TIJMET, Vol. 002 (2019) 60-63

The International Journal of

Materials and Engineering Technology

ISSN: 2667-4033
TIJMET ID: 190201009 (4 pages)
Type of the Paper: Article
Received 05.11.2019 Revised: 19.11.2019 Accepted: 09.12.2019 Published (Online): 13.12.2019
Journal homepage: http://dergipark.gov.tr/tijmet

DETERMINATION OF THE CRITICAL POINT ON SNIPER BARREL IN TERMS OF THE STRESS AND DEFORMATION CONCEPTS

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Abstract

The impact performance of the material is critical property in the weapon industry. In particular, pressure distribution concept in barrel has revealed the need to work on this issue. Therefore, the behavior of the barrel was investigated, when the explosion pressure was realized in the barrel. In this study, different pressure values were applied to the inside of the barrel to obtain critical stress region. The barrel of the new generation long range sniper weapon of the American Barret company, which is legendary with the M82A series, was used. 3D barrel model was created in SOLIDWORKS program. ANSYS workbench static structural toolbox was used to perform the proposed study. Within this study, the critical points in sniper weapon barrel were determined in terms of the stress and deformation concepts.

Keywords: Barrel, Numerical analyses, Pressure distribution, Deformation and stress values.

1. Introduction

The importance of the impact performance of the material is great. Especially, these concepts have been studied in the weapon industry for a long time. Penetration equations using analytical dependence between impact velocity and depth of penetration was derived by Ben-Dor et al. [1]. A model of high-speed penetration into ductile targets was universalized by Ben-Dor et al. [2]. Correlation between ballistic and residual velocities and impact were compared by Ben-Dor et al. [3] and Lambert-Jonas [4]. For this comparison Recht and Ipson [5] formulations were used by the authors. Propellent geometry was designed using mathematical optimization method by Yıldırım [6]. Barrel velocity and pressure values were determined using PRODAS software. Optimum web thickness value was calculated with non-linear regression method by using MATLAB optimization tool by using these values.

A new model has been developed which gives the pressure distribution within the barrel and the velocity of the projectile by Işık [7]. To confirm the model, several firing tests were performed with a 7.62 mm diameter barrel and ballistic parameters were measured. The barrels are considered as thin-walled circular tubes with special use. They are constantly exposed to high temperatures and pressures during operation. Therefore, the dynamic temperature data of the barrel and the stress values under continuous loading were examined using FEM software by Chang-wei et al. [8]. A trigger mechanism for a 20 x 102 mm caliber sniper rifle was designed by Gullerova [9]. Kinematic and dynamic quantities of the sniper rifle trigger mechanism were analyzed. Two analytical methods and one numerical method are considered to determined pressure profile by 10. Micković et al. [10].

The analytical methods of proportionate expansion and two-phase mixture were studied. Pressure profiles were computed numerically. The CFD model was formulated to illustrate the details of the flow field produced by the revolving barrel gun firing by Yu and Zhang [11]. Two different algorithms, which are second-order monotone upstream-centered schemes approach and the advection upstream splitting method solver was used to simulate the high-pressure muzzle flow field. At the end of the literature review, it was determined that stress distribution has critical importance. So, critical stress and deformation values were investigated according to the different explosion pressures in the barrel. In addition, M82A sniper weapon barrel was investigated in terms of the fatigue life under the different explosion pressure.

2. Materials and Methods

2.1. Numerical Analyses

The barrel of the new generation long range sniper weapon of the American Barret company, which is legendary with the M82A series, was used. 3D barrel model was created in SOLIDWORKS program as shown in Figure 1.

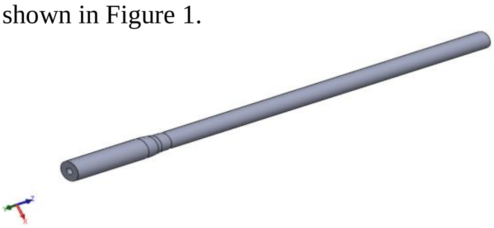

Figure 1. 3D barrel model

Mesh accuracy was performed to check the reliability of the meshing procedure. The mesh structure was shown in Figure 2. After mesh accuracy (Figure 3) procedure, it was determined that the 90000-element number is suitable for these analyses.

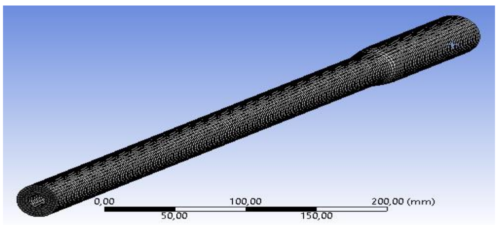

Figure 2. Mesh view of barrel

ANSYS workbench static structural toolbox was used to perform the proposed study. 200 MPa pressure was applied to the barrel for this analysis as shown in Figure 4.

