ANALYSIS OF THE STRESS AND DEFORMATION FOR THE ARTILLERY BREECH BLOCK BEFORE AND AFTER REPAIR

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Abstract

The mechanical structure of the breech block after repairing is different from the original breech block. It is assembly parts of the new front-end face, the original breech block, and the connecting screws. So analyzing the stress and deformation of the breech block is an important issue in the repair process for the breech block. The paper is focused on analyzing the stress and deformation of the breech block before and after repair using the finite element method (FEM) approach. Besides, the results of the FEM are compared with the analytical method approach. The comparison between the results of the analytical method and FEM results shows a very good agreement (before repair, the difference in maximal stress between the two methods is 2.12%). The study object of this paper is the wedge-type breechblock.

Keywords: *Stress; deformation; finite element method (FEM); wedge breech block; 85 mm Д44 gun.*

1. Introduction

The breech block is used to lock the bore, ignite the primer, unlock the bore and extract the empty cartridge cases. According to the moving direction of the breech block in locking and unlocking processes, the breech block can be classified into 2 kinds: sliding breech block and screw breech block. The wedge breech block is one of the several types of sliding breech block [1]. This kind of breech block with a simple structure can make reliable operation and can be easily manufactured, such as the breech block of the 85 mm Д44 gun, 130 mm M46 gun, 105 mm howitzer, and 100 mm D10T2C on T55 tank.

In firing, under the action of gases in the bore, the pressure acted on the breech block. Therefore, there are strains and stresses produced inside the breech block. As the number of shots increases, the front end face of the breech block is worn. That is the cause of the clearance between the rear end of the barrel and the front end of the breech block increase. When this clearance exceeds the working limit, the breech block must be repaired by replacing the new front end face [2-4] (Fig. 1).

Analyzing the stress and deformation of the breech block during the shot is an important issue when designing and repairing. Especially in the repair process for the

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breech block. However, in Vietnam researches focused on this issue is limited. Studies mainly solve the problem by the analytical method [5]. However, it is very difficult when using analytical methods to analyze the stress and deformation of the breech block after repair. Due to the breech block after repairing is a component of the new front end face, the original breech block, and the connecting screws.

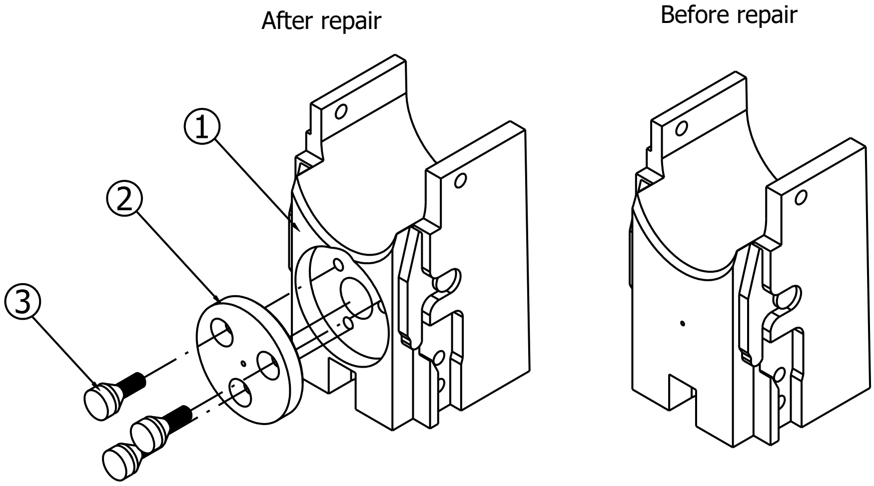


Fig. 1. Repair by replacing the new front end face.

1- original breech block; 2- new front and face; 3- connecting screws.

To solve this problem, the paper presents the finite element method (FEM) to study the stress and deformation of the wedge breech block before and after repair. Besides, the results of the FEM are compared with the analytical method to evaluate the reliability of the FEM approach. The object of this paper is the breech block of the 85 mm Д44 gun.

