Fatigue Analysis of a Leaf Spring used in Mini Truck for Optimum Load Conditions

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Abstract— The leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. There are mono leaf springs, or single-leaf springs, that consist of simply one plate of spring steel. These are usually thick in the middle and taper out toward the end, and they don't typically offer too much strength and suspension for towed vehicles. Drivers looking to tow heavier loads typically use multileaf springs, which consist of several leaf springs of varying length stacked on top of each other. Springs will fail from fatigue caused by the repeated flexing of the spring. We are also considering these cases also. (1) Modeling of Road Irregularity. (2) The life and safety of the vehicle on road. Presently used material for leaf spring is forged steel. In this project we are going to design leaf spring for the material composite material carbon. We are going to check the strength variations while changing reinforcement angle and layers. Structural Analysis is done on the leaf spring by using three different material carbon epoxy. Fatigue analysis is to find life and safety factor.

Key words: CATIA, FEA, Fatigue Analysis of a Leaf Spring

I. INTRODUCTION TO CATIA

CATIA version 5 is a process-centric computer-aided design/computer-assisted manufacturing or computer-aided engineering (CAD/CAM/CAE) system that fully uses next generation object technologies and leading edge industry standards. Seamlessly integrated with Dassault Systemes Product Lifecycle Management (PLM) solutions, it enables users to simulate the entire range of industrial design processes from initial concept to product design, analysis, assembly, and maintenance. The CATIA V5 product line covers mechanical and shape design, styling, product synthesis, equipment and systems engineering, NC manufacturing, analysis and simulation, and industrial plant design. In addition, CATIA Knowledge ware enables broad communities of users to easily capture and share know-how, rules, and other intellectual property (IP) assets.

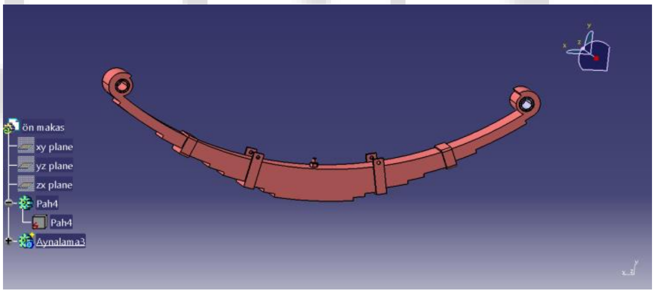
CATIA V5 builds on powerful smart modeling and morphing concepts to enable the capture and reuse of process specifications and intelligence. The result is an easily scaleable, Web-enabled system that covers all user requirements within the digital extended enterprise, from the simplest design to the most complex processes. This capability allows optimization of the entire product development process while controlling change propagation. CATIA V5 moves beyond traditional parametric or variational approaches, accelerating the design process and helping designers, engineers, and manufacturers increase their speed and productivity.

CATIA V5 has an innovative and intuitive user interface that unleashes the designer's creativity. Context-sensitive integrated workbenches provide engineers with the tools they need for the task at hand, and they are beneficial for multi-discipline integration. The workbenches have powerful keyboard-free direct object manipulators that maximize user productivity.

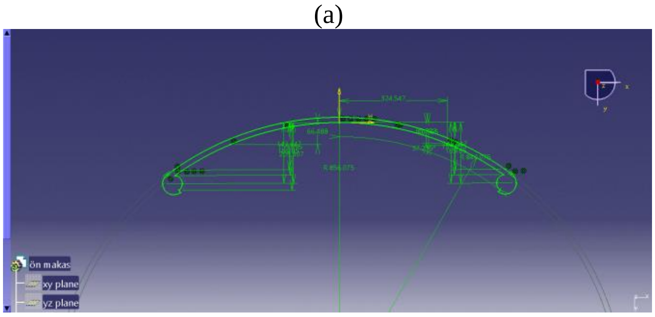
CATIA V5 applications are based on a hybrid modeling technology. These applications provide expanded digital product definitions, process definitions, and review functions capable of operating on projects with any degree of design complexity. CATIA V5 has produced domain-specific applications that have addressed global digital enterprise requirements that span the areas of mock-up, manufacturing, plant, and operations.

CATIA V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE (Knowledge Based Engineering) support. Catia V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE (Knowledge Based Engineering) support.

