Static Structural Analysis of Industrial and Automobile Suspension System

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Abstract— Suspension system is an important component in any automobile. Whenever any automobile is in moving condition, we need some system to absorb the shocks and jerks which happen because of irregularities, pits and holes on the road. Suspension system is employed for this vary role. Suspension systems may be of several types but for current study, compression helical spring has been considered. Conventionally low carbon steel (mild steel or structural steel) has been used for manufacturing the disc brake rotors but it is accompanied by a large weight which in turn increases the overall weight of vehicle. This increased weight increases the losses occurring in the vehicle during movement. It also reduces the mechanical efficiency. To counter these two problems, we must go for some other materials which can have lower weight & higher tensile strength, compressive strength etc. In this particular study six different materials have been tried & tested. These materials are Aluminium Alloy, Aluminium, Carbon Fibre, Epoxy Carbon, Epoxy E-Glass, High Carbon Steel, Inconel 625, Inconel 718, Stainless Steel and Titanium Alloy. These materials have been analysed for Total Deformation, Shear Stress, Shear Elastic Strain, Equivalent Stress, Maximum Principal Stress, Maximum Shear Stress & Weight. In the end a comparative analysis has been presented. In order to develop the model of disc brake rotor for conducting analytical solution in software, CATIA V5-6 R2017 software will be used to develop the model & ANSYS 19.2 will be used to analyze the model.

Keywords: Mechanical Efficiency, CATIA V5-6 R2017, ANSYS 19.2, Total Deformation, Shear Stress, Shear Elastic Strain, Equivalent Stress, Maximum Principal Stress, Maximum Shear Stress & Weight

I. INTRODUCTION

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other. The tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

A spring is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil springs.

When a conventional spring, without stiffness variability features, is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length (this approximation breaks down for larger deflections). The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring.

A coil spring is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded.

Under tension or compression, the material (wire) of a coil spring undergoes torsion. The spring characteristics therefore depend on the shear modulus, not Young's Modulus.

A composite material (also called a composition material or shortened to composite, which is the common name) is a material which is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements.

Following objectives for the current analysis are being selected-

- Selecting four wheelers for the current research project.
- Static structural analysis is to be performed for helical springs in order to analyse the working of springs.
- Static structural analysis will be focused in order to compare the working of helical springs foe different materials and if possible, a new material which may be more useful than the conventional material will be identified.
- Modal analysis of the helical springs will also be performed in order to obtain and examine various mode shapes for springs.

II. PROBLEM STATEMENT

For the current study purpose a compression helical spring will be analysed for different materials in order to optimize its design.

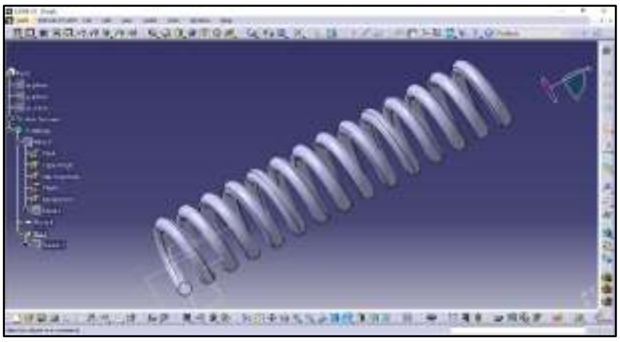

Fig. 1: Model of Helical Spring

A. Performance Parameters

Different performance parameters will be analysed on the basis of which a comparative analysis would be performed in order to optimize the design of Multi plate clutch. Some of the performance parameters are as follows-

– Total Deformation
– Shear Stress
– Shear Elastic Strain
– Equivalent Stress
– Maximum Principal Stress
– Maximum Shear Stress
– Weight

B. Materials to be Analysed

Different types of conventional and non-conventional materials will be used to prepare the comparative analysis among materials and the primary objective will be to choose whether we can use any other material than the conventional material which is generally used for development of clutches in automobiles. Some of the materials are listed below-

– Aluminium Alloy,
– Aluminium,
– Carbon Fibre,
– Epoxy Carbon,
– Epoxy E-Glass,
– High Carbon Steel,
– Inconel 625,
– Inconel 718,
– Stainless Steel and
– Titanium Alloy

III. ANSYS ANALYSIS OF SPRING

Helical compression spring's model is developed in CATIA V5-6 R2017. One must be able to work efficiently with ANSYS for simulation purpose because ANSYS is known as a software which is used for modelling of numerous mechanical components and their analysis in order to evaluate its performance. ANSYS just like all the other modelling software is a parametric software and hence if any slight change is made to one entity of the component, all the other entities of the component vary accordingly.