2. Methodology and Analysis

2.1. Analytical approach

The stress in the breech block is a combination of bending, shear, and compression and it is triaxial. However, the most critical is the bending stress, and therefore in the design, repair process, this is the starting point [6]. This means that shear stress and compression stress can be neglected. During the firing of a gun, the total force acting on the breech block must equal the propellant gas force (F_b) where

$$F_b = p_b \pi \frac{D^2}{4} \tag{1}$$

where p_b is the maximum pressure acting on the rear breech chamber, and it is calculated by the internal ballistic, D is the breech chamber diameter. Besides, this fore is assumed to be uniformly distributed on the circular surface of the front end face. To calculate the bending stress, the distributed force is substituted by two elements fore ($F_b/2$) as Fig. 2. Therefore, the maximal bending moment is calculated by [7]

$$M_b = \frac{F_b}{2}\left(\frac{b}{2} - 0.21D\right) \tag{2}$$

The maximal bending stress is calculated according to the formula

$$\sigma_b = \frac{M_b}{W} \tag{3}$$

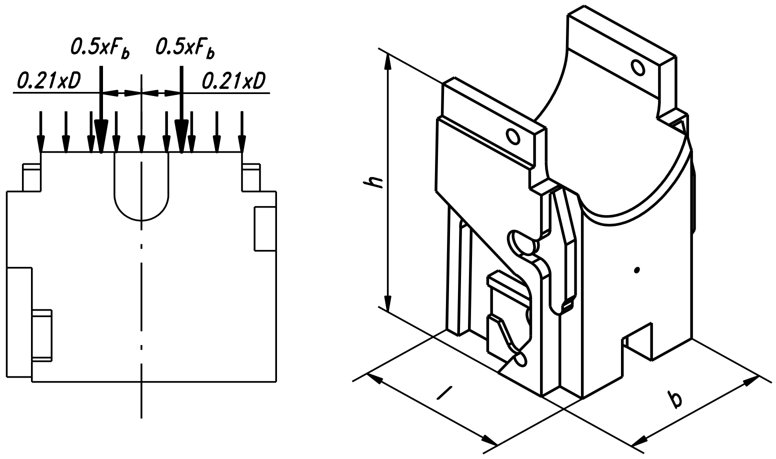


Fig. 2. Model of force acting on the breech block

where b is the width of the breech block, W is the elastic section modulus, and it is calculated by [8]

$$\mathrm{W} = \frac{1}{7} l h^2 \tag{4}$$

where h, l are the height and length of the breech block. For the 85 mm Д44 gun, the geometry parameters of the breech block are given in Table 1 [9].

Table 1. The geometry parameters of the breech block for the 85 mm Д44 gun

Notation	Parameters	Unit	Value
l	Length of the breech block	mm	235
b	width of the breech block	mm	150
h	Height of the breech block	mm	130
D	Breech chamber diameter	mm	104

So the maximal bending stress is defined as:

$$\sigma_b = \frac{7 p_b \pi D^2}{8 l h^2}\left(\frac{b}{2} - 0.21D\right) \tag{5}$$

However, this stress is the stress in static loading conditions. It needs to be multiplied by the dynamic loading coefficient. The coefficient is recommended to be at least 2.5. For the 85 mm Д44 gun, this coefficient is equal to 5.0.

2.2. Finite element modeling

This paper uses the finite element method with the ANSYS software to analyze the stress and deformation for the artillery breech block before and after repair. The complete analysis process is introduced as follows (Fig. 3):

