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INFLUENCE OF DEFECTS ON FATIGUE LIFE OF HELICAL COIL SPRING

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Abstract
A mechanical spring is defined as an elastic body whose primary function is to deflect or distort under load and which recovers its original shape when released after being distorted. Due to frequent failure of helical coil springs in various applications, analysis of fatigue life of the spring is required. In this study, Optical microscopy is performed to reveal the basic microstructure of the fractured surface and possible inclusions are also distinguished. Scanning electron microscopy (SEM) is used to characterize fine microstructure of the fractured surface and to reveal flaws that serve as crack initiation points. SEM images were taken of the defected spring and then sizes of defects were calculated from the images. These defects will be implemented in the cad model of helical coil spring and then fatigue analysis will be done to determine effect on fatigue life because of defects in helical coil springs.

Introduction
A mechanical spring is defined as an elastic body whose primary function is to deflect or distort under load and which recovers its original shape when released after being distorted. Although most material bodies are elastic and will not distort under load, they are not called as springs. Springs are designed so as to deflect by a relatively large amount when loaded. Consequently the load and deflection can be easily determined.
Because spring must deflect by a considerable degree for a given load it follows that a relatively large amount of energy must be stored when the spring is in deflected position. Since both the deflection and load for most springs are proportional to stress and energy is proportional to deflection times load, it follows that energy stored in spring is proportional to the square of the stress.
The most widely used material for spring is carbon steel. But in corrosive environment stainless steel spring is used. To assure that a coil spring serves its design, fatigue analysis of defective coil springs is valuable both for the short and long term agenda of car manufacturer and parts suppliers.

Major imperfections in coil manufacturing:
Raw material selection is always the most important decision in obtaining the best quality of any product including coil springs. The selection of the raw material usually includes the enforcement of cleanliness, microstructure, and decarburization inspection. Fig. 1 shows a typical raw material defect in the form of an inclusion; also shown is a microstructure matrix defect and decarburization.

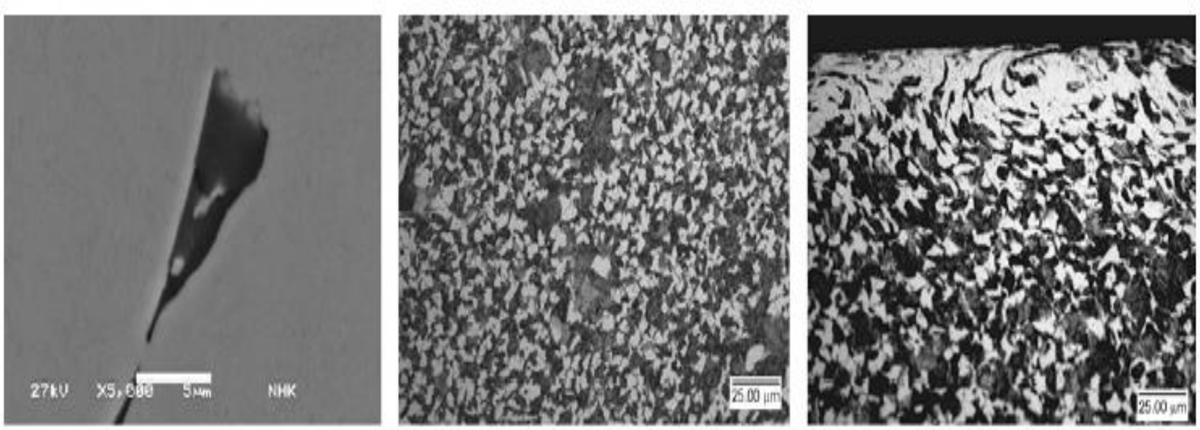


Fig 1 Defects in raw materials[1]

When manufacturing the coil after tempering the coil spring is shot peened. This process has two reasons, it cleans the surface of defects and scale caused by quenching, and introduces compressive residual stresses at the surface. After this setting is done, this does not cause defects in spring. Probably the next and last step is coating. Usually zinc is used as an ingredient in coating. Zinc works as an anode in protecting steel. The figure 2 above shows the effect of good coating on spring.

