International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Fatigue Life Prediction of Steel Leaf Spring for Light Passenger Vehicles Using Graphical Methodology.

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Abstract- Weight reduction has been the main primary focus of automobile manufacturer today. Leaf spring accounts for about 10-20 % of unsprung weight (the weight which is not transmitted to suspension system).

Since the experimentation process of fatigue life prediction of leaf spring is time consuming and heavy budget process, rarely available. So design engineer working in field of leaf spring always face challenges to formulate alternative method of fatigue life assessment. The present work in this paper provides weight reduction approach by reducing thickness of leaf spring and keeping all dimensions constant. Aim is to develop model showing effect of thickness on fatigue life and weight reduction using graphical method.

Keywords- Leaf spring, Fatigue life, graphical model, weight reduction, SUP 9

I. INTRODUCTION

A Reduced weight while increasing or maintaining strength of product is getting to be highly important research issue in this modern world. Weight reduction has been the main focus of auto industries in the present scenario. When it comes to R&D for automotive materials most effort goes into developing and using materials to make cars lighter. In spite of this, cars have considerably grown in weight over the last three decades because of increased safety requirements and comfort specifications. It is an enormous challenge to bend this curve and effectively reduce weight in order to meet future emission regulation. Studies indicate that 10% mass reduction relates to a 3% to 7% benefit in fuel consumption depending on the type of car and the drive cycle used. On average a weight reduction of 100kg delivers -10gr CO_2/km.

Weight reduction concept has been most important in automobile suspensions system such as leaf spring. Leaf spring is one of the important components of suspension system and it is widely used in automobiles. As we know that the weight of leaf spring is un-sprung weight of automobile. The elements whose weight is not transmitted to the suspension spring are called the unstrung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension leaf spring and shock absorbers.

Leaf spring contributes considerable amount of weight to the vehicle and need to be stronger enough. We will be focusing on reducing weight of leaf spring and increasing or maintaining the fatigue strength of Leaf spring for light commercial vehicle for Enhanced Mechanical properties to improve the performance over a life. The constant cross section design of leaf springs will be employed to take advantages of ease of design analysis and its manufacturing process.

The cost of materials constitutes nearly 60-70% 0f the vehicle's cost and contributes to the better quality and performance of the vehicle. Thus is becomes a potential unit to weight reduction. Weight reduction can be achieved by choosing better material and optimum design etc.

1.1 Design and Material of Leaf Spring:

The material used for leaf springs usually a plain carbon steel having 0.90 to 1.0% carbon. The leaf is heat treated after the forming process. The heat treatment of spring steel produces greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties [Khurmi Gupta. 2012]

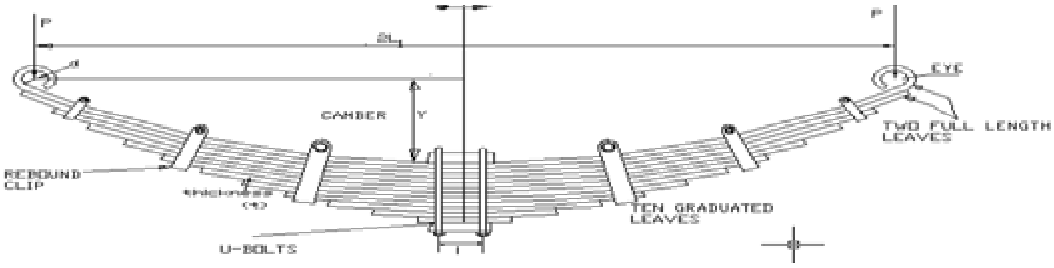

Fig 1: Leaf Spring

Table 1: Material Properties of Sup 9

Parameter	**Value**
Material selected – Steel	65Si7/ Sup9
Ultimate tensile strength,(Sut), MPa	1272
Yield tensile strength,(Sy), MPa	1081.2
Young's modulus E (N/mm2)	200124
BHN	380–432
Poisson's ratio, (μ)	0.266
Density,(ρ), kg/mm^3	0.00000785

Table 2: Design Parameters of the Leaf Springs

Parameter	**Value**
Full Length leaves	2
Graduated Leaves	6
Total Leaves (Full Leaves +Graduated Leaves)	8
Length (Span) Center To Center Distance	1270 mm
Camber	113 mm
Width	70 mm
Thickness	6 mm

Note: We have considered three extra set of leaf spring for case study which is having all parameters same only there is difference in their thickness.

