International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
March-2018 Volume 5, Issue-2
Email: editor@ijermt.org www.ijermt.org

DEVELOPMENT OF A FRAME WORK FOR PREMATURE FAILURE ANALYSIS OF SUSPENSION SYSTEM UNDER POOR OPERATING CONDITION

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ABSTRACT:
This paper presents the frame work for premature failure analysis of suspension system under poor operative condition. Prediction of premature failure of suspension system is very vital for commercial success of any passenger vehicle. Deflection capacity under dynamic condition plays important role in the life of any suspension system. All the suspension system are now a days designed very satisfactorily. However still premature failure of suspension system of vehicle has been observed. Poor operative service may be a major reason of this failure. In this paper a paper a, a frame work in the form of survey has been presented using which one may find the reason behind the pre mature failure of a suspension of a Vehicle. This survey sheet indicates the operating condition responsible for pre mature failure of the suspension system. Case study is also presented in this paper.
KEYWORDS: Suspension system, premature failure, poor operating condition, survey sheet

INTRODUCTION

Suspension system of vehicle is very important component which are responsible for proper handling of vehicle, isolation of passenger curb from road shock to provide comfort. A good suspension system is obtained with the help of two components: spring and damper. Spring is used as a shock absorber at restricted label and damper is provided to dissipate this shock energy smoothly. Although various types of suspension system are used in modern vehicles but active suspension system is mostly used in passenger cars.

Investigation of dynamic behavior and failure analysis of suspension system had attracted many researchers and a lot of literatures are available in various journals. Few significant contributions related with the present work are presented here. James M. Meagher ,et al [3] have presented theoretical model for predicting stress from bending agreed with the stiffness and finite element model within the precision of convergence for the finite element analysis. Wei Li ,et al [10] analyzed very high cycle fatigue (VHCF) properties of newly developed clean spring steel under rotating bending and axial loading. B. Pyttel ,et al , [2**]** conducted the long-term fatigue tests on shot peened helical compression springs at 40 Hz. Test springs were made of three different spring materials – oil hardened and tempered Si, Cr and Si, Cr, V-alloyed valve spring steel and stainless steel. The appropriate equations determining the effectiveness of dynamic stress reduction in resonant conditions as a function of coating parameters were derived. A. González Rodríguez, et al,[1] have proposed an adjustable-stiffness actuator composed of two antagonistic non-linear springs .The elastic device consists of two pairs of leaf springs working in bending conditions under large displacements. Rastogi, V., et al, [9] developed a model of suspension system with use of quarter/ half/ full car model In this paper ,dynamic behavior of suspension system with help of bond graph technique is studied. After going through extensive literature review, it has been observed that few significant work is available based on survey.

FRAME WORK FOR ANALYSIS

Fig. 1 is flow chart which shows the step by step procedure to perform the premature failure analysis. One may start analysis from doing the design of suspension system. In most of the case design are safe. So it may be a last step also. It has been observed that in many cases it has been observed that poor design or manufacturing defects are not behind the premature failure analysis. So premature failure may

be attributed to the poor operating condition. To confirm it a survey sheet has been developed which will be useful in such condition.

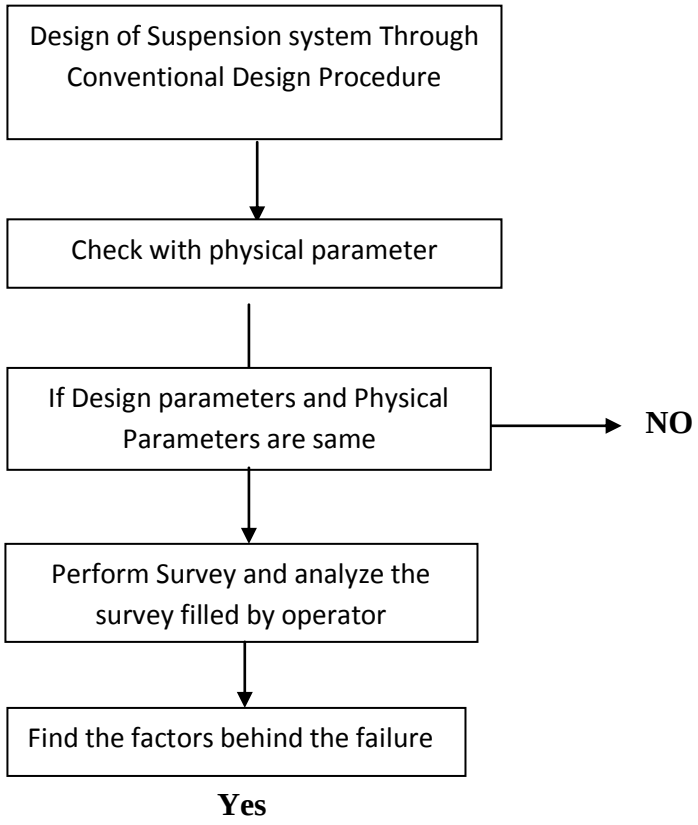

FIGURE: 1 FLOW CHART OF SUSPENSION SYSTEM FAILURE ANALYSIS

CASE STUDY:

For the failure analysis purpose specimens are procured from service centers of Tata Motors situated at different locations. Three specimen are shown in Fig. 2.