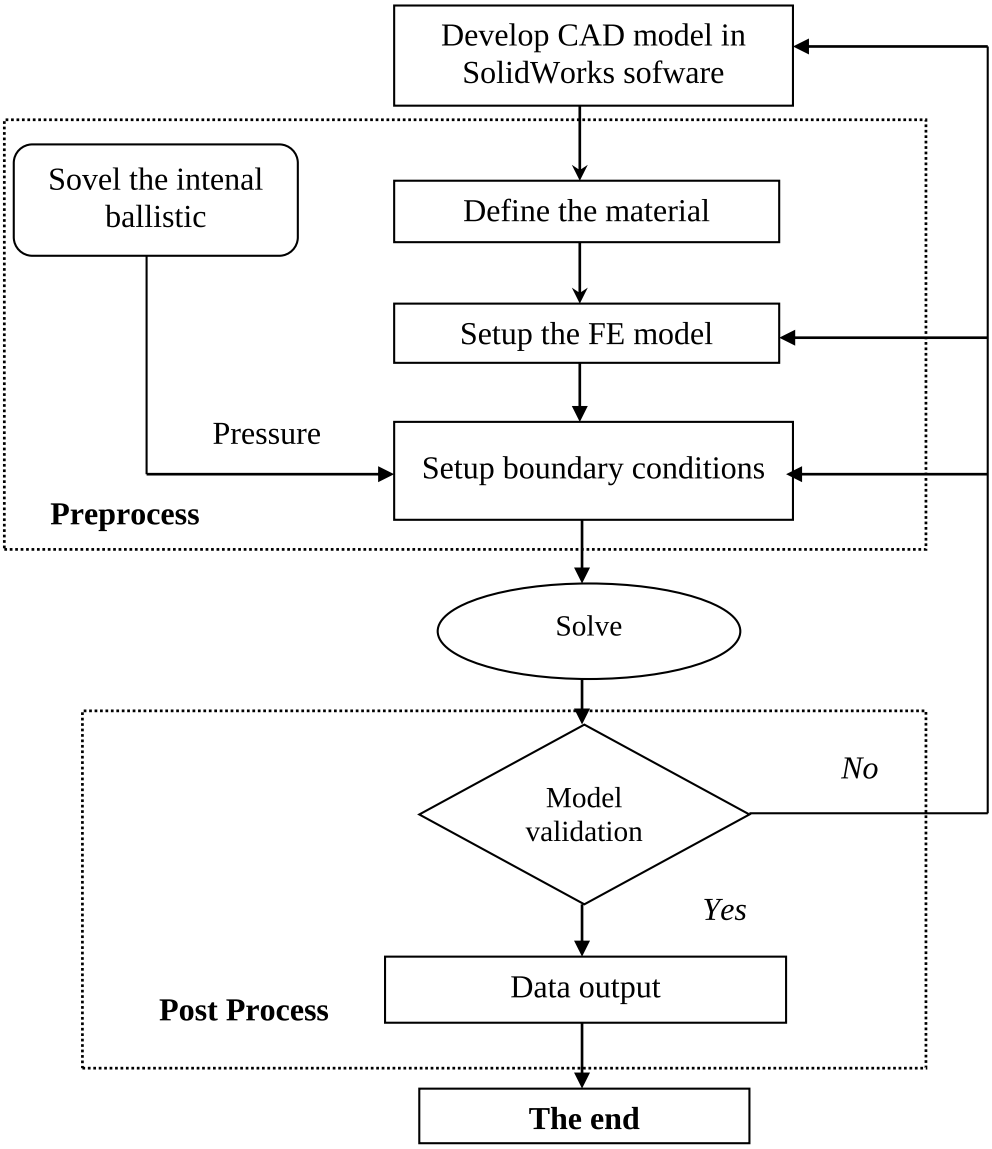


Fig. 3. Analysis process in FEM

In the preprocessing, the maximal pressure acting on the rear breech chamber is calculated by the internal ballistic and it is given in [10].