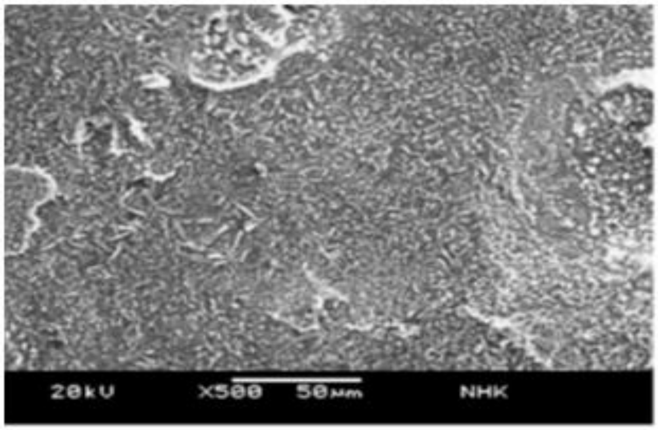


Fig 2 Results of good coating on coil spring[1]

Failure Analysis

The following defects were found in the springs which caused failure and the defects were analysed by Scanning Electron Microscopy done on the failed springs. The defects are listed below. After that fatigue analysis is done to study the influence of these defects.

1. Inclusion defect

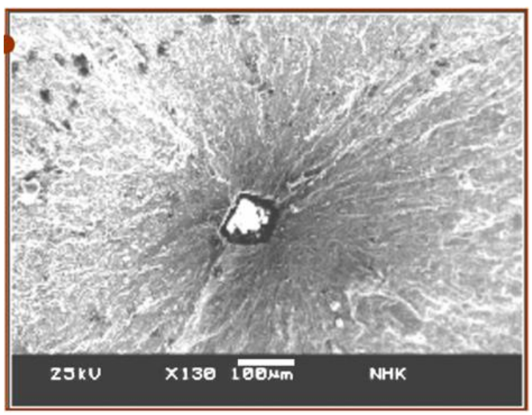


Fig 3 SEM image of inclusion[1]

2. Surface imperfection

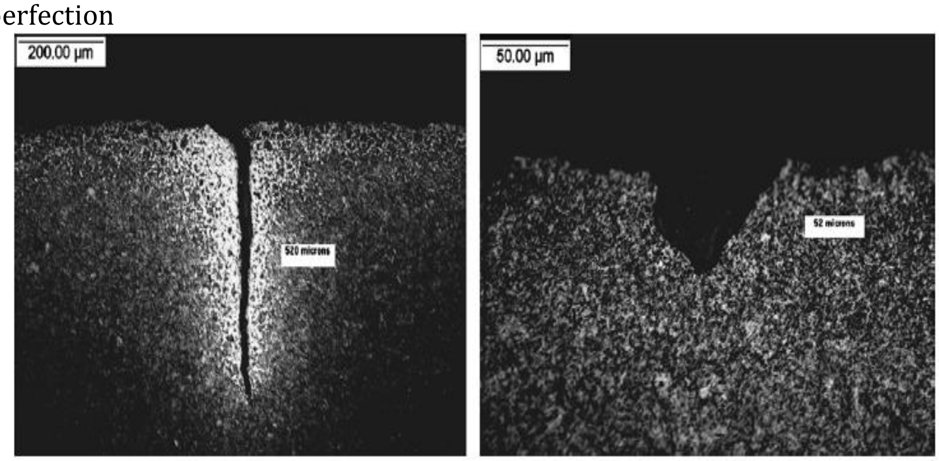


Fig 4 Surface imperfections in spring[1]

