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Study of Stress and Deformation by Mono Composite Leaf Spring

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Abstract

The purpose of this project work is to estimate the deflection and stress on the basis of Load changes as well as Young's Modulus in Mono Composite Leaf Spring by computer analysis. The emphasis in this project is given on the effect of Young's Modulus on deflection and stress produced in Leaf Spring and all the process will be done by the application of computer aided analysis using finite element concept. The component chosen for analysis is a leaf spring which is an automotive component used to absorb vibrations. Under operating conditions, the behavior of the leaf spring is complicated due to its clamping effects and interleaf contact; hence its analysis is necessary to pre-predict the displacement, and stresses. Although many projects have been made earlier regarding the concept of stress and deflection on leaf spring on the basis of load, but the new thing on these project is the estimation of leaf spring on the basis of Young's Modulus which makes these project unique because such project has not been made yet. Another thing that makes it differ is the use of CATIA software not only for modeling the Leaf Spring but also for the whole analysis. So all the process and analysis is based on the results obtained in CATIA software under given specified conditions.

Keywords: *Young's Modulus, leaf spring, CATIA, software, load*

INTRODUCTION

This report is made for the Submission of Minor project by our Group. The concept of this project comes from the question of effect of Young's Modulus and Load on stress and deflection. Since many projects has developed regarding the Load vs. Stress and Deflection. But the effect of Young's Modulus was not considered in any project made earlier [1]. Now in these report we are going to deal with these concept of Young's Modulus and Load effects on anybody. For analysis purpose we have selected the Leaf Spring as working material and the whole project analysis will made on that Leaf Spring. CATIA is the 3D interactive software mostly used for modeling of 3D objects. Now the companies are using Computer Software likes CATIA, Pro-E, Solidworks, Autocad etc. for designing purposed before the actual modeling or manufacturing of Specimens. This software allows the user to find out the possible error occurring in the design that might be difficult to find out through paper design [2].

In this project we are not only using the CATIA software for modeling purpose but also for Analysis too. Most of the projects similar to these made earlier uses the ANSYS software for analysis purpose which is specially designed for analysis of model. But this project will completely based on CATIA software [3].

OBJECTIVES OF THE PROJECT

The main objectives of our projects are stated below:

1. Deformation of body on the basis of Load and Young's Modulus of Elasticity.
2. Stress i.e., Max Principal Stress and Max. Von Miss Stress on the basis of Load and Young's Modulus.
3. Complete analysis of Leaf Spring. i.e., Max Deformation and Max. Stress with Magnitude.
4. Comparison of Theoretical and Analytical Values.
5. Changes of Max Safe Load on the basis of Young's Modulus.
6. CATIA software modeling and Analysis techniques**.**

MONO COMPOSITE LEAF SPRING

The term Mono Composite Leaf Spring is uses for the Unified Single Composite Leaf Spring. Since a leaf spring have many leaves, the lengthiest one at the top is Master leaf and it have eye on their ends for clamping, then after all leaves are graduated leaf spring. Now in this project the whole Leaf Spring is considered as Single body for the convenience in Analysis purpose on the Computer Software [4].

Fig. 1: *Mono Composite Leaf Spring.*

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ASSUMPTIONS

Many Assumptions has been made in this project, they are as follows:-

- The Whole Leaf Spring are considered as single Unified and termed as Mono composite Leaf Spring.
- Since, the leaf spring is considered as single unit so the friction between leaves is neglected.
- The Load applied on the leaf spring is distributed load.
- For the convenient in analysis, both the ends of the leaf spring from eye are fixed.
- The load will act on one direction only and the effect of poison ratio is neglected.
- U bolt and Sleeve clamping are not considered in leaf spring.

FEA (FINITE ELEMENT ANALYSIS)

Finite Element Analysis (FEA) has become common in recent years. Numerical solutions to even very complicated stress problems can now be obtained by FEA and the method is so important that even introductory parts treatments of Mechanics of Materials such as these modules should outline its principal features. In spite these advantages of FEA, the disadvantages of computer solutions must be kept in mind when using this and similar methods: they do not necessarily reveal how the stresses are influenced by important problem variables such as materials properties and geometrical features and errors in input data can produce wildly incorrect results that may be overlooked by the analyst.

PHASE OF WORKING

The whole analysis can be divided into different parts like

a) Leaf Spring Modeling.
b) Analysis on CATIA.
c) Evaluating the results.

