Analysis Of Premature Failure of Suspension System Based On Metallurgical Aspects

Chandan Kumar

Professor , Department of Mechanical Engineering,

Noida Institute of Engineering and Technology, Greater Noida, U.P, (India)

ABSTRACT

This paper presents the frame work for premature failure analysis of suspension system. 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. In the present work, analysis has been presented based on metallurgical aspects. One may find the reason behind the pre mature failure of a suspension of a car using this method. This frame work includes design of suspension system, and Metallurgical considerations like metal composition, using SEM Technique. Material defects reduces the life of components and leads to catastrophic failure of suspension system. Case study is also presented in this paper.

Keywords: Suspension system, SEM, Metallurgical, Premature failure analysis.

I.INTRODUCTION

Suspension system of vehicle is a vital component which is 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. Very often it has been observed that suspension system fail to perform intended task before the expected life. Analysis of such failure is required so that preventive action may be taken to avoid the premature failure of suspension system.

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. Karnopp D.[4] presented analytical results for actively damped suspension under random excitation. Over the years, both passive and active suspension systems have been proposed to optimize the vehicle quality. 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. K. Michalczyk [6] have presented the analysis of elastomeric coating influence on dynamic resonant stresses values in spring. The appropriate equations determining the effectiveness of dynamic stress reduction in resonant conditions as a function of coating parameters were derived. A. 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, very few literature on failure analysis based on metallurgical analysis is found.

II.ANALYSIS OF PREMATURE FAILURE

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. In next step results may be compared with physical parameters for the analysis purpose. If there is no major deference in designed value and Than metallurgical analysis may be performed to find the imperfection in the material of suspension system. It has been observed that in may cases all above three parameters are not behind the premature failure analysis. So premature failure may be attributed to the defects in materials. To confirm it a SEM analysis has been performed and one may analysis in future following the procedure presented in this paper.

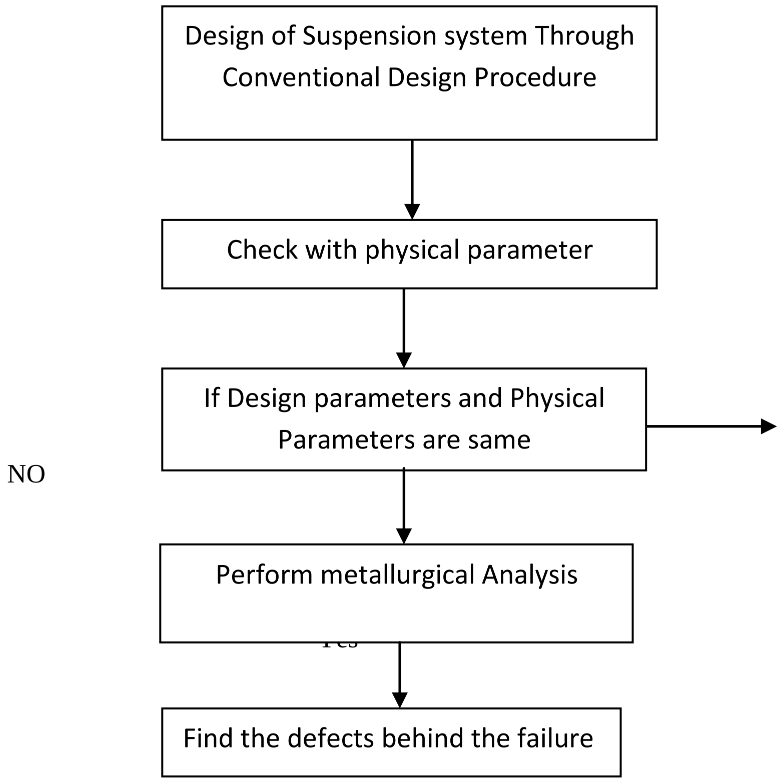

Figure:1 Flow chart of suspension system failure analysis

2.1. Case Study:

Specimen were procured from service centers of Tata Motors situated at different locations of country for Failure analysis purpose. Specimen are shown in Fig. 2.