3. Corrosion

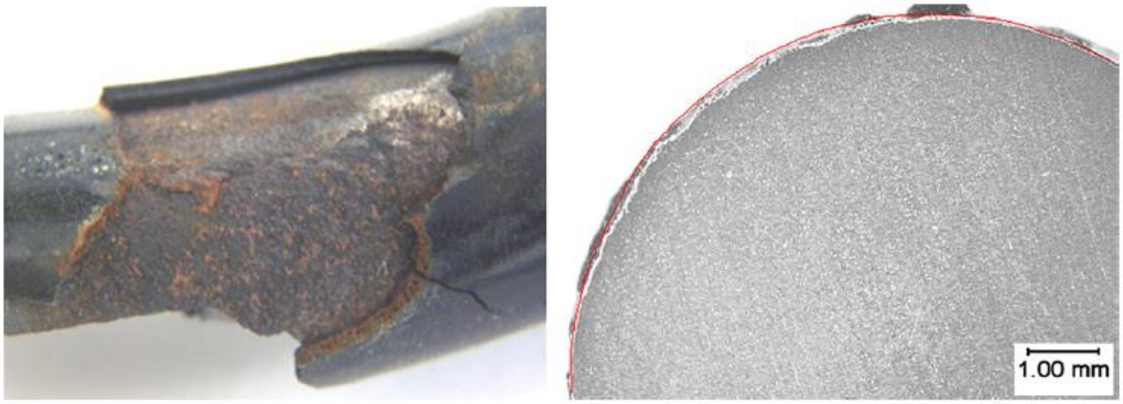
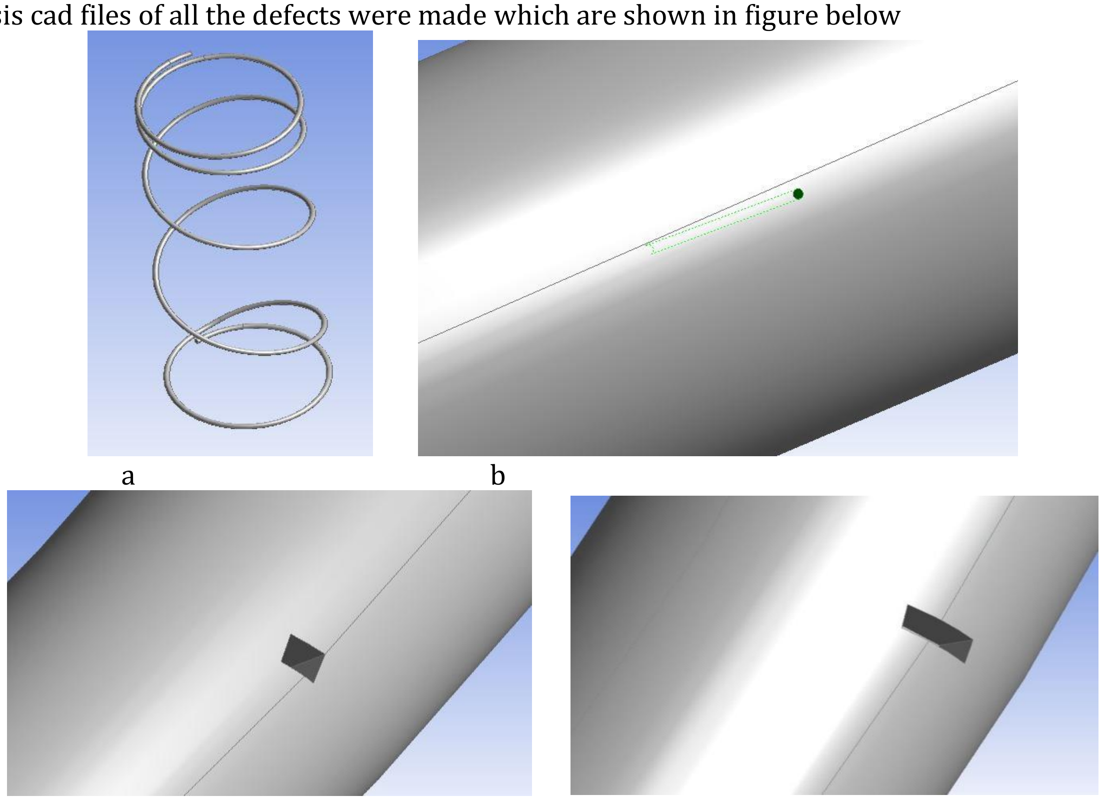


Fig 5 Coil spring which broke due to corrosion[1]

Analysis

Fatigue analysis is performed to study the influence of various defects on the fatigue life of helical coil spring. In this analysis alternating stress, fatigue life, Damage and safety factors were calculated. Where the Fatigue damage is defined as the design life divided by the available life. If the fatigue damage value is greater than 1 then it indicates failure before the design life is reached. Fatigue factor of safety is the contour plot of the factor of safety with respect to a fatigue failure at given design life. Analysis of each defect is done separately. For this cad models of the defects were made and then they were imported in the analysis software. The analysis software used is ANSYS.

