Material Selection and STATIC Analysis of Leaf spring Using FEA and Taguchi Method

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Abstract

Leaf springs are special kind of springs used in automobile suspension systems. The main function of a leaf spring is not only to support vertical load but also isolate road induced vibrations. In this project, a typical leaf spring configuration from a commercial mini load carrier vehicle is chosen for study. The study searches for a new material for leaf spring. Materials such as Silicon Manganese Steel, Carbon fibre, silicon carbide, Co-Cr-Ni alloy, Al oxide (99% alumina) and beryllium alloy are checked for their suitability against conventional material. The leaf spring is modelled using SOLIDWORKS and static analysis is carried out using ANSYS 16.0 Workbench.

The objective of the present work is to compare the stresses and deformation on various classes of materials chosen for study. Static analysis is carried out for different materials and is compared with each other to obtain ideal material for production. It was observed from the static analysis results that the Carbon fibre exhibits better properties in comparison with other materials. Further, the performance of the leaf spring mainly depends upon the loading conditions and material selection. Hence, the results obtained for the material Carbon fibre can be validated through Taguchi method. From the overall perspective of static analysis and validation through Taguchi Method confirms that the Carbon Fibre which is a composite material can be considered as ideal material for construction of leaf springs.

1.Introduction

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Leaf springs absorb the vehicle vibrations, shocks and bump loads (induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system. Semi-elliptic leaf sprigs are almost universally used for suspension in light and heavy commercial vehicle. For cars also, these are widely used in rear suspension. The blades are usually given an initial curvature or cambered so that they will tend to strengthen under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps.

The spring is mounted on the axle of the vehicle. The entire vehicle load rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, leading to deflection of the spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So to accommodate this change in length, shackle is provided at one end which gives a flexible connection. The front eye of the leaf spring is constrained in all directions, whereas rear eye is not constrained in X-direction. This rear eye is connected to the shackle. During loading the spring deflects the upper side of each leaf tip slides or rubs against the lower side of the leaf above it. This produces some damping which reduces spring vibrations, but since this available damping may change with time, it is preferred not to avail of the same. Moreover, it produces squeaking sound. Further if moisture is also present, such as inter-leaf friction will cause fretting corrosion which decreases the fatigue. Strength of the spring, phosphate paint may reduce this problem fairly.

G. Harinath Gowd and Venugopal goud [1] presented a static analysis of leaf spring using finite elements methods to study and determine the safe stresses and pay loads of a leaf springs. The analysis was done on the typical leaf spring configuration of TATA -407 light commercial vehicles. It is observed that the maximum stress is developed at the inner side of the eye sections, so care must be taken in eye design and fabrication and material selection. The selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.

S. Surya Teja et al [2] have aimed to present low cost fabrication of e glass epoxy leaf spring with end joints and also general study on the design by using CATIA V5R19 123 and ANSYS12.0 A single leaf with variable thickness and width of constant cross sectional area Epoxy glass leaf spring with similar mechanical and Geometrical properties of Multi leaf spring Compared to the steel spring, the Composite spring ha stresses that are Much lower, the natural frequency is higher and The spring weight is nearly 85 % lower with bonded end joint and with complete eye Bonded end joint unit. Structural steel and e glass epoxy resins deformation, stress and strain values are tabulated e glass epoxy resins have little deformation, max stress and less strain so fabrication of leaf spring by using e glass epoxy resins are best suited.

Pankaj Saini et al [3] has produced a research on design and analysis of composite leaf spring. In this paper the objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. The design constraint is stiffness. The materials selected were glass fibre reinforced polymer (E-Glass/epoxy), carbon epoxy and graphite epoxy is used against conventional steel. From the static analysis results it is found that there is a maximum displacements in e- glass/epoxy, graphite/epoxy and carbon/epoxy are 15mm, 15.75mm and 16.21mm. From the static analysis results, we see that the von-Misses stress in e-glass/epoxy, graphite /epoxy and carbon/epoxy are 163.22 MPa, 653.68 MPa and 300.3 MPa respectively. Among the three composite leaf springs, only graphite/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite mono leaf spring reduces the weight by 81.21% for e-glass/epoxy, 91.95% for graphite/epoxy, and 90.51% for carbon/epoxy over conventional leaf spring.

Rajagopal D et al [4] have done research on design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring and describes the significant economic potential of polymer composite and to replace automobile components (leaf Spring) against the steel. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings. A comparative study has been made between composite and steel leaf spring with respect to weight, cost and strength. From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications. Composite leaf spring reduces the weight by 85 % for E-Glass/Epoxy, over conventional leaf spring.

Rohit Gosh et al [5] have experimented to estimate the magnitude of bending stresses in the above mentioned leaves for a semi-elliptic multi-leaf spring made of steel. Their work validates the concept of cantilever beam employed in the theoretical analysis of multi-leaf spring. A lot of research work has been carried out in the context of leaf spring considering its material and a significant progress has been observed in the field of weight reduction, improvement of load carrying capacity when we replace the material of the spring by any advanced material like composites as E-glass/epoxy, carbon/epoxy etc. Dimensions of the multi-leaf spring are taken from practical understanding. The multi-leaf spring was modelled in CATIA V5R18 and the same were analyzed under similar conditions using ANSYS (Workbench16.0) software considering structural-steel as the spring material. Theoretical and software based results are presented and compared for validation.

Syambabu Nutalapati [6] has analyzed design constraint is stiffness. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance.

The material selected was glass fibre reinforced polymer (E-glass/epoxy) is used against conventional steel. The design parameters were selected and analysed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring.

Result shows that, the weight of composite leaf spring was nearly reduced up to 85% compared with steel material. The leaf spring was modeled in Pro/ENGINEER and the analysis was done using ANSYS 12.0 software. The fatigue life of both steel and composite leaf is compared using ANSYS software. From the static analysis results, we see that the von- Misses stress in the steel is 352.917 MPa. And the von- Misses stress in E-glass/Epoxy is 178.356 MPa.