$$\begin{cases} \dfrac{dv}{dt} = \dfrac{S}{\varphi.m}.p \\ \dfrac{dl}{dt} = v \\ \dfrac{d\omega}{dt} = \omega.\chi.\left(1+2.\lambda.z\right).\dfrac{dz}{dt} \\ \dfrac{dz}{dt} = \dfrac{p}{I_k} \\ p = \dfrac{f\omega\psi - \dfrac{\theta}{2g}\varphi m v^2}{W_0 - (1-\psi)\dfrac{\omega}{\delta} - \alpha\omega\psi + Sl} \\ p_b = \dfrac{1+\dfrac{1}{2}.\dfrac{\omega}{\varphi_1.\mathrm{m}}}{1+\dfrac{1}{3}.\dfrac{\omega}{\varphi_1.\mathrm{m}}} p_m \end{cases} \tag{6}$$

where S is the bore area, v is the velocity of the projectile, m is the mass of the projectile, p is the average pressure of powder gas in the barrel, l is the displacement of the projectile inside the barrel, I_k is the specific energy of the propellant, ω is the mass of powder charge, W_0 is the chamber volume, χ, λ, μ are the shape coefficients of powder, ψ is the mass fraction of burnt powder, z is the relative thickness of burnt powder, f is the specific energy of powder, φ is the coefficient of projectile fictitious mass, δ is the powder density, α is the co–the volume of powder gas, p_m is the maximal pressure in the bore.

For the 85 mm Д44 gun, after solving the system of the differential equation (6) with the main input parameters are listed in Table 2, the analytical results obtained from the ANSYS are presented in Fig. 4. According to these results, the maximal pressure in the bore is 250.3 MPa.

Table 2. The main input parameters for solving the system of the differential equation of interior ballistic [11, 12]

Notation	Parameters	Value
d	Caliber of gun	0.085 m
W_0	Chamber volume	$3.94 \cdot 10^{-3}$ m^3
l	Displacement of the projectile inside the barrel	3.594 m
m	Mass of the projectile	9.54 kg
ω	Mass of powder charge	2.48 kg
I_k	Specific energy of the propellant	$1270 \cdot 10^3$ KG.s/m^3
α	Co–the volume of powder gas	1

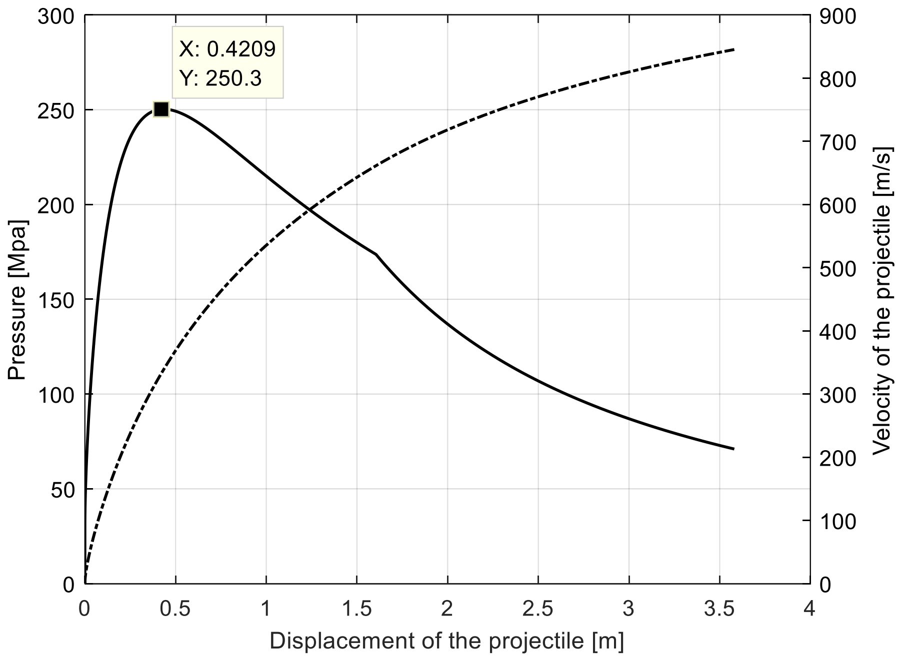
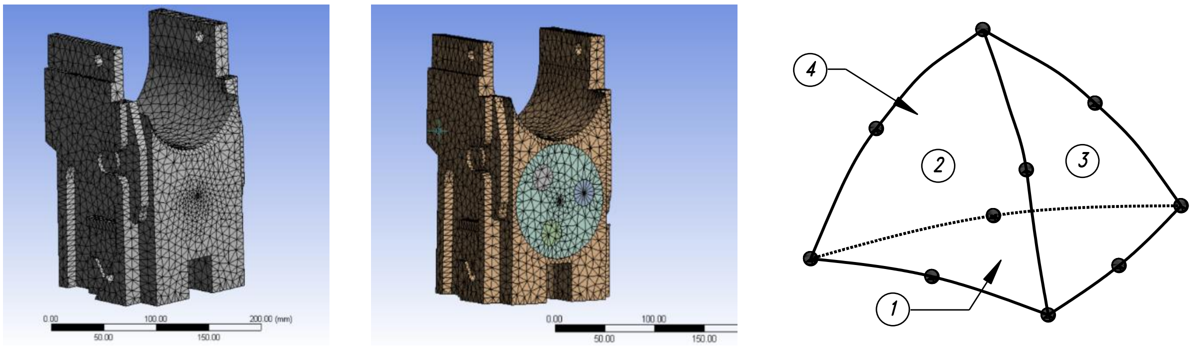