Modelling of the spring has been conducted on CATIA V5-6 R2017. Step by step procedure for modelling of helical compression spring is as discussed below-

There are different procedures available for modelling of helical compression spring namely top-down approach & bottom -up. Here we utilize bottom-up approach for the modelling of helical compression spring-

– Create below cited sketch using the helical compression spring data already calculated in the chapter of "Problem Statement". All the components (Only one component is there in this study) will be modelled separately according to bottom-up approach.
– After the modelling of all the components in Part Design workbench of CATIA V5-6 R2017, these will be assembled as and when needed.
– After developing the model in CATIA V5-6 R2017 proceed as follows-
– Begin with the analysis process of the 3D model in ANSYS & drag the icon of module for static structural.
– Select material structural steel.

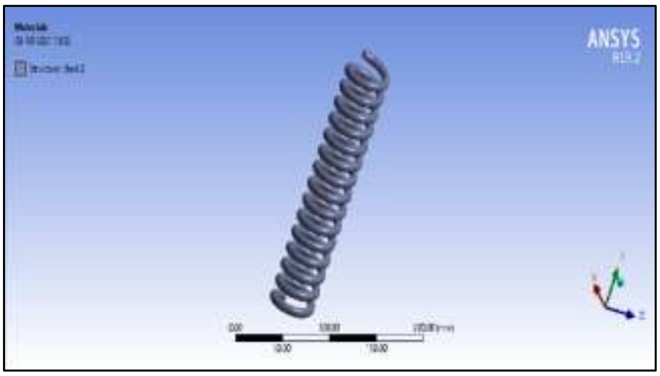

Fig. 2: Applying the material on the model

– Complete the meshing of the component

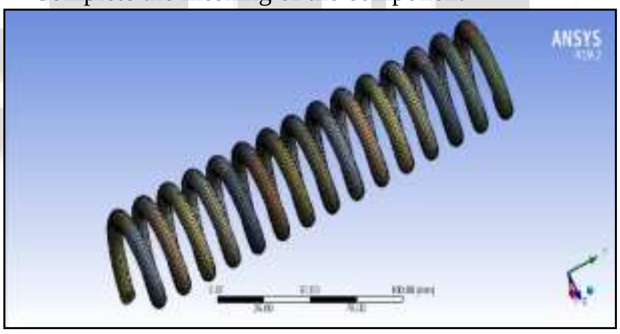

Fig. 3: Meshing of the Model

– Apply boundary condition

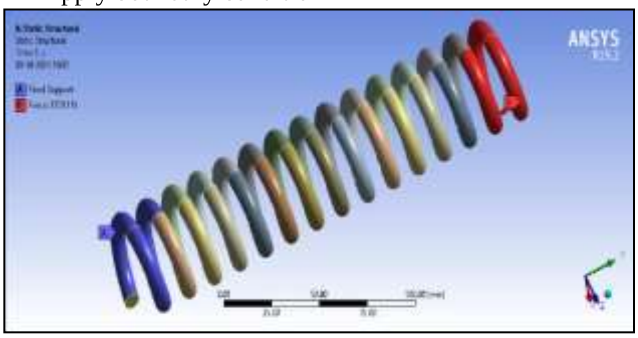

Fig. 4: Applying Boundary Conditions

– Run the analysis
– Get the results.

Analysis of conventional material helical spring yields several results. For example, shear stress and total deformation patterns have been presented here.