Table 3: Thickness of the Leaf Springs

Sr. No	**Set of leaf spring**	**Thickness of leaves of spring**
1	First set	6 mm
2	Second set	8 mm
3	Third set	10 mm
4	Fourth set	12 mm

II. FATIGUE LIFE ESTIMATION BY GRAPHICAL METHOD.

Since experimentation fatigue life prediction of leaf spring is time consuming process. So we have adopted graphical method. This method involves application of Marin equation which involves size, surface, reliability temperature etc factors of particular design shape and material of leaf spring. Here we have adopted this method for material En 47 and then for SUP 9. Considering the design, material, processing parameters of leaf spring for SUP 9 showed in table (4) which is well explained by Shigley.

Table 4: Parameters of SUP 9 for Graphical Method

Parameters for graphical method.	**Leaf spring set thickness**			
	6mm	**8mm**	**10mm**	**12mm**
S_{ut}	1272	1272 Mpa	1272 Mpa	1272 Mpa
S_y	1081 Mpa	1081 Mpa	1081 Mpa	1081 Mpa
$s_e^{'} = 0.5S\ ut$	636 Mpa	636 Mpa	636 Mpa	636 Mpa
$\sigma_{\min}$ at 1g	218.28 Mpa	122.27 Mpa	78.56 Mpa	54.57 Mpa
$\sigma_{\min}$ at 0.3g	727.60 Mpa	409.27 Mpa	261.93 Mpa	181.90 Mpa
$S_a = (\sigma_{\max} - \sigma_{\min})/2$	254.66 Mpa	143.254 Mpa	91.67 Mpa	63.66 Mpa
$S_m = (\sigma_{\max} + \sigma_{\min})/2$	472.94 Mpa	266.025 Mpa	170.25 Mpa	118.235 Mpa
K_{load}	1	1	1	1
K_{surface}	1	1	1	1
$K_{\text{temp} \leq 450}$	1	1	1	1
$K_{\text{reliability}}$	0.81	0.81	0.81	0.81
K_{size}	0.814	0.807	0.79	0.791
S_e	423.48	417.78	413.12	409.50

