STATIC STRUCTURAL ANALYSIS ON HELICAL SPRING USED IN AUTOMOBILES

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Abstract- In the present study static structural analysis has been performed on helical spring using different materials to predict the resultant outcomes from different material properties. Helical spring is tested for different conditions which include von-mises stress, total deformation, compressive deformation, torsional deformation and transverse deformation. In all the materials used for the analysis of helical spring showed different results. Among the results obtained tungsten showed the best results for all the output parameters and according to the study can be considered for the future applications. Results obtained in the study are represented using different tables and graphs to provide a clear picture of results on different material helical spring. With the use of tungsten material helical spring is found to provide better results for all the conditions which can help in automotive and other sectors for the overall development.
Keywords: Helical Spring, Von-mises stress, Total Deformation, Ansys, static structural.

I. INTRODUCTION

With the increase in population and gradual degradation due to lower maintenance of roads these has been a high requirement of suspension systems these days. With the use of conventional materials used in the suspension system and high weight ratio some advancement in suspension system is required. Keeping this problem in focus a study using different materials for the selection of appropriate material for suspension system is carried out. Cylindrical spiral spring is considered for the study in this research work and is tested for various conditions using Ansys simulation tool.

Cylindrical helical spring is shown in figure 1 which may be in compression or tension. The major stresses produced in this are shear due to twisting. The load applied is parallel to the axis of spring. The cross-section of the wire may be round, square or rectangular. These springs are wound in the form of a helix of a wire.

In some three wheelers the front suspension is at one side of tire. Normally, it is observed that the vehicle drifts towards one side due to high weight of front suspension system. The study is performed to reduce the weight of helical compression spring used in three wheeler front suspension system. The objective of the present work is to optimize the front suspension system's component i. e. helical compression spring by achieving minimum of 8% to 10% reduction in weight and so in cost.

Fig. 1 Cylindrical helical spring

II. LITERATURE REVIEW

(Pawar and Desale, 2018)[1]showed thathelical compression spring used in suspension system or shock absorber is a mechanical device designed to smooth out or damp shock impulse and dissipate kinetic energy. A helical compression coil spring which used in transport three wheeler is belonging to the medium segment of the Indian automotive market. It is observed that, the vehicle drifts towards one side due to high weight of suspension system. This problem can be solved by redesigning and optimizing front suspension spring. For the present study the IS 4454 material was taken for consideration. Optimization of the spring was done by reducing total number of turns and prototypes of the spring were made. As per design the springs were made of material IS 4454 and experimental test was conducted. The static analysis using finite element method has been done in order to find out the detailed load vs defection of the spring. The experimental investigation was performed to calculate the stiffness and vertical acceleration of helical compression spring. The theoretical calculations were also done. For experimental test the universal testing machine was used to find load vs defection of spring and quarter car test rig used to find the vertical acceleration of helical compression spring.

(Alsahlani, Khashan and Khaleel, 2018)[2] explained that suspension system plays a very important role in new vehicles. Its duty is to damp, smooth out the shock impulse furthermore to absorb or dissipate energy so that the suspension system provides the comfort and safety for the passengers and vehicles. In this paper, the simulation of spring is carried out by using Solid works 2018 with specific dimensions and analysis it with finite element analyzer ANSYS 14. Three materials are selected to simulate the spring steel, copper alloy, and carbon composite. The deformation, strain, stress and shear stress are obtained numerically under various values of load (1500, 2000 and 2500) N. The results showed that the deformation in carbon composite is less than steel and copper alloy so that the carbon composite is the best material for helical spring and can withstand the load and deflection.

(Gzal, Groper and Gendelman, 2017)[3]aimed at determining the stress distribution in elliptical cross-section helical springs with small helix angle (less than 10º, often termed as close-coiled springs) considering the effect of wire curvature, subjected to axial static load. Also presented both analytical and finite element analysis, validated by an experimental study conducted on an actual automotive valve spring. A novel analytical expression for the stress distribution in such springs is developed based on the theory of elasticity. In particular, this expression leads to the analytic formula for the maximum resultant shear stress and its location along the spring's cross-section as a function of the aspect ratio. Contrary to the case of the circular cross-section, this maximum shear stress location is not invariant. The proposed analytical expression agrees well with the computed FEA results and is in very good correlation with the experimentally obtained figures. As an additional outcome of this study, a method to experimentally measure the shear stress in helical springs using strain gauge was described.

