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Submission date: 26-Aug-2019 04:38PM (UTC+0700)

Submission ID: 1163559178

File name: s_Distribution_of_Firing_Pin_Rifle_by_Impact_Force_Using_FEM.pdf (1.03M)

Word count: 1916

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To cite this article: E P Riyanto *et al* 2019 *J. Phys.: Conf. Ser.* **1198** 042009

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Design Optimization in Stress Distribution of Firing Pin Rifle by Impact Force Using Finite Element Modelling

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Abstract. Failure is able to be the crucial problem if this occurred on the important component. A rifle is crucial tools that is used by every soldier, often a failure at the time of firing resulting from a broken firing pin so that the rifle is no longer functioning. Several factor that affected in fracture of firing pin i.e. high temperature, impact load, and improper material selection. In this investigation tried to minimize stress distribution with redesign firing pin using finite element analysis. The design concept used similar material DIN 34CrNiMo6, where the calculation design of stress distribution is achieved from Von Mises stress by finite element software. The result of simulation showed the improvement design able to reduce stress distribution and control the author's goal is to redesign the shape of the firing pin so that it has a better ability than the previous form. The result showed significant influence, distribution stress not reached fracture area.

1. Introduction

Rifle is one of the main tools of the defence system used by every soldier as an individual weapon. The rifle consists of several component part which are a set of systems that cannot work independently, and the component parts have their respectively functions, one of the most important components of the rifle is a firing pin. In general, small components are always neglected and considered not important because it does not give a big influence. The failure does not see at size of a component, but it visible from the effect and contribution caused by the component.

Firing pin is small component in rifle that gave big contribution as starting exploit ion in the shooting, where if the firing pin breaks when the rifle on shooting process then its process can no longer function.

Firing pin used material DIN 34CrNiMo6 as known as high strength steel that having high hardenability, fatigue strength and toughness [1–3], in other condition this material susceptibility by several factor due firing process that affected in fracture of firing pin i.e. cyclic high temperature, impact load, explosion emission, embrittlement and improper design. The three main methods to prediction the fatigue analysis used finite element analysis i.e. stress-life, strain-life and crack-propagation [4]. In this investigation aims to predict the fatigue analysis in stress-life with minimize stress distribution by redesign firing pin.

2. Methodology

2.1. Simulation design parameter

The design concept used similar material, where from XRF metal analysis Niton XL2 showed firing pin used AISI 4340 that equivalent to DIN 34CrNiMo6 [5–7]. The calculation design of stress distribution is achieved from von Mises stress by finite element software. The mechanism started by calculation dimension firing pin and primer thickness, which the mechanism is shown in Figure 1.



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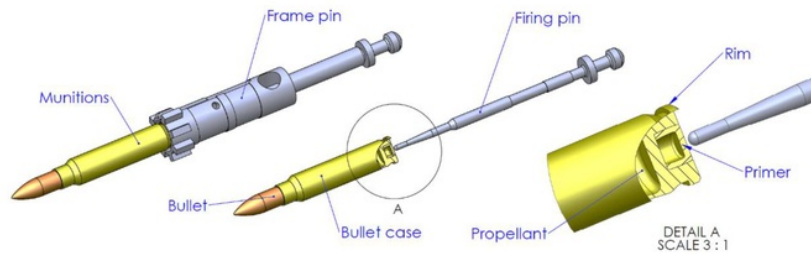


Figure 1. Mechanism of firing pin and primer position

The distance between firing pin and primer 0.6 mm, then firing pin move 1 mm until pushed the primer. The plastic deformation has done in this simulation, the primer material used brass CuZn30 where for mechanical properties are shown in Table 1 and for value stress-strain curve was achieved from another article [8].

Table 1. Mechanical properties primer material
brass CuZn30

Elastic modulus	Rigidity modulus	Poisson's ratio	Density
ksi	ksi		lbs/cu.in
16000	6000	0.33	0.308

On the calculation simulation the impact velocity is achieved by calculation radius and degree of hammer position, where the approximate of firing process is 600 bullet/minutes with estimation the initial angle of hammer 45 degree with reciprocal process and radius hammer 35 mm. Therefore, the linear velocity is achieved at 330 m/s and time process for one bullet is 0.003 second.

