Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

INVESTIGATION ON SPRING CHARACTERISTICS FOR SMALL ARMS

R. Abidin[1,*], M. A. Ahamat[2], A. Arif[1], T. Ahmad[1] and M. Murad[1]

[1]Department of Mechanical Engineering, Faculty of Engineering, UniversitiPertahananNasional Malaysia, Sungai Besi Camp, 57000 Kuala Lumpur, Malaysia

[2]Universiti Kuala Lumpur, Malaysia France Institute, Seksyen 14, Bandar BaruBangi, Selangor, Malaysia

Published online: 10 September 2017

ABSTRACT

The reliability of mechanical spring is essential to ensure the arm does works as intended. Thus, it is important to understand the behavior of spring in arm to increase the reliability of arm and improve defence technology. This paper presents the simulation on reliability of springs in three small arms, namely weapon X, weapon Y and weapon Z. The springs that are used in these weapons were modelled in SOLIDWORK and the properties such as shear stress, von Mises stress and potential for failure were predicted based on the simulation results. The simulation was extended to find alternative materials to fabricate the firing spring of weapon Z. It was found that the stainless steel AISI 304 yielded the lowest percentage of potential for failure of 8.5%. Future work is on the testing of spring reliability under actual operating conditions since it is essential to get a data on the fatigue failure or failure due to wear.

Keywords: spring mechanism; bolt spring; firing spring; small arm.

Author Correspondence, e-mail: razaliabidin@upnm.edu.my

doi: http://dx.doi.org/10.4314/jfas.v9i3s.28

1. INTRODUCTION

This paper presents the investigation of spring characteristics in small arm. Small arms include revolvers, self-loading pistols, rifles, carbines, assault rifles, submachine guns and light machine guns which are fall under the Small Arms and Light Weapons (SALW) protocol [1]. Spring is an essential component in a small arm since it will determine the total mass and the velocity of bolt and bullet round/min when it exploded. Usually, optimized projectiles and improved chemical propellants are the methods used to obtain greater firepower and reduced the weight of arm. However, a better performance of arm achieved through these methods always hindered by the physics of recoil forces generated by gunpowder weapons and the momentum of their projectiles. Lighter weapons have lower recoil energy and reduce the momentum of bullet leaving the arm. An improvement in gun powder technology is no longer possible since it will lead to a higher cost.

Mechanical spring is an elastic body that may deflect or distort when a force is applied, and return to its initial form once the force is removed [2]. A mechanical spring may act as a flexible joint between two parts in mechanical components and can be defined as an elastic body whose primary function is to deflect or distort under load [3]. There are three types of main spring which is compression, tension and torsional springs. Springs may also be classified as wire springs, flat springs or special shape springs and the variation within these divisions [4].

Mechanical springs usually undergo a straight-line load-deflection [5]. Stresses in helical spring are determined by spring dimensions and the application's load and deflection requirements. Compression springs are stressed in torsion. Maximum stress occurs at the inner surface of the wire which is the load varies as the spring is deflected, producing a range of operating stresses that influence the life of the spring. There are three main aspects to be consider in designing the spring that have stronger spring; first the heavier spring wire, second the smaller coil and last but not least the more number of active coil(N), the less load we will have to apply in order to get it to move a certain distance. Compression springs are often installed to operate over a rod or inside a hole. These installations help reduce buckling of the spring body.

Springs are also used in other applications. A pre-stressed spring was used in earth quake measurement [6]. For a re-centering spring, a proper design is required to ensure the spring works as intended [7]. A calibration of spring is required to ensure the effective spring constant is within the designed range [8].Spring are usually made from alloy of steel and the most common spring steel are music wire, oil tempered wire, chrome silicon, chrome vanadium and 302 and 17-7 stainless steel and spring are manufactured either by hot or cold-working process depend on the application and also the size of the material.

Table 1 shows the materials that usually used to make spring. In small arm, music wire possesses the desired characteristic of the small arm spring and also the cheapest among them. The other types of material also have the same characteristic such as oil-tempered wire. In this research, we will study the effect of this type of material to the small arm and based on [9].On guide to recoil spring, the spring strength will affect the performance of the small arm. Therefore, the higher spring strength will give good performance of small arms. In the other hand, the higher spring strength will increase the force to trigger the small arm.