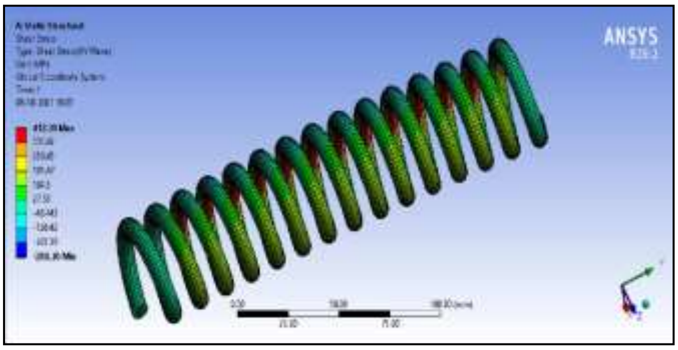

Fig. 5: Shear Stress Distribution for Spring

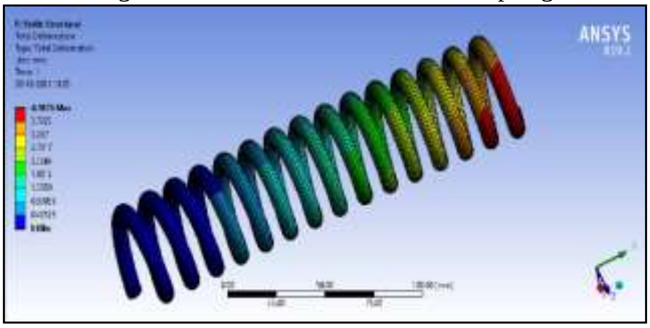

Fig. 6: Total Deformation Distribution for Spring

Similar analysis has been done for other materials too. Static structural analysis yields following results-

S. No.	Material	Parameter	Parameter Value
01	Aluminium Alloy	Total Deformation	12.007 mm
02		Shear Stress	412.29 MPa
03		Shear Elastic Strain	0.0015446 mm/mm
04		Equivalent Stress	899.47 MPa
05		Maximum Principal Stress	674.68 MPa
06		Maximum Shear Stress	519.28 MPa
07		Weight	0.26252 Kg
08	Aluminium	Total Deformation	12.092 mm
09		Shear Stress	412.29 MPa
10		Shear Elastic Strain	0.0015556 mm/mm
11		Equivalent Stress	899.47 MPa
12		Maximum Principal Stress	674.68 MPa
13		Maximum Shear Stress	519.28 MPa
14		Weight	0.25684 Kg
15	Carbon Fiber	Total Deformation	130.72 mm
16		Shear Stress	599 MPa
17		Shear Elastic Strain	0.0066555 mm/mm
18		Equivalent Stress	1054 MPa
19		Maximum Principal Stress	708.27 MPa
20		Maximum Shear Stress	608.48 MPa
21		Weight	0.17059 Kg
22	Epoxy Carbon	Total Deformation	335.18 mm
23		Shear Stress	676.75 MPa
24		Shear Elastic Strain	0.0014399 mm/mm
25		Equivalent Stress	1199.1 MPa
26		Maximum Principal Stress	737.9 MPa
27		Maximum Shear Stress	692.24 MPa
28		Weight	0.14121 Kg
29	Epoxy E-Glass	Total Deformation	297.71 mm
30		Shear Stress	675.16 MPa
31		Shear Elastic Strain	0.013503 mm/mm
32		Equivalent Stress	1176 MPa
33		Maximum Principal Stress	796.83 MPa
34		Maximum Shear Stress	678.86 MPa
35		Weight	0.18955 Kg
36	High Carbon Steel	Total Deformation	3.927 mm
37		Shear Stress	412.43 MPa
38		Shear Elastic Strain	0.00050192 mm/mm
39		Equivalent Stress	910.18 MPa
40		Maximum Principal Stress	667.09 MPa
41		Maximum Shear Stress	525.49 MPa
42		Weight	0.74397 Kg
43	Inconel 625	Total Deformation	5.1222 mm
44		Shear Stress	412.47 MPa
45		Shear Elastic Strain	0.00065078 mm/mm
46		Equivalent Stress	754.05 MPa
47		Maximum Principal Stress	538.33 MPa
48		Maximum Shear Stress	429.66 MPa
49		Weight	0.79989 Kg
50	Inconel 718	Total Deformation	5.0963 mm
51		Shear Stress	412.13 MPa
52		Shear Elastic Strain	0.00064949 mm/mm