Scope of the work from Literature Survey:

From the literature survey, the authors have identified some of the gaps in the selection of materials for a leaf spring. Hence the authors have made an attempt to study the behaviour of ferrous, non-ferrous and composite materials by carrying static and modal analysis. The authors further embarked to identify the ideal material for the manufacturing of leaf spring through Taguchi method.

2.Static Analysis of A Leaf Spring

2.1.Silicon Manganese Steel (55Si2Mn90):

The static structural solution of the equivalent stress for the given parameters for manganese silicon steel gives the maximum von misses as 705.38 MPa as shown in the figure 1.The static structural solution of the deflection for the given parameters for manganese silicon steel gives the maximum value as 77.959 mm.

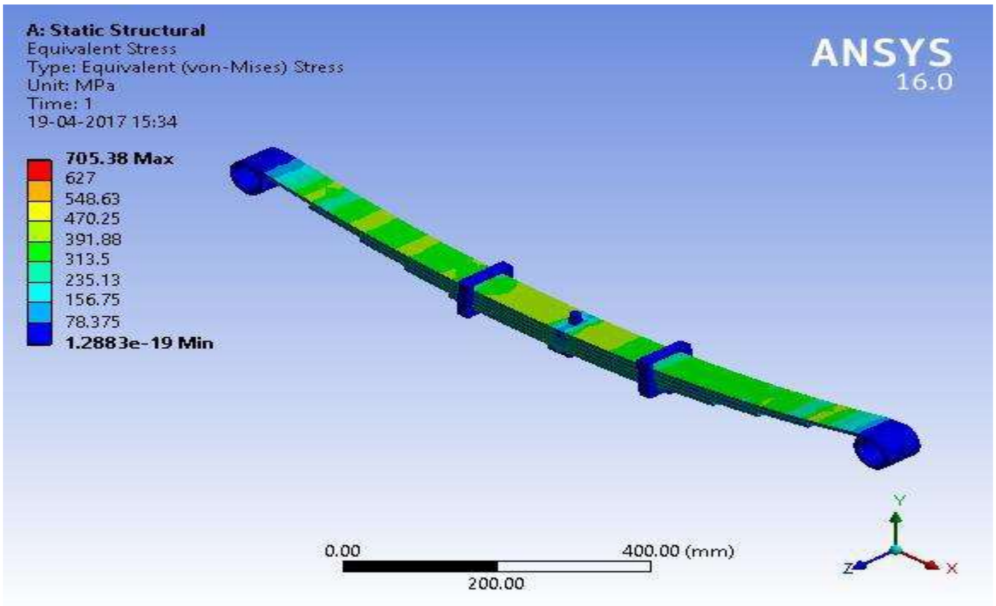

Fig 1. Equivalent Stresses of 55Si2Mn90

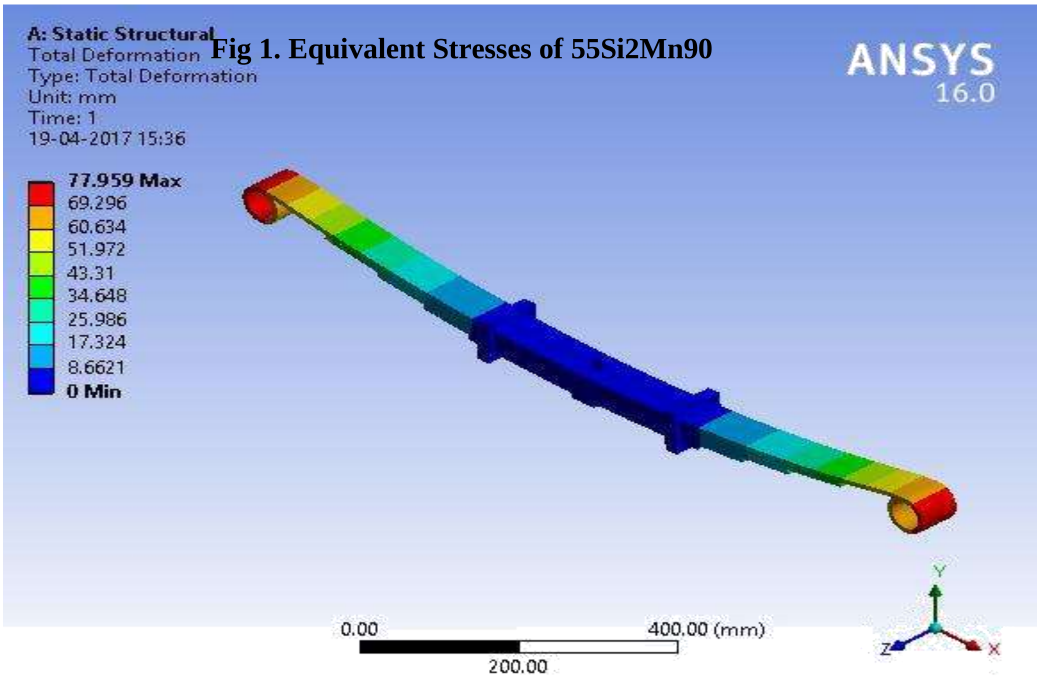

Fig 2. Total deformation of 55Si2Mn90

2.2. Carbon Fibre:

The static structural solution of the equivalent stress for the given parameters for carbon fibre gives the maximum von misses as 673.8 mm as shown in the figure 3. The static structural solution of the deflection for the given parameters for manganese silicon steel gives the maximum value as 39.853 mm.