(Jain *et al.*, 2017)[4]revelled thathelical spring for shock absorber used in suspension system which is designed to reduce shock impulse and liberate kinetic energy. In a vehicle, it increases comfort by decreasing amplitude of disturbances and it improves ride quality by absorbing and dissipating energy. When a vehicle is in motion on a road and strikes a bump, spring comes into action quickly. After compression, spring will attempt to come to its equilibrium state which is on level road. Helical springs can be made lighter with more strength by reducing number of coils and increasing the area. In this research work, a helical spring is modeled and analyzed to substitute the existing steel spring which is used in suspension. By using different materials, stress and deflection of helical spring can be varied.

(Sequeira, Singh and Shetti, 2016)[5]explained thatautomobile sector due to the demanding need of rapid innovation and tough competition, the old products are reengineered by new product with composite materials. Regularly new innovations are carried out in suspension area of vehicles. Fiber Reinforced Material [FRP] components are the main interest of automobile industry for replacing the steel components due to “high strength to low weight” ratio. To reduce the weight and fuel consumption to some extent, automobile industries are using the Glass Fiber Reinforced Plastic [GFRP] open coil springs in suspension system of vehicle at the place of steel open coil springs.

(Yıldırım, 2016)[6]In his study, in order to carry out such spring formulation and get closed-form solutions for the vertical tip deflection, Castigliano’s first theorem is directly employed to the linear elastic problem of cylindrical helical springs with large pitch angles. Derivation takes into account for the whole effect of the stress resultants such as axial and shearing forces, bending and torsional moments on the deformations.

III. DESIGN OF SPRING

Design parameters and Dimensions obtained for the helical spring [All the dimensions are in mm]

Table 1 Dimensions of helical spring

Parameter	**Dimension (mm)**
Outside diameter (D_o)	88
Inside Diameter (D_i)	64
Spring Wire diameter (d)	12
Number of coil (N)	12.5
Pitch (p)	24.8
Free length (L)	315

Fig. 2Helical spring

Table 2 Material property

Mechanical Properties	**IS 4454**	**E-glass**	**Kevlar**	**Silicon Nitride**	**Tungsten**
Density (Kg/m^3)	7850	1540	1400	3170	19300
Young's Modulus (EX) (MPa)	206000	85000	30000	304000	407000
Poisson's Ratio (PRXY)	0.3	0.33	0.2	0.24	0.28
Shear Modulus (MPa)	79231	31955	12500	122580	158980

The main factor to be considered in the design of spring is the strain energy of a material used. Specific strain energy in the material can generally be expressed as U $=\sigma 2/\rho E$ Where U = strain energy $\boldsymbol{\sigma}$ = stress, $\boldsymbol{\rho}$ = density, E = young's modulus.

IV. BOUNDARY CONDITION

As this spring is used in the Three Wheeler Vehicle's front suspension it is necessary to find out the load acting on the spring in actual practice in static condition as well as in dynamic condition. Normally total weight of the vehicle with driver and load is about 975 Kg, concentrated at the center of gravity of the vehicle. It is assumed that this total weight is equally divided into two springs of rear suspension and one spring of front suspension. So the front suspension spring is experiencing load approximately 3188.25 N for safer side it is rounded up and taken as 3200 N.

For providing the suitable boundary conditions Fixed support at the top of one side in helical spring is provided with force applied from the opposite end of helical spring.

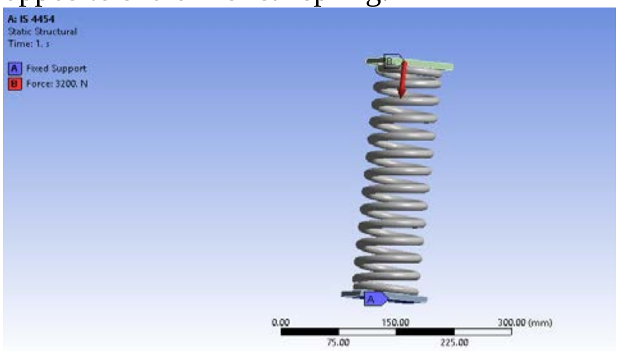


Fig. 3Force and fixed support

V. RESULTS

Different values obtained for Maximum Shear Stress (MPa), Deformation (mm), Von-Mises Stress (MPa), Compression Deformation (mm), Torsional Deformation (mm), Transverse Deformation (mm)