Fig. 4. Pressure and velocity vs. trajectory of the projectile

The material of the breech block of the 85 mm Д44 gun is OXH-1B steel [9, 12]. The mesh on the breech block before and after repairing is given in Fig. 5. Where, the element type selected is solid 92, a tetrahedron with 10 nodes. As the tetrahedron elements allow the finite analysis software to a grid complex geometric model easily. It is suitable for the shape required by the breech block before and after repair.



a) *b)* *c)*

Fig. 5. Mesh on the breech block before (a), after (b) repair and Solid 92 element (c)

3. Results and Discussion

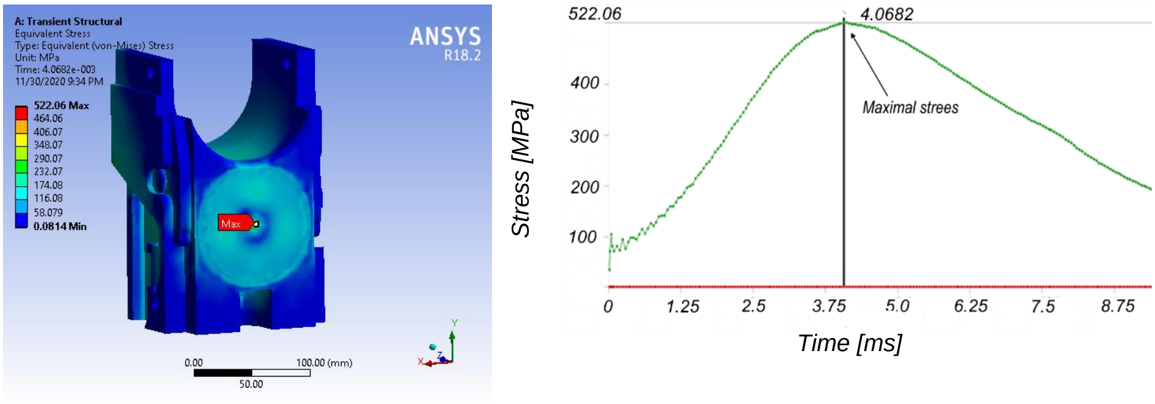
3.1. Before repair

Substituting the input data in Tab.1, and the results of interior ballistic in Fig. 4 into equation (5), we can calculate the maximal bending stress in static loading conditions by the analytical method as Tab. 3. In dynamic loading conditions, the maximal bending stress equal to $\sigma_b = 511\,\text{MPa}$.