53		Equivalent Stress	751.49 MPa
54		Maximum Principal Stress	539.74 MPa
55		Maximum Shear Stress	428.87 MPa
56		Weight	0.77895 Kg
57	Stainless Steel	Total Deformation	4.3654 mm
58		Shear Stress	412.36 MPa
59		Shear Elastic Strain	0.00055978 mm/mm
60		Equivalent Stress	904.91 MPa
61		Maximum Principal Stress	670.82 MPa
62		Maximum Shear Stress	522.44 MPa
63		Weight	0.7345 Kg
64	Titanium Alloy	Total Deformation	9.0364 mm
65		Shear Stress	412.2 MPa
66		Shear Elastic Strain	0.0011679 mm/mm
67		Equivalent Stress	890.88 MPa
68		Maximum Principal Stress	680.69 MPa
69		Maximum Shear Stress	514.31 MPa
70		Weight	0.43786 Kg

Table I: Result Analysis for Different Materials

IV. RESULT ANALYSIS

Total of eleven different materials have been used in this work in order to identify the appropriate material. The materials include Aluminium Alloy, Aluminium, Carbon Fibre, Epoxy Carbon, Epoxy E-Glass, High Carbon Steel, Inconel 625, Inconel 718, Stainless Steel, Structural Steel and Titanium Alloy. All the materials need to be investigated & analysed on 6 different process parameters. Result analysis & discussion for each & every process parameter is being done as follows-

– Graph of equivalent (von-mises) stress distribution is indicating that for aluminium, aluminium alloy, Inconel 625, Inconel 718, Titanium Alloy and Stainless Steel the value of equivalent (von-mises) stress much lesser than for structural steel material but as one moves towards composite materials there is a sudden increment in equivalent stress value. Overall figure shows that for Epoxy Carbon, equivalent stress is maximum. According to this criterion any one of the aluminium, aluminium alloy, Inconel 625, Inconel 718, Titanium Alloy and Stainless Steel may be used as the replacement material for structural steel which will produce better results.

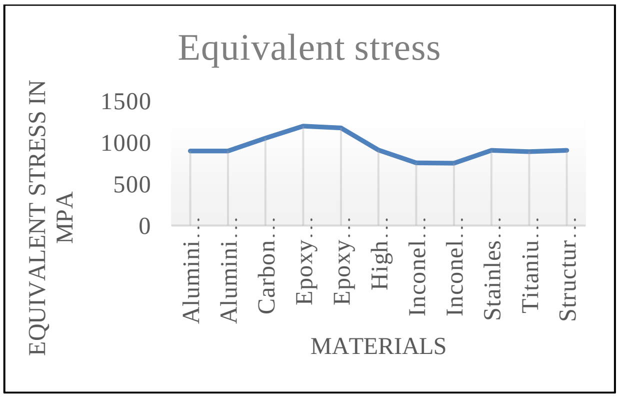

Fig. 7: Equivalent Stress Pattern

– Graph of total deformation distribution is indicating that for high carbon steel the value of total deformation is lesser than structural steel. For Inconel 625, Inconel 718 and stainless steel, the value of total deformation is approximately equal to that of structural steel but as one moves towards composite materials there is a sudden increment in total deformation value. Overall figure shows that for Epoxy carbon, total deformation is maximum. Hence according to this criterion Inconel 625, Inconel 718 or stainless steel may be used as the material for given component and structural steel can be replaced by these materials.

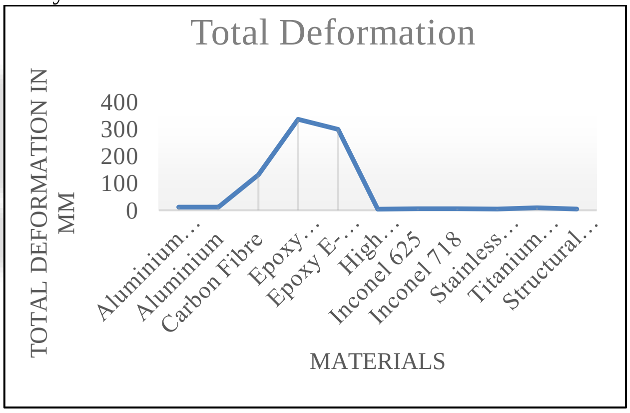

Fig. 8: Total Deformation Pattern

– Graph of maximum principal stress distribution is indicating that for epoxy carbon and epoxy E-Glass the value of maximum principal stress increases suddenly as compared to structural steel but as one moves towards Inconel 625, Inconel 718 and high carbon steel, there is a decrement in maximum principal stress value. Overall figure shows that for composite materials, maximum principal stress is maximum & for Inconel materials, maximum principal stress is minimum. Hence according to this criterion, Inconel materials can be more efficiently used as the materials for helical compression springs.