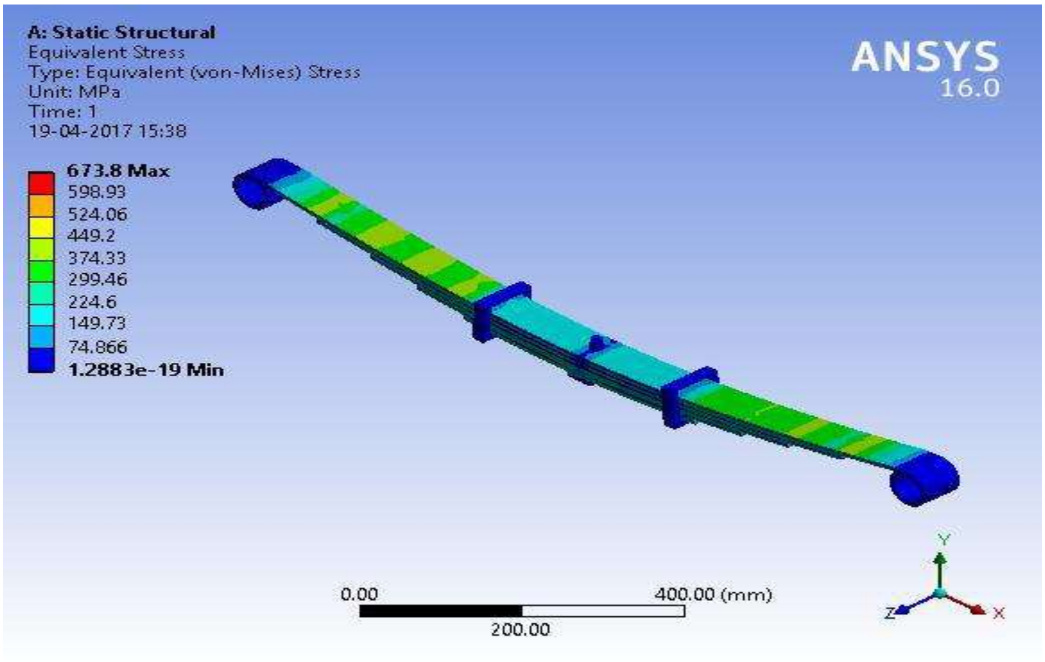

Fig 3. Equivalent stress of Carbon Fibre

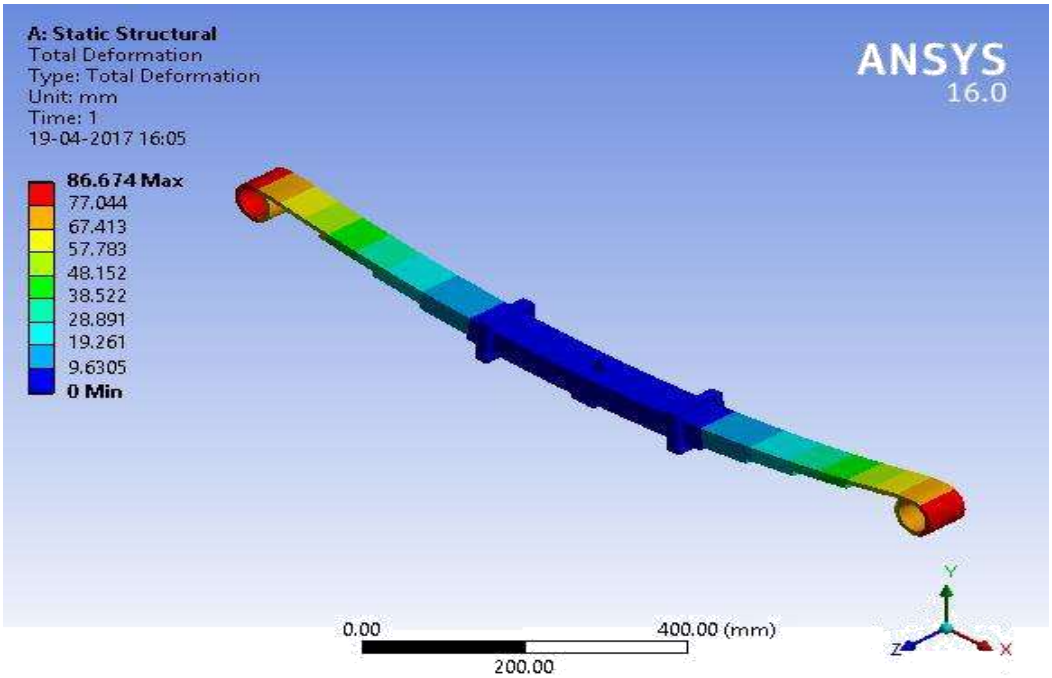

Fig 4. Total Deformation of Carbon Fibre

2.3. Cobalt-Chromium-Nickel (Co-Cr-Ni) Alloy:

The static structural solution of the equivalent stress for the given parameters for Cobalt-Chromium-Nickel gives the maximum von misses as 711.3 MPa as shown in the figure 5.

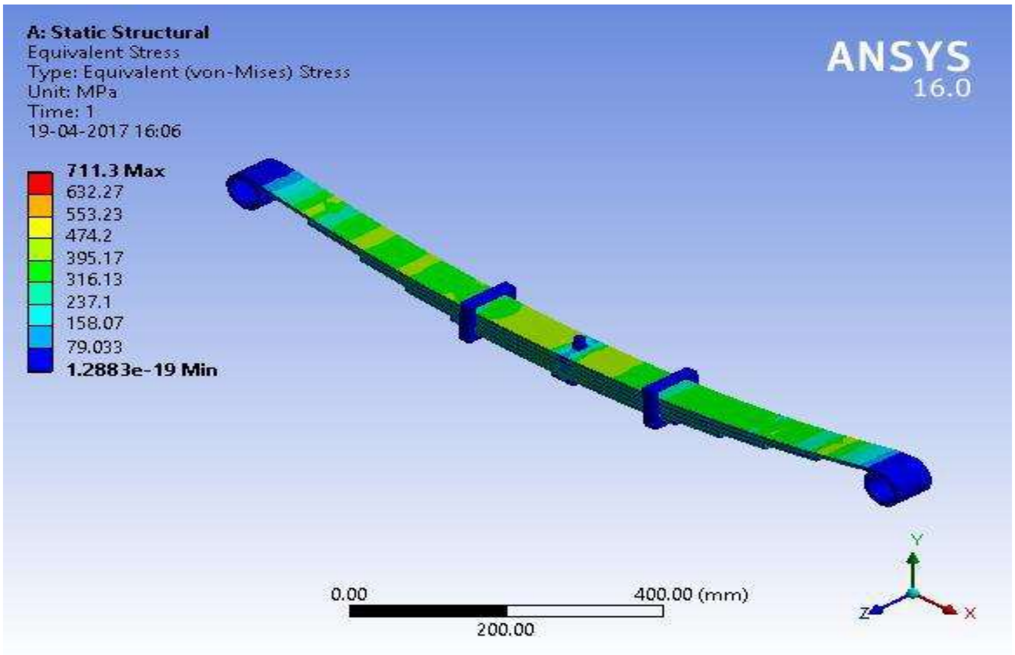

Fig 5. Equivalent stress of Co-Cr-Ni Alloy

The static structural solution of the deflection for the given parameters for Cobalt-Chromium-Nickel gives the maximum value as 86.674mm

