INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 6.078
(Volume 6, Issue 3)
Available online at: www.ijariit.com

Design and analysis of helical spring profiles in an electric vehicle suspension system using finite element method

Arko Banerjee
arkokkr@gmail.com
SRM Institute of Science and Technology, Chennai, Tamil Nadu

ABSTRACT

Automobile suspension plays an important role in vehicle safety, passenger comfort and safety. During a mechanical deformation/vibration the suspension would absorb most of the energy (mechanical vibrations) and would ensure safety and comfort, most of the kinetic energy would be dissipated as Vertical motion in the vehicle. In this research paper a helical spring related to an electronic vehicle system with two different profiles under the effect of a uniform load have been studied. A model is created for an electric vehicle helical coil spring with modified profiles of the helical spring as circular and triangular fillet by using modelling software Solid works 2017. This research paper deals with the detailed analysis of the suspension system by using ANSYS workbench 18.1 simulation software. Using the Finite element approach, results are compared on the basis of Static Structure analysis. In addition, the results for the various spring profiles are compared.

Keywords— *FEA, Solid Works, Shock Absorber, ANSYS, Static Structure Analysis*

1. INTRODUCTION

An Electric vehicle chassis as a matter of fact any chassis is mounted on the axes through some form of spring/shock absorber/damper for the vehicle safety and passenger comfort as the spring/shock absorber/damper absorbs most of the energy (mechanical vibrations). Shocks absorbers are the primitive and the most essential part of a vehicles suspension system ensuring ride comfort and safety. Every moving vehicle must have a good suspension to absorb shock of the tires/frame/wheels interacting with the irregularities in the road. The energy of the road shock/mechanical vibrations causes the spring to oscillate; the oscillation is restricted to a reasonable level by shock absorber. The purpose of Shock Absorber is to dissipate kinetic energy into vertical motion of the vehicle or any other motion that arises due to the irregularities of the road. Traditionally automotive suspensions designs have been looked over or have been compromised between three criterions namely vehicle handling, load carrying and passenger comfort.

2. PROFILES

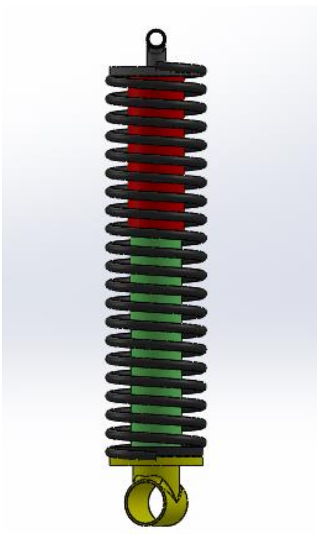


Fig. 1: Shock absorber model with circular profile

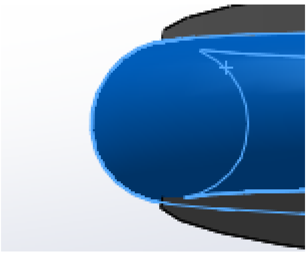


Fig. 2: Expanded model of circular profile

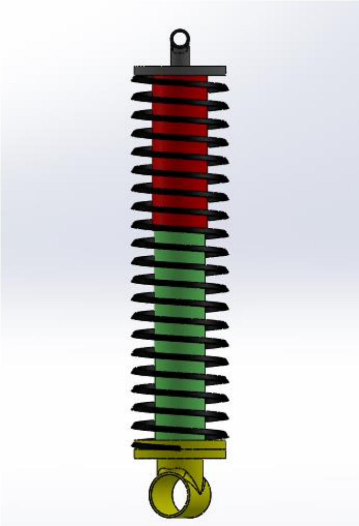


Fig. 3: Shock absorber model with triangular profile

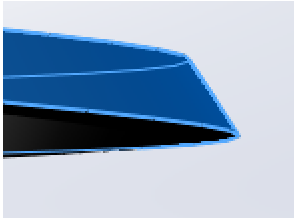


Fig. 4: Expanded model of triangular profile

3. RESEARCH METHODOLOGY

The finite element analysis supports distinctive analysis package, ANSYS workbench 18.1 is one of those. The 3D modelling is a process of transformation program which creates an ANSYS input record from the geometry portrayal created in Solid works 2017. Once the 3D model is successfully created, the transformation program translates the solid works model(sldasm) into an ANSYS input record i.e. IGES format. The input can be viewed in either of the software. The converted input file is imported into ANSYS for further processing. Once the import is successful the meshing has taken place by selecting appropriate 3D element size and shape.

