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WORD COUNT 1834
TIME SUBMITTED 21-APR-2023 10:48AM
PAPER ID 98949493

Journal of Physics: Conference Series

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To cite this article: A Yusup *et al* 2019 *J. Phys.: Conf. Ser.* **1198** 032007

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Finite Element Failure Analysis on 34crnimo6 Firing Pin in Fatigue Fracture

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Abstract. Weapon made by Pindad Company is an individual assault weapon which is set as standard weapon of TNI. Firing pin is one part of a weapon that has an important role in the shooting cycle. If the firing pin is damaged, it will result in the weapon not being able to fire. Damage to the firing pin can be caused by several things, such as material properties, treatment, design, cyclic load and heat factor. In this case, the authors use the finite element method to determine which factors are most influencing by impact and heat factor that made the failure of the firing pin. At the end of the paper, the authors draw the conclusion that the heat factor from the explosion has major influence in the fatigue fracture, and carbon content increasing caused CO2 emission from explosion as additional factor, which made the firing pin become brittle.

1. Introduction

The Indonesian National Army (TNI) as a state defence tool has various tasks to be carried out, which every duty have to be finished perfectly. A failure is avoided in defence department, caused fatal condition about salvation of country. The SS2 V3 is standard weapon made by Pindad Company that is used by every soldier, the problem has been founded when 23 soldier went to training for shooting, where the firing pin having fracture under normal condition. In one month 23 soldier able to spend 158 of firing pin and 100.000 bullets, which is mean thus one firing pin able to be used in about 634 bullets.

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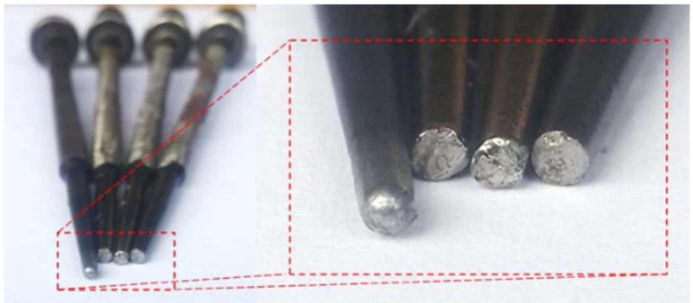

Figure 1. Fatigue fracture in firing pin

However, the breaking of the firing pin is fatal when it comes to gunfire with the enemy. Due to the breaking of the firing pin, it will result in SS2 V3 weapons not able to be fired. DIN 34CrNiMo6 is material used in firing pin, which is known as advanced high-strength steels that amount contain of martensitic matrix [1].

In failure analysis several factor must be predicted from visible and hidden factor, but is needed to eliminate factor for reduce trial and error in investigation. Frequently in loading and unloading process made an object having fatigue, majority several investigation in DIN 34CrNiMo6 used stress and strain controlled in define fatigue life [2–4]. Finite element was chosen caused more conservative in trial and error to define optimum parameters [5]. This investigation the effect of impact force and thermal transfer were chosen in prediction fatigue life of firing pin.

2. Methodology

The fracture condition is influenced by several factor in this investigation, firing pin having punch by hammer and made the velocity then impact to the primer of the bullet. In the reciprocal shooting process approx. spend 720-760 bullets per minute with the velocity about 710 m/s, and magnitude heat that is transferred by exploiting amount 150 - 200 degree Celsius.

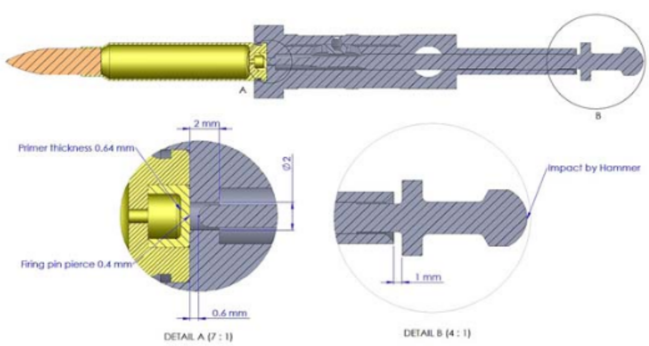

Figure 2. Geometry and mechanisms of firing pin process

On the boundary condition simulation showed in Figure 3, the symmetry simulation condition was conducted with tetra hexagonal meshing control. Fatigue S-N curve used based on ASME carbon steel curve that was derive from elastic modulus of material.

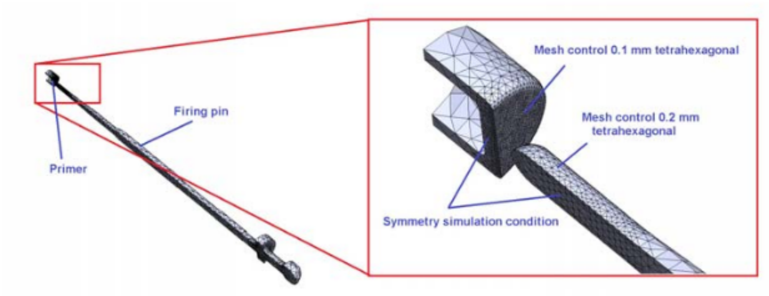

Figure 3. Finite element boundary condition in firing pin

Chemical properties of firing pin is achieved from XRF metal analysis testing Niton XL2 that is shown in Table 1, which state material as AISI 4340 and this material equivalent with DIN 34CrNiMo6 [6–8]. CuZn30 is material of the primer of the bullet, where having plasticity deformation and the magnitude of value strain-stress curve is achieved in other investigation [9].