Table 3 Static Analysis Result

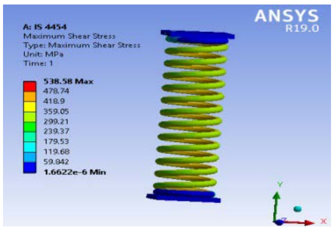
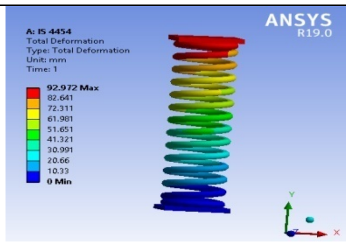
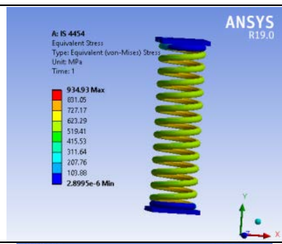
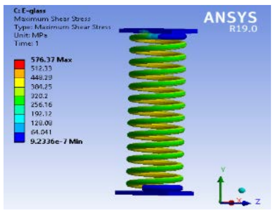
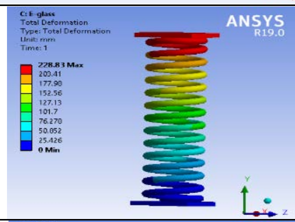
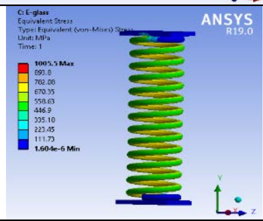
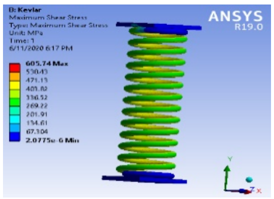
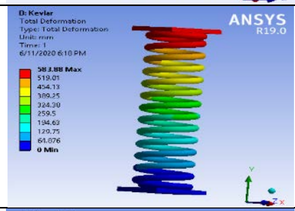
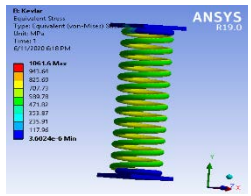
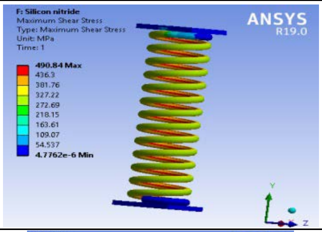
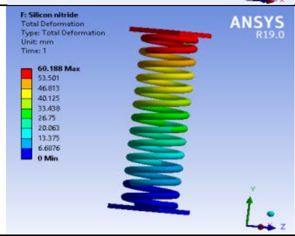
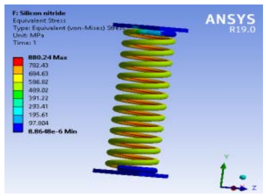
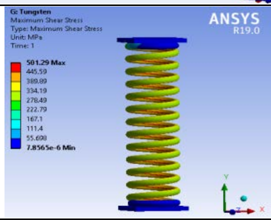
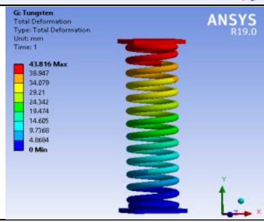
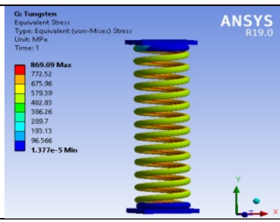
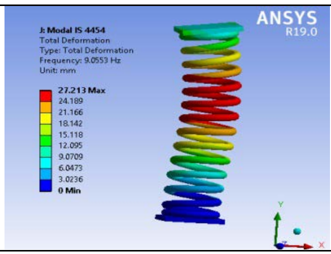
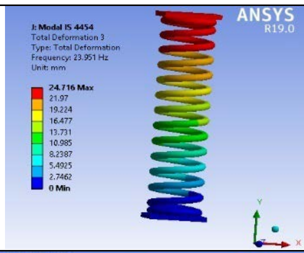
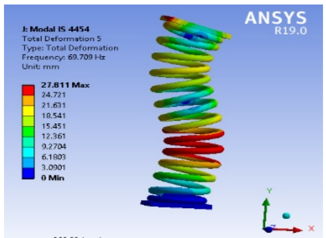
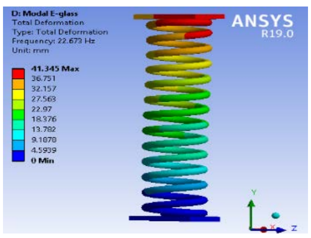
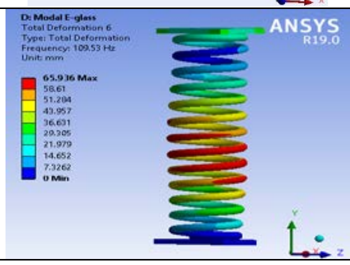
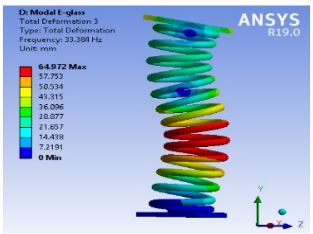
	Maximum shear stress	**Total Deformation**	**Equivalent Von-Mises Stress**
IS 4454			
E-glass			
Kevlar			
Silicon Nitride			
Tungsten			