Table 1. Properties of materials that commonly used for spring production

Mechanical Properties	Music Wire ASTM A228	Steel AISI 304	Hard Drawn ASTM A227	Oil Tempered ASTM A229
Young's Modulus, E (MPa)	207,000	193,000	207,000	207,000
Modulus of rigidity, G (MPa)	79,000	69,000	79,000	79,000
Density (g/cm^3)	7.86	7.92	7.52	7.35
Minimum diameter (mm)	0.1	0.13	0.13	0.5
Maximum diameter (mm)	6.35	9.5	16	16

While, a small arm spring designer may consider a failure at 100,000 cycles only due to low force acting on that spring [10]. The Von Mises stress is used by designer to predict the limit stress of their design; the design is considered failed when the Von Mises stress is higher than the yield strength of the material used [11].

This paper presents the study on the reliability of springs in small arms namely as weapon X, weapon Y and weapon Z through simulations. The reliability of the current design of spring in these weapons is presented before the simulation results of alternatives materials that may produces a more reliable spring.

2. EXPERIMENTAL

This section provides related theory on spring that was modelled in the SOLIDWORK and simulation procedures of the forces within the spring.

2.1. Fundamental Forces in a Spring

A round helical-wire helical compression spring may be loaded with axial force (F) [12]. The torsion (T) was determined using Equation (1):

$$T = \frac{FD}{2} \quad (1)$$

where D is the mean coil diameter and F is the applied compression force on the spring. The shear stress (τT) in spring wire due to torsional force was determined:

$$\tau_T = \frac{F \times \frac{D}{2} \times \frac{d}{2}}{\frac{\pi D^4}{32}} = \frac{8FD}{\pi d^3} \quad (2)$$

where d is the diameter of the wire. The average shear stress in the spring's wire due to force F was calculated by

$$\tau_F = \frac{F}{\frac{\pi D^2}{4}} = \frac{4F}{\pi d^2} \quad (3)$$

Then, the maximum shear stress in the spring wire was calculated by

$$\tau_T + \tau_F = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2} \quad (4)$$

or

$$\tau_{max} = \frac{8FD}{\pi d^3}\left(1 + \frac{1}{\frac{2D}{d}}\right) = \frac{8FD}{\pi d^3}\left(1 + \frac{1}{2C}\right) \quad (5)$$

where $C = D/d$ also known as the spring index. Alternatively, the maximum shear stress was calculated using Equation (6)

$$\tau_{max} = (K_s)\frac{8FD}{\pi d^3} \quad (6)$$

where $K_s = 1 + \frac{1}{2C}$ also known as the shear stress correction factor. The Von Mises stress within the spring was calculated by

$$\left[\frac{(\sigma_1+\sigma_2)^2+(\sigma_2+\sigma_3)^2+(\sigma_3+\sigma_1)^2}{2}\right]^{1/2}=\sigma_v(7)$$

2.2. Simulation

There sample of small arms were chosen for the simulation which are weapon X, weapon Y and weapon Z. Due to confidentiality of intellectual property, the actual model of the weapons is not disclosed in this paper.

