Influence of assembly pre-tension between gun barrel and reciever on stress state during the shot.

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Česká republika

Abstract

The simulation of a gun loading during the shot enables weight reducing while maintains demanded safety. In process of computational strength proof a gun must have gone through of many functionality load cases. One of them is presented in this paper as FEM analysis in program ABAQUS. Presented models represent two different variants of an assembly preload, and include various initial conditions and diverse load pressures in a barrel. Some particular approaches to modelling the shot are discussed from the point of view of computational effectivity and results of the simulations show different influence of the assemblage pre-tension under different boundary conditions.

Key-words: ballistics; overloading; final element method

1. Introduction

Barrel of the gun provides kinetic energy, needed for motion of the projectiles, using combustion of the propelling charge. The components of the analysis gun operate usually below 300 MPa, but pressure can exceed up. This could be possible danger therefore all guns have to pass the test with a half bigger pressure than work pressure without fatal damage.

Motion of the projectile is ballistic discipline which is classified into three major disciplines interior, exterior and terminal ballistics. Interior ballistic deals with the interaction of the gun, projectile and propelling charge before emergence of the projectile from the muzzle of the gun. Exterior ballistics generally encompasses the period from when the projectile has left the muzzle until impact the target, but have one especial part which is intermediate ballistics. The intermediate ballistic deals with the initial motion of the projectile as it is exiting the muzzle of the barrel. Terminal ballistic covers all aspect of events occur when the projectile reaches the target. [1,2]

Structural final element analysis is essential for a bad design prediction, but value of results is on the same level as initial condition witch analyses used. The aim of this paper presents combination of the initial conditions and shows differed influence of the assemblage pre-tension.

1 Ballistics

Base of the investigation ballistics is pressure in the gun barrel which was measured in the cartridge chamber. Temperature load was not included because measurement was not possible. Weight of the projectile was use 10g and charge mass 3,3g.

1.1. Internal ballistics

The interior ballistic describe motion of the projectile in the barrel. Gas energy from propellant charge has changed into the kinetic energy projectile and heat transfer between gas and the barrel. From measured we see pressure during shot and from it we investigate position, speed and acceleration.

$$m_k \cdot \frac{dv}{dt} = s_k \cdot p_s - \sum F_{pr} \tag{1}$$

Pressure at the projectile base is different to measure because inhomogeneity of combustion and motion of the projectile made pressure different around axle of the barrel.

$$\frac{p_d}{p_s} = 1 + \frac{\omega}{2 \cdot m_k} \tag{2}$$

Rotation in barrel and friction of the projectile make resistance force. This force is convert into the axel force and torsion around the axel.

$$I_{zz} = m_k \cdot k^2 \tag{3}$$

$$F_{Pr} \approx (\mu + \tan\alpha) \cdot F_T \tag{4}$$

$$F_R = s_k \cdot p_s \tag{5}$$

$$F_T = \left(\frac{k}{\frac{d}{2}}\right)^2 \cdot F_R \cdot \tan\alpha \tag{6}$$

$$F_{Pr} = \left(\frac{k}{\frac{d}{2}}\right)^2 \cdot (\mu + \tan\alpha) \cdot \tan\alpha \cdot F_r \cdot \left(\frac{m_k}{m_k + \frac{\omega}{2}}\right) \tag{7}$$

1.2 Intermediate ballistics

Validation of the motion is possible with muzzle velocity, but this velocity included acceleration of the projectile after leaving the muzzle. This acceleration must be applied but amount of acceleration is hardly detectable. Amount

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is function of the muzzle pressure and influence have design of the muzzle of barrel. The design is made for eliminating this effect because interaction between gas from the barrel and projectile belittle accuracy of the shot.