Table 4 Modal Analysis Table

	Maximum shear stress	**Total Deformation**	**Equivalent Von-Mises Stress**
IS 4454			
E-glass			

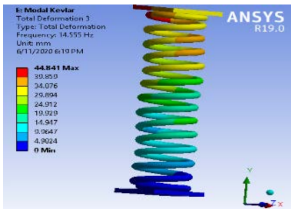
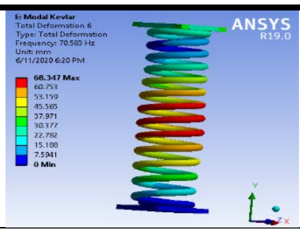
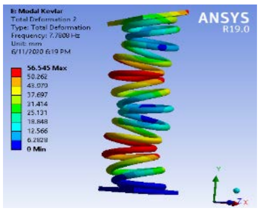
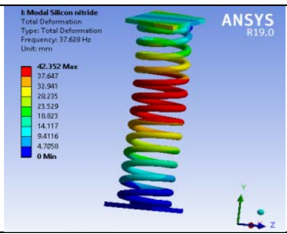
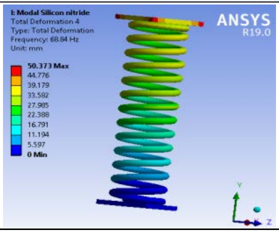
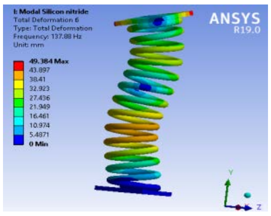
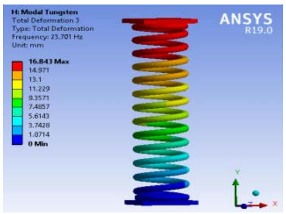
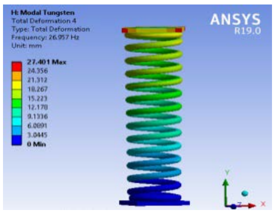
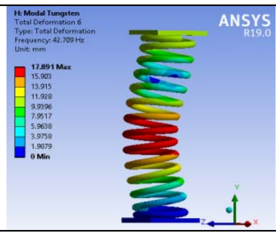
Kevlar			
Silicon Nitride			
Tungsten			

Table 5Result comparison table

Outcomes	**IS 4454**	**E-glass**	**Kevlar**	**Silicon Nitride**	**Tungsten**
Maximum Shear Stress (MPa)	538.58	576.37	605.74	490.84	501.29
Deformation (mm)	92.972	228.83	583.88	60.188	43.816
Von-Mises Stress (MPa)	934.93	1005.5	1061.6	880.24	869.09
Compression Deformation (mm)	27.213	41.345	44.841	42.352	16.843
Torsional Deformation (mm)	24.716	65.936	68.347	50.373	27.401
Transverse Deformation (mm)	27.81	64.942	56.45	49.384	17.891