Table 3. The calculation results by the analytical method

Parameters	Notation	Value	Unit
Maximal bending moment	M_b	*57994.9*	kN.mm
Elastic section modulus	W	*56735.1*	mm^3
Maximal bending stress	σ_b	*102.2*	MPa

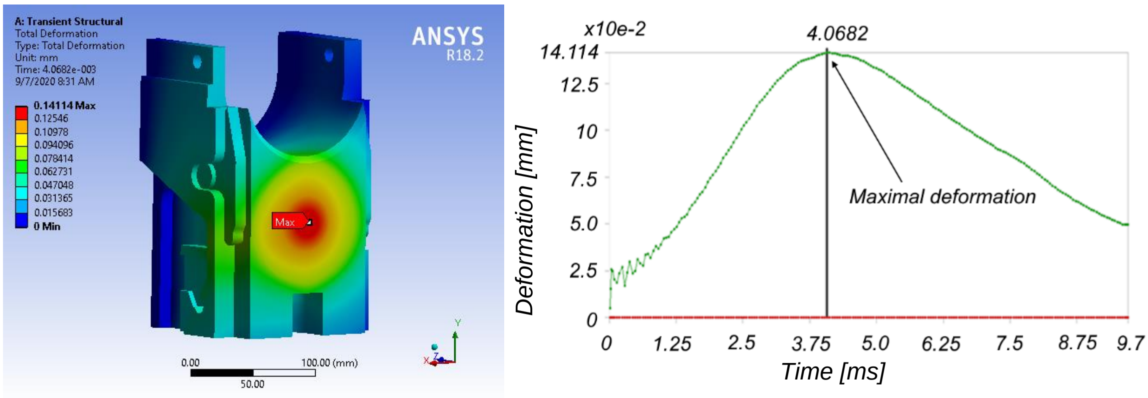
The stress of the breech block simulated by FEM and the change of the stress at this point is shown in Fig. 6. The greatest stress focus on the location near the holder hole of the firing pin. The maximum stress is 522.06 MPa, and it appears at time t = 0.004682s. These results indicate that the difference in maximal stress between the two methods is 2.12%. So, the comparison shows a very good agreement between the results of the analytical method and FEM results.



(a) *(b)*

Fig. 6. The stress on the breech block (a)
and the change of the stress at the point of maximal stress (b)

Figure 7 shows the deformation of the breech block and the change of the deformation at the point of maximal stress. Similar to the case of stress analysis, just after firing, the deformation increase before decreasing gradually. The peak-deformation is 0.14114 mm at the 4.0682 ms.

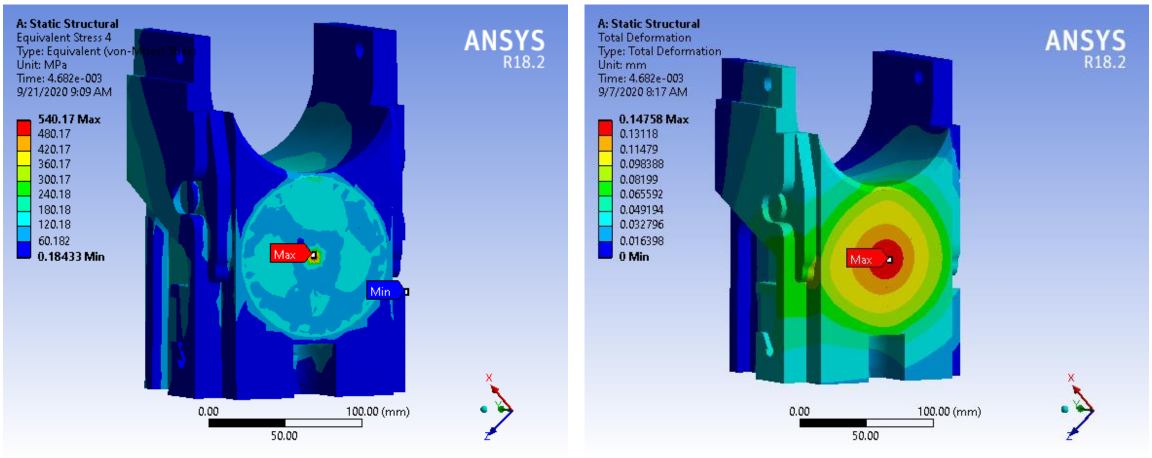


(a) *(b)*

Fig. 7. The deformation of the breech block (a) and the change of the deformation at the point of maximal stress (b)