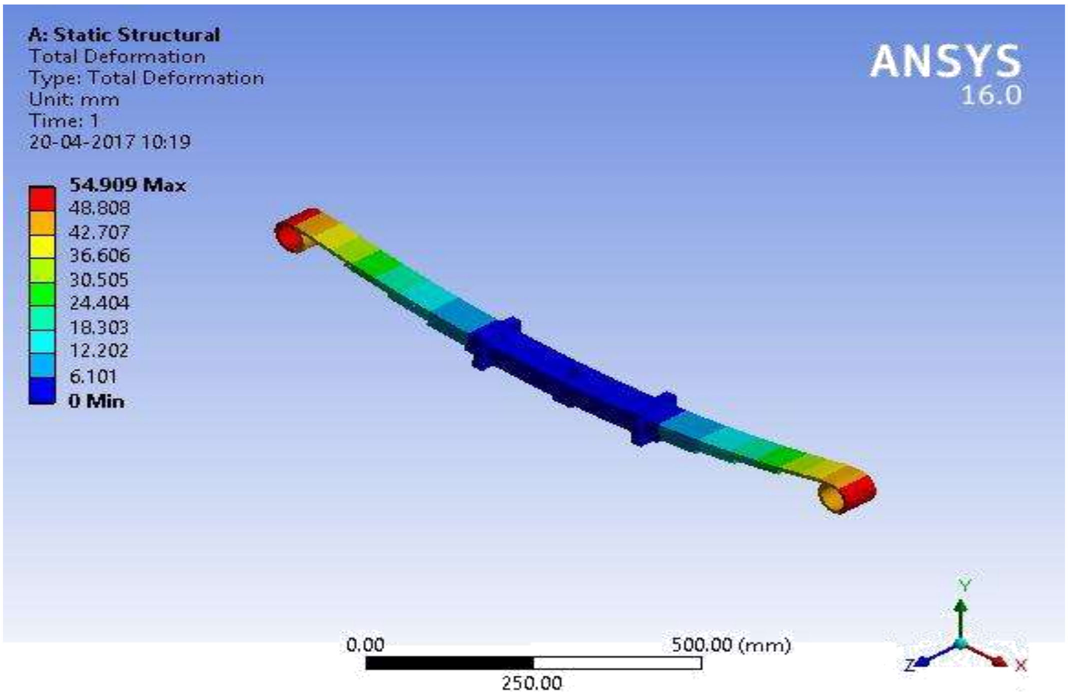

Fig 6. Total deformation of Co-Cr-Ni alloy

2.4.**Silicon carbide (SiC):**

The static structural solution of the equivalent stress for the given parameters for silicon carbide gives the maximum von misses as 724.15 MPa as shown in the figure 7.The static structural solution of the deflection for the given parameters for silicon carbide gives the maximum value as 40.715 mm.