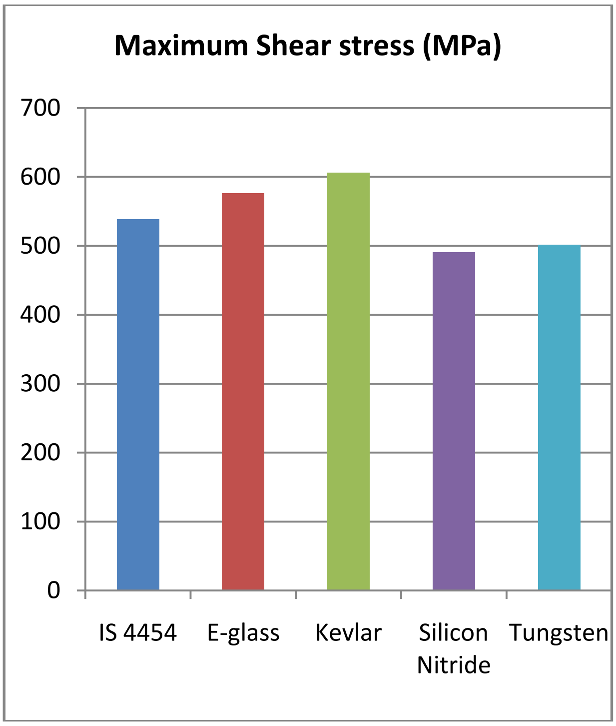


Fig. 4 Maximum shear stress graph

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of shear stress are obtained for Kevlar. Among all the materials used in the static analysis of helical spring silicon nitride showed the minimum values for shear stress

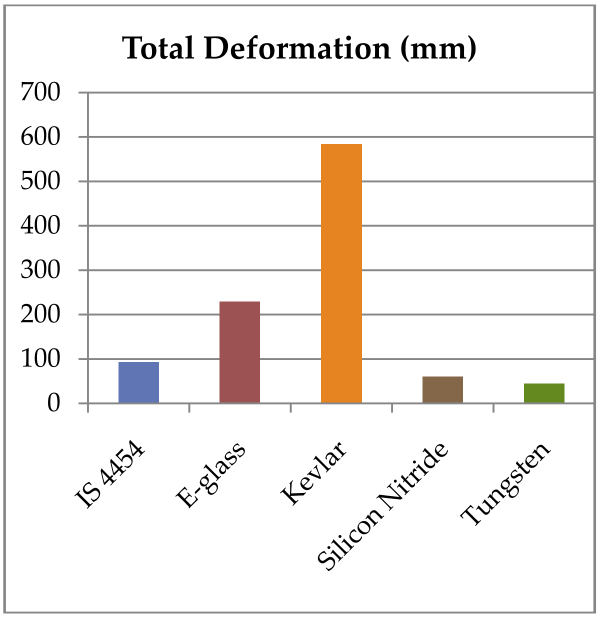


Fig. 5 Total Deformation graph for different materials

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of Total Deformation are obtained for Kevlar. Among all the materials used in the static analysis of helical spring Tungsten showed the minimum values for Total Deformation