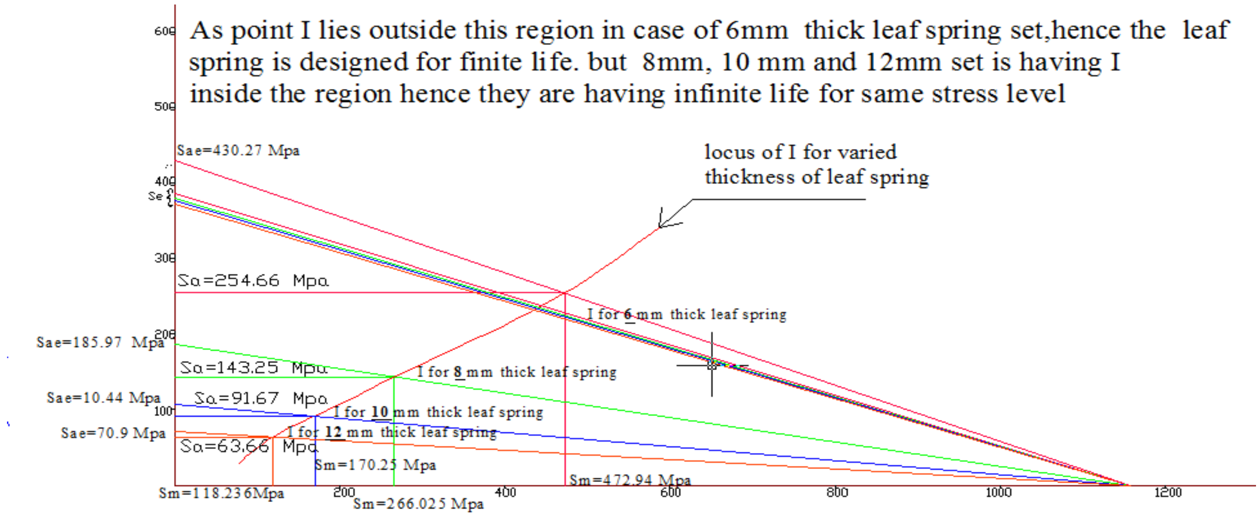

Fig 2: Alternating Stress versus Mean Stress Plot (EN 47)

Figure 2 shows an alternating stress verses mean stress plot for 6 mm, 8 mm, 10 mm and 12mm thick leaf spring set of EN 47 material. It is observed that the intersection of alternating and mean stress line of 6 mm thick leaf spring lies outside the region AC. As the point I of remaining leaf i.e. 8 mm, 10 mm and 12 mm lies within the line AC the component is designed for infinite life.

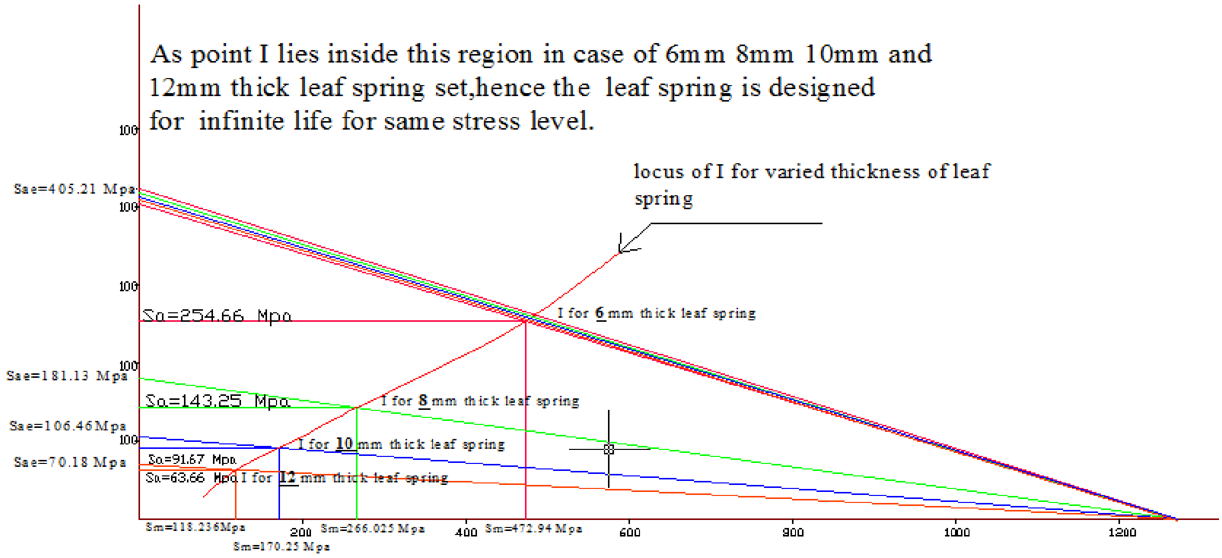

Fig 3: Alternating Stress versus Mean Stress Plot (Sup 9)

So it was challenging for us to reduce its weight and increase or maintain fatigue life. if we try to increase thickness of en 47 spring more than 6 mm. then its weight will have being increased due to which unprung weight of vehicle will be increased which undesirable. So we decided to take SUP 9 material instead of EN 47 material. Parameters of SUP 9 material required for graphical methods are showed in table 4.