3.2. After repair

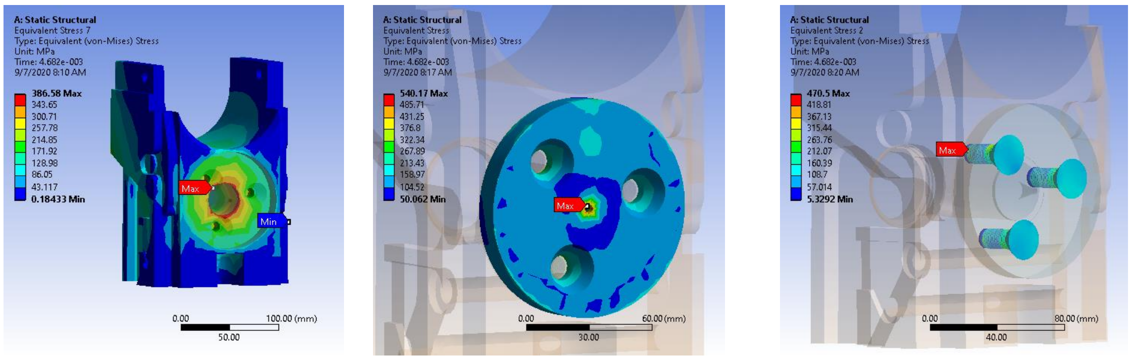
As explained above, the breech block after repairing is a component of the new front end face, the original breech block, and the connecting screws. The stress and deformation of the breech block after repairing are shown in Fig. 8a, 8b. According to Fig. 8, this stress and strain are unevenly distributed, and greater than in the right part. The main cause is the weakened breech block on the right part of the structure.



(a) *(b)*

Fig. 8. The stress (a) and the deformation (b) of the breech block after repairing

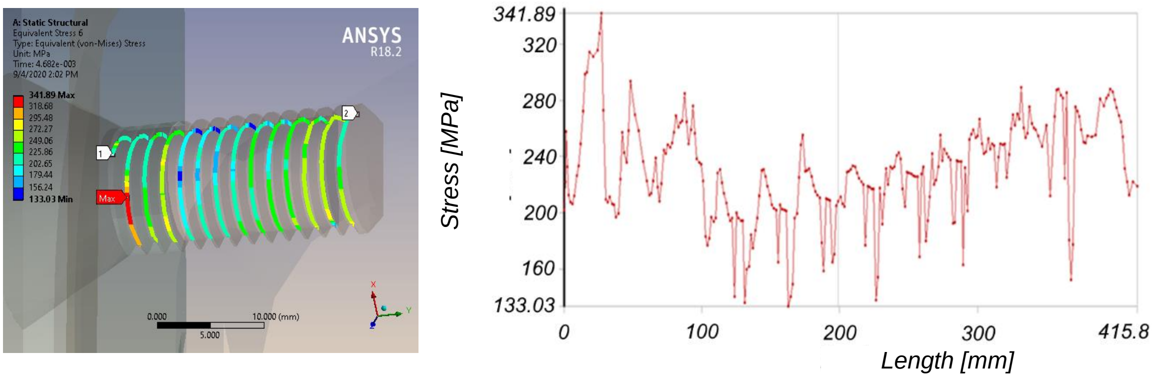
Figure 9 shows the stress on the new front end face, the original breech block, and the connecting screws. The maximal stress on each part is 368.58 MPa, 540.17 MPa, 470.5 MPa respectively. This means that the stress on the new front end face is highest, and this stress value is lower than the yield stress of the breech block material. So, the working requirement of the breech system is good.