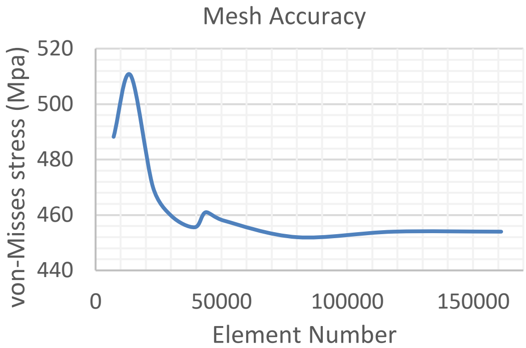

Figure 3. Mesh accuracy

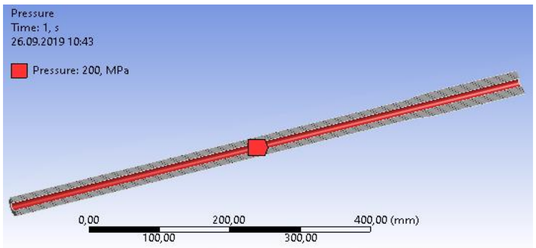

Figure 4. Applied pressure

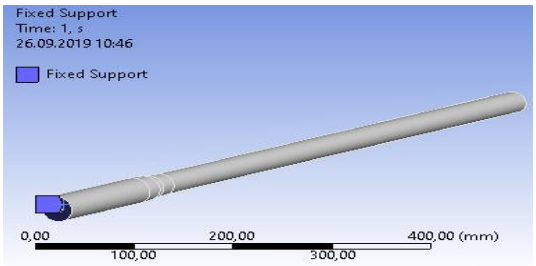

Figure 5. Support point and position

Fixed support was applied to the system to perform the study as shown in Figure 5.

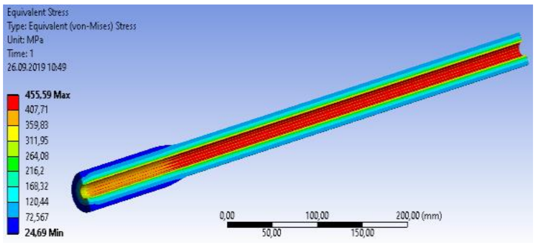

Figure 6. von-Mises stress result

Von-Mises stress distribution and deformation results were obtained according to the applied pressure as shown in Figure 6 and Figure 7.

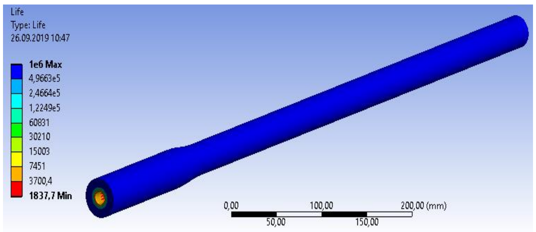

Figure 7. Deformation result

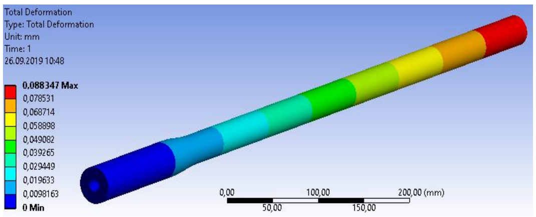

Figure 8. Fatigue life

At the end of the analyses, the fatigue life of the barrel was determined according to the applied pressure.

2.2. Theoretical Validation of the Analyses Results

When the geometry of the M82A gun barrel was investigated, it was clearly seen that the system behavior is thick walled cylinder (in Figure 9). According to the Equation 1, if the r/t ratio is bigger than 10, the system calls as thin walled cylinder.

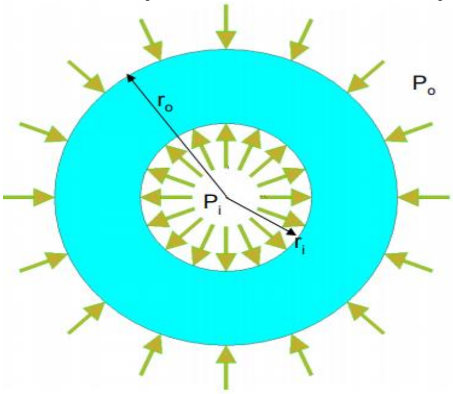

Figure 9. Thick walled cylinder

$r_i = 6{,}35$ mm
$r_0 = 15{,}5$ mm
$t = 9{,}15$ mm
$p_0 = 0$ Mpa
$p_i = 200$ Mpa

$$\frac{r_i}{t} > 10 \qquad (1)$$

$$\sigma_h = \frac{p_i r_i^2 - p_0 r_0^2}{r_0^2 - r_i^2} + \frac{r_i^2 r_0^2 (p_i - p_0)}{r^2 (r_0^2 - r_i^2)} \qquad (2)$$

When the p_i was applied to the barrel and equation (2) was used, it was observed that the results of the theoretical and the analysis results overlapped.