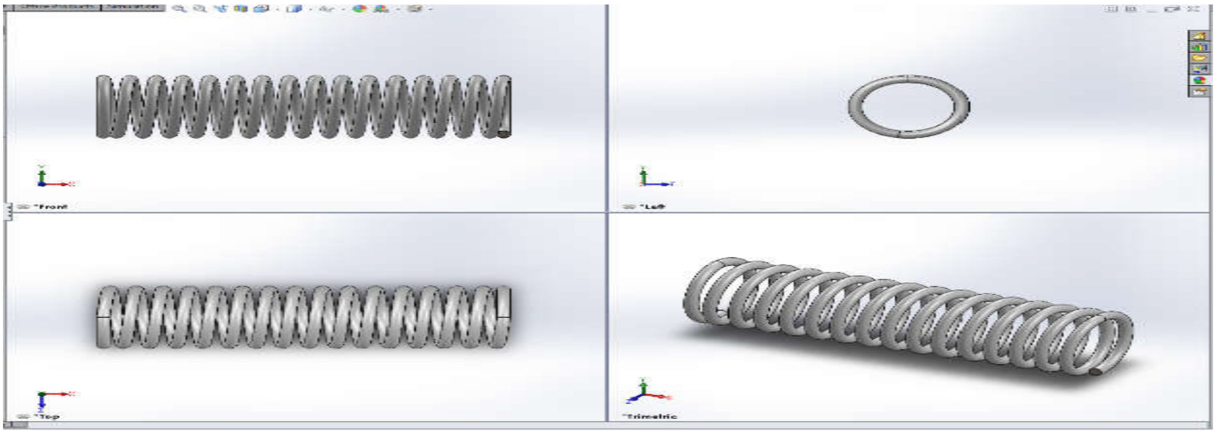

Fig.1. Spring model in SOLIDWORK

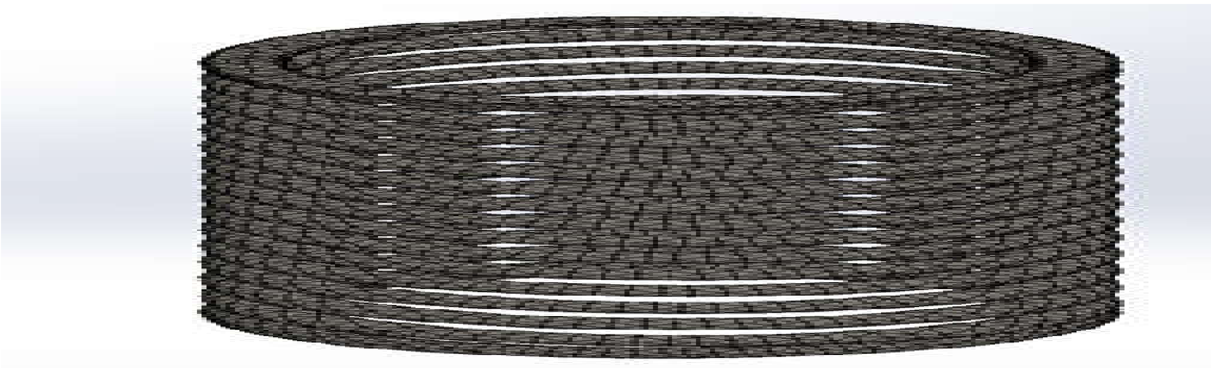

Fig.2. Curvature mesh on spring

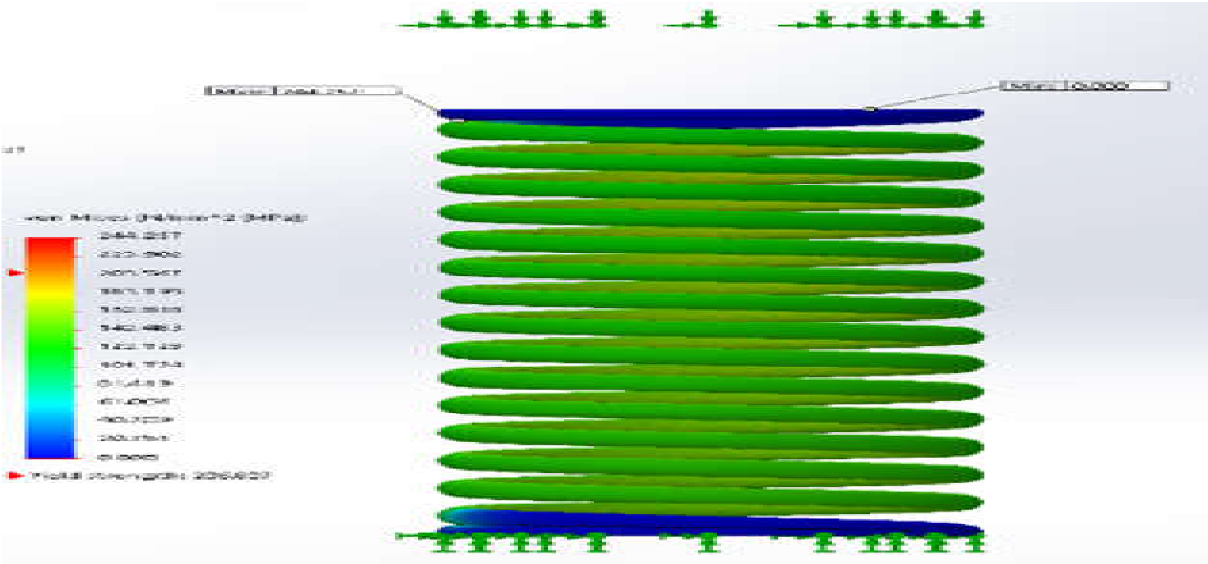

Fig.3. Stress analysis within a spring

Table 2. Specifications of springs and forces exerted for weapons X, Y and Z

Type of Spring	Action Spring X	Bolt Spring Y	Recoil Spring Z	Firing Spring Z
Wire diameter, D1 (mm)	1.83	1.15	1.01	0.82
Outer diameter D2 (mm)	22.87	13.8	9.62	2.5
Free length, L (mm)	245	72.5	127	12
Number of active coil, N	40	14	30	16
Number of total coil	42	14	32	18
Type of material	Stainless steel AISI 304	Music wire	Music wire	Music wire
End-type design	Closed ground	Open	Closed ground	Closed ground
Mass (g)	5.4	2.9	5.0	0.5
Yield strength (MPa)	1978	2130	2172	1634
Force exerted (N)	84	45	40	70

Springs with dimension and made of material as listed in Table 2 was modelled in the SOLIDWORK (Fig. 1). For the firing spring of weapon Z, the analysis was extended to include the effect of oil tempered MB A229, stainless steel AISI 304, music wire ASTM A 226 and hard drawn ASTM A227 as spring‘s materials on the reliability of the spring. The axial force applied on the spring is presented in Table 2, according to operating condition of each weapon. Then, the spring model was meshed using curvature meshing (Fig. 2). To ensure the size of mesh does not affect the results, we carried out several tests using different size and number of mesh until the changes in the obtained results were less than 0.01 %. Analysis on the stress profile within the spring was done as in Fig. 3.

3. RESULTS AND DISCUSSION

This section presents the mechanical properties of springs for weapon X, Y and Z. Then, prediction on the reliability of the spring based on Von Mises stress is presented. For the weapon Z, results on the effect of material on the spring's reliability are presented. Table 3 shows the maximum load that can be exerted to the springs in the weapons X, Y and Z. The spring constant for weapon Z is the highest. A higher magnitude of force is required to compress this spring. The spring of weapon Y has the highest maximum shear stress. This may be due to its geometry that leads to a higher stress concentration factor in the spring.