Before analysis cad files of all the defects were made which are shown in figure below



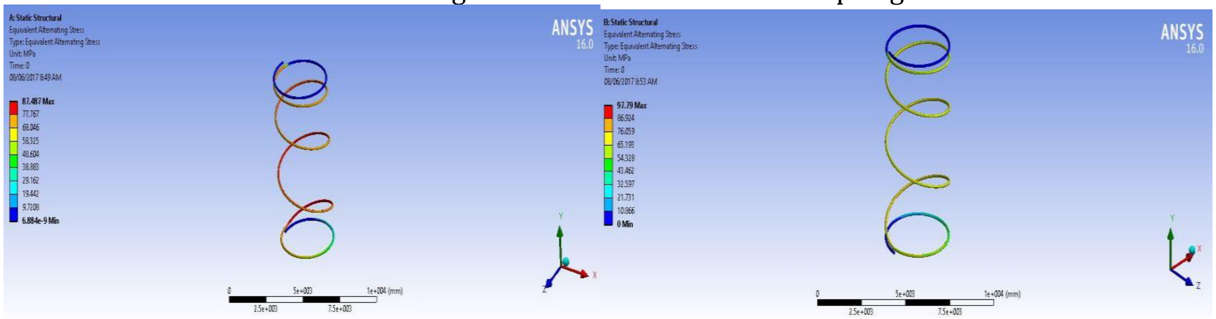
a b c d

Fig 6 Cad files all defects as listed below

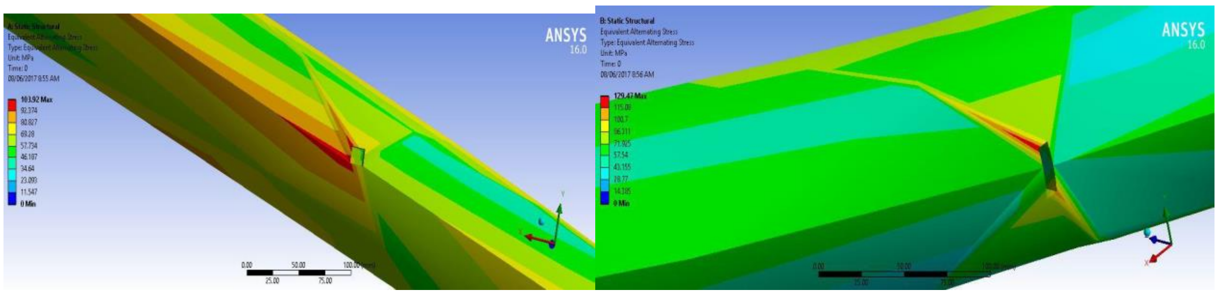
a) Non defective
b) Inclusion
c) Surface imperfection
d) Corrosion

Results and discussion

The fig below shows the results on alternating stress for various models of spring as mentioned above.