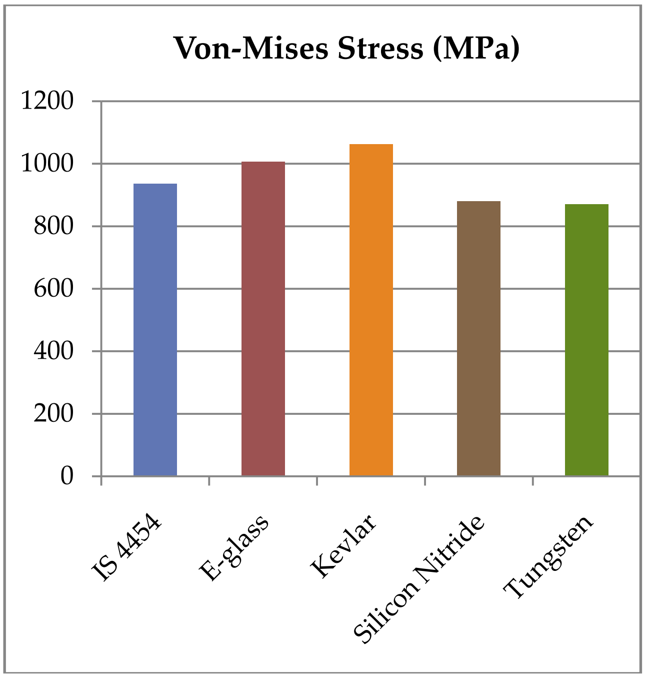


Fig. 6Von mises stress

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of Von-Mises Stress are obtained for Kevlar. Among all the materials used in the static analysis of helical spring Tungsten showed the minimum values for Von-Mises Stress.

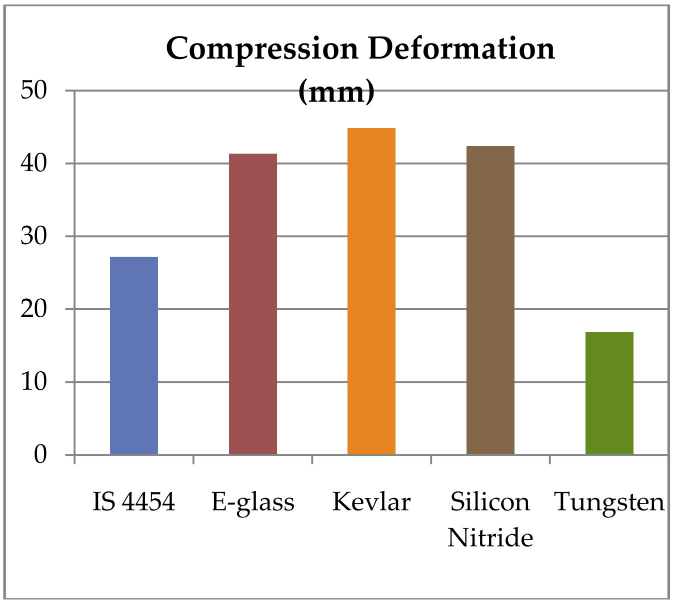


Fig. 7 Compression Deformation comparison graph

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of Compression Deformation are obtained for Kevlar. Among all the materials used in the static analysis of helical spring Tungsten showed the minimum values for Compression Deformation.

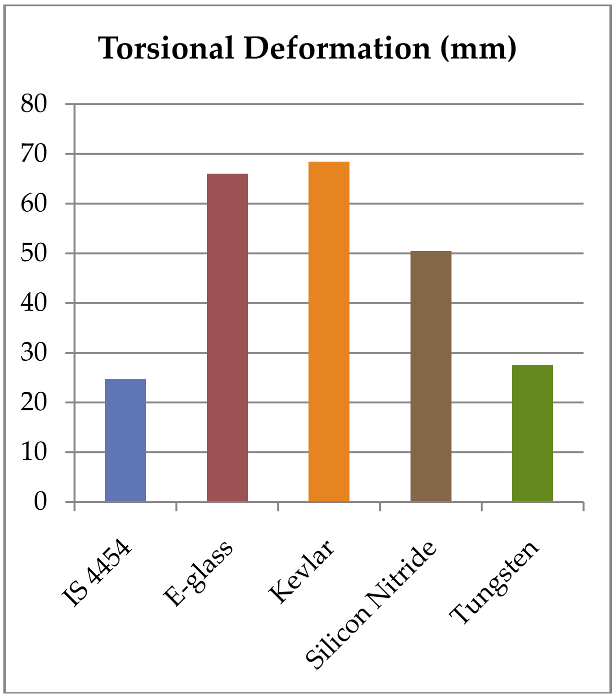


Fig. 8 Torsional deformation comparison graph

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of Torsional Deformation are obtained for Kevlar. Among all the materials used in the static analysis of helical spring Tungsten showed the minimum values for Torsional Deformation.