Vons Mises stress indicates the percentage of potential failure for a spring. The spring will fail if the maximum value of Von Mises stress within the spring is greater than the tensile or yield strength of the material. Table 4 shows the result of von Mises stress for each type of the spring. It can be seen that the spring in weapon Y has the highest potential for failure, which is 59 %. The open-end type may be the reason on this high potential of failure.

Table 4 shows the value of maximum and minimum strain for the springs in weapons X, Y and Z. The recoil spring in weapon Z has the highest value of minimum and maximum strain, while the bolt spring in weapon Y has the lowest maximum and minimum strain. This may be due to the difference in number of active coil and the free length of the spring.

Table 3. Properties of the springs

Type of Spring	Action Spring X	Bolt Spring Y	Recoil Spring Z	Firing Spring Z
Spring constant, K (kN/m)	0.23	0.09	5.1	4.1
Maximum force, F_{max} (N)	84	42.3	37	68
Shear modulus, G (GPa)	76	79	76	79

Maximum shear stress, (MPa)	795.8	1685	1460	785
Safe travel, x (mm)	121.3	44.5	65	0.32

Table 4. Result of Von Mises stress in simulation

Type of Springs	Maximum Von Mises Stress, (MPa)	Yield Strength of the Materials Used (MPa)	Percentage of Potential Failure of the Spring (%)
Action spring for X	2905	1978	32
Bolt spring for Y	5162	2130	59
Recoil spring for Z	2286	2172	5
Firing pin for Z1	2351	1634	33

Table 5. Strain within the springs

Type of Materials	Minimum Value of Normal Strain	Maximum Value of Normal Strain
Action spring X	1.293×10^{-6}	0.0861
Bolt spring for Y	0.00735×10^{-6}	0.283×10^{-3}
Recoil spring Z	3.378×10^{-6}	0.273
Firing pin spring Z	2.646×10^{-6}	0.175

The firing spring of weapon Z was chosen for this simulation. As in Table 6, stainless steel AISI 304 has the lowest percentage of potential to fail. This is due to the lowest Von Mises stress within the spring, compared to springs that made of other materials. Another possible explanation is the stainless steel AISI 304 has the highest yield strength amongst these materials. Music wire ASTM A226 has the highest potential to fail with the predicted value of 38 %, almost 5 times of the value for stainless steel AISI 304.