4. MESHING OF THE MODEL

The resultant geometry has been imported into Ansys 18.1. 3D solid mesh has been created with tetrahedral elements. The tetrahedral element is a robust and efficient element, with unique capabilities, used as a major element in mesh. The number of nodes in the circular profile is 16680 and the triangular profile has 11796 nodes. The spring prolife area is found to be critical under the stress concentration so very fine meshing has to be carried out to get closer and efficient results.

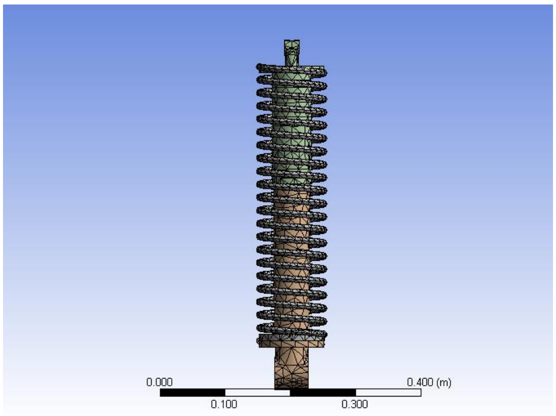


Fig. 5: Mesh of circular profile

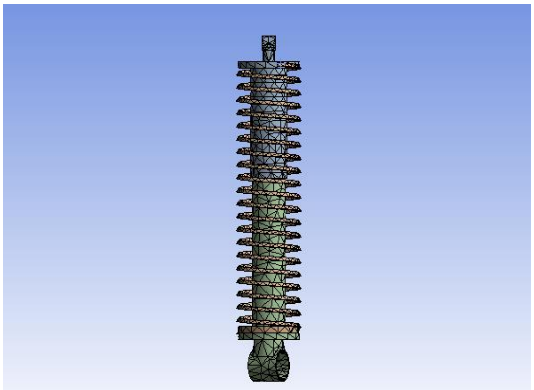
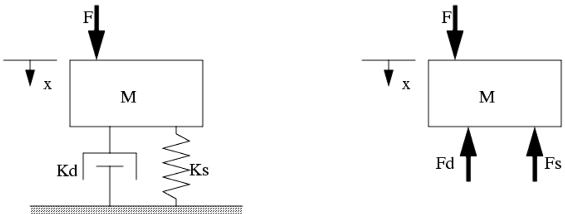


Fig. 6: Mesh of triangular profile

5. DESIGN AND CALCULATION OF HELICAL SPRING SHOCK ABSORBER-

Note: All the values are experimental basis

- Mean diameter of a coil D = 48 mm
- Diameter of wire d = 8 mm
- Number of turns (n) = 16
- Free length (Lf) = 256 mm
- Pitch (p) = 16 mm
- Spring index (c = D/d) = 6
- Outer diameter of spring coil (Do = D + d) = 56 mm
- Total weight of= 1000 kg
- Velocity= 50 kmph
- road surface varies with an amplitude of Y = 50mm
- Damping ratio of ξ = 0.5
- Spring constant = 46714.2N/m(f=kx)



$$+\uparrow \sum F_y = -F + F_d + F_s + M\left(\frac{d}{dt}\right)^2 x = 0$$

$$\therefore F = K_d\left(\frac{d}{dt}\right)x + K_s x + M\left(\frac{d}{dt}\right)^2 x$$

Fig. 7: Damping force diagram

(Angular frequency) Ω = 2πf = 2π (**V** × 1000) /3600) = 1.74 **V**rad/s

ω = 1.74 × 50 (**V**)= 87 rad/s ~= 90rad/s

The natural frequency of the vehicle is given By

ωn = √k/m=√46714.2/1000= 0.216rad/s

where k= (Spring constant = 46714.2N/m)