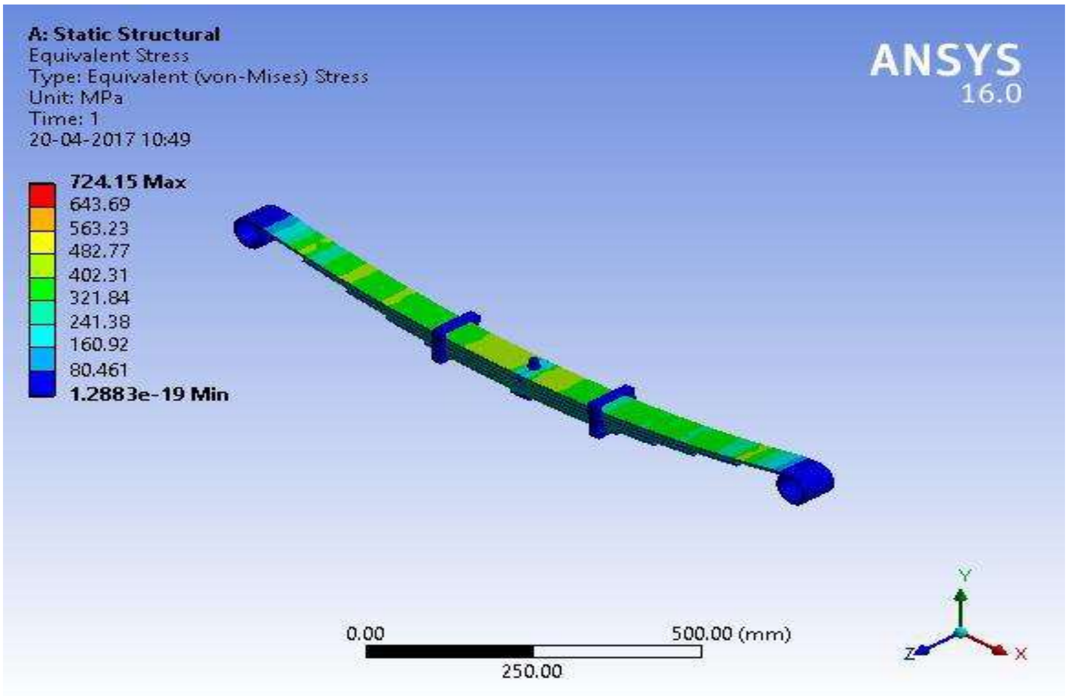

Fig 7. Equivalent stress of silicon carbide

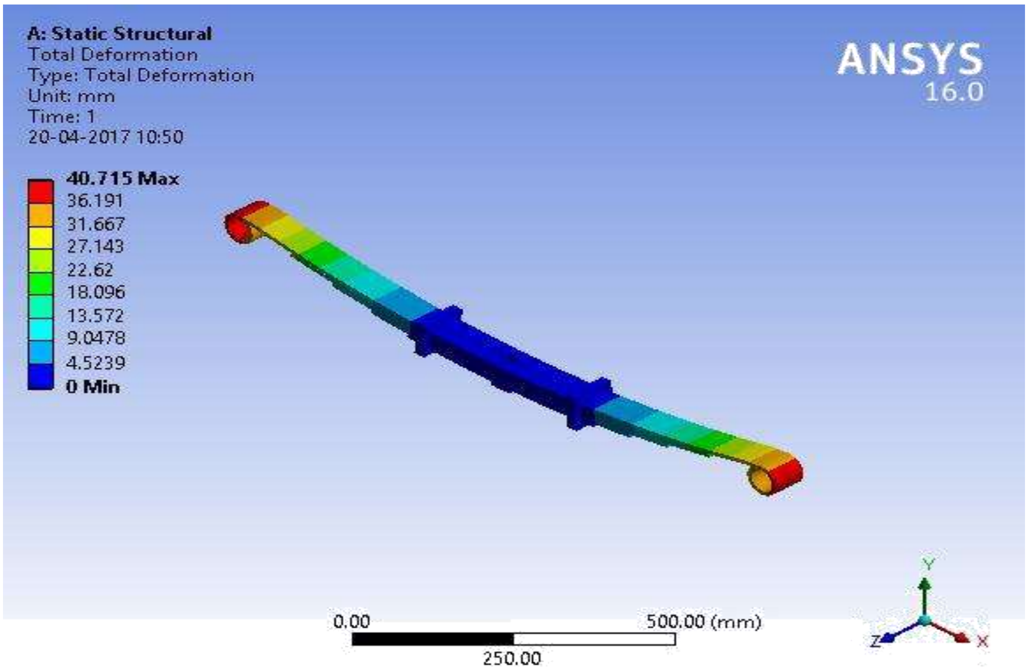

Fig 8.Total Deformation of Silicon Carbide

2.5.BERYLLIUM SULPHUR (Be-S200):

The static structural solution of the equivalent stress for the given parameters for Beryllium sulphur gives the maximum von misses as 731.7 MPa as shown in the figure 9.

The static structural solution of the deflection for the given parameters for Beryllium sulphur gives the maximum value as 54.9 mm.