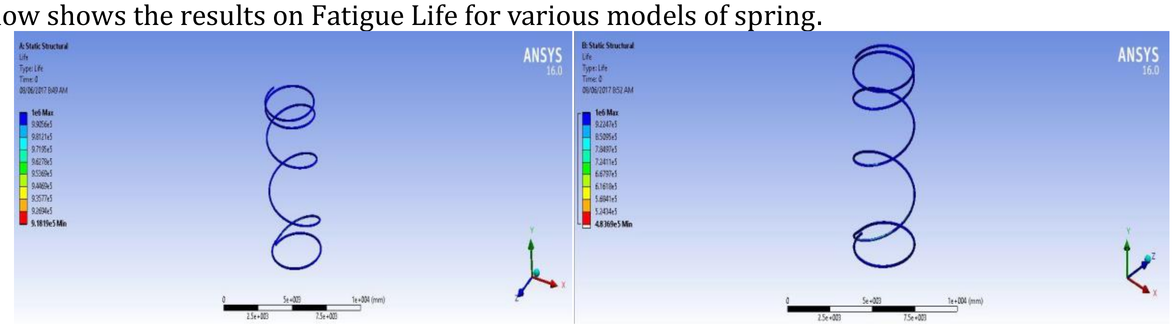
a b



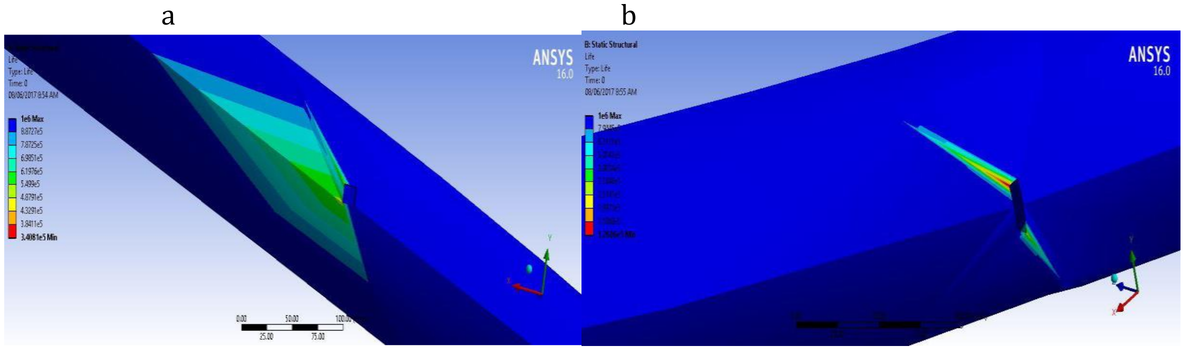
c d

Fig 7 Alternating stress of spring for a, b, c and d model.

The fig below shows the results on Fatigue Life for various models of spring.



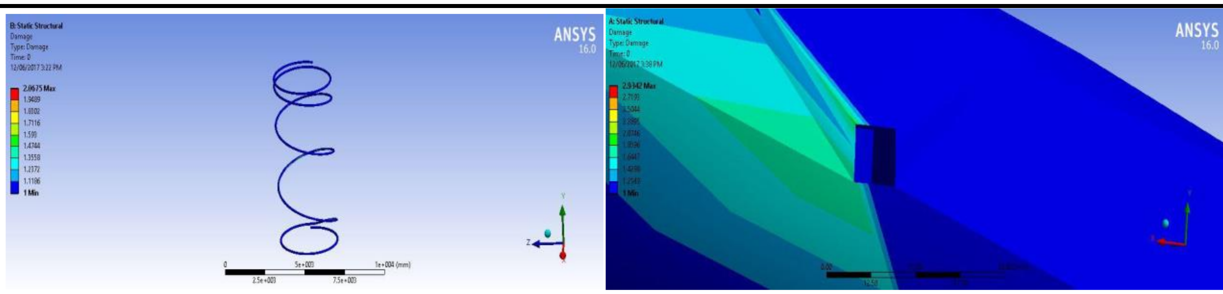
a b



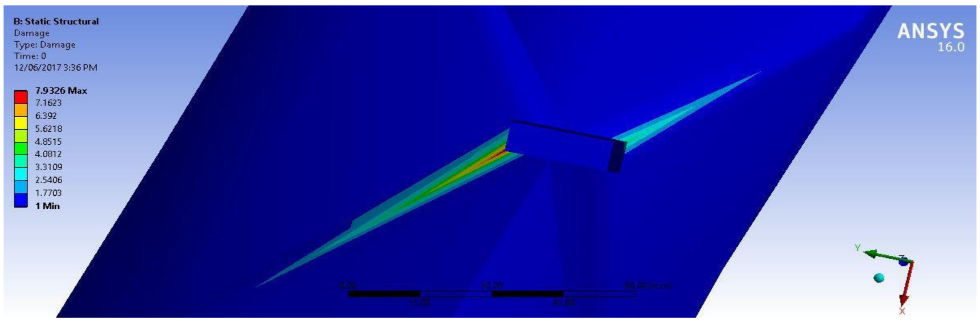
c d

Fig 8 Fatigue Life of spring for a, b, c and d model.