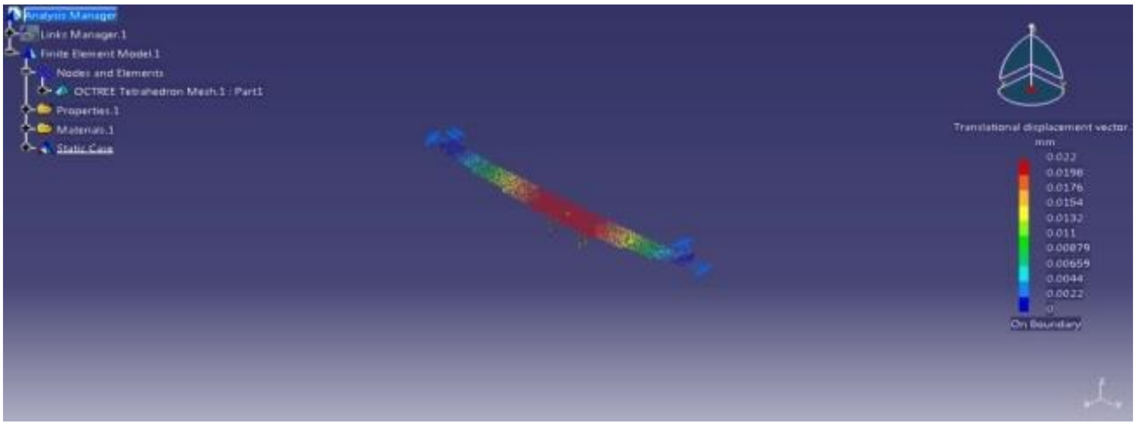


Fig. 2: *Representation of Translational Displacement of Mono Leaf Spring.*

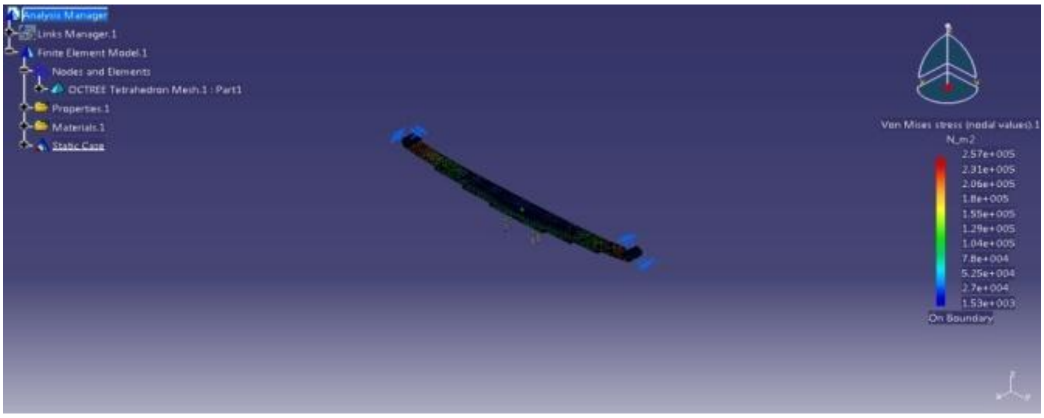


Fig. 3: *Representation of Von-Miss Stress of Mono Leaf Spring.*

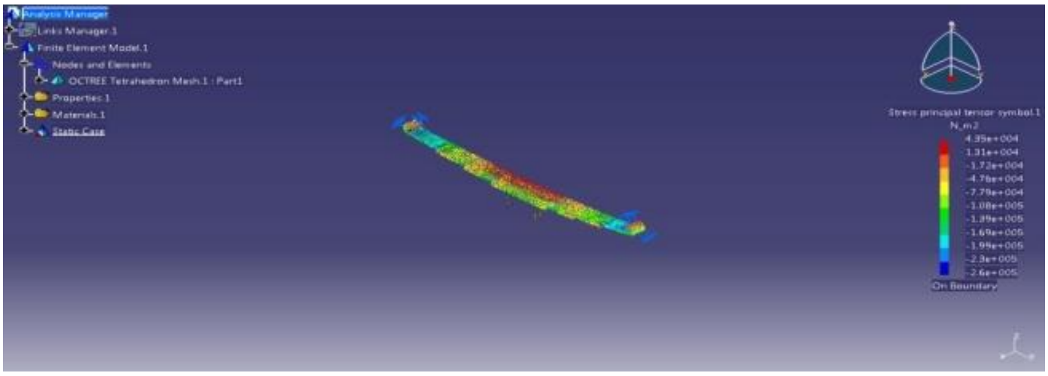


Fig. 4: *Representation of Principal Stress of Mono Leaf Spring.*

PROCEDURE OF WORKING

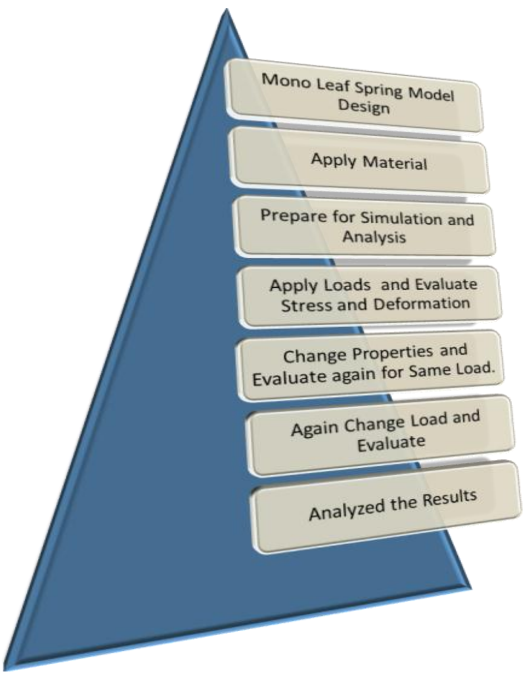


Fig. 5: *Procedure of Working.*

MODELING OF LEAF SPRING

GEOMETRIC PROPERTIES OF LEAF SPRING

- Camber = 80 mm
- Span = 1220 mm
- Thickness = 18 mm
- Width = 60 mm
- Number of full length leaves nF = 1
- Number of graduated leaves nG = 3
- Total No. of leaves n = 4

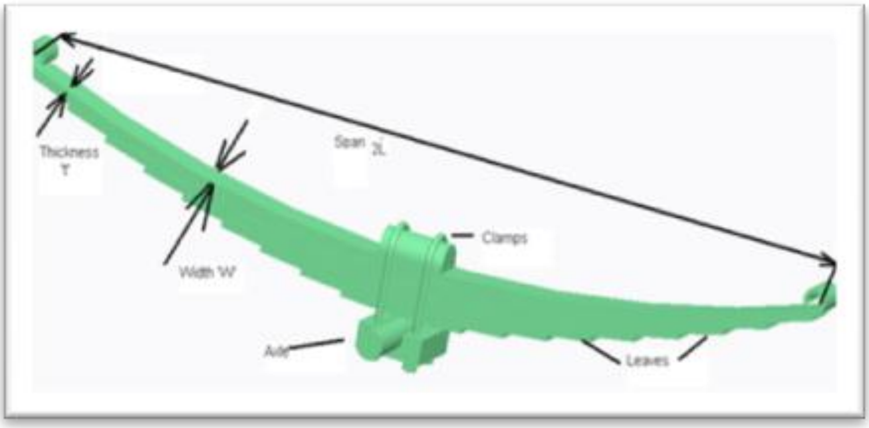


Fig. 6: *Components of Mono Leaf Spring.*

PROPERTIES OF MATERIAL

Parameters	Value
Material	Steel
Poison Ratio	0.32
Yield Strength	$2.52*10^8 N/m^2$
Thermal Expansion	$1.175*10^{-5}$ Kdeg
Octree Tetrahedron Mesh • Element Size • Sag • Shape	 12 mm 2.5 mm Linear

In the multi leaf structure leaf spring various problems arises such as producing squeaking sound, fretting corrosion thereby decreasing the fatigue life.

MODELING OF LEAF SPRING IN CATIA:-

1. Starting with new part design on CATIA software.
2. Selecting the Plane Y-Z for working and then Click tool Workbench for activating the plane.
3. Design a curve through polyline command on Catia.
4. Creating an offset plane at the one end of curve and activate that plane.
5. Design a rectangular box with specific dimension in that plane.
6. Now use the Sweep command to make that rectangle in whole curve.
7. Then repeat the same process for designing and the final assembly becomes Mono Leaf Spring.

After the modeling of CATIA Model, the material steel is applied which have some specific properties. Then it is transferred for analysis on the same software. Here the size of nodes and elements are decided and then after analysis are made by changing the loads and Young’s Modulus of Steel.