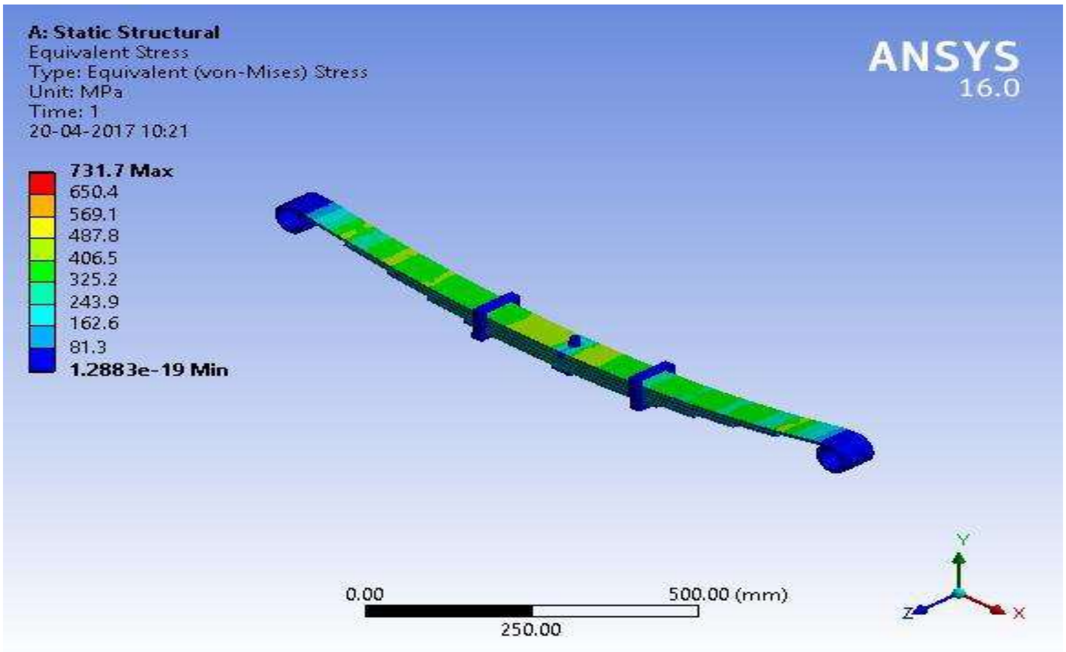

Fig 9. Equivalent stress of Beryllium sulphur-200

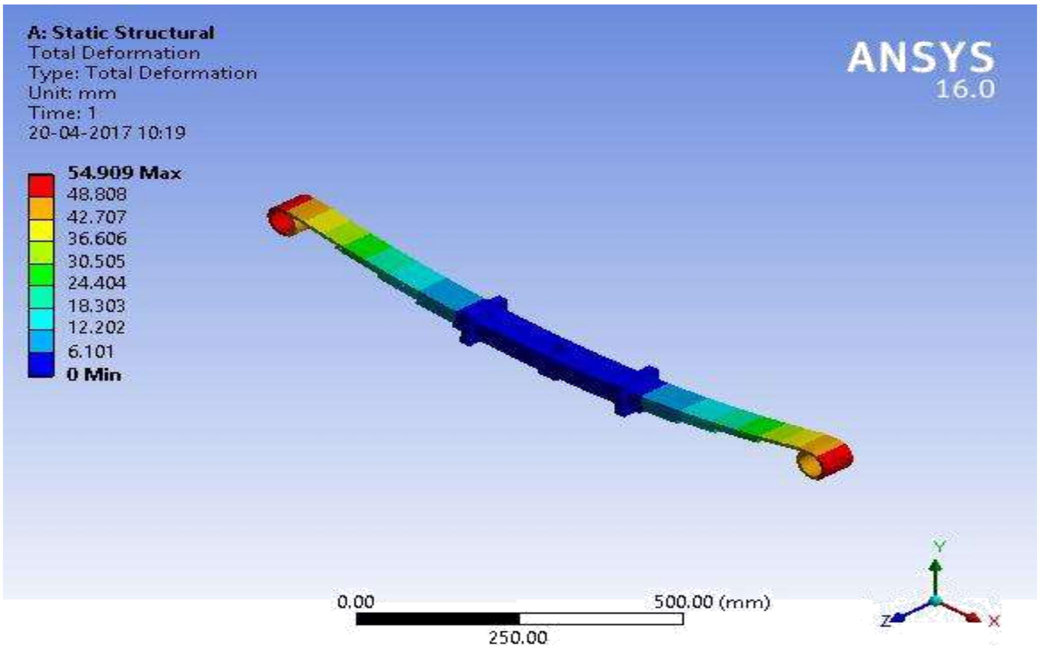

Fig 10.Total Deformation of Beryllium Sulphur-200

2.6. Aluminium oxide (99% alumina):

The static structural solution of the equivalent stress for the given parameters for Aluminium oxide gives the maximum von misses as 708 MPa as shown in the figure 11.
The static structural solution of the deflection for the given parameters for Aluminium oxide gives the maximum value as 44.856 mm as shown in the figure 12.

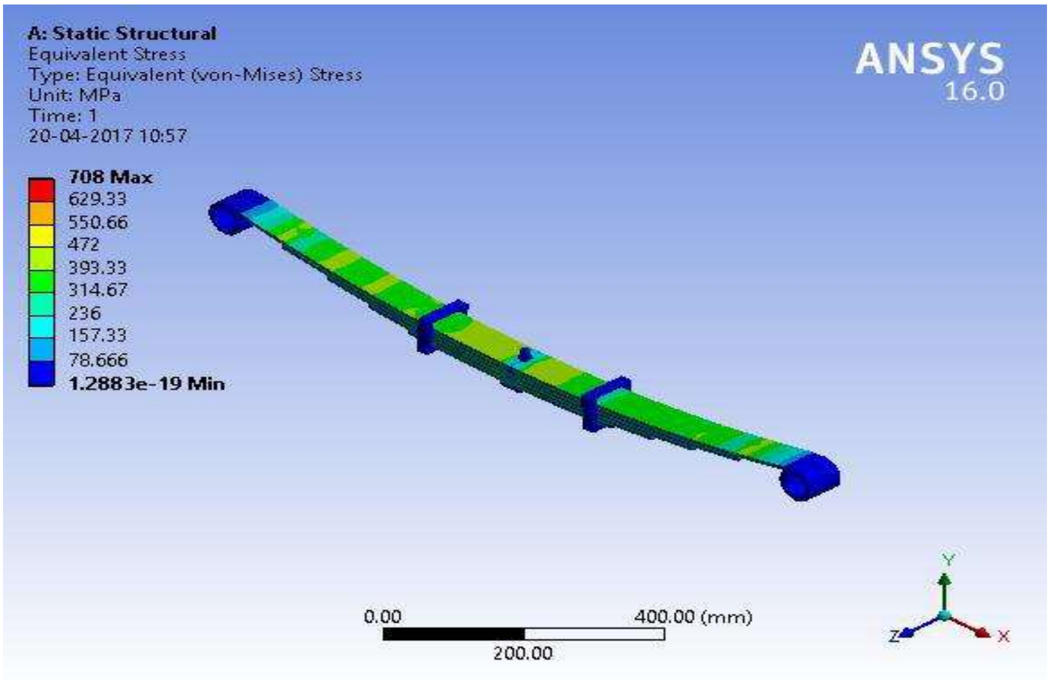

Fig 11. Equivalent stress of Aluminium oxide

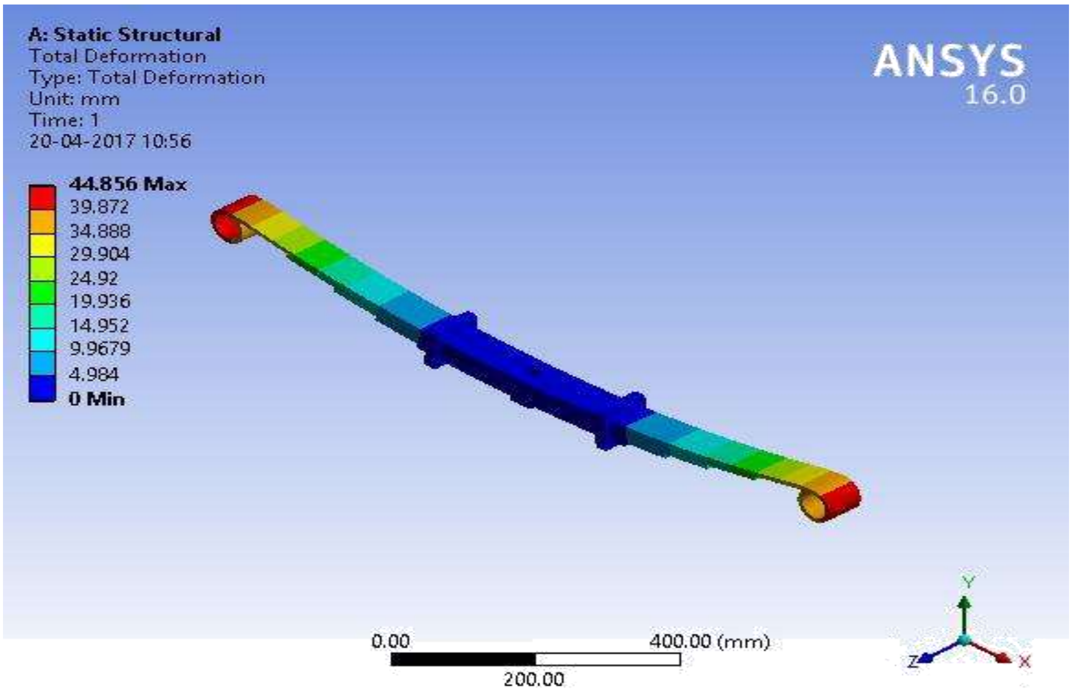

Fig 12. Total Deformation of Aluminium oxide

3. Results and Discussions

A brief study of leaf spring was done using ANSYS software. The results of stress and deflection for each material are discussed below.