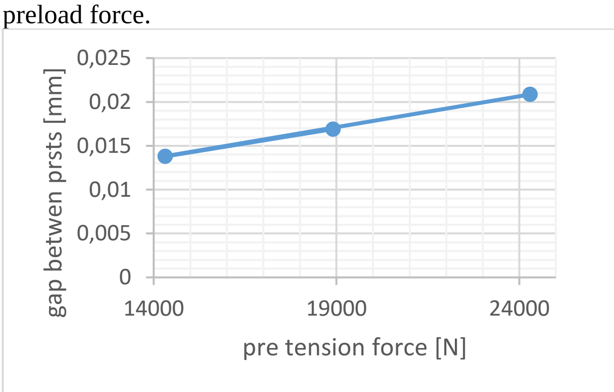
2 Finite element analysis

The presented approach comprises two steps. In the first step a pre-tension of the assembly is computed as implicit FEA and second step is load by shot, which is computed in explicit version FEA.

2.1 Assembly preload

The model included tree parts, barrel, receiver and breech. The receiver and barrel are connected by a screw thread with two different manufacturing tolerances. The screw thread was simplified to the rings and preload was made as displacement between the parts. This hard load has to develop axel force equivalent like tightening torque.

For modelling hard load in program ABAQUS are two options. First is control displacement by amplitude function, but this function after calculation made gap between the parts. This solution is very powerful for search right value of displacement, which corresponding with axel preload force.



But for modelling next step in ABAQUS explicit is necessary eliminate gap between the parts. This is possible by second variant of modelling by function "interference fit". This variant of modelling needed model with penetration into the each other and calculation of this penetration converts to the contact force without gap between parts.

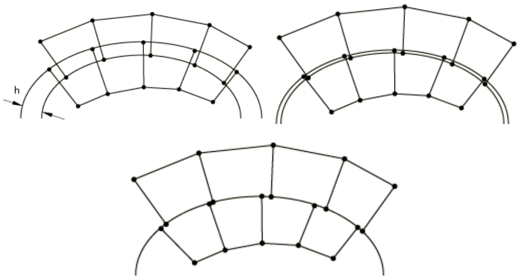


Fig. 1 *Process of calcining contact interference fit*

2.2 Modelling of the shot

This part of modelling was made in explicit version FEA and solved interaction between pre-tension gun and projectile. For this analysis was used only tree parts, barrel, receiver and breech without projectile. Other parts of the gun were replaced by mass point in the centre of gravity. The mass point represents weight and moment of internal.

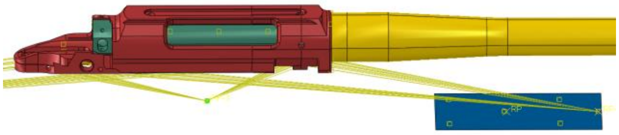


Fig. 2 *Simulation assembly with mass point*

For test is relevant use the worst initial condition. Calculation was done on two different variants of boundary conditions. First represents test in the rigid stand and second shot from lying position. Because in rigid stand all kinetic energy absorbs into the gun, but when the gun is held by human, gun can move and rotate around shoulder. This could be a cause of bending of barrel. Resist of the shoulder is represented by spring into the centre of the gun-stock.

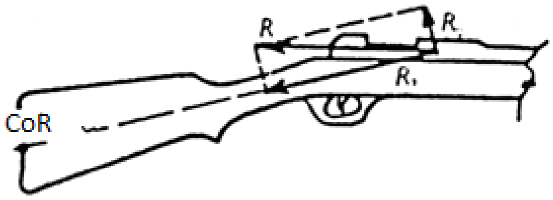


Fig. 3 *Kinematic situation on the gun during the shot (CoR centre of rotation)*

Pressure in barrel is changing in time and load area is changed with projectile position. ABAQUS has users subroutine and for this type of load was used function VDLOAD, when user defined elements and value of pressure by user script as time function. For pressure distribution was used model from [3] which definite pressure as function of time and location. Pressure loading had two periods, in first is pressure in chamber without moving of the projectile. This part was simulated by pressure amplitude and the second period by VDLOAD function.