Frequency ratio: - r = ωn/ ω= 0.216/90 = 0.0024

X/Y = {1 + (2ξr) 2 / (1 + r2)2+ (2ξr) 2}1/2

where (Y=50 and Damping ratio of ξ = 0.5) = (1+0.0024+0.0048)0.5= 0.5036

X/+Y = 0.5036

Thus, the displacement of a vehicle at 50 km / hrs is given by

X= 0.5036 × Y = 0.5036 × 0.05 = 0.02518 m = 25.18mm

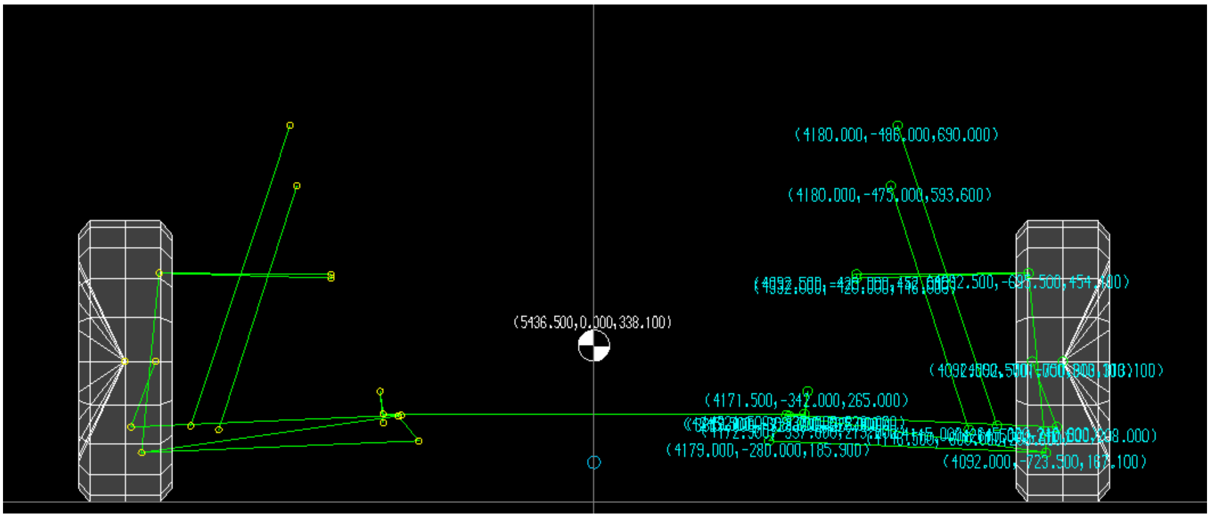
This indicates that a 50mm bump in the road is transmitted as a 25.18mm deflection to the chassis.

6. FINITE ELEMENT ANALYSIS OF SHOCK ABSORBER

Finite element analysis is one of the most popular mechanical engineering applications. Solves engineering problems by boundary conditions and numerical technique. This method is applicable for complex geometry, any material properties and boundary conditions for loading conditions. For stress analysis, constrains are applied on the one side of spring(fixed) and force is applied at the free end of the spring (non-fixed side). By giving these conditions, total deflection and equivalent strain are calculated on the basis of static structural analysis.

7. ANALYTICAL DESIGN TEMPLATE

A helical springs analytical design was plotted in lotus Software under the load of 1000kg



8. STATIC STRUCTURAL ANALYSIS

A static structural analysis calculates structural analysis, which calculates effects of steady loading conditions on a structure, while ignoring conditions like inertia and damping effects, such as those caused by time varying loads. A static analysis can however include steady inertial loads (gravity and rotational velocity), and time varying loads that can be approximated as static equivalent loads. Static analysis used to determine the displacement, stress, strain and forces in structures or components caused by loads that do not include significant inertia and damping effects. Steady loading and response conditions are assumed, i.e. the loads and structure's response are assumed to vary slowly with respect to time. These kinds of loading that can be applied in a static analysis include; A static structural analysis can either be linear or nonlinear. All type of nonlinearities is allowed- large deformations, plasticity, creep, stress stiffening, contact(gap)elements, hyper elastic elements etc.