Table 1. Chemical and mechanical properties firing pin material DIN 34CrNiMo6

Chemical composition	C	Cu	Si	Mn	Cr	Mo	Ni	Fe	Lec
(Weight %)	0.345	0.302	0.275	0.604	0.822	0.239	2.97	balance	0.561

Mechanical properties	Elastic modulus	Poisson's ratio	Tensile strength	Yield strength	Thermal expansion	Thermal conductivity
	MPa		MPa	MPa	/K	W/(m.K)
	210000	0.28	1200	1000	1.1e-005	14

3. Result and Discussion

The finite element analysis is used to calculate contact force between firing pin and primer, then value of contact force used to calculate the fatigue life time. The brittle condition was used in this simulation, where Goodman mean stress correction was chosen. In Figure 4 showed the simulation has conducted in two comparisons, where the first prediction the simulation used normal contact stress and the second simulation having additional heat as a fracture factor.

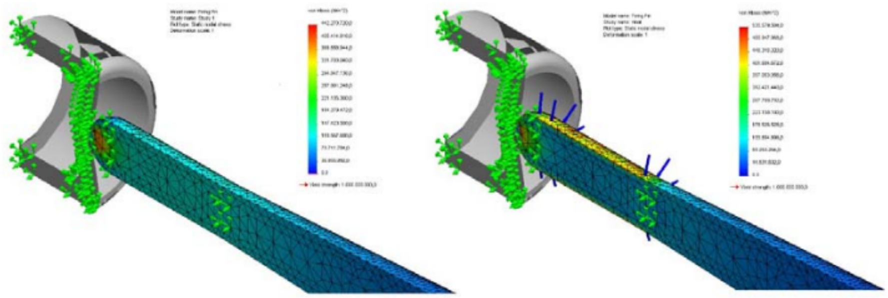

Figure 4. Max von Mises value as fatigue parameter prediction; **(A)** normal contact force condition; **(B)** normal contact condition with addition heat transfer

The simulation result showed the maximum von Mises stress at normal contact stress in Figure 4 **(A)** approx. at 442 MPa below the yield strength of firing pin and result for addition heat factor amount 536 MPa. These result were used as parameter to predict fatigue life time cycle, where several investigation has validated the accuracy of von Mises in assessment the fatigue life [10–12].

(A) **(B)**

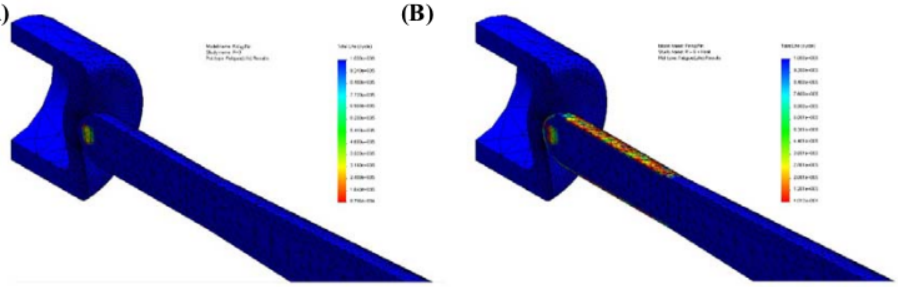

Figure 5. Fatigue life prediction base on zero-based loading (R=0); **(A)** normal contact force condition; **(B)** normal contact condition with addition heat transfer

The zero-base loading condition was chosen as prediction in condition infrequently firing process, where from result. The fatigue fracture amount 8.795e+004 cyclic was obtained in the first simulation and cyclic life time reduced after addition heat factor amount 4.012e+004 cyclic as is shown in Figure 5, these simulation explained that the factor of normal contact stress and heat transfer not gave significant contribution in influence fatigue fracture of firing pin.

(A) **(B)**

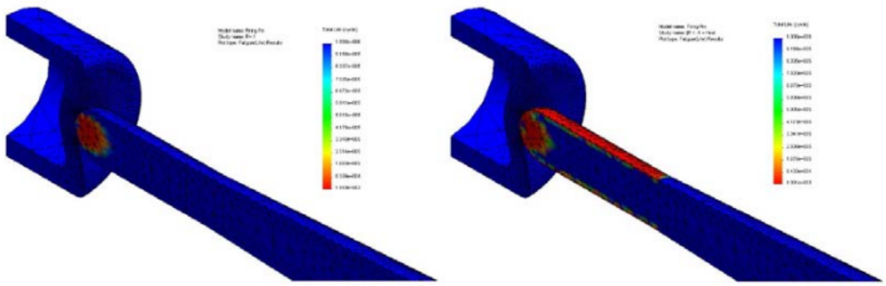

Figure 6. Fatigue life prediction base on fully-reversed loading (R=-1); **(A)** normal contact force condition; **(B)** normal contact condition with addition heat transfer

The rapid fire was depicted in Figure 6, the significant decreasing in cyclic of life time was happen in the prediction base on fully-reversed loading. In Figure 6 (B), the cycle life time amount 1.091e+003 is nearly close the fracture condition in normally at 634 cycle, but the fully-reversed loading is not completely the only factor the fatigue factor of firing pin caused the shooting process need to reload the ammunition to spend 634 bullet per firing pin.

Hence, the other prediction has comes from the several factor, where the prediction represent that has occurred the embrittlement caused microstructure transformation and the increasing carbon content of CO2 emission by explosive process [13].

4. Conclusion

The study in prediction fatigue life by finite element analysis in factor impact force and thermal can be drawn as preliminary investigation, where from the result showed a significant influence has occurred. The impact and thermal factor is visible factor that able to be predicted and there are still some other factors that is difficult to be predicted.

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