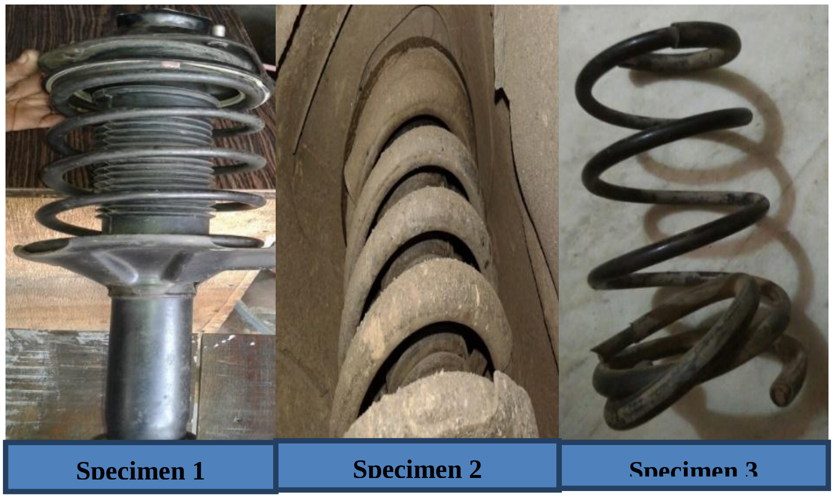

Figure 2: Specimens of Coil Spring

2.2 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

International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.04, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

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:

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.

3 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..

3.1 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.

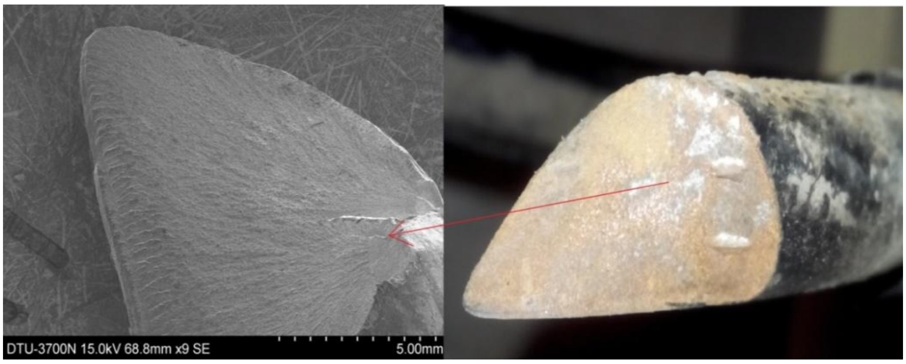

Figure 3: Broken Coil Spring

3.2 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.