8.1 Static structural analysis for circular profile

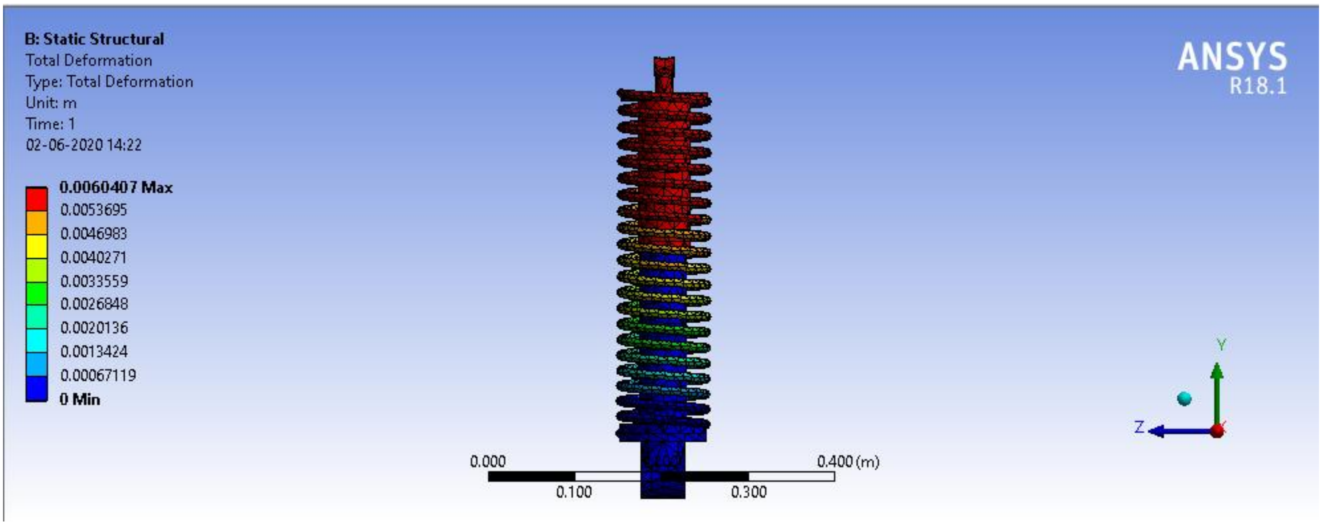


Fig. 8: Pictorial representation total deformation in a circular profile

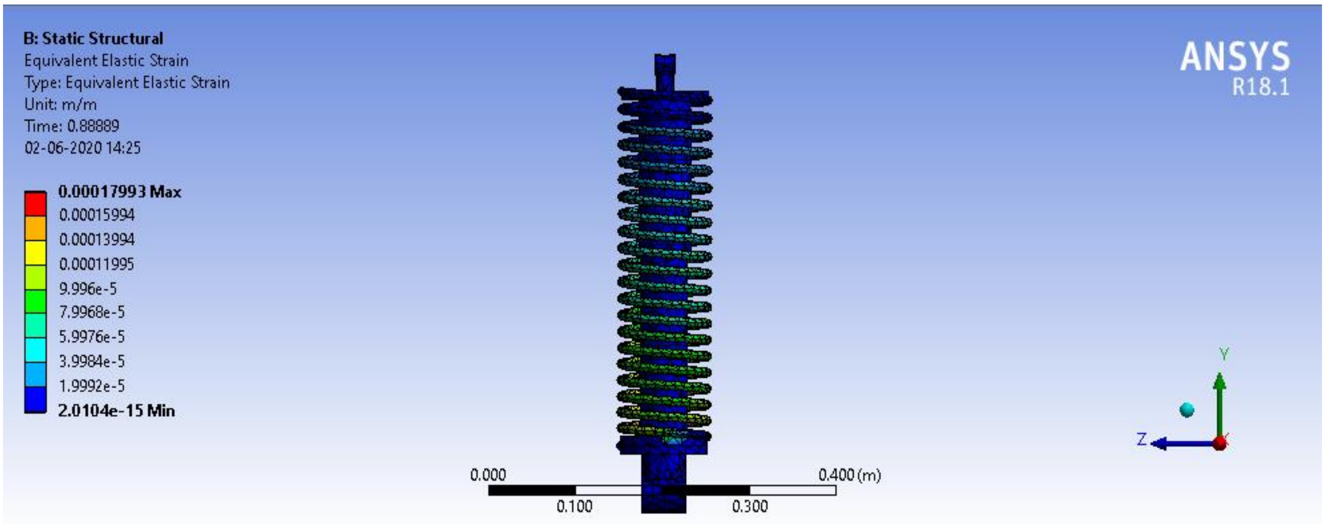


Fig. 9: Pictorial representation of equivalent elastic strain in circular profile