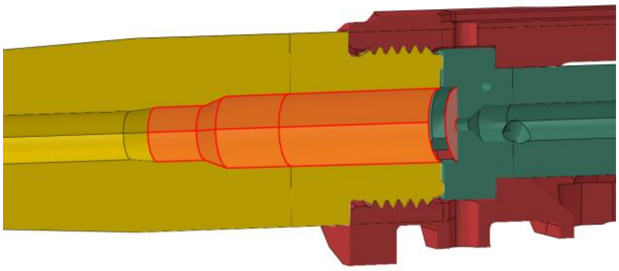


Fig. 4 *Area of first pressure amplitude*

The load from friction in barrel was applied by axel force and torque. But ABAQUS has not any function for this type of load, only choice was to use amplitude and distributing load to the nodes. First choice was distributing coupling but this solution with 130 couplings slowed down the calculation. Because of this is more effective mapped load of the surface nodes in to the barrel.

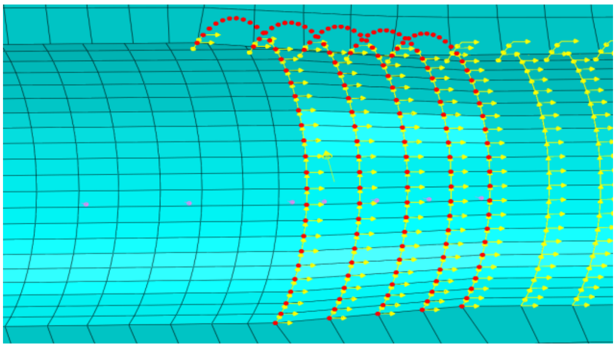


Fig. 5 *Load distributed by nodes*

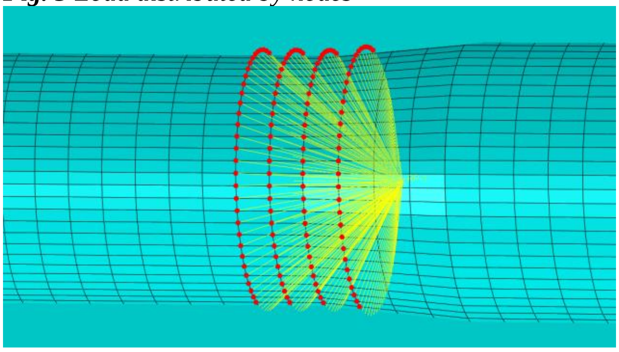


Fig. 6 *Load distributed by coupling*

For precision is important a mesh size and calculation of time grows with number of element and their size. It was used detail modelling accordingly by sub-model function and general model with large mesh size. This made more effective two-stage solution with better precision in assembly contact. The sub-model used whole mode as initial condition and import nodes displacement to the borders nodes.

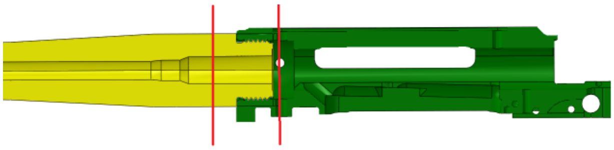


Fig. 7 *Position of submojeling connection area*

3 Tension in assembly

Calculation of the pre-tension showed provisional critical locations on barrel and showed difference between screw thread with normal tolerance and with small overlap. In the normal screw thread is critical first screw gap and corner in front of thread, but in screw thread with overlap is first and last screw gap.

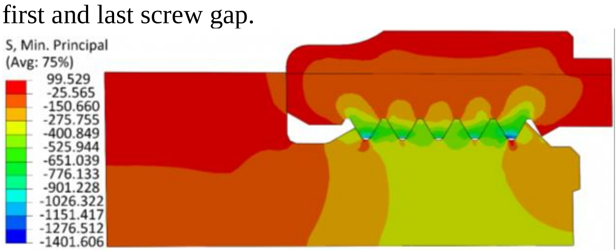


Fig. 8 *Streeses in pre loaded screw tread with overlap*

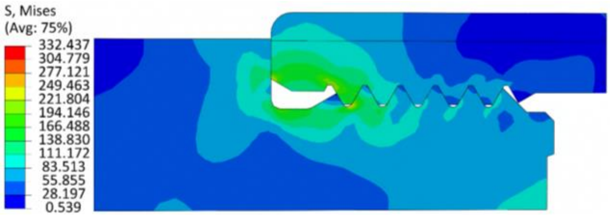


Fig. 9 *Stresses in pre loaded screw tread with normal tolerance*

Location of maximum tension is in the top of barrel, that is valid for all models. It is consequence with gravitation load of the barrel.

