Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 03 March-2026, Page No.-9225-9229

DOI: 10.47191/etj/v11i03.14, I.F. – 8.595

Survey of Stress and Deformation of The 14,5mm Gun Barrel When Firing

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ABSTRACT: For weapons designed and manufactured in Vietnam, surveying the loads on the barrel and other gun components during firing is essential. The 14.5mm gun is no exception; a thorough investigation of the barrel stress under pressure during firing is necessary. This paper utilizes the specialized software ANSYS WORKBENCHES to investigate barrel stress under propellant pressure. The results are used to assess barrel strength. Further more, the research findings serve as a reference for students and technical staff interested in this topic.

KEYWORDS: 14,5mm Gun; Barrel; Stress; Deformation; Temperature.

I. INTRODUCTION

During and after World War 2, 14.5mm guns were strongly researched and developed. Initially, the guns were used for personal equipment by infantry against light armored vehicles and low-altitude aircraft, then improved and used for air defense purposes. The gun is equipped for the navy and army with 1-barrel, 2-barrel and 4-barrel variants as shown in figure 1. As for the single-barrel 14.5 mm gun used for infantry, it is increasingly improved such as using ammunition boxes, can use semi-automatic ammunition feeding style, modernly designed viewfinder and increased magnification multiplier... There have been many publications on the stress in the barrel wall when firing as documents [2], [3], [4]. However, these studies usually only focus on small calibers such as 7.62mm or 12.7mm, while 14.5mm has not been published. Therefore, it is extremely necessary to survey the stress of the gun barrel when shooting.

Fig. 1. Some 14.5mm caliber gun models

II. CONTENTS

A. Simulation of a 14.5mm gun barrel.

The 14.5mm barrel sample and a cross-sectional sample of the barrel according to the 2D model are shown in figure 2 below.

In this article, the stress caused by the pressure inside the barrel along the entire length of the barrel will be investigated.

According to document [1] we have: Bullet chamber volume: $30cm^3$, barrel diameter: 14.5mm, barrel groove diameter: 14.95mm, number of spiral grooves in the barrel: 8 grooves, mass of B32 penetrating warhead: 64 g, mass of propellant: 30 g, type of propellant: pyrocxiline 5/7 CB.

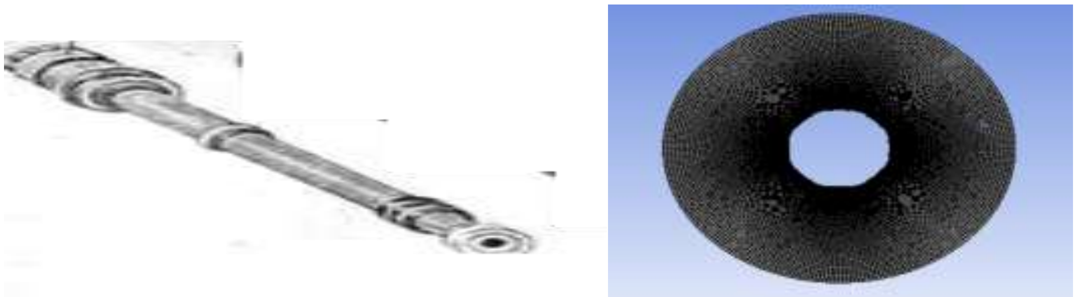

Fig. 2. Barrel with 2D planar model of a barrel cross-section

B. Structural parameters and balistic of the barrel

Look up the gun barrel material parameters according to the technical documents used and use them as input parameters for the stress survey problems presented in table 1.

Table 1. Material properties of 14.5mm gun barrel

Temperature (^{0}C)	E- elastic modulus (Pa)	α- thermal expansion coefficient (1/^{0}K)	λ- thermal conductivity coefficient (W/m.^{0}K)	ρ- density (kg/m^3)	C- specific heat capacity (J/(kg.^{0}K))	υ- Poisson's coefficient
20	$2.14x10^{11}$	$1.01x10^{-5}$	48	7820	440	0,3
100	$2.11\ x10^{11}$	$1.19\ x10^{-5}$	46	7800	466	0,3
200	$2.06\ x10^{11}$	$1.25\ x10^{-5}$	42.7	7770	508	0,3
300	$2.03\ x10^{11}$	$1.32\ x10^{-5}$	42.3	7740	529	0,3
400	$1.85\ x10^{11}$	$1.38\ x10^{-5}$	38.5	7700	563	0,3

C. Calculate the pressure on the gun barrel when firing

1. Differential equation of ballistic:According to document [5] published on differential equation of ballistic, we have: According to document [5] published about the system of differential equations in the projection algorithm, we have:

$$\begin{cases} dz/dt = s_1.p.I_k \\ d\psi/dt = s1.\chi.(1+2\lambda z+3\mu z^2).dz/dt \\ dv/dt = s2.p.S/(\varphi m) \\ dl/dt = v \\ dT/dt = (\theta T1/f\omega\psi)\left((f\omega/\theta).(d\psi/dt) - T.(f\omega/(\theta T1)).((d\psi/dt) - \varphi mv.(dv/dt)\right) \end{cases} \tag{1}$$

Quantities and explanations are taken from the cited document [6].