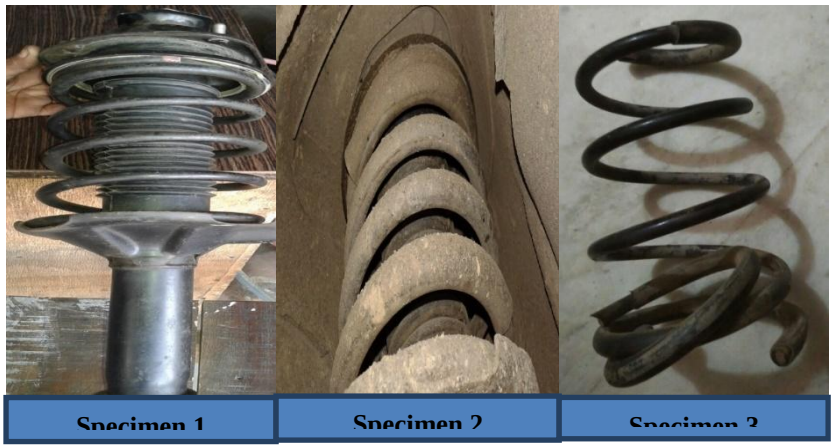

Figure2: Specimens of Coil Spring

DESIGN ANALYSIS

Analysis begins with the design of spring of the suspension system. For that parameters of TATA Indica car has been taken and presented below

The different parameter of vehicle was obtained from physical model of Tata Indica eV2
Length: 3690mm
Width: 1665mm
Height: 1485mm
Displacement: 1396cc
Max Power:69bhp@4000RPM
Max Torque:140Nm@1800RPM
NO. OF Cylinder:4
Wheel Base: 2400mm
Kerb Weight: 1080 Kg
Seating Capacity: 5
Gross Weight = Kerb Weight + Passenger weight + Luggage weight
WG = 1080 + (5*70) + (5*10)
WG = 1480 Kg
From standard
The ratio of weight distribution is F/R: 49/51
Weight acting on each front wheel
W = (0.49* WG)/2
= (0.49* 1480)/2
W = 362.6 Kg
So, the reaction force acting on wheel,
P = W*g
= 362.6*9.81
P = 3557 N (Approx.)

PHYSICAL PARAMETERS:

We measured and determined the physical parameters of spring presented in table

Table 1: PHYSICAL PARAMETERS

Solid length L_s	87.5mm
Wire diameter of the spring	12.5mm
Outer diameter	137mm
Total no of coil	7
Active no of coil	5
Rigidity	G=80N/mm^2
Spring index, C	9.96
Shear stress factor K_s	1.050
The torsional shear stress, τ_1	577.67
Direct shear stress, τ_2	28.99
Result and shear stress, τ	606.66 and548.66
Stress factor, K	1.145
Maximum shear stress induced in wire τ,	661.43N/mm^2
Deflection of the spring, δ	140.57mm
Free length of the wire, L_F	249.15
Spring rate or stifness, K	25.30
Pitch	41.525

Results obtained by design and physical measurements/ Experiment of specimen are presented in the table 2.

TABLE 2: DESIGN VALUES AND PHYSICAL VALUES

Design Parameter	Design Value*	Physical Parameter		
		Specimen 1	Specimen 2 (a)	Specimen 3 (b)
Wire Diameter (in mm)	12.5	13.4	13.4	13.4
Outer Diameter (in mm)	137	142	147	147
Inner Diameter (in mm)	112	114	120.2	120.2
Mean Diameter (in mm)	124.5	128	133.6	133.6
Solid Length (in mm)	87.5	93.8	94.2	94.2
Spring Index	9.96	9.55	10.03	10.03
Free Length (in mm)	249.15	265	273	295
Pitch (in mm)	41.525	44	54.6	59
Number of Coil	7	7	7	7

By observing the data presented in the table.2 it appears that all three specimens are as per design. So, the poor design of suspension spring is not the reason behind premature failure of these springs.