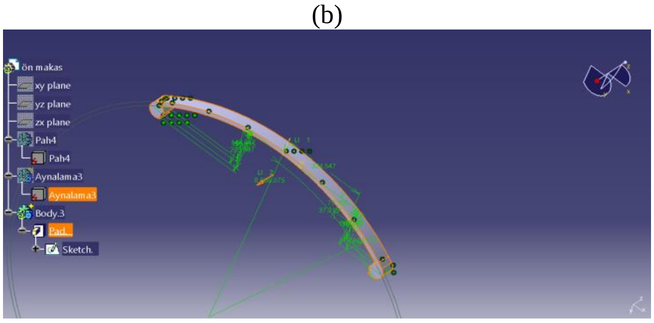
A. *Model design*



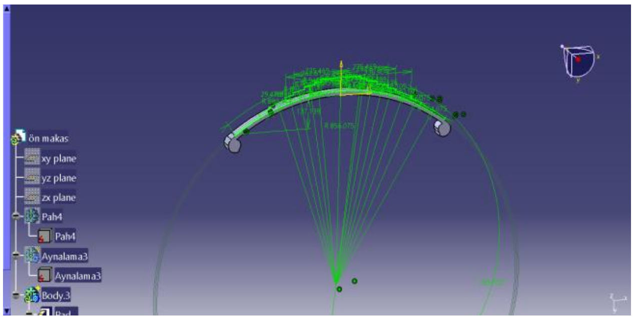
(a)



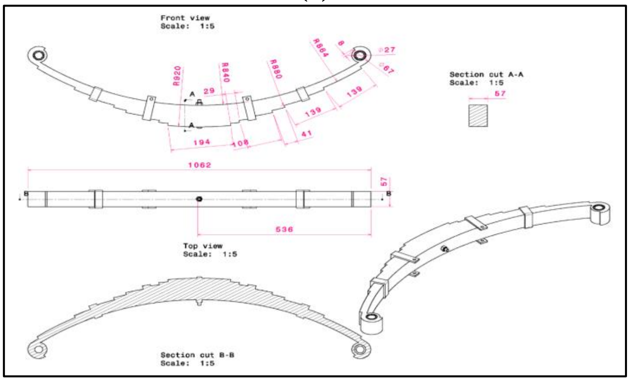
(b)



(c)



(d)



(e)

Fig. 1: Model Design (a),(b),(c),(d),(e)

II. Introduction to FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". .

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements

A. *Analysis of leaf spring by forged steel*

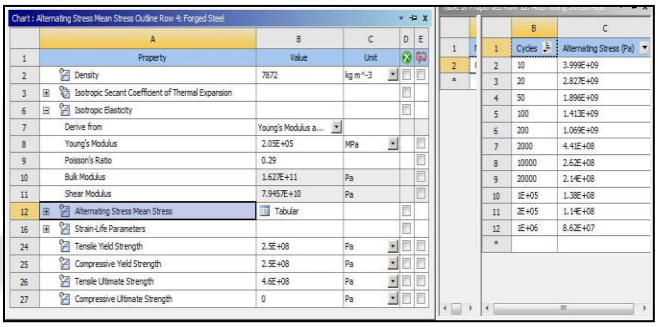


Chart : Alternating Stress Mean Stress Outline Row 4: Forged Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7872	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulus a...			
8	Young's Modulus	2.05E+05	MPa		
9	Poisson's Ratio	0.29			
10	Bulk Modulus	1.627E+11	Pa		
11	Shear Modulus	7.9457E+10	Pa		
12	Alternating Stress Mean Stress	Tabular			
16	Strain-Life Parameters				
24	Tensile Yield Strength	2.5E+08	Pa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	4.6E+08	Pa		
27	Compressive Ultimate Strength	0	Pa		

	B	C
1	Cycles	Alternating Stress (Pa)
2	10	3.999E+09
3	20	2.827E+09
4	50	1.896E+09
5	100	1.413E+09
6	200	1.069E+09
7	2000	4.41E+08
8	10000	2.62E+08
9	20000	2.14E+08
10	1E+05	1.38E+08
11	2E+05	1.14E+08
12	1E+06	8.62E+07
*		