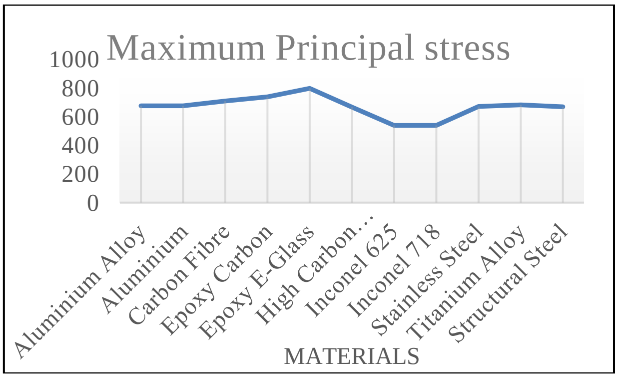

Fig. 9: Maximum Principal Stress Pattern

- Graph of shear elastic strain distribution is indicating that for Inconel 625 and Inconel 718 the value of shear elastic strain approximately equal to that of structural steel but as one moves towards composite materials there is a sudden increment in shear elastic strain value. Overall figure shows that for Epoxy E-Glass, shear elastic strain is maximum & for Inconel materials, shear elastic strain is minimum and hence these materials can be used as the replacement for structural steel.

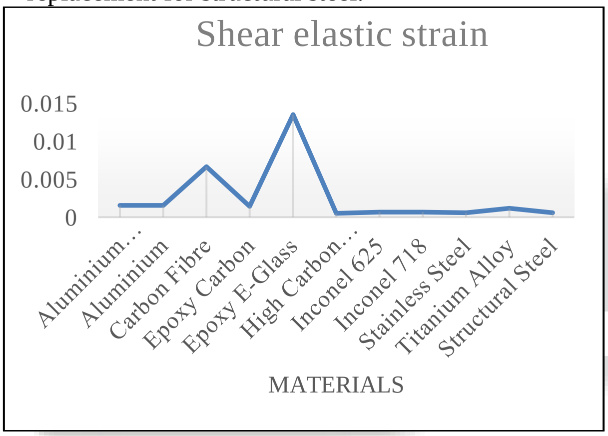

Fig. 10: Shear Elastic Strain Pattern

- Graph of sear stress distribution is indicating that for aluminium, aluminium alloys, high carbon steel, Inconel 625, Inconel 718, stainless steel and titanium alloy the value of shear stress is approximately equal to that of structural steel but as one moves towards composite materials there is a sudden increment in shear stress value. Overall figure shows that for Epoxy carbon, shear stress is maximum & for Inconel materials, shear stress is minimum.

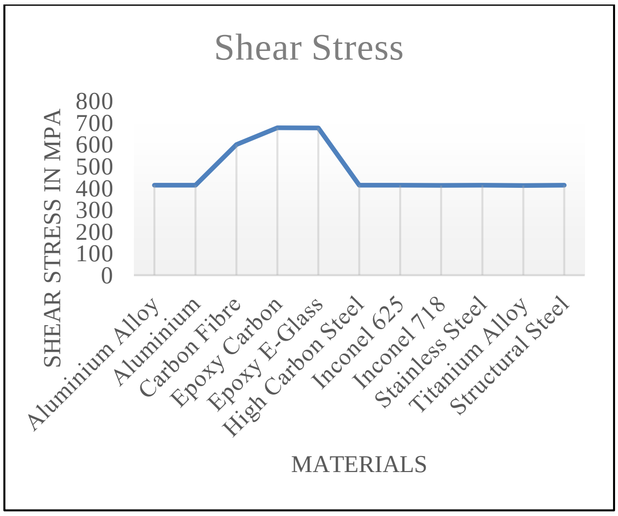

Fig. 11: Shear Stress Distribution

- Graph of Maximum Shear Stress distribution is indicating that for aluminium, aluminium alloys, high carbon steel, stainless steel and titanium alloy the value of maximum shear stress is approximately equal to that of structural steel but as one moves towards composite materials there is a sudden increment in strain energy value. For Inconel 625 and Inconel 718, the value of maximum shear stress is much lesser than structural steel. Overall figure shows that for Epoxy carbon, maximum shear stress is maximum & for Inconel materials, maximum shear stress is minimum.