Table 6. Effect of materials on the potential of failure for the firing spring of weapon Z

Type of Materials	Value of Von Mises Stress, (MPa)	Yield Strength of the Materials, (MPa)	Percentage of Potential for Failure (%)
Music wire ASTM A228	3497	2172	38
Steel AISI 304	2446	2240	8.5
Hard drawn ASTM A227	4609	1790	61
Oil tempered ASTM A229	4635	1785	62

The reliability of springs for small arms that were studied in this paper shows that the stress concentration factor is responsible for a higher sheer stress within a spring. It is beneficial for a spring to be designed with a low stress concentration factor. This will provide an opportunity in using material with lower yield stress, which is usually available at a lower cost. Furthermore, a lower stress in the spring may reduce the reliability of these springs.

The firing spring of weapon Z that is made of stainless steel AISI 304 has the lowest potential of failure compared to other materials that were simulated in this work. However, the cost of stainless steel may be one of the factors that will influence the decision to use this material in spring fabrication.

Future work has to deal with the testing of these springs in its operating conditions. These tests are essential since the friction between spring, and it enclosure was not included in the current work. Any changes in wire dimensions due to abrasion may influence the risk of spring failure. However, this prediction is only possible if the actual experiment has been conducted.A degradation in spring constant may exist after a spring undergone a certain number of compression cycles [13]. A lower spring constant may affect the performance of an arm since the exerted force by the spring is not according to their design. A method to test the spring constant under various number of compression cycle would be very useful to ensure an arm is working as intended. Furthermore, this parameter may assist in determination of period of service before the spring needs to be replaced.

4. CONCLUSION

Each weapon requires a specific dimension of spring to ensure its optimum performance and reliability. In this work, springs of three types of small arms namely weapon X, weapon Y and weapon Z were studied in terms of its reliability. According the simulation results, percentage of potential failure of the spring was varied between 5 % and 59 %. A further investigation on the alternative materials on the firing spring of weapon Z indicates that stainless steel AISI 304 has the lowest potential of failure. However, the cost of stainless steel may be the drawback for its applications in the small arm technology. It is essential to carry out testing on the spring reliability under its operating conditions, particularly due to possible wear on the spring that may reduce its reliability.

5. ACKNOWLEDGEMENTS

We would like to thank UniversitiPertahananNasional Malaysia for the financial support through conference grant scheme.

6. REFERENCES

[1] United States Government. General and complete disarmament: Small arms. Washington DC: United States Government, 2000

[2] Christine C. Rings and springs. Assembly Automation, 2008, 28(4):295-300

[3] Ranjan B. Mechanical engineering version 2. New Delhi: India Institute of Technology, 2012

[4] Richard G. B.,Nisbett J. K.Shigley'smechanical design. New Delhi:Tata McGraw-Hill Education, 2011

[5] Dave S. How to make spring. 2007, http://educypedia.karadimov.info/library/springs.pdf

[6] Long-He X, Xiao-Wei F, Zhong-Xian L. Development and experimental verification of a pre-pressed spring self-centering energy dissipation brace. Engineering Structures, 2016, 27:49-61

[7] Sanjukta C, Koushik R, Samit RC. Design of re-centering spring for flat sliding base isolation system: Theory and a numerical study. Engineering Structures, 2016, 126:66-77

[8] Guebum H, Hyo-Sok A. Calibration of effective spring constants of colloidal probes using reference cantilever method. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2016, 489:86-94

[9] Wilson S. A guide to recoil spring. 2014

[10] United States Army. U.S marine corps technical manual for M16A2 and M4.Washington DC:United Stated Government, 1984

[11] Pyttel B. Fatigue behaviour of helical compression spring at a very high number of cycles- Investigation of various influences. International Journal of Fatigue, 2013, 60:101-109

[12] Richard M C. Defining yield stress and failure stress.Acta Mechanical, 2011, 196:239-244

[13] Kong Y S, Omar M Z, Chua L B, Abdullah S. Fatigue life prediction of parabolic leaf spring under various road conditions. Engineering Failure Analysis, 2014, 46:92-103

How to cite this article:
Abidin R, Ahamat M A, Arif A, Ahmad T, Murad M. Investigation on spring characteristics for small arms. J. Fundam. Appl. Sci., 2017, 9*(3S), 349-359.*