METALLURGICAL INVESTIGATION

This section presents the metallurgical analysis of fracture helical coil spring. Chemical, visual inspection and SEM analysis has been performed. This analysis investigates the cause of failure due to corrosion effect on the spring material or any material defects involved..

FATIGUE ANALYSIS

Suspension coil spring is manufactured through cold drawing process which required ductility. In the figure two images are shown; first capture by SEM and second real image. In the figure, fracture in part is developed due to localized stress. Change in the geometry of spring in operating conditions, Due to this geometry change and localized stress introduces stress concentration at a point on second coil or first active coil from kurb in suspension spring. Due to higher stress at a point in spring under dynamic loading condition, crack formation initiated and growth of crack takes place. Consequently, after some time, failure of coil spring takes place.

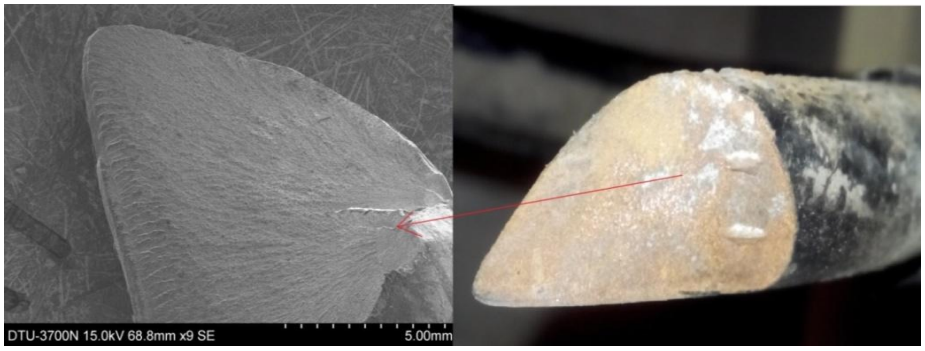

Figure3: Broken Coil Spring

SCANNING ELECTRON MICROSCOPIC ANALYSIS

The fracture part of helical spring is investigating through SEM analysis Spectro max for SEM analysis where at from fracture helical spring and polished using standard metallographic technique and etched with gyceria (30 ml dilute solution of HCl, 15ml HNO_3 and 45ml glycerol). SEM evaluation was come out on the fracture surface of coil spring the failed spring was cut from for SEM study its fracture reason.