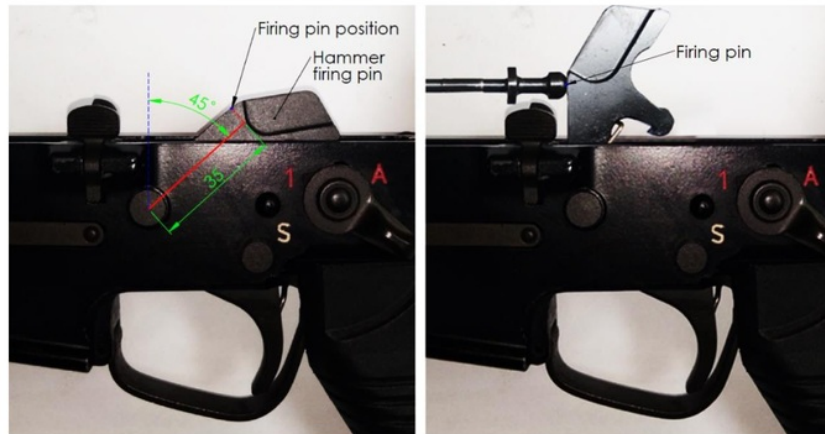


Figure 2. Geometry calculation on firing pin impact position

2.2. Firing pin design parameter

In Figure 3 showed the comparison between initial condition and fracture condition of firing pin, where the estimation fracture length is approximated 3.32 mm. The fracture occurred in under normal condition on range 600 firing process.

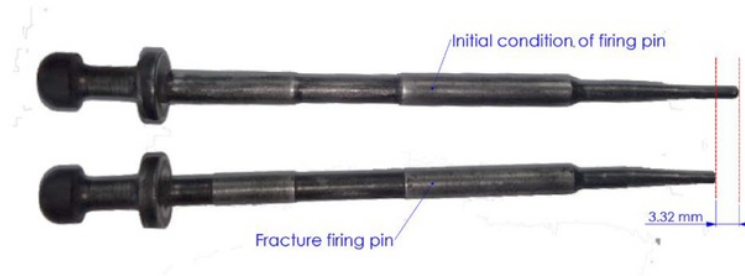


Figure 3. Estimation fracture length on firing pin

However, several factors had contribution in fatigue fracture of firing pin i.e. material selection, cold or heat treatment, microstructure formation by explosion process, but in this investigation tried to minimize influence of fatigues fracture with considering the design concept.

Normally, the calculation diameter of tip firing pin must smaller than inner frame pin at below 2mm, and length of tip must bigger than inner gate frame at 2 mm and added with 0.4 mm for push primer brass condition. The result calculation of new design firing pin is shown on Figure 4, which small improvement has been conducted.

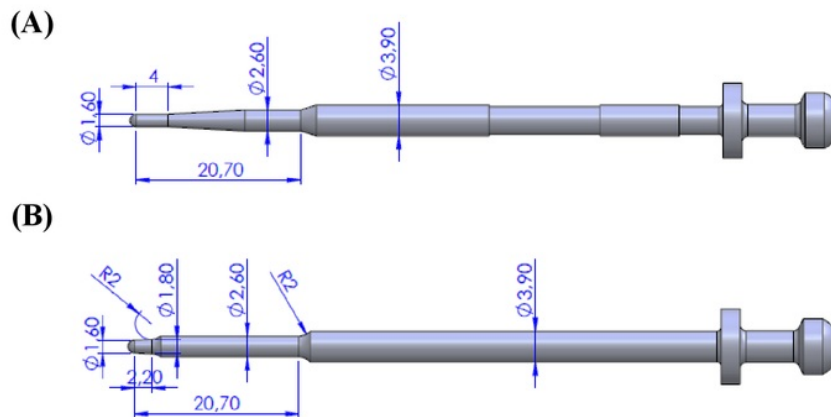


Figure 4. Dimension of firing pin (A) initial design of firing pin; (B) new design improvement of firing pin

3. Result and discussion.

The simulation used finite element software that the significant result was achieved. The symmetry condition was chosen with 100 step and time step increment 3e-005 second, where the von Mises stress distribution is used as fatigue fracture parameter [9,10].

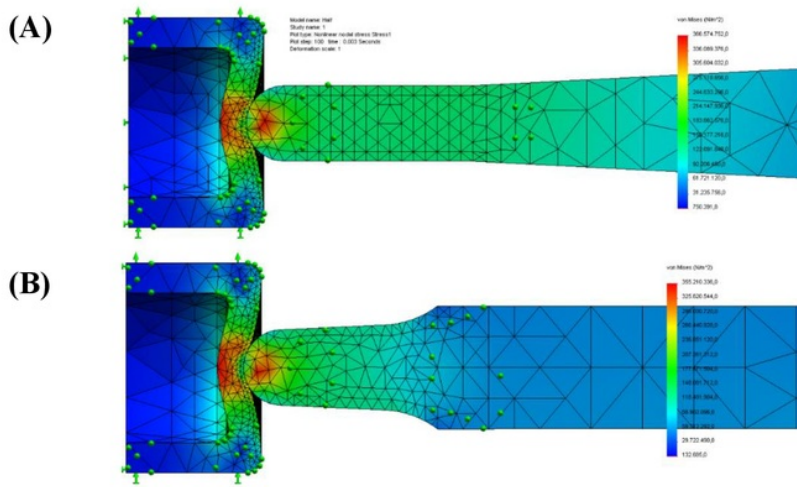


Figure 5. Von Mises stress distribution at step 100 or at time 0.003 second (A) Initial firing pin; (B) new design improvement of firing pin

