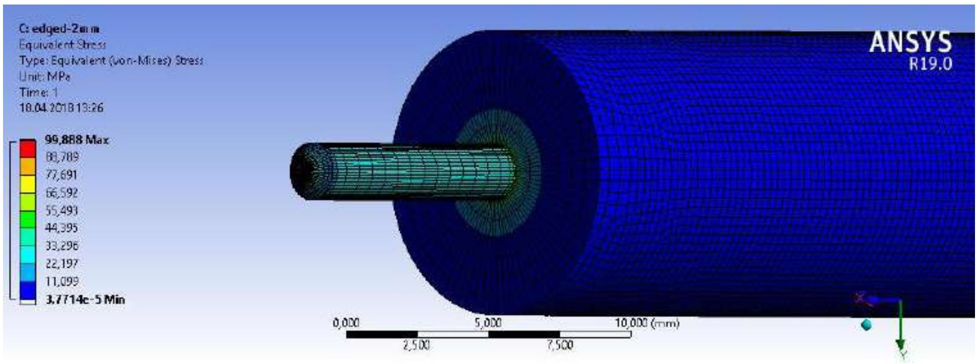

Figure 19. Von-Mises stress distribution of chamferedstriker

Maximum deformation value is obtained at the tip of the chamferedstriker (Fig. 20)

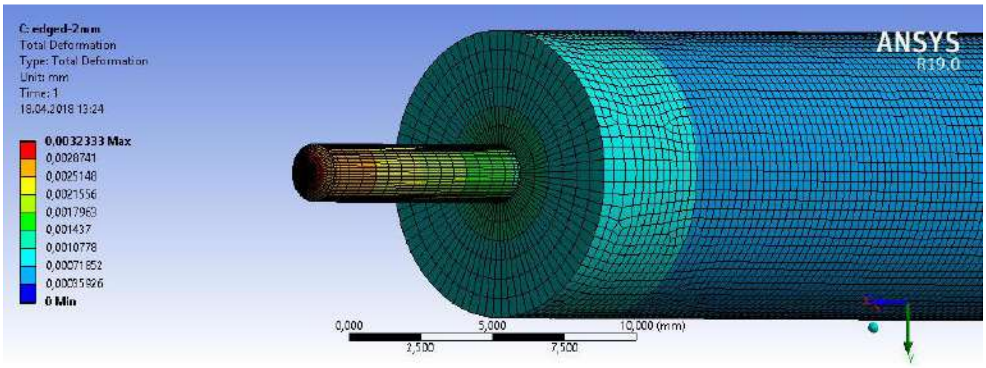

Figure 20. Deformation values of chamferedstriker

Fatigue life is determined for the chamferedstriker by using structural analysis (Fig 21). The root of the chamferedstriker is found as the critical point.

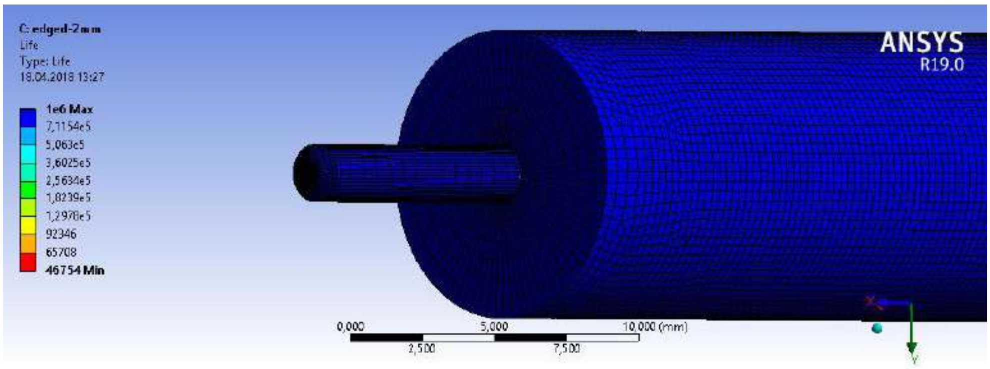

Figure 21. Fatigue life of chamferedstriker

Factor of safety for the chamfered striker is obtained (Fig. 22). Safety factor value is found under the one. When the factor of safety concept investigated in figure 22, it is seen that critical region is at the root of the chamfered striker. Minimum factor of safety is obtained on the chamfered striker among the performed analyses.