Thus 6 mm thick leaf spring of EN 47 materials is designed for finite life so to increase its fatigue life we can adopt the 8 mm, thickness but while adopting increased thickness spring weight will be increased. Since this increase in weight will increase unsprung weight this is undesirable. so that we have adopted to change material from EN 47 to SUP 9 material.

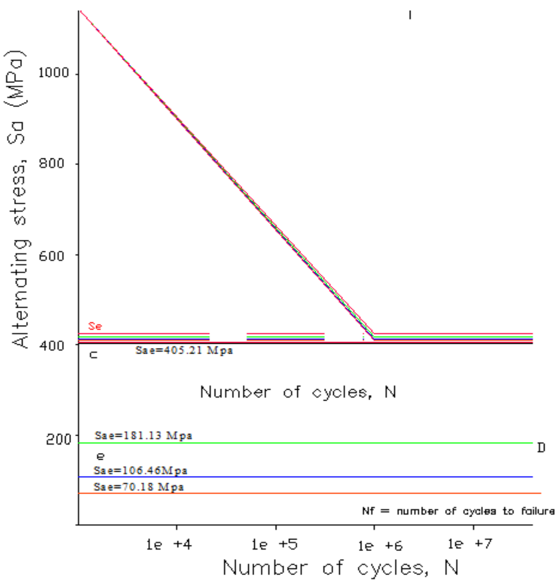

Fig 4: Alternating Stress versus Number of Cycles

By observing figure no 3 we can predict that by using SUP 9 material. We have increased the fatigue life of leaf spring set. Since the intersection of the alternating and mean stress line lies outside the region AC of 6mm thick leaf spring. For advanced leaf spring fatigue study we moved to Alternating stress vs. number of cycle graph of SUP 9 material. This provides valuable information to predict the fatigue life of SUP 9 material at different thickness (i.e. 6 mm, 8 mm, 10 mm, and 12 mm)

Point D represents the endurance limit that for various thickness of 65 SI 7. Line CB represents equivalent alternating stress. The intersection of alternating stress at point B will give the number of fatigue life. Since the line CB is below endurance limit it is having infinite life. Let consider calculation for 6 mm thick leaf spring set for SUP 9 material.

From Figure 4 *S-N* plot, it is observed that Δ *ABC* is similar to Δ*ADE.*

Hence, $AC/AE = CB/DE$

$AC = \log A - \log C = 0.4513,$

$AE = \log A - \log E = 0.4318,$

$DE = \log D - \log E = \log 10^6 - \log 10^3 = 3$

$$CB = \frac{0.451 \times 3}{0.431} = 3.139$$

Total $CB = 3 + 3.192 = 6.1392$

Number of cycles = $10^{6.139}$ = 1377209.469 cycles to failure.

Table 5: Fatigue life of leaf spring at different thickness

Leaf spring set of thickness.	**Fatigue life of spring**
6 mm	13.77×10^5
8 mm	3097.41×10^5
10 mm	99311.60×10^5
12 mm	1490157×10^5

III. RESULT

1. By using SUP 9 material instead of EN 47 we have increased fatigue life.
2. Their by we have not increased weight to increase fatigue life i.e. indirectly we have reduced weight of spring.
3. It is found that leaf spring fatigue is increased by increasing thickness.

Practically it is observed that mostly people in ruler area prefer to increase thickness or number of leaf though this procedure increase fatigue life but simultaneously. it reduced freedom i.e. defection of spring because of which comfort of vehicle is reduced and in major cases it may transmit heavy impact to chassis which causes breaking of chassis.

We can say that people try to save their maintenance cost of leaf spring but they may get heavy loss if chassis get cracked

CONCLUSION

Weight of leaf spring suspension system account for about 10% to 20 % of vehicles weight we know that the cost of material constitute nearly 60-70% of vehicle cost. For achieving improved ride characteristics, increased fuel efficiency and material saving we can use better material giving better fatigue life so we can take that material and reduce thickness less than existing thickness of spring, up to the thickness which will be satisfying the fatigue life of existing spring. Though reduction of material for each spring is less but we know that vehicles are manufactured in tonnages and for each vehicle 4 springs are needed means almost this will give definitely large reduction in material cost. And another think is study of effect of change in thickness on fatigue life.