From result in Figure 5 (B) showed the significant improvement stress distribution, the stress not able to reach fracture area at formerly distance 3.32 mm. The initial design showed the stress distribution has through the fracture area, where in Figure 5 (A) indicate that the green colour in normal condition below from yield strength, but this condition has been indicated the area has received more stress than the new design of firing pin. The max von Mises occurred on tip of firing pin with value approx. 367 MPa at initial design and the max von Mises decreased at new design of firing pin with value approx. 355 MPa. In this condition the max von Mises still on safety condition below yield strength of DIN 34CrNiMo6 at range 1000-1100 MPa and max von Mises comparison not showed significant improvement, but the stress distribution showed the significant contribution.

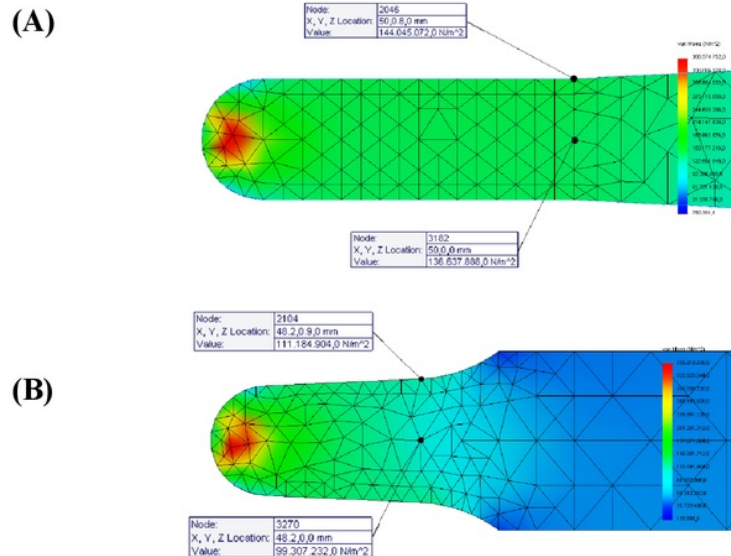


Figure 6. Magnitude von Mises in several node from tip firing pin distance (A) Initial firing pin at distance 4.8 mm; (B) design improvement of firing pin at distance 3 mm

In Figure 6 (A) of initial specimen, the node has taken two point in middle (node 3182) and edge (node 2046), where on edge achieved more stress than in middle area. In Figure 6 (B) at node 2104, the new design used different dimension on edge with diameter 1.8 mm that it's able reduce in stress distribution.

Generally, the fracture area at range 3.32 mm from tip as shown in Figure 3 and if refer to Figure 6 (A), the stress distribution has reached the fracture area. Otherwise the distribution of stress decreased and not distributed into fracture area on the new design of firing pin.

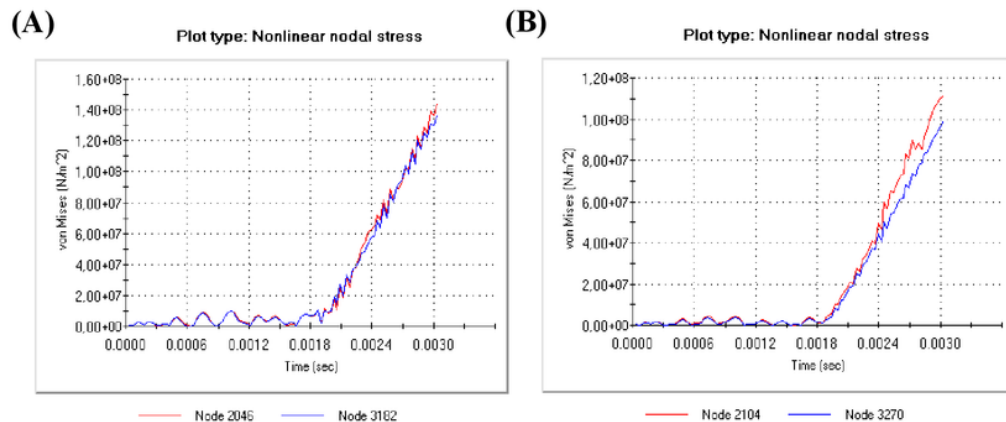


Figure 7. Curve time versus von Mises stress at specific node (A) Initial firing pin at node 2046 and 3182; (B) design improvement of firing pin at node 2104 and 3270

The curve in above related to Figure 7, where the von Mises value was achieved from time at 0.003 second in condition maximum. In the curve showed the impact between firing pin and primer occurred at time 0.001818 second.

4. Conclusions

The simulation results showed the effect by design also gave big contribution, where in new design improvement able to minimize the stress distribution and able to be controlled. However, several factors caused fatigue fracture cannot be avoided, but this investigation able to be considering as one of solution in mitigation fatigue fracture of firing pin DIN 34CrNiMo6.

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