The fig below shows the results on Damage of spring for various defective models of spring.



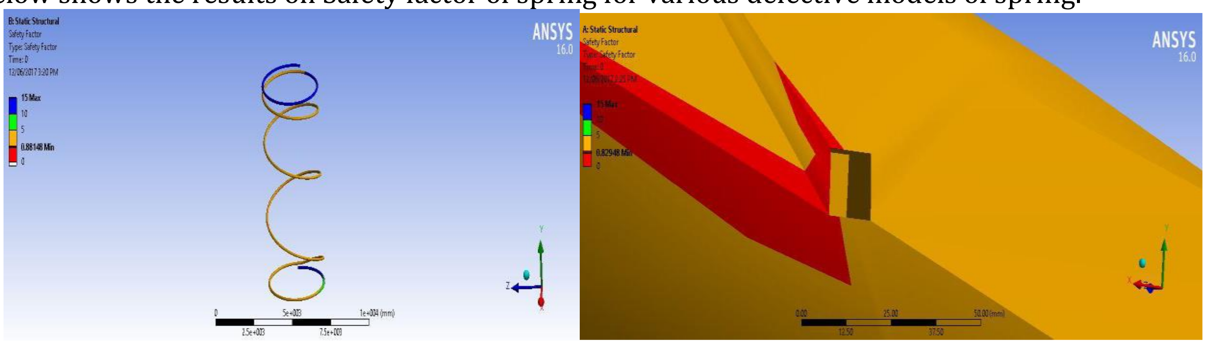
b c



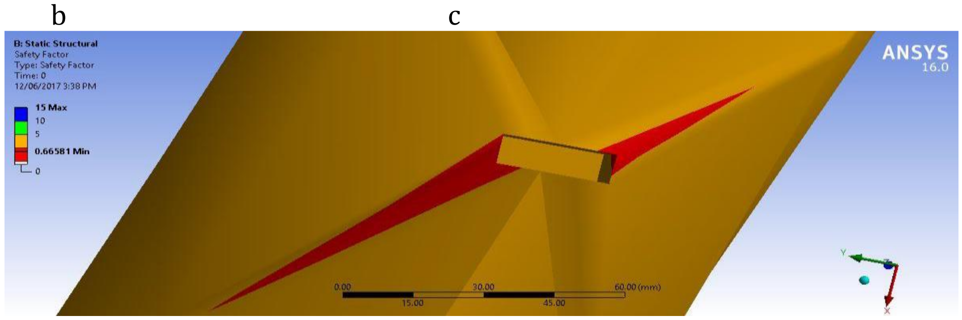
d

Fig 9 Damage of spring for b, c and d model.

The fig below shows the results on Safety factor of spring for various defective models of spring.



b c



d

Fig 10 Damage of spring for b, c and d model.

Table 1 FEA results.

Sr. No.	Parameters	Alternating Stress (MPa)	Fatigue Life	Damage	Safety factor
1	Non-defective	87.487	$9.18*10^5$	-	-
2	Inclusion	97.49	$4.83*10^5$	2.06	0.8814
3	Surface defect	103.92	$3.4*10^5$	2.93	0.823
4	Corrosion	129.47	$1.2*10^5$	7.92	0.665

From the above result table it can be seen that the damage value for every defect is greater than 1 which indicates the failure of spring before the design life. Also it can be observed that the safety factor is below 1 which shows that the spring will fail before the design life. The fatigue life results show that the fatigue life of spring decreases by 8.5% and the fatigue life of spring with surface defect decreases by 8.8% whereas the fatigue life because of corrosion is decreased by 9.5%.

Conclusion

In this paper, influence of various defects like inclusion, surface defect and corrosion on fatigue life of helical coil spring was studied. A three-dimensional (3D) FEM model was developed to study the stress concentration around the inclusion that appears under design loads. It is observed that, there is high stress concentration at the point of defects which leads to fatigue crack generation. Fatigue analysis of non-defective helical coil spring was done and alternating stress and fatigue life was calculated. Similarly fatigue analysis of helical coil spring with defects was done and compared with non-defective. It was observed that there was considerable reduction in fatigue life due to the defects.

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