8.2 Static structural analysis for triangular profile

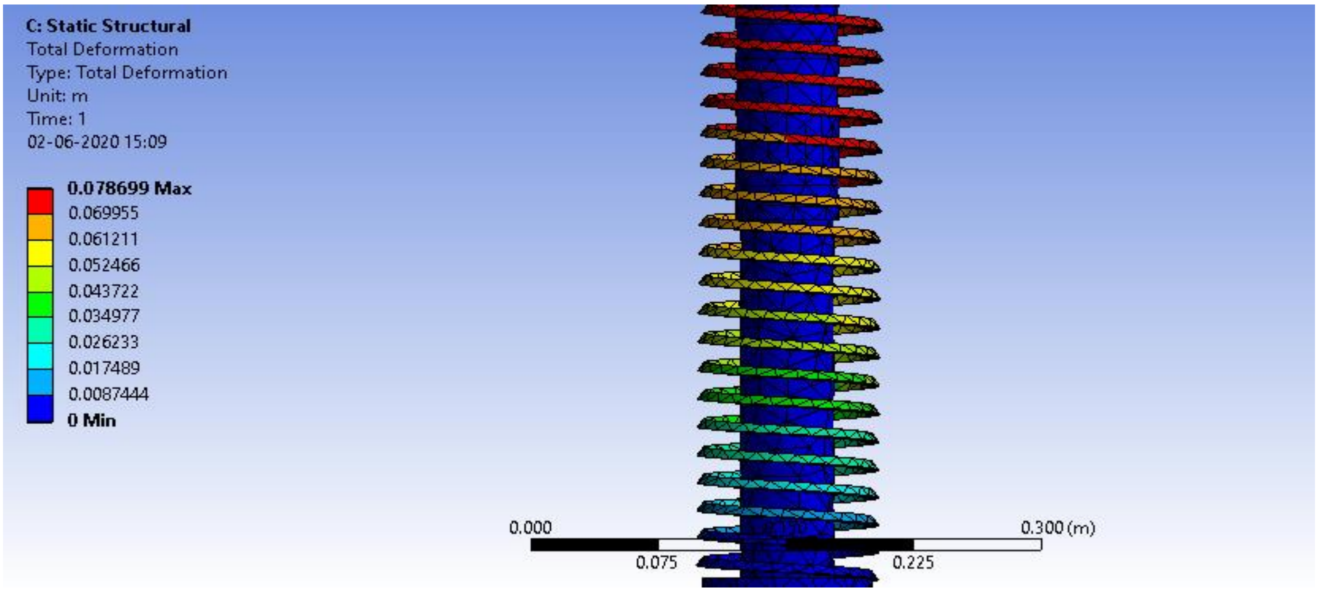


Fig. 10: Pictorial representation total deformation in a triangular profile

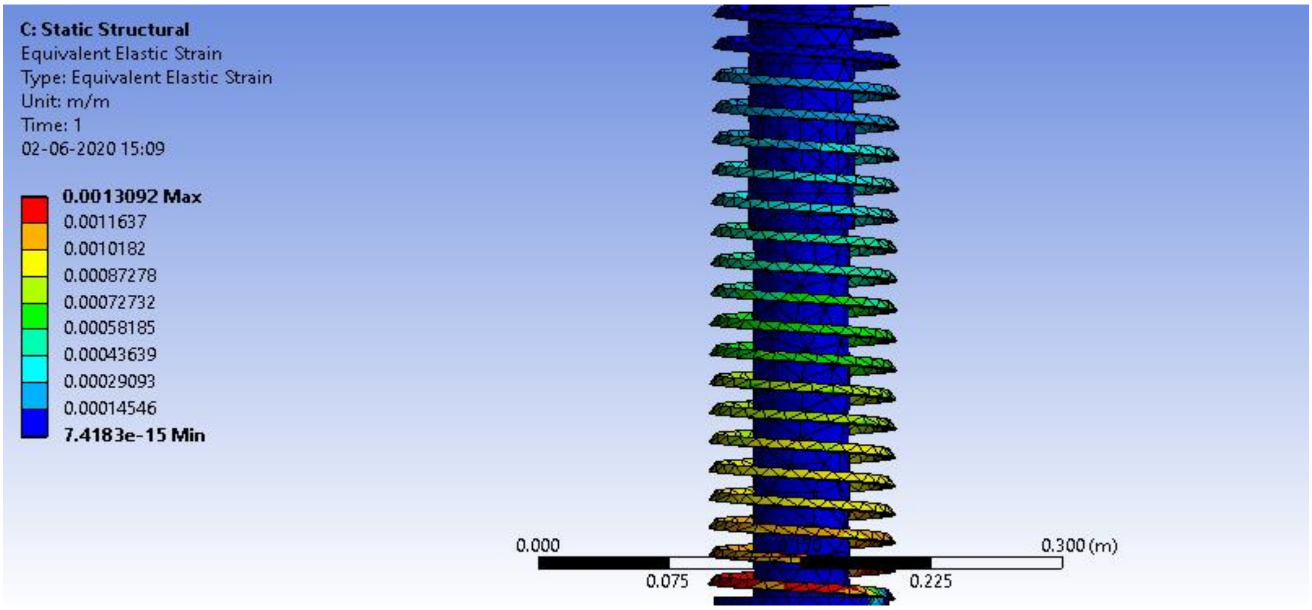


Fig. 11: Pictorial representation of equivalent elastic strain in triangular profile

9. ANALYSIS OF RESULT OBTAINED

The analysis has been done based on boundary conditions. The results obtained are tabulated below.