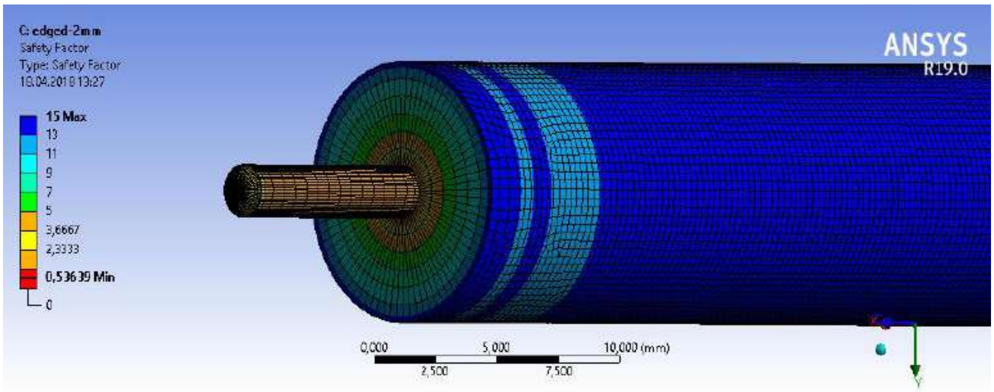

Figure 22. Safety factor of chamferedstriker

4. Results and Discussions of the Analyses

In this study, effect of striker geometry on fatigue life was investigated. Flat, spherical and chamfered geometries were used at the tip of the striker. Stress values were obtained 59.76 MPa, 64.76 MPa and 99.88 MPa for flat, spherical and chamfered striker respectively. The obtained parameters are given in Table 1.

Table 1. Obtained parameters from the analyses

Striker Type	Stress (Mpa)	DeformationX(1e-3) (mm)	Minimum Fatigue Life (cycles)	Minimum Factor of Safety
Flat	59,76	2,94	511770	0,896
Spherical	64,76	3,04	312160	0,827
Chamfered	99,88	3,23	46754	0,536

Considering fatigue analysis, 511770 cycles for flat striker, 312160 cycles for spherical striker and 46754 cycles for chamfered striker were achieved as minimum life.

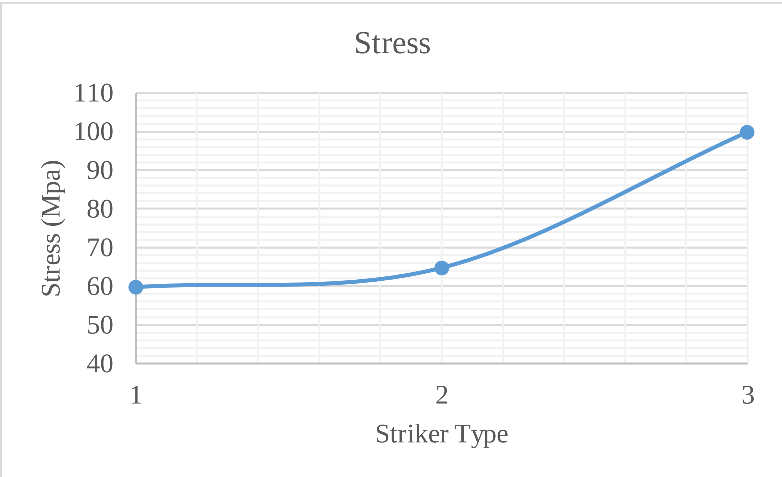

Figure 23. Comparison of the stress value (**1:** Flat striker, **2:** Spherical striker, **3:** Chamfered striker)

Comparison graphics were given in figure 23 and figure 24 for the stress and deformation values. Chamfered striker has the maximum stress and deformation value according to applied load.