3. Results and Discussion

Stress, deformation and fatigue life of barrel obtained according to different pressure values were determined by analysis as given in Table 1. ANSYS workbench static structural toolbox was used to perform the proposed study.

Table 1. Analyses results.

Pressure (Mpa)	Stress (Mpa)	Deformation (mm)	Life (cycle)
25	56,94,8	0,01104	1000000
50	113,9	0,02208	200105
100	227,79	0,04417	16148
150	341,69	0,06626	4400
200	455,59	0,08834	1827
250	569,48	0,11043	1028
350	683,38	0,13253	640

Generally, barrels are made of heat-treated special materials. Therefore, these materials can withstand these stresses when subjected to high stress values.

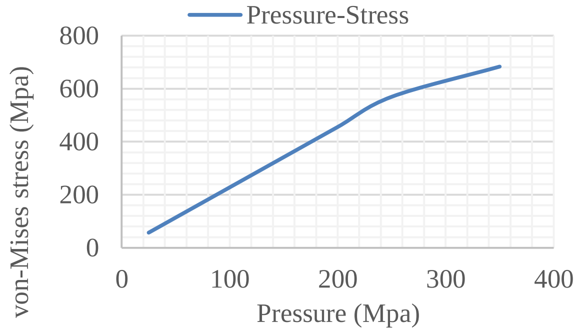

Figure 10. Pressure-Stress curve

At the end of the study, critical points in sniper weapon barrel were determined in terms of the stress (in Figure 10) and deformation (in Figure 11) concepts. Maximum Von-Mises stress was obtained as 683 MPa (in Figure 10), when the 350 MPa pressure was applied.

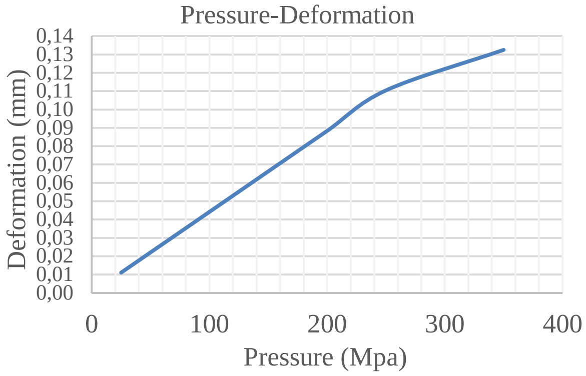

Figure 11. Pressure-Deformation curve

Maximum deformation value was obtained as 0,13253 mm at tip of barrel (in Figure 11), when the 350 MPa pressure was applied.

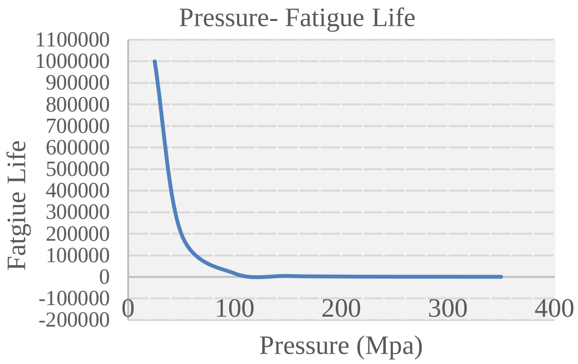

Figure 12. Pressure-Fatigue life curve

Also, Fatigue life was determined for the barrel according to applied different pressure values (in Figure 12). The minimum fatigue life of barrel was achieved as 640 cycles, due to applied pressure value was high.

Conclusions

The behavior of the barrel was investigated, when the explosion pressure was realized in the barrel. In this study, different pressure values were applied to the inside of the barrel to obtain critical stress region. It was seen that the pressure formed inside the barrel decreases from inside to outside. Therefore, it was considered that it would be appropriate to produce them using functional graded material method while producing barrels. By means of this method, both lighter and more durable barrels will be produced since the inside of the barrel having critical stress value will have higher mechanical properties. In addition, the fatigue life of the barrel will also be increased.

Acknowledgement

I would like to express my deepest appreciation to organizing committee of TICMET19 in the selection of my study which was presented in the conference organized on 10-12 October, 2019 in Gaziantep University.

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