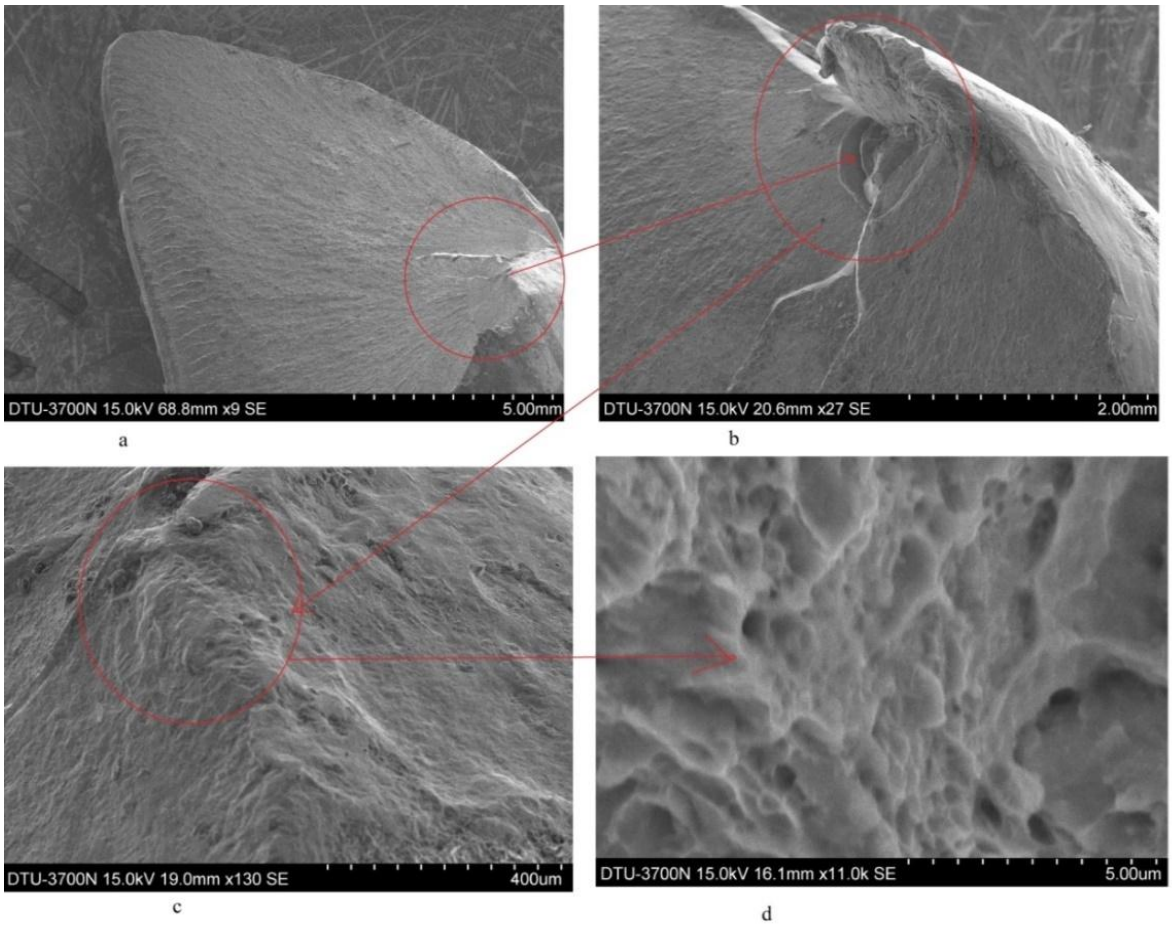

FIGURE 4: SURFACE IMPERFECTIONS IN COIL SPRING

The figure 8 shows surface imperfection in suspension coil spring, in the figure 'a' 5mm optical zoom the surface of fracture area was not proper some cold particle is presented this fracture reason, in figure 'b' increased zoom to show the better fracture condition to shows fracture area the crack recognized slowly and after some time suddenly break due to holes find out in the figure 'c' shows easily as well as in figure 'd' shows. So, the surface imperfections can produce to some hardness in material to make crack, tool marks, surface impurities due to the raw material, scale embedded of base material during cold drawing. Two different surface defect holes sufficient to cause fails coil spring in figure 15 (c) and the second figure 15 (d) surface defects are inherited in the raw material.
So specimen-1&2 failed due to defects in materials. For analysis did not revealed the reason of failure of third specimen.

SURVEY ANALYSIS

To find the cause of premature failure of third specimen a survey based on operating condition was required because coils were ok from design, manufacturing and materials point of view. So poor operating condition may be the one reason for the premature failure analysis.

Premature failure of suspension system has been observed even when the material without any defects or surface imperfection is used, the suspension system fails during operation without completing its intended life. This may be due to the poor operative condition which may be over loading or poor road condition or both. To identify the road of the poor operative condition, the suspension system survey may be employed. Sample survey form is available online. One may send the link of this form

(https://docs.google.com/forms/d/1UhG0bSV3r8m3rN5VHmI2Z7lm2vhJ3KCKQT_sMY1Ti6E/viewform?c=0&w=1). The user of the vehicle will fill this form which will be further analyzed by the

engineer to conform that the poor operating condition(s) are behind the premature failure of the suspension system.

RESULT AND DISCUSSION

Drivers of respective cars filled the survey sheets with the link given in section 4. After the analysis of data it has been concluded that driver of car of third suspension system used it as passenger car. Which was always over loaded and the area where it was used was prone to poor road condition.

TABLE-3: SUMMARY OF SURVEY SHEET

Parametrs	Speciman1	Speciman1	Speciman1
Avg. No. of Pass	5	5	7
Avg. Load (kg)	450	500	700
AVG Speed	40	35	45
Area	urban	Semi Urban	Semi Urban

In the presented framework study, it is observed that the design of all spring (test specimen) is ok. These specimens are not failure due to poor design. It is observed that specimen 3 failed due to poor operating conditions. This spring was not physically damaged but lost its dynamic behavior. The specimen 3 was completely broken into two separate parts due to poor operating condition as per information provided by rider in survey sheet. The vehicle drives on poor road condition at higher speed and may be failed due to the metallurgical impurities such as inclusion, surface imperfection, and poor maintenance.

CONCLUSION

In this work framework has been developed to find out the reason behind the premature failure of suspension system. Using this framework one may find the possible reason of the premature failure of a suspension system. The failure of most of the spring is due to poor operative condition and the surrey sheet presented in this paper will help the engineers to find the reason behind the premature failure. They may also suggest the user to take preventive action to avoid the premature failure analysis.

The third spring has been broken even if the design as per requirement. The analysis reveals that the spring was under poor operating conditions. At the same time surface imperfection, has been observed through the metallurgical analysis. Which is the prime reason behind the stress concentration at the broken section.

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