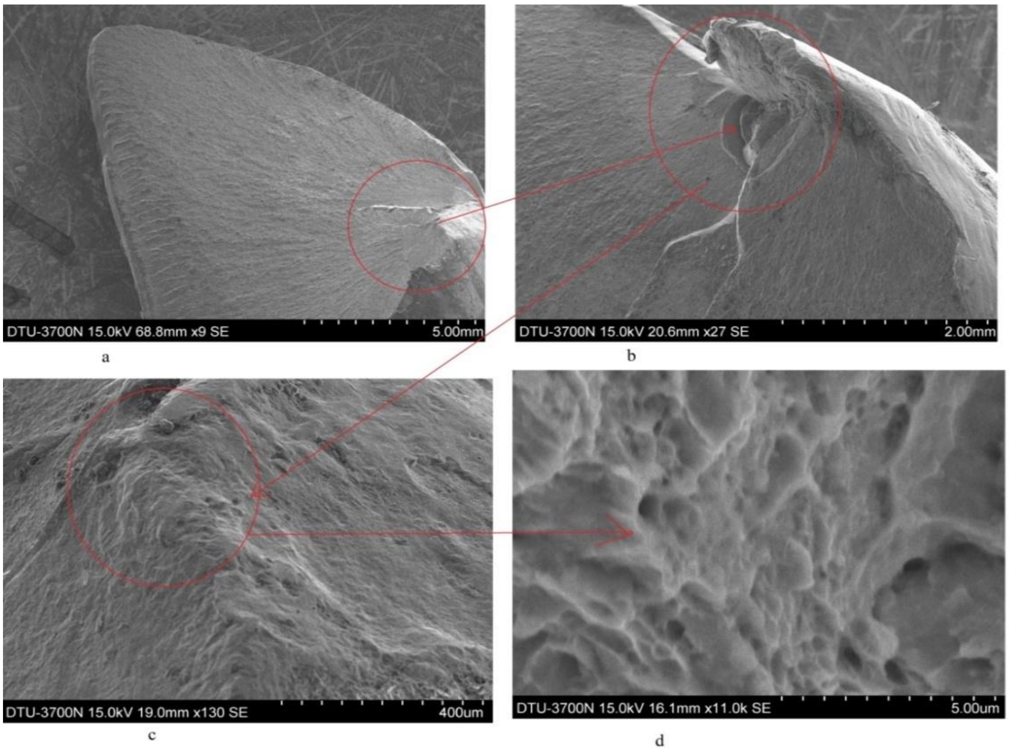

Figure: 4 Surface Imperfections in Coil Spring

The figure 4 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

IJARSE
ISSN: 2319-8354

'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 4 (c) and the second figure 4 (d) surface defects are inherited in the raw material. This type of fault can found when the surface defects diagnosis through the flaw detector does not worked normally. These types of imperfection in raw material occurred before manufacture of coil because this defect not due to coil manufacturing. If some pre-active impurities present in the surrounding occur decarburization in raw material during heating for manufacturing of coil. While a surface imperfection caused by coil manufacturing is often not accompanied by decarburization shows in the figure 4'd'.