The graphical method can be used to study effect of geometry and material on fatigue life hence leaf spring assembly graphical model developed is efficient and beneficial.

REFERENCES

[1] Hiroyuki Sugiyama, Ahmed A. Shabana, Mohamed A. Omar, Wei-Yi Loh: "Development of nonlinear elastic leaf spring model for multi body vehicle systems" Received 22 September 2004: received in revised form 7 February 2005: accepted 7 February 2005. Elsevier Science Direct www.elsevier.com [6925-6941]

[2] Jan Willem Van Der Wiel "Future Of Automotive Design & Materials Trends And Developments In Design And Materials" [2-24]

[3] Kumar Krishna and Aggarwal M.L: "A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools" Research Journal of Recent Sciences Received 24th January 2012, revised 27th January 2012, accepted 30th January 2012. ISSN 2277-2502. [92-96]

[4] M.A. Osioenko, Yu.I. Nyashin, R.N. Rudakov "A Contact problem in the theory of leaf spring bending" International Journal of Solid and Structures .February 2003 [3129-3136]

[5] M. M. Rahman, A.K. Ariffin, N. Jamaludin and C. H. C. Haron: "Influence of Surface Treatments on Fatigue Life of a Free Piston Linear Generator Engine Components Using Narrow Band Approach" 2006 Tech Science Pres. [69-82]

[6] M.Venkatesan, D.Helmen Devaraj: "Design and Analysis of Composite Leaf Spring in Light Vehicle" International Journal of Modern Engineering Research (IJMER) ISSN: 2249-6645 [213-218]

[7] Mouleeswaran Senthil Kumar, Sabapathy Vijayarangan: "Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi-leaf Spring for Light Passenger Vehicles Using Life Data Analysis" Received 13 January 2007: accepted 06 May 2007. ISSN 1392–1320 [141-146]

[8] Perttu Kainulainen "Analysis of Parabolic Leaf Spring Failure" Savonia University of Applied Sciences 2011. [10-46]

[9] R.A. Claudio, J.M. Silva, C.M. Branco, J. Byrne: Fatigue Life Prediction of Shot Peened Components. Ciencia Technologic Dos Materials, Vol. 20, 2008. [99-105]

[10] Shaikh Mubassar Ali, Susan c. Mantell, and ellen k. Longmire: "Experimental Technique for Fatigue Testing of MEMS in liquids" Journal of Microelectromechanical systems, vol. 21, no. 3, June 2012 [520-522]

[11] Shiva Shankar Gulur Siddaramann and Vijayarangan Sambagam, "Mono Composite Leaf Spring for Light Weight Vehicle"–Design, End Joint Analysis and Testing, ISSN 1392–1320 220-225 (2007). [220-225]

[12] Shishay Amare Gebremeskel: "Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle" Global Journals Inc. (USA) Online ISSN: 2249-4596 Print ISSN: 0975-5861. [20-30]

[13] Subrata Banerjee, Dinkar Prasad, and Jayanta Pal: "Design, Implementation, And Testing of a Single Axis Levitation System for the Suspension of a Platform" Received 8 November 2005: accepted 26 September 2006. Elsevier Science Direct www.elsevier.com/locate/isatran. [239-246]

[14] Vinkel Kumar Arora, Gian Bhushan and M. L. Aggarwal "Fatigue Life Assessment of 65Si7 Leaf Springs a Comparative Study" Hindawi Publishing Corporation Published 29 October 2014

[15] Khurmi Gupta Textbook Machine Design 2012.

[16] J.A.Charles , F.A.A Crane, J.A.G Furness "Selection and use of Engineering Material" third edition Book Elsevier Publication 2006.

[17] Shigley's "Mechanical Engineering Design" Eight Edition.

[18] V.B. Bhandari "Textbook Machine Design"