Fig. 2(a): Material Properties

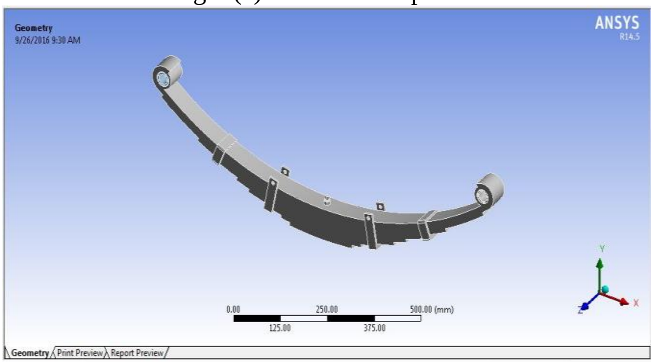


Fig. 2(b): Imported model

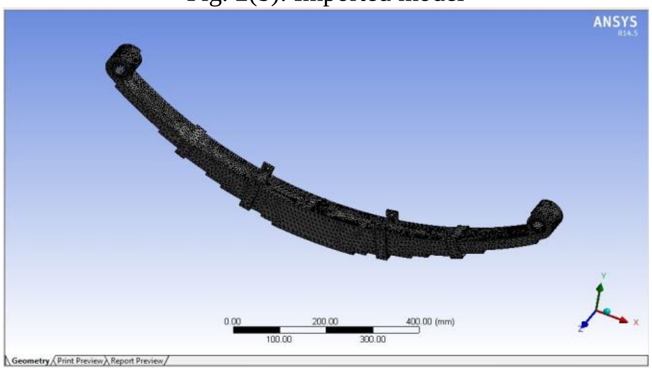


Fig. 2(c): Meshed model

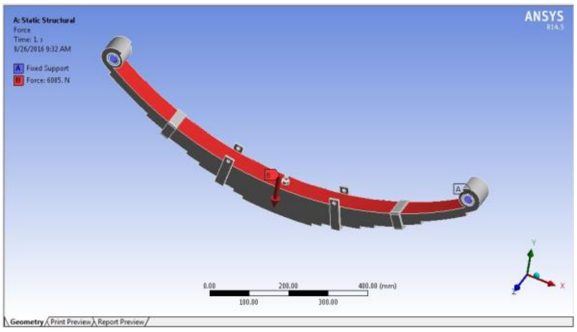


Fig. 2(d): Loads applied model

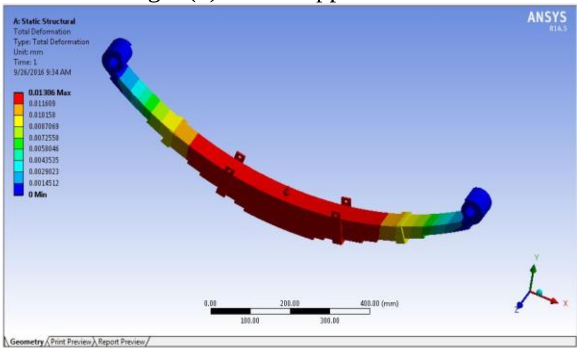


Fig. 2(e): Deformation

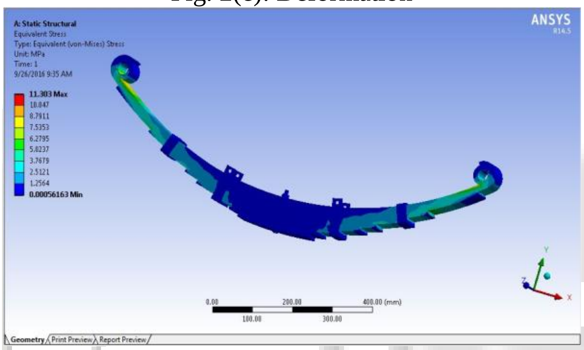


Fig. 2(f): Stress

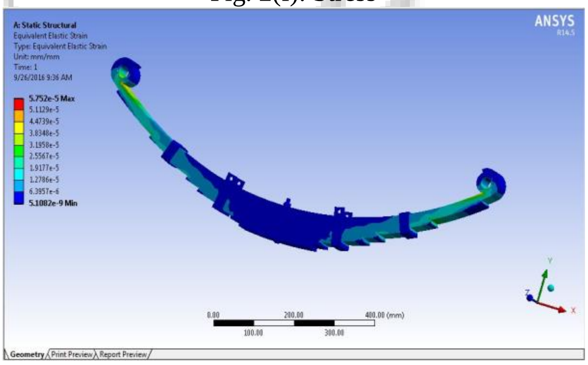


Fig. 2(g): Strain

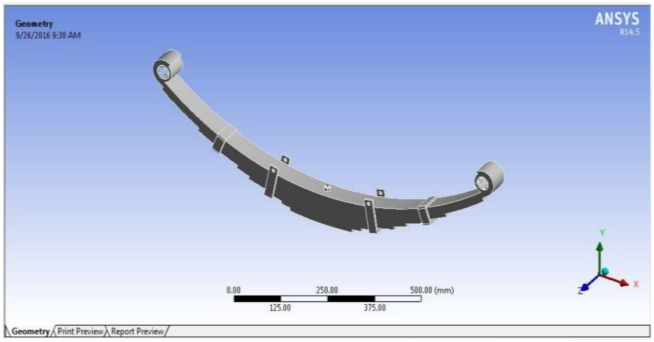


Fig. 3(b): Imported model

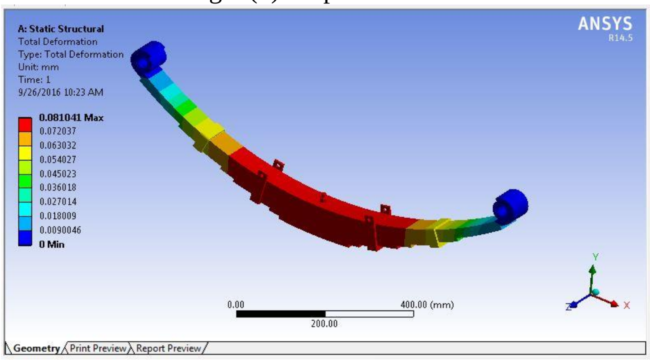


Fig. 3(c): Deformation

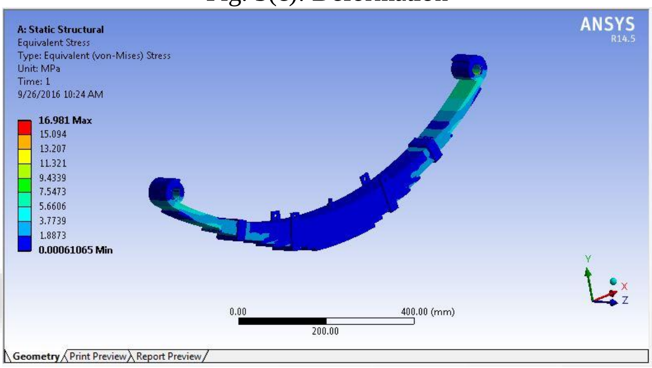


Fig. 3(d): Stress

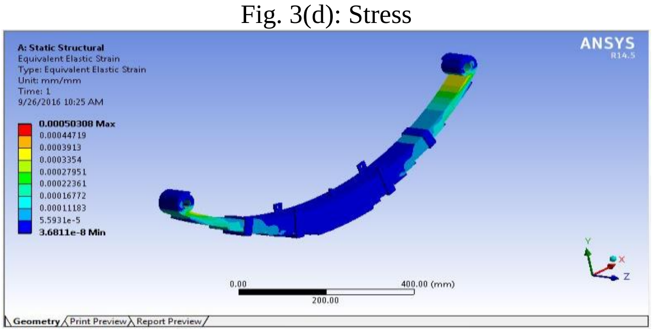


Fig. 3(e): Strain