2. Method for solving of differential equations and results:

The differential equation is solved by the Runge-Kutta method, using MATLAB software to solve. Input parameters include structural characteristics of the gun barrel, bullets, propellant characteristics, and packing conditions, refer to documents [6], [7]. The results of solving the problem of pressure and warhead velocity we get are shown in Figure 3 below:

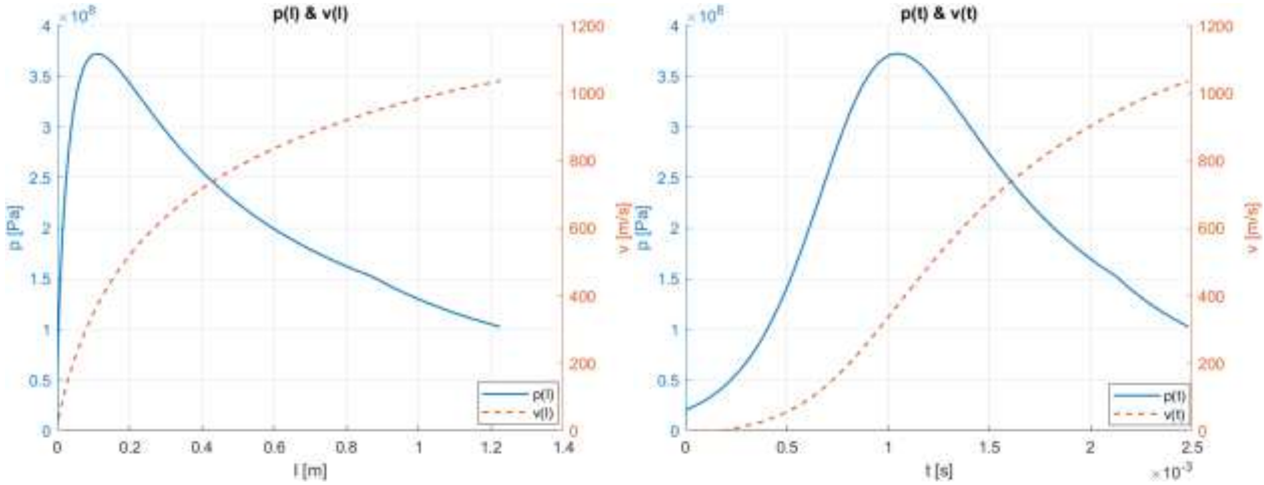

Fig. 3 . Graph of pressure against the distance of the warhead and over time

Table 2. Projection art values at some special cross-sections of the barrel

Gas pressure (Mpa)	Bullet movement speed (m/s)	Temperature (K)	Bullet movement time (10^{-3} s)
P_m= 372,2	V_m = 371,1	T_m = 1349,5	t_m = 1.03
P_k = 152,1	V_k = 945,2	T_k = 1216,3	t_k = 2,1
P_d = 102,6	V_d = 1036,2	T_d = 1156,4	t_d = 2,4

This calculation result is consistent with the announcement in the technical documents accompanying the gun.

D. Method for determining stress on the barrel

To calculate the stress of the gun barrel, the authors used ANSYS Workbench software with the Transient Structural module. Survey results were performed at one side Pmax of the gun barrel. According to technical and tactical features. The theoretical rate of fire is 200 rounds/minute (this depends on the operation of the combat battery as well as the operating conditions of the gun). Therefore, the authors will calculate that when firing 1 shot, it takes 0.5 seconds. in which the time the bullet moves in the barrel is 0 ÷ 0.0024s.

1. Temperature and stress fields of the gun barrel when firing the first shot: After running on the software, we have the results shown on the graph in Figure 4. The calculation results show that the temperature distribution in the combustion chamber is relatively similar. The maximum temperature in the sides of the combustion chamber reaches 828.19 ÷ 859.8°C. The maximum temperature at the barrel cross-sections is smaller than the combustion chamber cross-section and gradually decreases over time due to heat release from the barrel surface to the environment.