The explicit FEA showed motion in the critical location from the top to the side, this could be caused by oscillation of barrel during the shot.

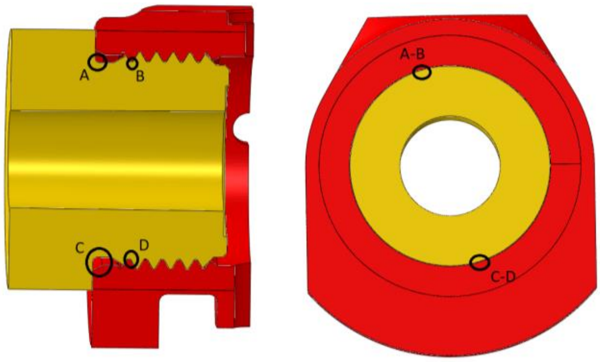


Fig. 10 *Positions of heighted stressed areas in screw tread with normal tolerance*

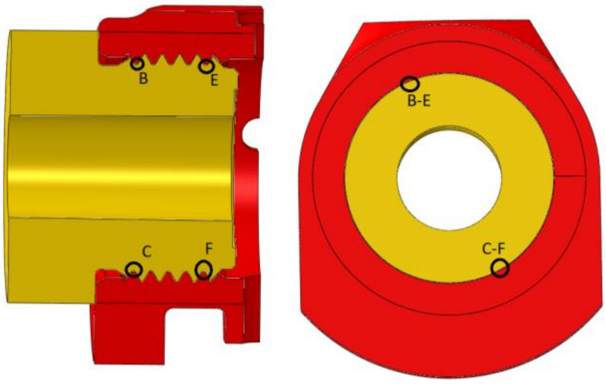


Fig. 11 *Positions of heighted stressed areas in screw tread with overlap*

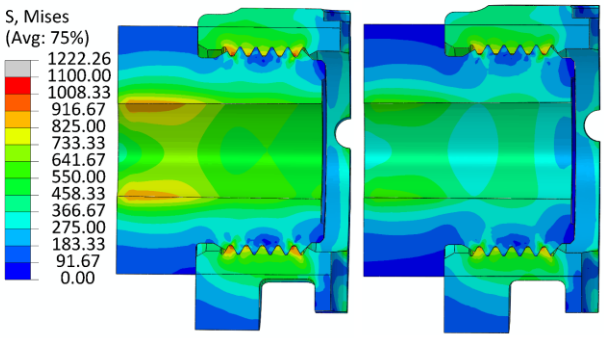


Fig. 12 *The overlap screw tread in moment of maximum ressure in barrel left test pressure and right work pressure*

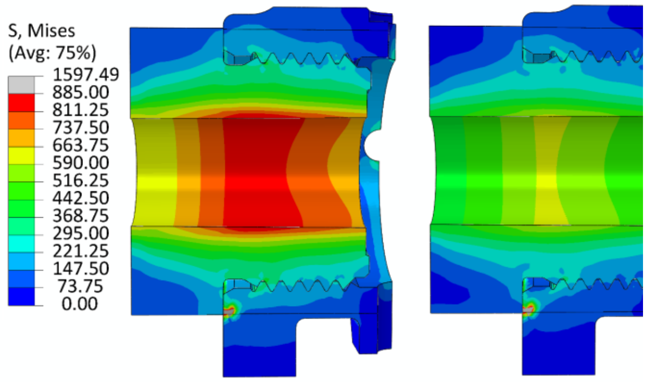


Fig. 13 *The screw tread with normal tolerance in moment of maximum pressure in barrel left test pressure and right work pressure*

Value in this location allows to compare influence of initial condition. From figure (14) was possible to see the worst variant of the load case. It was the test shot with screw thread with overlap and pressure influence was smaller than influence of the overlap. The comparison of the stress in the same position on all models showed differences between them and showed influence of gun with and without choice to moving. This showed that worse option is a gun with potential of moving.