B. *Analysis of Carbon Epoxy*

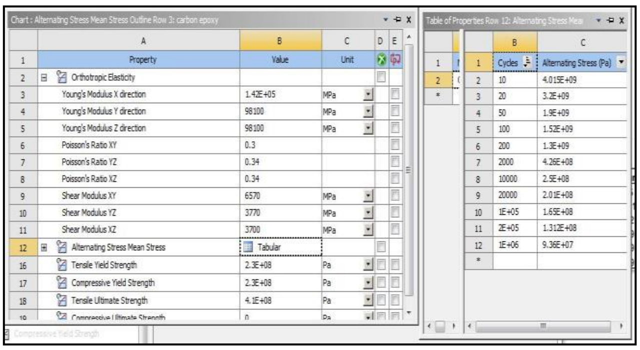


Chart : Alternating Stress Mean Stress Outline Row 3: carbon epoxy

	A	B	C	D	E
1	Property	Value	Unit		
2	Orthotropic Elasticity				
3	Young's Modulus X direction	1.42E+05	MPa		
4	Young's Modulus Y direction	98100	MPa		
5	Young's Modulus Z direction	98100	MPa		
6	Poisson's Ratio XY	0.3			
7	Poisson's Ratio YZ	0.34			
8	Poisson's Ratio XZ	0.34			
9	Shear Modulus XY	6570	MPa		
10	Shear Modulus YZ	3770	MPa		
11	Shear Modulus XZ	3700	MPa		
12	Alternating Stress Mean Stress	Tabular			
16	Tensile Yield Strength	2.3E+08	Pa		
17	Compressive Yield Strength	2.3E+08	Pa		
18	Tensile Ultimate Strength	4.1E+08	Pa		
19	Compressive Ultimate Strength	0	Pa		