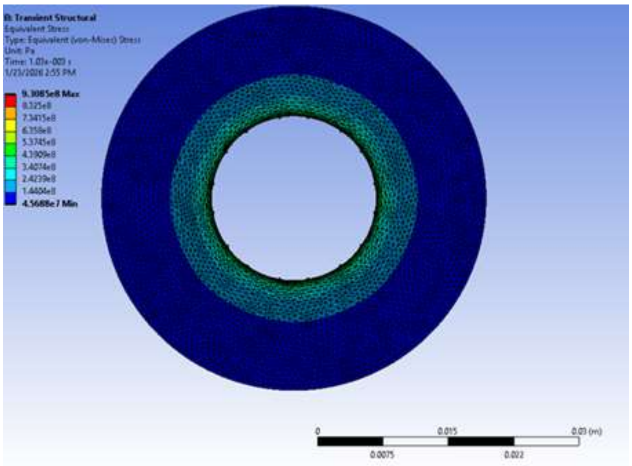

Fig. 4. Stress distribution at cross section Pmax when firing at 0.00103s

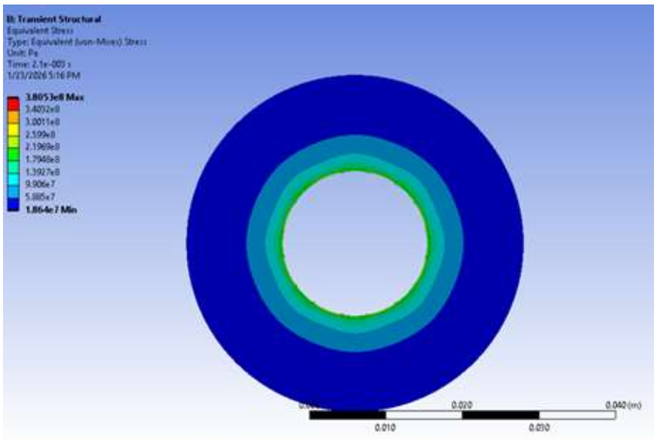

Fig. 5. Distribution at cross section Pk when fired at 0.0021s

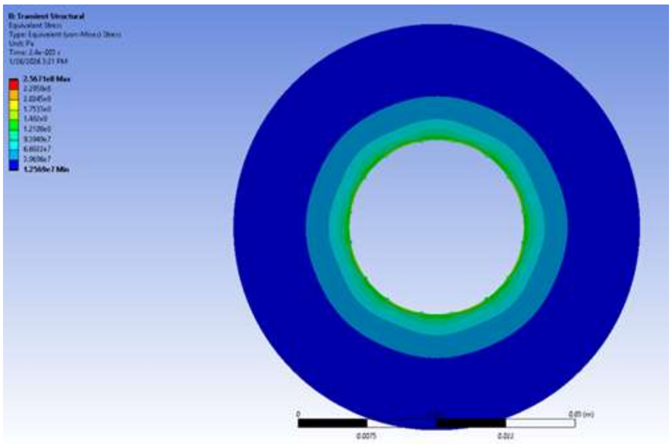

Fig. 6. Stress distribution at Pd cross section when firing at time 0.0024s

Based on the results obtained from specialized software, we synthesize and obtain a table of stress values on the barrel wall of the part with spiral grooves as shown in Table 3.

Table 3. Value of special cross-sections on the barrel

Location	Stress (Pa)		Safety factor (σ_b = 980 MPa)
	Max	Min	
At the cross section P_{max}	$9,308.10^8$	$4,57.10^7$	n = 1.05
At the cross section P_k	$3,805.10^8$	$1,8.10^7$	n = 2.56
At the cross section P_d	$2,5671.10^8$	$1,26.10^7$	n = 3.80

2. Temperature and stress fields of the gun barrel when firing 5 shots continuously: After 5 consecutive shots, the temperature on the barrel wall increases steadily according to the same law. After each shot, the heat decreases due to heat release and then increases again due to the additional heat of the following shot.

Regarding the stress due to pressure load, there is a slight increase but not significant. We can ignore this stress increase.

III.RESULTS AND DISCUSSION

The results of the survey on the temperature field and stress of the gun barrel when firing one shot and firing multiple shots in a row can lead to the following observations:

- The barrel surface temperature in the bullet chamber is greater than the temperature in the part with the spiral groove and the temperature in the cross-sections of the barrel when fired is different, so there is a temperature distribution along the barrel length.

- After each shot, the maximum temperature at the barrel cross-sections increases. That is due to the influence of the previous shot, the initial temperature before the next shot of the gun barrel is higher than that of the previous shot.

- When firing a shot, the maximum stress at the combustion chamber cross-sections reaches about 1,308x108 Pa, while at the spiral groove cross-sections, the stress at the Pmax cross-section is the largest and is equal to 9,308x108 Pa.

- When firing 5 shots continuously, the maximum stress in the combustion chamber reaches about 5.5806 x 108 Pa, at the cross-sections of the barrel is 5.246 x 108 Pa. Compared to the materials used to make the 14.5mm gun barrel (σb = 980 Mpa), the safety factor n = 1.05 ÷ 3.80 proves that the gun barrel is durable enough.

IV. CONCLUSIONS

The article presents the results of solving the launching algorithm problem and calculating the barrel wall temperature of the gun barrel and from there it is used to investigate the temperature field and stress of the barrel when fired.

The results show the temperature distribution along barrel length and barrel wall temperature after each shot when fired continuously. This leads to increased stress and temperature of the barrel and can affect shooting accuracy and barrel life, which is the quality of the barrel.

It can be seen that with the current barrel thickness, the gun barrel is durable enough to shoot, the barrel's safety factor is: 1.05 ÷ 3.80. When firing a machine gun, the barrel wall heat increases significantly, so you should only fire in short bursts. In case of absolute necessity, fire a series of 20 bullets.

ACKNOWLEDGMENT

The authors would like to thank the technical assistance of the Faculty of Special Equipment of Le Qui Don Technical University.

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