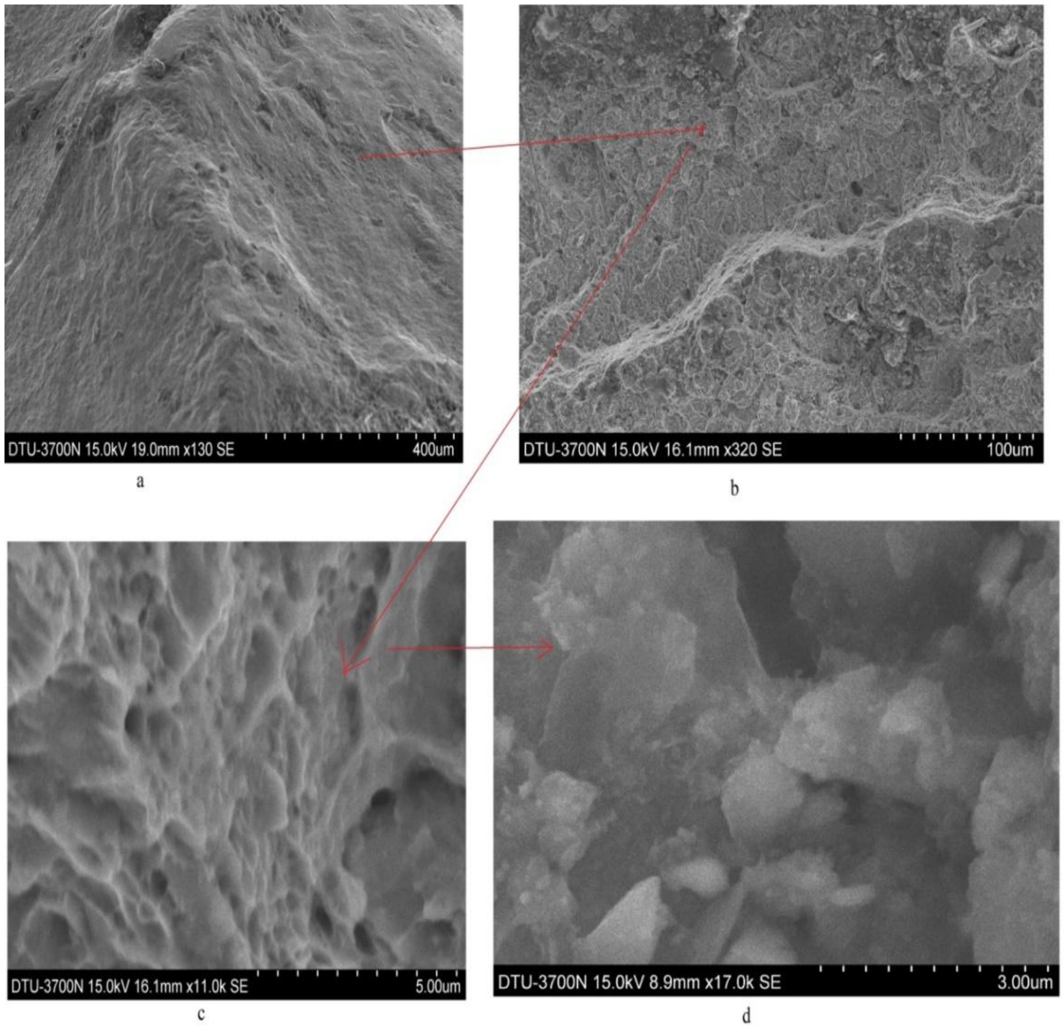

Figure: 5 Internal Defects in Coil Spring

Figure 5 shows internal crack in coil due to improper manufacturing process, In a figure 'a' small holes and crack is seen, so the more zoom in figure 'b' at 100um the coil structure have not similar over the all reason because material microstructure changed in dark reason due to phase change of material in improper heating process, this type of defect find improper heating process for example the material continuous heating properly can result prior austenite grain size increased significantly. Inappropriate heating treatment even result in microstructure to adopting pearalite in place of mrartensite, these types of defect can easily have recognized because the clear change in hardness. In figure 16 'a, c, d' shows small hole and crack of surface imperfection due to manufacturing or tempering process, the inter granular surface covered by an oxide due to trapped quench oil being heated in tempering furnace. These types of defect usually take place when heating system was not proper, the quenching crack and holes reduced the suspension coil spring life and causes premature failure.

Figure: 6 'a, b, c, d', shows the corrosion and decarburization in suspension coil spring due to poor maintenance and environment condition, in figure 'a' clearly shows more cold stone on coil they are as well as seen in figure 'b' and these cold stone easily shown in figure 'd' in darker in SEM image. These corrosive particles cause premature failure in suspension coil spring. However, the modern coating technology can prevent corrosion in coil spring and also improve service life of coil

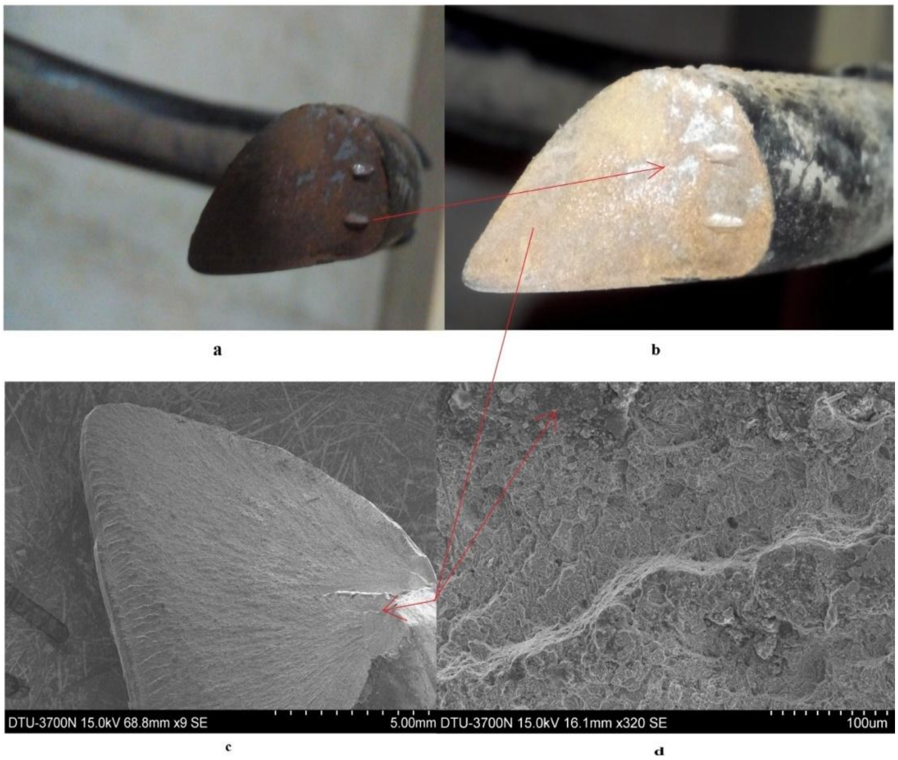

Figure 6 :Corrosion in Coil Spring

.

3.3 Chemical Composition

The chemical composition of helical coil spring material was determined by using optical emission analyzer spectrometer model DV4 and given a table. The chemical analysis shows that the material is in accordant with low alloy steel. However, ASTM E415-2008 method used to perform analysis.

Table 5: Material Composition Percentage of Suspension Spring

Material	Percentage in New Spring	Percentage in Fracture Spring
Iron (Fe)	96.74	96.64
Carbon (C)	0.514	0.524
Silicon (Si)	1.40	1.40
Manganese (Mg)	0.706	0.706
Sulfur (S)	0.006	0.006
Phosphorus (P)	0.023	0.023
Nickel (Ni)	0.009	0.009
Chromium (Cr)	0.594	0.594
Molybdenum (Mo)	0.002	0.002
Copper (Cu)	0.008	0.008

IV.RESULT AND DISCUSSION

In the presented framework study, it is observed that the design of all spring (test specimen) are ok. These coils did not failed due to poor design. Metallurgical analysis revealed that the specimen 3 was completely broken into two separate part due to the metallurgical impurities such as inclusion, surface imperfection, and poor maintenance. Chemical composition was also as per norms and requirements. Defect like corrosion present in specimen 3, and internal defects are the prime reason behind the premature failure of specimen 3.