3.1 Variation of von-Misses stress:

Table 1. Variation of von-Misses stress for different materials.

Sl.no.	Material	Von-Misses stress (MPa)
1	55Si2Mn90	705.07
2	Carbon fibre	673.8
3	Co-Cr-Ni alloy	711.3
4	Al-oxide (99% alumina)	708
5	Silicon carbide	724.15
6	Be-S200	731.7

3.2.Variation of deformation of various materials:

Table 2. Total deformation of different Materials

Sl.no.	Material	Total deformation (mm)
1	55Si2Mn90	77
2	Carbon fiber	39.853
3	Co-Cr-Ni alloy	86.6
4	Al-oxide(99% alumina)	44.856
5	Silicon carbide	40.715
6	Be-S200	54.9

3.3.Material Selection And Validation By Taguchi Method

The selection of material was validated with the help of single objective optimization tool called taguchi method and the results were discussed in this chapter. From the static analysis of leaf spring, the carbon fibre was found as the flexible and most suitable material among all the alternatives tested. Here, the standard taguchi method was employed in order to select the material along with their mechanical properties with respect to the ANSYS results of Von-misses stresses and the deformation values. The main effect plot results of Taguchi for Von-misses stresses and deformation were drawn and shown in figures 13,14,15 and 16 respectively.

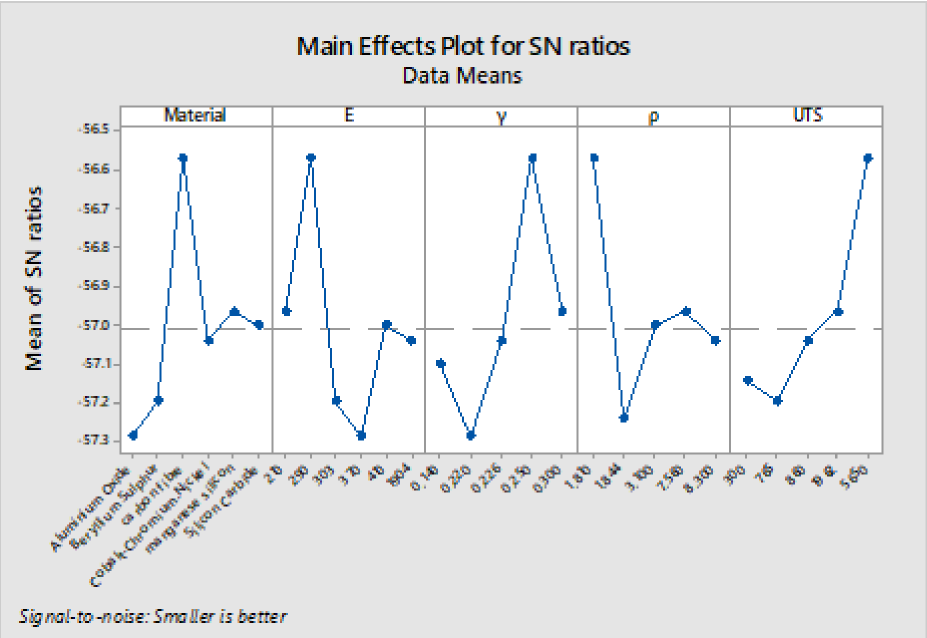

Figure 13. Mean of S/N Ratios of Von-Misses Stresses

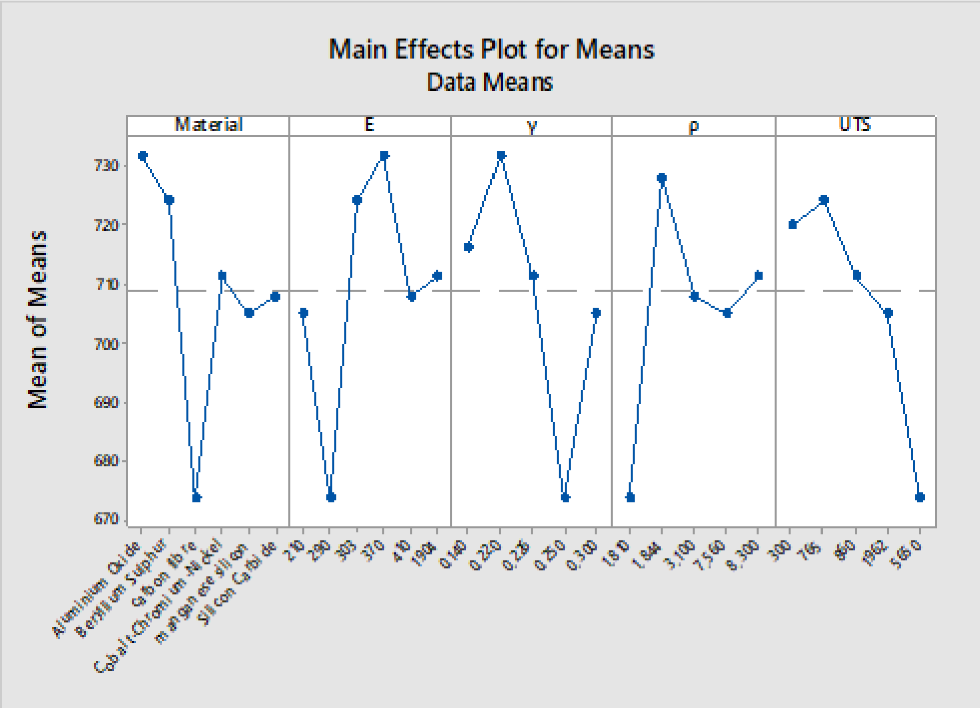

Fig 14. Mean of S/N Ratios of Von-Misses Stresses

From the figures 13 and 14, it is found that the carbon fibre is the most suitable material for the leaf spring in order to sustain the required mechanical properties. Similarly, Taguchi method was employed for the results of deformation with change in materials. The results showed that the carbon fibre is most suited and less deformation was observed the same is observed in the figures 15 and 16.