Table of Properties Row 12: Alternating Stress Mea

	B	C
1	Cycles	Alternating Stress (Pa)
2	10	4.015E+09
3	20	3.2E+09
4	50	1.9E+09
5	100	1.52E+09
6	200	1.3E+09
7	2000	4.26E+08
8	10000	2.5E+08
9	20000	2.01E+08
10	1E+05	1.65E+08
11	2E+05	1.312E+08
12	1E+06	9.36E+07
*		

Fig. 3(a): Material properties

C. *Fatigue Analysis of Forged Steel*

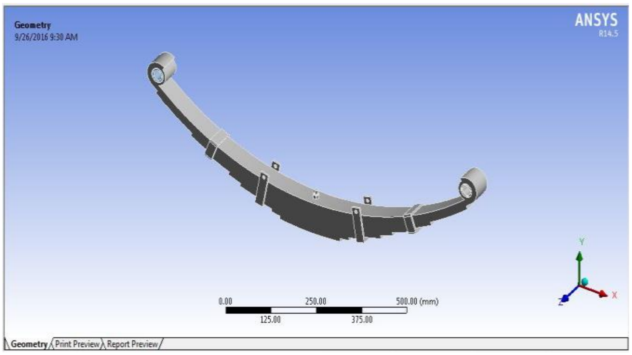


Fig. 4(a): Imported model

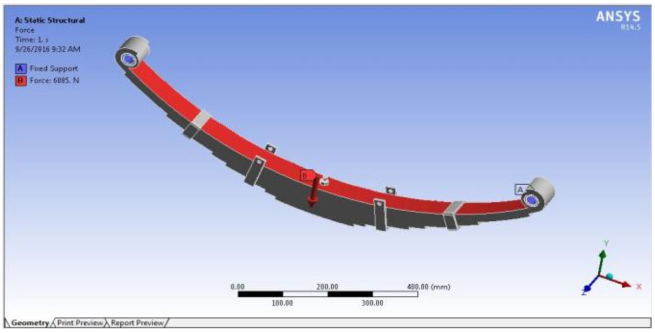


Fig. 4(b): Loads applied

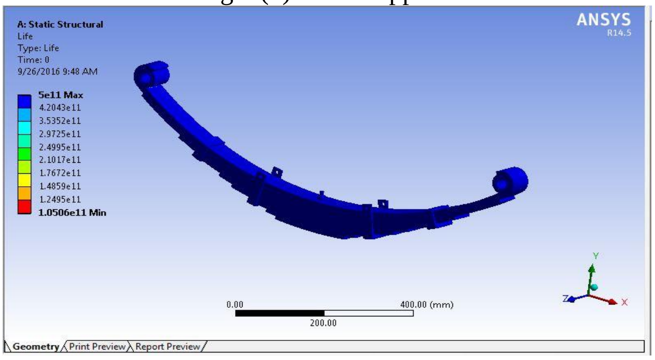


Fig. 4(c): Life

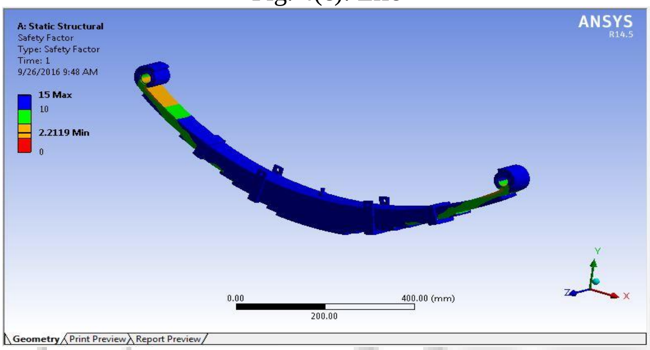


Fig. 4(d): Safety factor

D. Carbon Epoxy

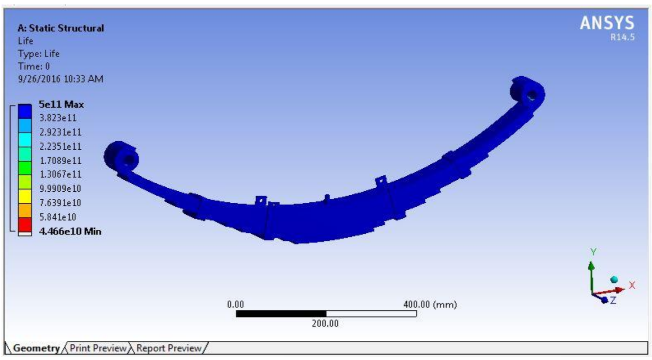


Fig. 5(a): Fig. Life

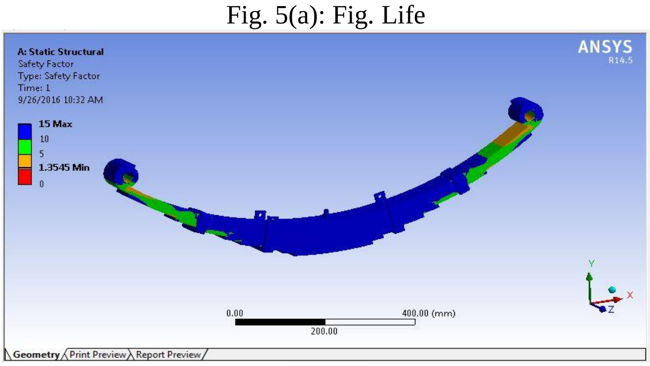


Fig. 5(b): Fig. Safety factor

III. Conclusion

The leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in satiation in the motion of the suspension. For this reason some manufacturers have used mono-leaf springs. A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm.

In these project we design on CATIA v5 software and done analysis to find the accurate bearing stress and life of the component for that we done structural and fatigue analysis for three materials forged steel, carbon epoxy and by observing the materials the stress is at a required condition on forged steel in normal condition. Life and safety factor we can observe and safe the design on it

References

[1] Mahmood M. Shokrieh, Davood Rezaei. Analysis and optimization of a composite leaf spring. Composite Structures 60 (2003) 317–325.
[2] J.J. Fuentes, H.J. Aguilar, J.A. Rodriguez, E.J. Herrera. Premature fracture in automobile leaf springs. Engineering Failure Analysis 16 (2009) 648–655.
[3] Al-Quershi HA. Automobile leaf springs from composite materials. Journal of Materials Processing Technology 118 (2000) 58–61.
[4] C. Subramanian, S. Senthilvelan. Joint performance of the glass fiber reinforced polypropylene leaf spring. Composite structure 93(2011) 759-766.