9.1 Spring profile comparisons

The calculated equivalent stress and total deformation are shown in the following table. The spring profiles circular to triangular results shown in the table.

Profile	Maximum Equivalent Strain(m/m)	Total Deformation (mm)
Circular	0.0001799	6.04
Triangular	0.0013092	78.7

The minimum displacement for circular profile is 0 mm and maximum displacement is observed at 6.04mm for circular profile whereas the minimum and maximum displacement for triangular prolife is 0 and 78.7mm respectively. The equivalent strain value is maximum 0.0013092 for triangular profile and minimum 0.0001799 for circular profile.

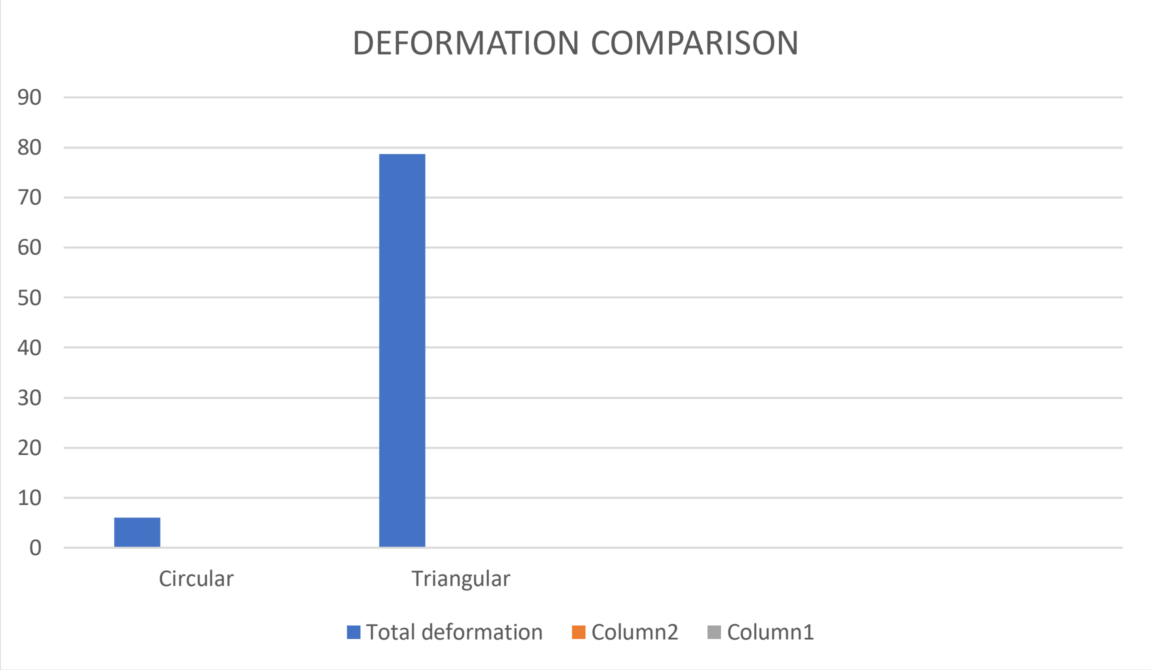


Fig. 12: Static analysis chart

From this graph we can clearly state that the total deformation in a circular profile is much lesser than the total deformation in a triangular profile.

10. CONCLUSION

- Design optimization of helical springs with a circular and a triangular profile was studied.
- From the analysis the circular profile has a lesser total deformation and a lesser equivalent maximum strain compared to triangular profile

11. FUTURE SCOPE

- Analysis of helical spring can be performed and tested in spring cases.
- There is a growing opportunity for changing spring profile and use of composite materials for helical spring in the future. Many more profiles can be tested for implication by FEM method for e.g. square, rectangle, square fillet, hexagon etc.

12. REFERENCES

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