(a) *(b)* *(c)*

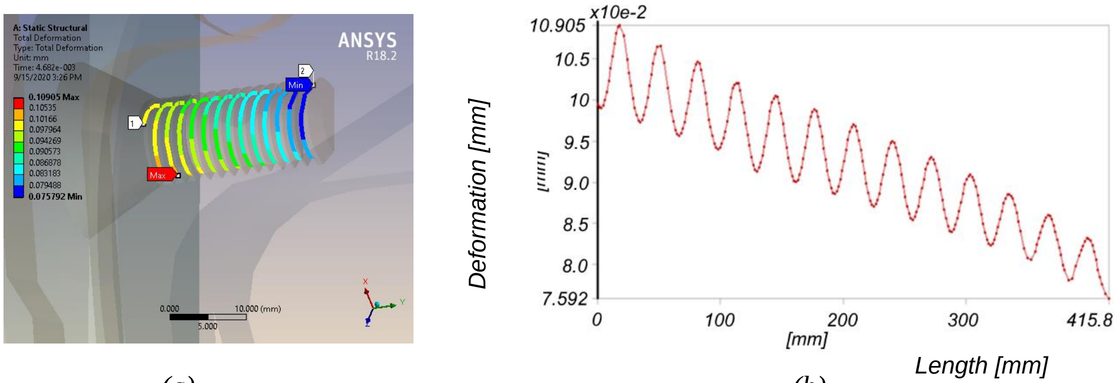
Fig. 9. The stress on the new front end face, the original breech block, and the connecting screws.

For the connecting screw, the stress on the thread root is unevenly distributed, and the maximal value at the contact position between the connecting screws and the new front end face (341.89 MPa) (Fig. 10). The deformation at the screw head position is highest before decreasing gradually (Fig. 11). The largest deformation at this section is 0.10905 mm and the smallest deformation is 0.075792 mm.



(a) *(b)*

Fig. 10. The stress on the thread root (a) and the stress vs. length of thread root of the connecting screw of the connecting screw



(a) *(b)*

Fig. 11. The deformation on the thread root (a) and the deformation vs. length of thread root of the connecting screw of the connecting screw

4. Conclusion

This paper presented an approach to analyze the stress and deformation of the wedge breech block before and after repair. Based on the simulation results, the conclusion can be drawn as follows:

- The comparison of the analytical and finite element method results shows good agreement. So, the FEM may be utilized in the process of analyzing the stress and deformation of the wedge breech block.

- Based on FEM, we can analyze the stress and deformation of all parts on the breech block after repair (the new front end face, the original breech block, and the connecting screws). When applying to the 85 mm Д44 gun, all parts ensure the working conditions.

This research has some limitations. Future research will focus on the combination the pressure and thermal loads, and experiment research.

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PHÂN TÍCH ỨNG SUẤT, BIẾN DẠNG CỦA KHÓA NÒNG PHÁO TRƯỚC VÀ SAU SỬA CHỮA

Nguyễn Văn Hưng, Trương Tư Hiếu

Tóm tắt: *Kết cấu cơ khí của khóa nòng pháo sau khi sửa chữa khác với khóa nòng ban đầu. Nó là cụm chi tiết được cấu thành bởi mặt gương khóa nòng mới, khóa nòng ban đầu và các vít liên kết. Vì vậy, phân tích ứng suất và biến dạng của khóa nòng là một vấn đề quan trọng trong quá trình sửa chữa khóa nòng. Bài báo tập trung phân tích ứng suất, biến dạng của thân khóa nòng pháo trước và sau sửa chữa bằng cách tiếp cận phương pháp phần tử hữu hạn (FEM). Bên cạnh đó, kết quả của phương pháp FEM được so sánh với kết quả tính bằng phương pháp giải tích. Kết quả so sánh cho thấy sự đồng nhất của các kết quả tính toán tốt (trước khi sửa chữa, sự khác biệt về ứng suất cực đại giữa hai phương pháp là 2,12%). Đối tượng nghiên cứu của bài báo này là loại khóa nòng then pháo.*

Từ khóa: Ứng suất; biến dạng; phương pháp phần tử hữu hạn (FEM); thân khóa nòng then; pháo 85 mm Д44.

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