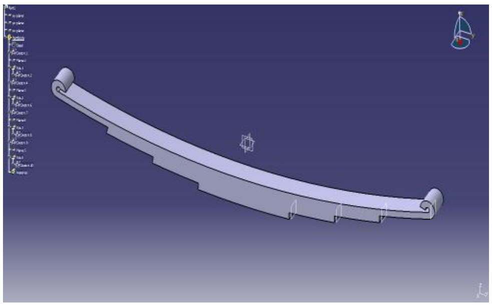


Fig. 7: *Modeling of Leaf Spring in CATIA.*

ANALYSIS AND SIMULATION INTRODUCTION

The use of numerical methods to simulate the behavior of engineered systems during operations and accidents brings major benefits in understanding the parameters, which is essential for decision makers. Complex situations involves statics, dynamics, non-linearity, laminar, turbulence, thermal effects, shocks and impacts can be understood through the use of analysis software only.

GENERATIVE STRUCTURE ANALYSIS

Generative structural analysis is useful to get the various structural characteristics of your parts in a 3D environment. Using these software tools allows you to analyze your parts to determine their structural qualities and defects before they are manufactured. The Generative Structural Analysis workbenches utilize the Finite Element Method of numerical approximation. This method works by breaking it down into smaller, more No. of simplified pieces. These broken down pieces are termed as elements. Elements are connected together at what are commonly known as nodes. The illustration below provides greater clarity.

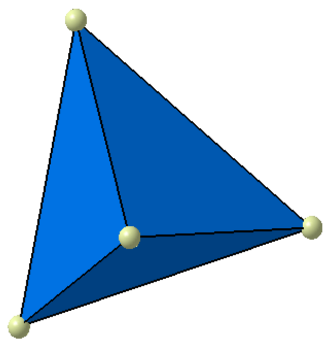
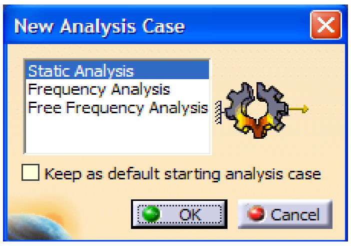


Fig. 8: *Linear Element.*

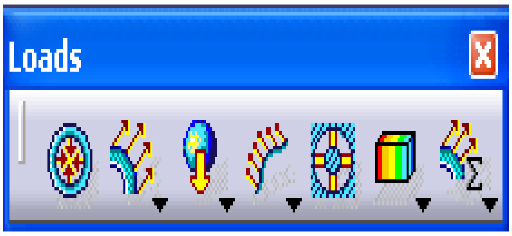
Below are an original model and its finite element model representation. The representation will vary based on the size and shape of the elements. This allows the user to customize analysis. Based on the simplicity and size of the elements, the analysis can be very simple or very complex based on the requirements of the analysis.

PROCESS OF ANALYSIS AND SIMULATION

- To begin the analysis on the part, select Start > Analysis & Simulation > Generative Structural Analysis workbench.

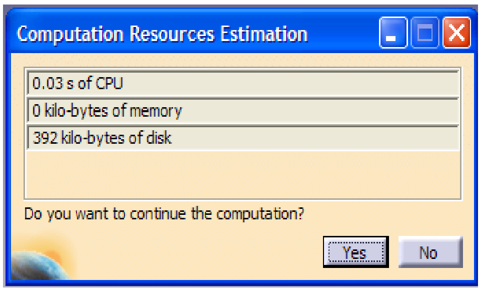


- When the New Analysis Case box shown, keep the Static Analysis selection and press OK Model of Leaf Spring from Part Module is imported on Analysis and Simulation Module on catia.
- Now after Starting Static Analysis, element and node size should be defined.
- To apply a bending load to the above part, the Loads toolbar is utilized. Select Distributed Force and a box of the same name appears.



- Through the restrain tool box, clamps are made on both the ends of Leaf Spring.
- Now by using Load tool box, distributed load is applied at the bottom leaf in Z direction.

- Now leaf spring becomes ready for computation.



In Computation, many processes are performed by the computer which depends upon the type of work and the time of computation depends on the size of computation and computer speed.

COMPUTATION PROCESS PROCEDURE OF FINITE ELEMENT ANALYSIS

- Discretization of the continuum.
- Formation of element stiffness matrices.
- Formation of global stiffness matrices.
- Formation of load vector.
- Formation of global nodal displacement vector.
- Assembly of global stiffness nodal displacement load equations.
- Incorporation of specified boundary conditions.
- Solution of Simultaneous equations.
- Computation of element strains and stresses.