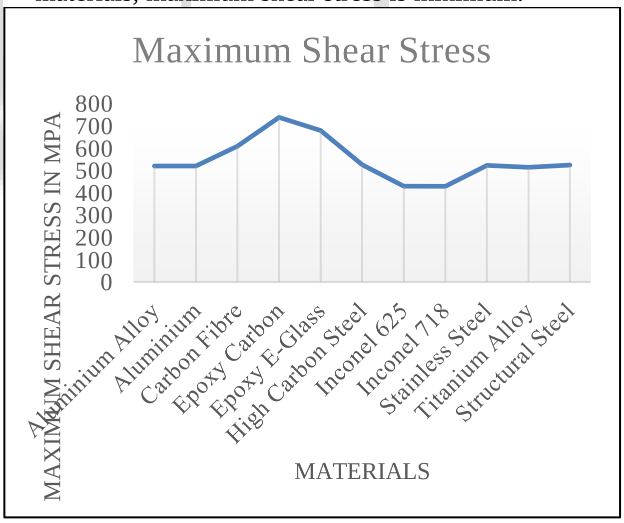

Fig. 12: Maximum Shear Stress Pattern

- Graph of weight distribution is indicating that for aluminium, aluminium alloys, composite materials and titanium alloy, the value of weight suddenly decreases as compared to structural steel. For high carbon steel, Inconel materials and stainless steel, weight is approximately equal to structural steel. Overall figure shows that for aluminium along with its alloys & composite materials there will be a drastic reduction in weight in comparison to the weight of structural steel.

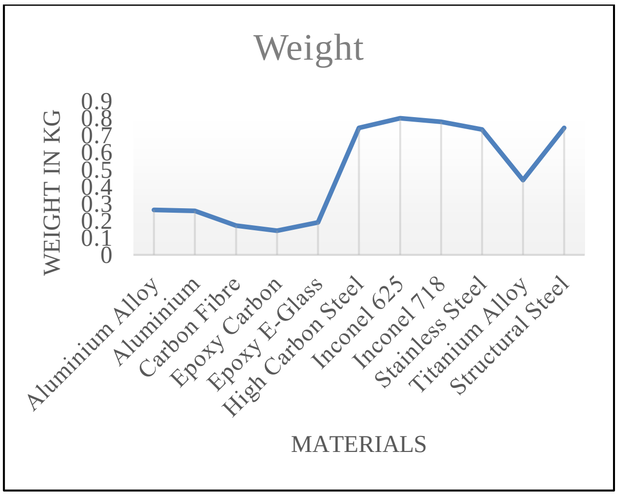

Fig. 13: Weight Comparison among Materials

V. CONCLUSIONS

Looking at the numerical analysis & ANSYS simulation of all these materials it is proposed that

- Inconel 625 and Inconel 718 both may be used as the alternate material when compared to structural steel (low carbon steel or mild steel) for the manufacturing of helical compression spring which is being used as suspension system for two wheelers.
- This proposal is being made because by doing so one can clearly reduce the overall weight of suspension system to be used in two wheelers considerably.
- The deformation plot also confirms the above proposal although one can see a slight increment in total deformation in case of Inconel materials.
- Equivalent stress in case of Inconel 718 is minimum across all the materials.
- Shear elastic strain is minimum in case of Inconel materials.
- It also shows that the performance of a suspension system may be increased by applying changes in materials.
- As the current time is asking us to move towards some newer methods of manufacturing, there has been the incorporation of some newer kind of materials like Inconel materials. In the present analysis Inconel 625 & Inconel 718 too have been incorporated & one can see that Inconel materials are proved to be better materials than mild steel in a lot of aspects.

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