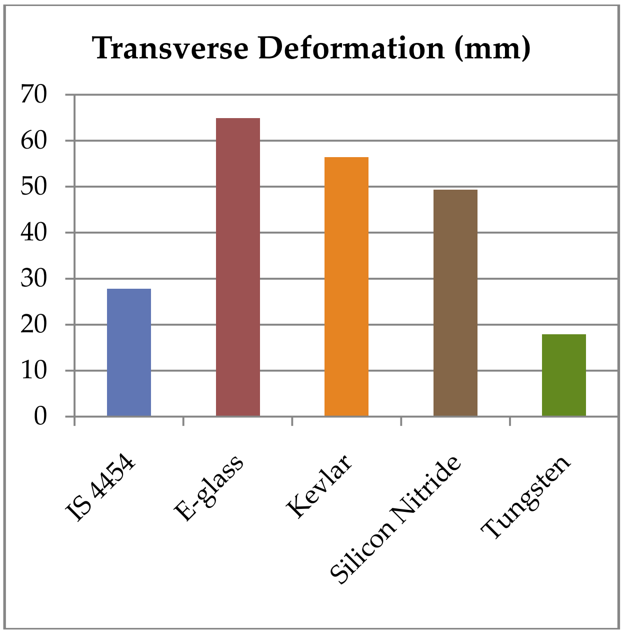


Fig. 9Transverse deformation graph

Above mentioned graph shows different values obtained after performing the static structural analysis on helical spring. Maximum Values of Transverse Deformation are obtained for Kevlar. Among all the materials used in the static analysis of helical spring Tungsten showed the minimum values for Transverse Deformation.

VI. CONCLUSION

Based on the results mentioned in the previous chapter following conclusion can be drawn from the research work.

- For the purpose of analysis 5 models of Suspension Spring were Successfully developed using different materials.
- Tungsten showed minimum values of von-mises stress among all the other material used for the analysis.
- Suspension spring with Tungsten material showed the least deformation for all the load condition.
- Tungsten spring show lowest compression, torsional and Transverse deformation at all condition.
- Based on the results it can be concluded that the suspension spring made of Tungsten is the best suitable alternative to be used in the suspension system.

REFERENCES

[1] H. B. Pawar and D. D. Desale, “Optimization of Three Wheeler Front Suspension Coil Spring,” *Procedia Manuf.*, vol. 20, pp. 428–433, 2018, doi: 10.1016/j.promfg.2018.02.062.

[2] A. Alsahlani, M. K. Khashan, and H. H. Khaleel, “Design and analysis of coil spring in vehicles using finite elements method,” *Int. J. Mech. Prod. Eng. Res. Dev.*, vol. 8, no. 4, pp. 615–624, 2018, doi: 10.24247/ijmperdaug201864.

[3] M. Gzal, M. Groper, and O. Gendelman, “Analytical, experimental and finite element analysis of elliptical cross-section helical spring with small helix angle under static load,” *Int. J. Mech. Sci.*, vol. 130, pp. 476–486, 2017, doi: 10.1016/j.ijmecsci.2017.06.025.

[4] A. Jain, S. Misra, A. Jindal, and P. Lakhian, “Structural analysis of compression helical spring used in suspension system,” *AIP Conf. Proc.*, vol. 1859, 2017, doi: 10.1063/1.4990233.

[5] A. A. Sequeira, R. K. Singh, and G. K. Shetti, “Comparative Analysis of Helical Steel Springs with Composite Springs Using Finite Element Method,” *J. Mech. Eng. Autom.*, vol. 6, no. 5A, pp. 63–70,

2016, doi: 10.5923/c.jmea.201601.12.

[6] V. Yıldırım, “Exact determination of the global tip deflection of both close-coiled and open-coiled cylindrical helical compression springs having arbitrary doubly-symmetric cross-sections,” *Int. J. Mech. Sci.*, vol. 115–116, pp. 280–298, 2016, doi: 10.1016/j.ijmecsci.2016.06.022.

[7] Calder C.A, Jenkins C. Stress Analysis of a Helical Coil Automobile Spring using Rosettes. Experimental Techniques. 1988; 17-20.

[8] Jiang W.G, Henshall J.L. A Novel Finite Element Model for Helical Springs, Finite Elements in Analysis and Design. 2000; 35: 363-7.

[9] Sudhakar K.V. Failure Analysis of an Automobile Valve Spring. Engineering Failure Analysis. 2001 ;8: 513-520.

[10] Dammak Fakhreddine, Taktak Mohamed, Abid Said, Dhieb Abderrazek, Haddar Mohammed. European jor. of Mechanics-A/Solids. 2005; 24: 1068-1078.