STATIC ANALYSIS PARAMETER

- STATIC MODEL ANALYSIS
- Test Run- 85 N. 105 N, 125 N
- Material Used :- Steel
- Density:- 7860 Kg/m3
- Yield Strength:- 2.5*108 N/m2
- Poisson Ratio :- 0.3
- OCTREE tetrahedron mesh:-
  - Element size- 12 mm
  - Sag- 2.5 mm
  - Shape- Linear

TEST RUN

Loads	**85 N**	**105 N**	**125 N**
S. No.	**Properties to be Change Young's Modulus"E"**		
1.	E=2.1*10^{11}N/m2		
2.	E=1.5*10^{10}N/m2		
3.	E=1.8*10^{11}N/m2		
4.	E=2.3*10^{11}N/m2		
5.	E=3.5*10^{12}N/m2		

THINGS TO BE ANALYZED

1. Maximum Von Mis Stress. Max. Principal Stress and Max Deformation on the basis of:-

a. Load Changes

b. Young's Modulus(E)

2. Things to be noted:-

a. Max Deformation

b. Max. Principal Stress

c. Max Von Miss Stress

3. Graph to be plotted:-

a. Max Principal Stress Vs Load

b. Max Von Miss Stress Vs Load

c. Deformation VS Load

d. Deformation vs. Young's Modulus(E)

SPECIFICATION OF LEAF SPRINGS

- Overall Span Length = 1220 mm
- Eye Diameter = 30 mm
- Camber Length = 80 mm
- No. of Leaves = 4
- Width = 60 mm
- Thickness of leaf = 18 mm

RESULT OF ANALYSIS

Table 1: *Analysis-1 (Test Run 85 N).*

1.	**E= $2.1*10^{11}$ N/m^2**		
	Von Miss Stress (N/m^2)	**Deformation(mm)**	**Principal Stress (N/m2)**
Max.	$2.57*10^5$ N/m^2	0.00165	$4.35*10^4$ N/m^2
Min.	$1.53*10^3$ N/m^2	-	$-2.6*10^5$ N/m^2
2.	**E= $1.5*10^{10}$ N/m^2**		
Max.	$2.57*10^5$ N/m^2	0.022	$4.35*10^4$ N/m^2
Min.	$1.53*10^3$ N/m^2	-	$-2.6*10^5$ N/m^2
3.	**E=$1.8*10^{11}$ N/m^2**		
Max.	$2.57*10^5$ N/m^2	0.00183	$4.35*10^4$ N/m^2
Min.	$1.53*10^3$ N/m^2	-	$-2.6*10^5$ N/m^2
4.	**E= $2.3*10^{11}$ N/m^2**		
Max.	$2.57*10^5$ N/m^2	0.00143	$4.35*10^4$ N/m^2
Min.	$1.53*10^3$ N/m^2	-	$-2.6*10^5$ N/m^2
5.	**E=$3.5*10^{12}$ N/m^2**		
Max.	$2.57*10^5$ N/m^2	$9.42*10^{-5}$	$4.35*10^4$ N/m^2
	$1.53*10^3$ N/m^2	-	$-2.6*10^5$ N/m^2

Table 2: *Analysis-2 (Test Run 105 N).*

1.	**E= 2.1*10^11 N/m^2**		
	Von Miss Stress (N/m^2)	**Deformation(mm)**	**Principal Stress (N/m2)**
Max.	3.17*10^5 N/m^2	0.00194	5.37*10^4 N/m^2
Min.	1.89*10^3 N/m^2	-	-3.2*10^5 N/m^2
2.	**E= 1.5*10^10 N/m^2**		
Max.	3.17*10^5 N/m^2	0.0271	5.37*10^4 N/m^2
Min.	1.89*10^3 N/m^2	-	-3.2*10^5 N/m^2
3.	**E=1.8*10^11 N/m^2**		
Max.	3.17*10^5 N/m^2	0.00226	5.37*10^4 N/m^2
Min.	1.89*10^3 N/m^2	-	-3.2*10^5 N/m^2
4.	**E= 2.3*10^11 N/m^2**		
Max.	3.17*10^5 N/m^2	0.00177	5.37*10^4 N/m^2
Min.	1.89*10^3 N/m^2	-	-3.2*10^5 N/m^2
5.	**E=3.5*10^12 N/m^2**		
Max.	3.17*10^5 N/m^2	0.000166	5.37*10^4 N/m^2
	1.89*10^3 N/m^2	-	-3.2*10^5 N/m^2