V. 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 possible reasons are identified as poor design, physical parameters are not as per design, the physical property may be responsible and imperfection of the material used for manufacturing.

The case study reveals that all the spring is as per the design. The stiffness of the specimen has been decreased during the operation.. Metallurgical analysis has been performed. From metallurgical investigation, it was found that the internal crack, Inclusion are present. There defects lowered the stiffness of spring under fatigue loading.

The third spring has been broken even if the design as per requirement. The analysis reveals that the spring has surface imperfection, has been observed through the metallurgical analysis. Which is the prime reason behind the stress concentration at the broken section. One may apply he procedure presented in this paper for the analysis of premature failure of a suspension system.

REFERENCES

[1.] A.GonzálezRodríguez, J.M. Chacón, A. Donoso, A.G. González Rodríguezd, “Design of an adjustable-stiffness spring: Mathematical modeling and simulation, fabrication and

[2.] Experimental validation ” Mechanics and Machine theory, vol-46 No. 12 pp. 1970-1979, (Jul 2011).

[3.] 3.B. Pyttel , D. Schwerdt, C. Berger, “Very high cycle fatigue – Is there a fatigue limit”,International Journal of Fatigue, vol-33 No. 1 pp. 49-58 (January 2011).

[4.] James M. Meagher and Peter Altman, “Stresses from flexure in composite helical implantable leads”,Medical Engineering and Physics, vol. 19 No. 7 pp.668-673, S1350-4533(96) 00022-7, (September 1997).

[5.] Karnopp D.,“Analytical results for optimum actively damped suspension under random excitation”, Journalof VibrationAcoustic Stress and Reliability in Design, Vol. 111 No. 3 pp. 278-282, (01 July 1989).

[6.] Karnopp D.C., Margolis D.L., and Rosenberg R.C., “System dynamics, a unified approach”, 2nd edition, J Wiley New York, NY, ISBN 0-471-45940-2, (1990)

[7.] K. Michalczyk., “Analysis of the influence of elastomeric layer on helical spring stresses in longitudinal resonance vibration conditions”, Archives of civil and mechanical engineering, vol. 13 No.1 pp. 21-26, (March 2013).

[8.] MA.Rosenberg R.C., Karnopp D.C., “Introduction to physical system dynamics”, McGraw Hill, New York, NY (1983).

[9.] Paynter, H.M., “Analysis and design of engineering systems”, MIT Press, Cambridge, (1961).

[10.] TameshwerNath, VikasRastogi, “Quarter/Half/full car models for passive suspension (with pid controller)”, NCRAME national conference of recent advances in mechanical engineering , (2012).

[11.] Wei Li , Tatsuo Sakai, Masami Wakitac, Singo Mimura,"Influence of microstructure and surface defect on very high cycle fatigue properties of clean spring steel", International Journal of Fatigue, Vol. 60 pp. 48-56, (March 2013).

[12.] Yogesh Chaubey, Chandan Kumar, Sandeep Chauhan "Failure Analysis of Suspension System: Case Study-Tata Indica", IJSRD - International Journal for Scientific Research & Development, Vol. 3, No. 09 pp. 1085-1090 (2015).

[13.] A. Mukherjee. Junction structures of bondgraph theory from analytical mechanics viewpoint. in: Proceedings of CISS-1st Conference of International Simulation Societies, Zurich, Switzerland, 1994, 661–666.

[14.] A. Mukherjee, V. Rastogi, A. D. Gupta. A study of a bi-symmetric electro-mechanical system through umbra lagrangian generated by bond graphs and noether's theorem. Simulation, 2007, 83(9): 611–630.

[15.] A. Mukherjee, R. Karmakar. Modelling and Simulation of engineering System through Bond Graph. Narosa publishing House, New Delhi, 2000. Reprinted by CRC press for North America and by Alpha Science for Europe

[16.] A. Mukherjee, V. Rastogi, A. Gupta. A methodology for finding invariants of motion for asymmetric systems with gauge-transformed umbra lagrangian generated by bond graphs. Simulation, 2006, 82(4): 207–226.

[17.] Design Data book, PSG publication

[18.] Element of Machine design B.V Bhandari, TMH