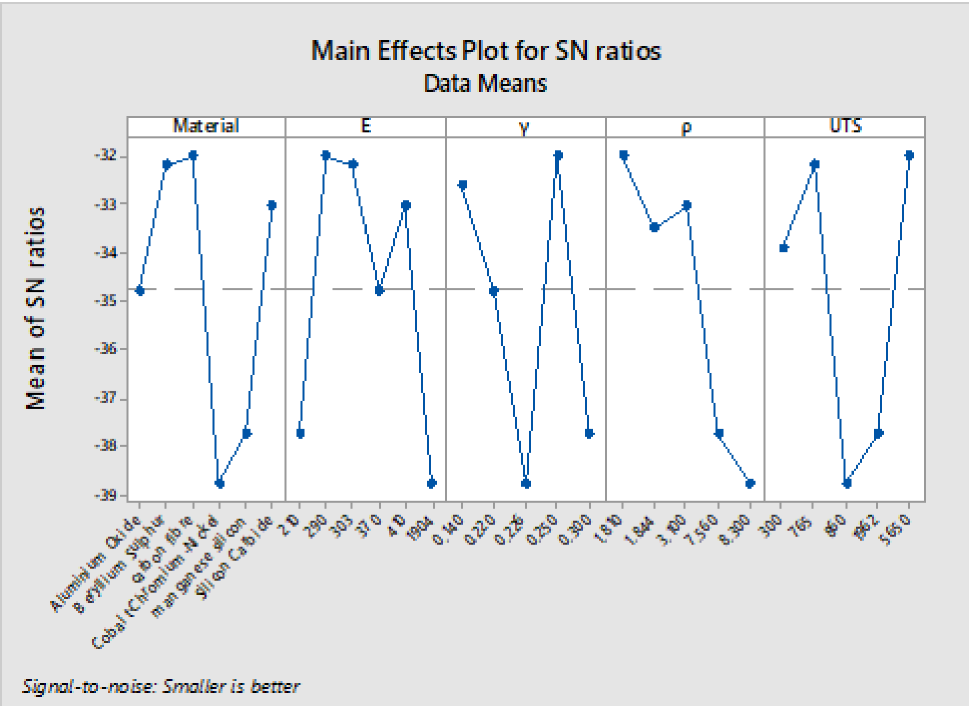

Fig 15. Mean of S/N Ratios of Von-Misses Stresses

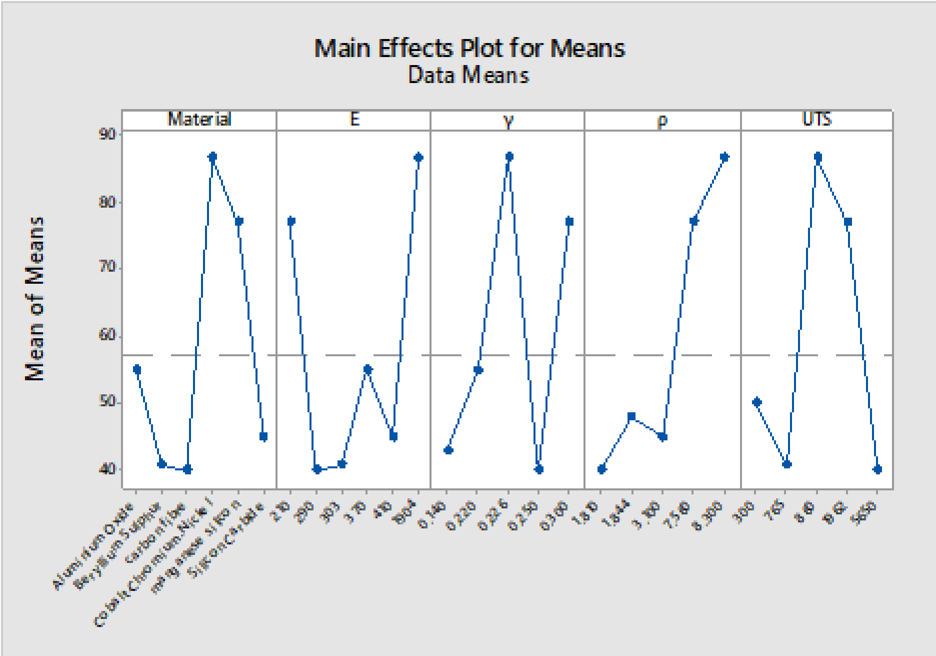

Fig 16. Mean of S/N Ratios of Von-Misses Stresse

4. Conclusions

The objective of the work is to study the behaviour of Leaf Springs adopted for automobile under static loading conditions. The material properties of the leaf spring were altered and the behavior of the leaf spring was analyzed through static analysis. The modelling was done in Solid Works and analysis is carried out through ANSYS 16.0. The following conclusions were drawn from this work.

- It is observed from the static analysis that the composite material, namely carbon fibre is the best possible material of construction for Leaf Springs. The stresses and deformation are minimum for Carbon fibre and maximum for Be-S 200 and Co-Cr-Ni Alloy respectively.
- The factor of safety is highest for Carbon fibre and least for other materials.
- The values of CO-Cr Ni alloy are also closer to the carbon fiber reinforced composite leaf spring plate. The values of Von mises stress and deformation for CO-Cr Ni alloy is below the permissible values of the material. Therefore, carbon fiber reinforced composite plate and CO-Cr Ni alloy can be successfully used to replace the current existing materials for a mini load carrier type of automobile applications.
- The validation of material selection was successfully carried out using Taguchi-TOSIS method. The results shown that Carbon fibre is a best suitable material for the fabrication of leaf spring, which is duly good in agreement with the static analysis results in material selection.

Taking, the results of analysis into perspective it can be finally concluded that carbon fibre is the best material.

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