Table 3: *Analysis-3 (Test Run 125 N).*

1.	**E= 2.1*10^11 N/m^2**		
	Von Miss Stress (N/m^2)	**Deformation(mm)**	**Principal Stress (N/m2)**
Max.	3.77*10^5 N/m^2	0.00231	6.4*10^4 N/m^2
Min.	2.25*10^3 N/m^2		-3.83*10^5 N/m^2
2.	**E= 1.5*10^10 N/m^2**		
Max.	3.77*10^5 N/m^2	0.0323	6.4*10^4 N/m^2
Min.	2.25*10^3 N/m^2		-3.83*10^5 N/m^2
3.	**E=1.8*10^11 N/m^2**		
Max.	3.77*10^5 N/m^2	0.00269	6.4*10^4 N/m^2
Min.	2.25*10^3 N/m^2		-3.83*10^5 N/m^2
4.	**E= 2.3*10^11 N/m^2**		
Max.	3.77*10^5 N/m^2	0.00211	6.4*10^4 N/m^2
Min.	2.25*10^3 N/m^2		-3.83*10^5 N/m^2
5.	**E=3.5*10^12 N/m^2**		
Max.	3.77*10^5 N/m^2	0.000139	6.4*10^4 N/m^2
	2.25*10^3 N/m^2		-3.83*10^5 N/m^2

EVALUATION OF RESULTS ON THE BASIS OF ANALIZED DATA

STRESS

The magnitude of the Stress is independent to the value of Young's Modulus, it vary with load only.

Table 4: *Principal Stress vs. Loads.*

S. No.	Load (Newton)	Max. Principal Stress(N/m^2)
1.	85	$4.35*10^4$
2.	105	$5.37*10^4$
3.	125	$6.40*10^4$

- Changes in Stress for difference of 20N load-
- For 20N – $(5.37-4.35)*10^4$ N/m^2 or $(6.4-5.37)*10^4$ N/m^2
- So for 1N load = 10200/20
- Change in stress for 1N Load = 5