[5] Abdul Rahim Abu Talib, Aidy Ali, G. Goudah, Nur Azida Che Lah, A.F. Golestaneh. Developing a composite based elliptic spring for automotive applications. Materials and Design 31 (2010) 475–484.
[6] M. Venkatesan “Design And Analysis Of Composite Leaf Spring In Light Vehicle”, International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.1, Jan-Feb 2012 pp-213-218 ISSN: 2249-6645.
[7] M.M. Patunkar “Modeling And Analysis of Composite Leaf Spring Load Condition By Using FEA”,(IJMIE) International Journal of Mechanical & Industrial Engineering, Volume 1 Issue 1-2011.
[8] U. S. Ramakanth, K. Sowjanya “Design and analysis of automotive multi-leaf springs using composite materials” International Journal of Mechanical Production Engineering Research and Development (IJMPERD) ISSN 2249-6890 ,Vol. 3, Issue 1, Mar 2013, 155-162 © TJPRC Pvt. Ltd.
[9] B.VijayaLakshmi, I. Satyanarayana “static and dynamic analysis on composite leaf spring in heavy vehicle” International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974,IJAERS/Vol. II/ Issue I/Oct.-Dec.,2012/80-84
[10] Y. N. V. Santhosh Kumar & M. VimalTeja “Design and Analysis of Composite Leaf Spring” International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012

[11] Dara Ashok, M.V. Mallikarjun and Venkata Ramesh Mamilla “design and structural analysis of composite multi leaf spring” International Journal of Emerging trends in Engineering and Development ISSN 2249-6149 ,Issue 2, Vol.5 (July 2012)
[12] Ghodake A. P., Patil K.N. “Analysis of Steel and Composite Leaf Spring for Vehicle” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) eISSN: 2278-1684 Volume 5, Issue 4 (Jan. - Feb. 2013), PP 68-76
[13] Ashish V. Amrute, Edward Nikhil karlus, R.K.Rathore “Design And Assessment Of Multi Leaf Spring” International Journal Of Research In Aeronautical And Mechanical Engineering Issn (Online): 2321-3051 Vol.1, Issue 7(Nov 2013),Page (115-124)
[14] Mechanical Design by R.S. Khurmi and J.K. Gupta, S. Chand Publications.