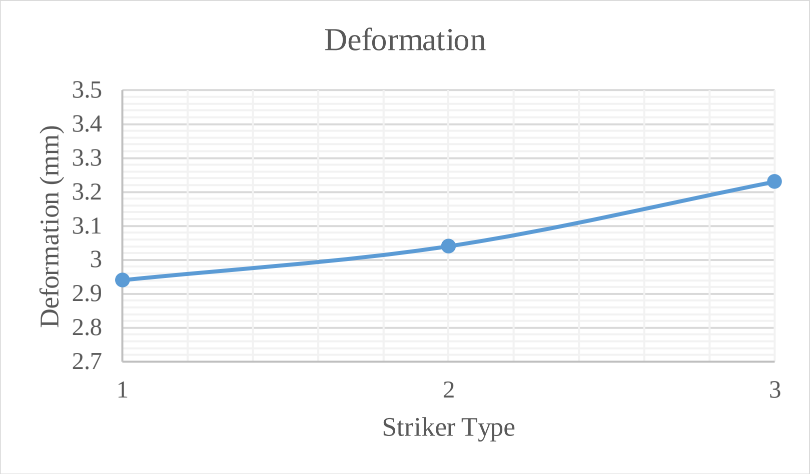

Figure 24. Comparison of the deformation value (**1:** Flat striker, **2:** Spherical striker, **3:** Chamfered striker)

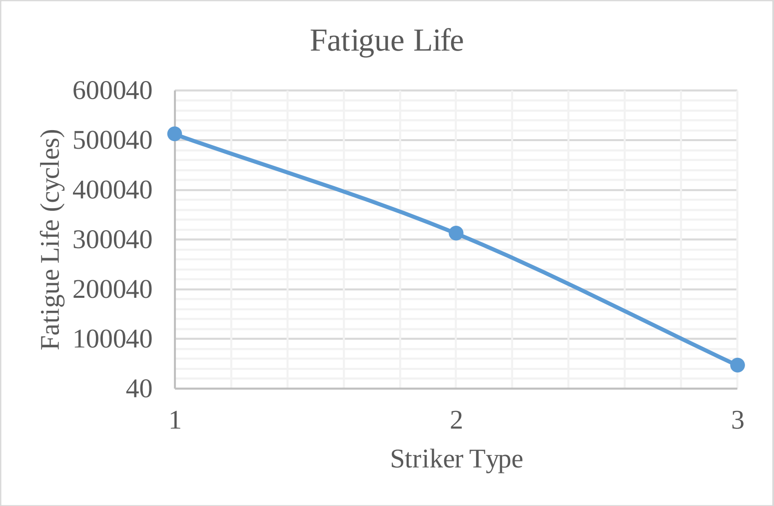

Figure 25. Comparison of the fatigue life (**1:** Flat striker, **2:** Spherical striker, **3:** Chamfered striker)

Fatigue life and safety factor comparison were investigated in figure 25 and figure 26. Chamfered striker has the minimumfatigue life and factor of safety value according to applied load and boundary conditions.

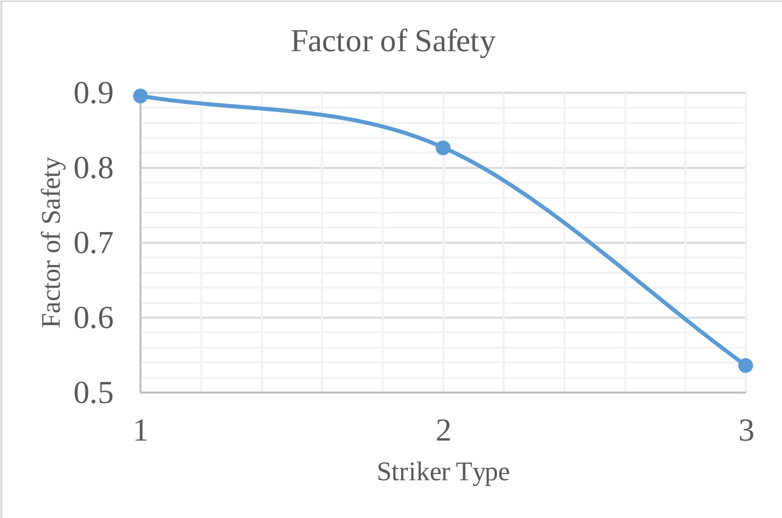

Figure 26. Comparison of the factor of safety (**1:** Flat striker, **2:** Spherical striker, **3:** Chamfered striker)

5. Conclusion

New designed Gatling gun striker is investigated in terms of fatigue life according to aim of the study.Three different striker geometries, which are flat, spherical and chamfered, is used to perform the study. Firstly, the system has been modeled and analyzed. When the analysis results are investigated, it is observed that despite being no significant difference between flat and spherical shaped striker in terms of the minimum factor of safety, the considerable difference was attained in terms of fatigue life. At the end of the study, it is clearly seen that flat geometry is the most reliable geometry in terms of fatigue life when analysis results are examined.

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