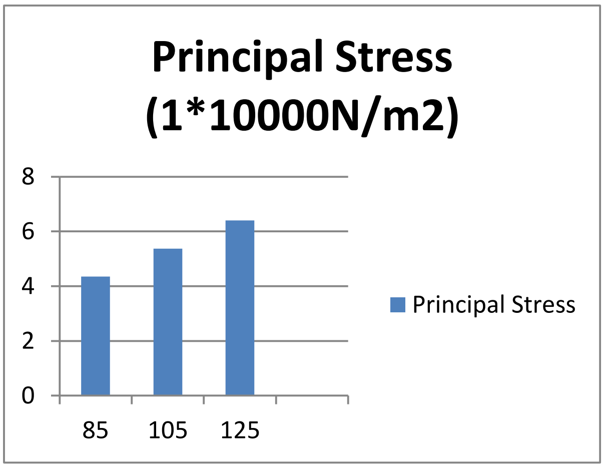


Fig. 9: *Principal Stress vs. Load.*

Table 5: *Von Miss Stress vs. Loads.*

S. No.	Load (Newton)	Max. Von Miss Stress (N/m^2)
1.	85	$2.57*10^5$
2.	105	$3.17*10^5$
3.	125	$3.77*10^5$

- Changes in Von Miss Stress for difference of 20N load-

For 20N - $(3.17-2.57)*10^5$ N/m^2 or $(3.77-3.17)*10^5$ N/m^2

- So for 1N load = 60000/20
- Change in stress for 1N Load = 3000N/m^2

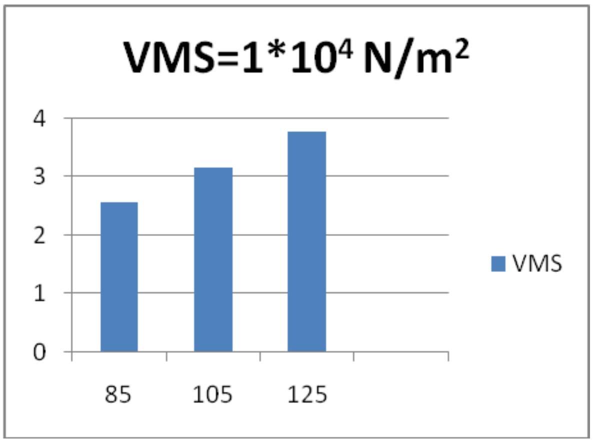


Fig. 10: *Von-Miss Stress vs. Load.*

DEFORMATION

Table 6: *Effect of Young's Modulus on Deformation.*

a) For Load 85 N

S. No.	Young's Modulus (E)in N/m^2	Deflection(mm)*1000
1.	$E_1 = 1.5*10^{10}$	0.022*1000= 22
2.	$E_2 = 1.8*10^{11}$	0.00183*1000= 1.83
3.	$E_3 = 2.1*10^{11}$	0.00165*1000= 1.65
4.	$E_4 = 2.3*10^{11}$	0.00143*1000= 1.43
5.	$E_5 = 3.5*10^{12}$	$9.42*10^{-5}$*1000= 0.0942

b) For Load 105 N

S. No.	Young's Modulus (E)in N/m^2	Deflection (mm)*1000
1.	$E_1 = 1.5*10^{10}$	0.0271*1000= 27.1
2.	$E_2 = 1.8*10^{11}$	0.00226*1000= 2.26
3.	$E_3 = 2.1*10^{11}$	0.00194*1000= 1.94
4.	$E_4 = 2.3*10^{11}$	0.00177*1000= 1.77
5.	$E_5 = 3.5*10^{12}$	0.000166*1000= 0.166

c) **For Load 125 N**

S. No.	Young's Modulus (E)in N/m^2	Deflection (mm)*1000
1.	$E_1 = 1.5*10^{10}$	0.0323*1000= 32.3
2.	$E_2 = 1.8*10^{11}$	0.00269*1000= 2.69
3.	$E_3 = 2.1*10^{11}$	0.00231*1000= 2.31
4.	$E_4 = 2.3*10^{11}$	0.00211*1000= 2.11
5.	$E_5 = 3.5*10^{12}$	0.000139*1000= 0.139

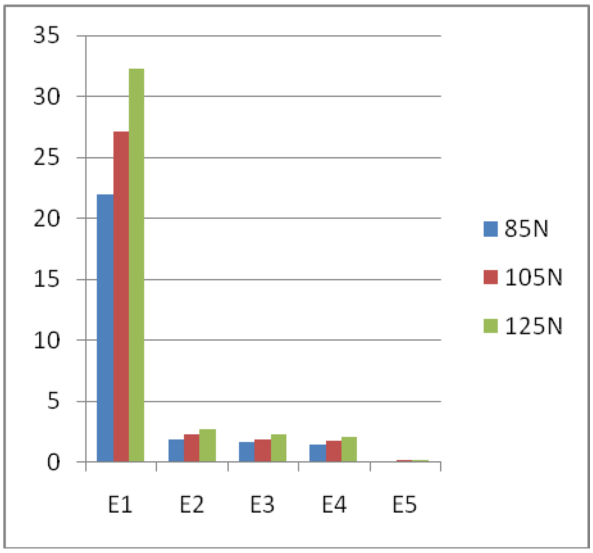


Fig. 11: *Young's Modulus vs. Deflection.*

- Since Deflection = (PL/AE)
- Here P = Force

  L = Length

  A = Area

  E = Young's Modulus
- For constant P, L, and E :

  Deflection is inversely proportional to change in Young's Modulus.
- From the above analysis, we concluded that-
- Deflection decreases with increase in Young' Modulus.

Table 7: *Effect of Load on Deformation.*

a) For E = $1.5*10^{10}$ N/m^2

Load (N)	Deflection (mm)*1000
85	0.022*1000= 22
105	0.0271*1000=27.1
125	0.0323*1000=32.3

b) For E= $1.8*10^{11}$N/m^2

Load (N)	Deflection (mm)*1000
85	0.00183*1000=1.83
105	0.00226*1000=2.26
125	0.00269*1000=2.69

c) For E=$2.1*10^{11}$ N/m^2

Load (N)	Deflection (mm)*1000
85	0.00165*1000=1.65
105	0.00194*1000=1.94
125	0.00231*1000=2.31

d) For E= $2.3*10^{11}$ N/m^2

Load (N)	Deflection (mm)*1000
85	0.00143*1000=1.43
105	0.00177*1000=1.77
125	0.00211*1000=2.11

e) For E= $3.5*10^{12}$ N/m^2

Load (N)	Deflection (mm)*1000
85	$9.42*10^{-5}$*1000=0.0942
105	0.000166*1000=0.166
125	0.000139*1000=0.139