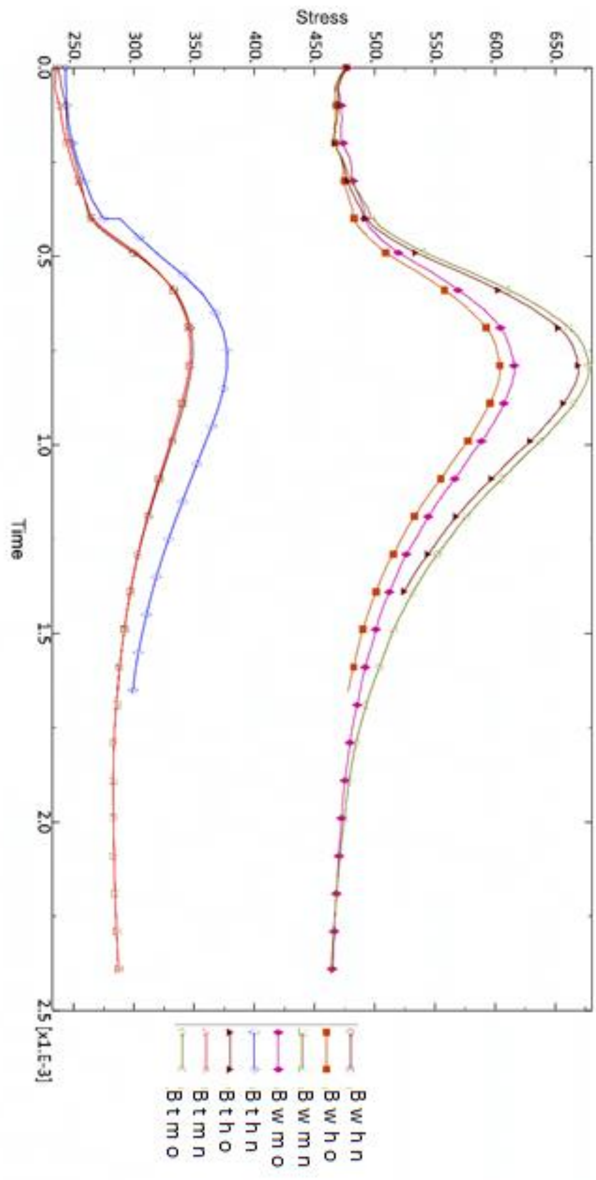


Fig. 14 *Sress in poit B w-work pressure t-test pressure h-rigid boundary contition m-gun with can move o-overlaped screw tread n-normal screw tread*

4 Conclusions

Critical zone was identified according to the simulated pre-loading and shot. In pre-loading part was the worst barrel with overlap in screw thread and the same in simulation of the shot. In this simulation was presented influence of initial conditions, influence was compered on the same point on models and the result change of pressure had bigger influence than boundary conditions when motion of gun impaired tension in screw thread.

Model was made in ABAQUS standard and explicit, for modelling was used techniques as user's subroutine or contact interference fit.

Ballistics parameters was feuded on measurement pressure in chamber and for distributing pressure was used model form [3].

Nomenclature

m_k	Projectile mass
s_k	Surface of projectile
p_s	Pressure on projectile
F_{pr}	Projectile resistance force
p_d	Pressure on breech
ω	Charge mass
I_{zz}	Polar moment of inertia of projectile
k	Radius of gyration of projectile
α	Rifling angle
μ	Coefficient of friction

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