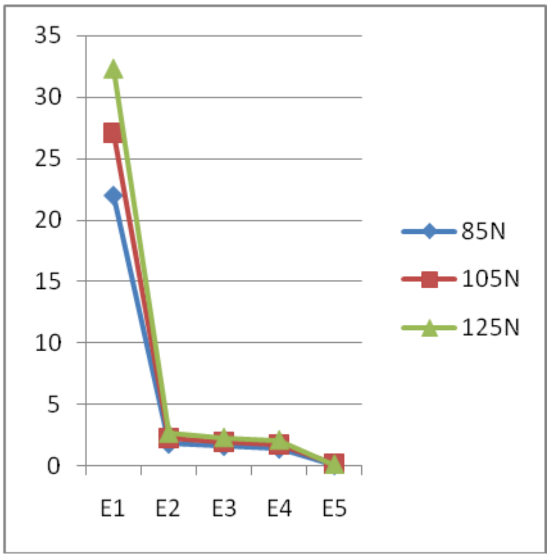


Fig. 12: *Load vs. Deformation.*

Table 8: *Variation of Deflection Rate.*

S. No.	Young's Modulus	Deflection Rate Between Loads.
1.	$E_2 = 1.8*10^{11}$	0.43
2.	$E_3 = 2.1*10^{11}$	0.37
3.	$E_4 = 2.3*10^{11}$	0.34

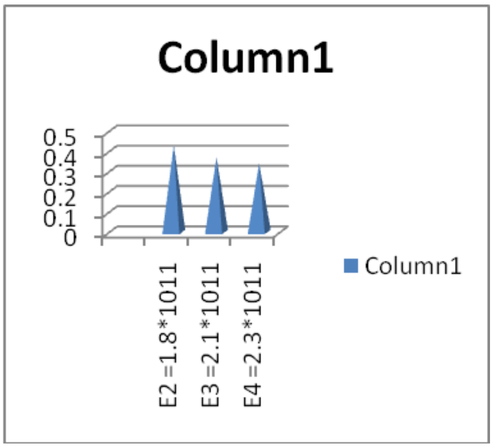


Fig. 13: *Deformation Rate.*

CONCLUSION

We have started these project with the question of effect of Young's Modulus on Stress and Deflection, by the analysis in work piece i.e., Leaf spring we are here come to conclude that-

1. Stress i.e., Principal Stress and Von Miss Stress are independent of the

Value of Young's Modulus, their values are vary with load only.

Theoretically:- Stress= Load/Area

So, there is no effect of Young's Modulus on the value of Stresses.

2. Deflection depends not only on Load but also on Young's Modulus too.
3. For Constant Young's Modulus, the deflection increases with load linearly.

   Theoretically:-

- **δ** = PL/AE
- Here, P= Load, L= Length, A=Area, E= Young's Modulus
- For Constant A, L, and E
- **δ** directrly depends on Load.
- i.e., Deflection will increase with increase in Load.

4. Rate of increase in deflection with load vary with different value of Young's Modulus. From the above analysis, we concluded that, increase of deflection rate decrease with increasing value of Young's Modulus.
5. Finally, from the analysis we come to conclusion that, value deflection decreases with increase in Young's Modulus.

- Theoreticallly:-
- **δ** = PL/AE
- Here, P= Load, L= Length, A=Area, E= Young's Modulus
- For Constant A, L, and P
- The magnitude of deflection is inversely proportional to Young's Modulus.

6. Ductility of anybody also depends upon the Young's Modulus, as the Young's Modulus decrease, ductility increases.
7. Rigidity of body increases, with increase in Young's Modulus.
8. Maximum safe load in Leaf Spring is decreases with decrease in Young's Modulus, although deflection increases and exceeds the limits.

These are the some conclusions that we got from the result of Analysis of Leaf Spring under different condition and after evaluating the result conclusion stated are defined

RESULT AND FUTURE SCOPE

RESULT

After whole analysis, finally we have found the importance of Young's Modulus determination, because its value directly affects the strength and capacity of any body.

FUTURE SCOPE

Since a material have many properties which defines the material strength and limitations and it is not easy to determine each of the properties in a single project, so there is a vast scope in this field to determine the effect of material properties. In this project the effect of Young' Modulus have been estimated only on Stress and Deformation in Static Case, many more things can also be perfomed to make more different reports. Finally, our project gets completed with the conclusions stated above that we get from this analysis.

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