

Design and Fatigue Analysis of McPherson Strut Assembly Coil Spring

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ABSTRACT: Today Automobile industries are looking for Safety, Quality & Optimum Cost in Vehicle components. & the replacements of any components are very expensive. In such cases many components in automobiles are fails due to fatigue. & major characteristics of fatigue failure are, components are failed suddenly without any warning. This failure damages the other part of the vehicle; to avoid this type failure we need to analyze fatigue conditions of each component. From this analysis we know fatigue strength & life of component.

Suspension System is a mechanical device. It reduces the effort of travelling over on rough surface, leading to improve ride quality & providing comfortable to the vehicle driving system. When a vehicle is travelling on unconditioned road, wheel strikes on bump due to this Strut Assembly subjected sudden loads. The spring in the Strut Assembly gets compressed quickly & tries to regains its original position after some time. When such conditions are repeated continuously the Coil Spring in the Strut Assembly will fail due to fatigue load. To avoid such failure's we need to Design a Coil Spring in Such a way that it can Withstand Heavy loads.

The main objective of this paper is to Design a Coil Spring for McPherson Strut Suspension System. And analyze this Modified model in Static, Fatigue Loading Conditions. We chose good fatigue strength material, among the existing materials by its Mechanical Properties.

Here modelling has been done in CATIA-V5/, Pre-processing of meshing has been done in Hypermesh & solver is used as ANSYS Workbench.

KEYWORDS: Bump loads, Strut Assembly, Coil Spring, CATIA V5, Hypermesh and ANSYS.

I. INTRODUCTION

Today all automotive industries are demanding more efficient vehicles, such like Vehicle must be light weight, high durability, less expensive and good ride qualities. To design such automotive vehicles, our automotive design engineers are implementing new ideas and technologies.

If we all think about vehicle performance, we always think of mileage of vehicle, torque, fuel efficiency and zero-60 acceleration. But all power generated in engine is waste, if the vehicle driver cannot control the vehicle. For this reason only the automobile engineers turned their attention on vehicle suspension system.

The vehicle suspension system provides comfort ride and safety to the passengers from road shocks, apart from this suspension system always maintains a contact between road surfaces and wheels to provide steering stability with good handling. If road is flat, there is no irregularities on the road, suspension system would not necessary to the vehicle. But in reality roads are not free from bumps, path holes and many imperfections. These can interact with the vehicle wheels.

When vehicle moves on bump roads, bumps in the road causes the vehicle movement in up and down directions. In certain time vehicle with high speed clashes the road bump and experiences very high shock loads, due this shock load vehicle components are un-controlled from their function and damages will happen. To avoid this automobile engineers introducing suspension system to the vehicle.

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Mainly Automobile Suspension systems are two types, Rigid Suspension System and Independent Suspension. In Rigid Suspension System Both Right and left Wheel attached to the same solid axle. When one of the hits the road bumps, its upward movement causes a slight tilt of other side wheel. But In Independent Suspension System allows one wheel to move up and down with minimum effect to the other wheel. McPherson Strut Suspension is type of Independent Suspension System.

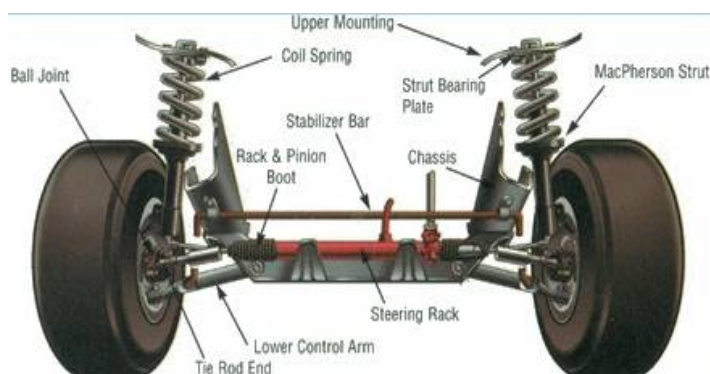


Fig 1.1 McPherson Strut Suspensions with front wheels.

II. PROBLEM DEFINITION

The McPherson Strut Suspension System consists of Coil spring, when vehicle is travelling on a road and wheels of vehicle suddenly strikes a bump, the coil spring in the suspension system compressed quickly, the compressed spring will try to regain its original length by lifting the vehicle upward. But Weight of vehicle will push the spring down below its normal length. This bouncing process is repeated again and again till shock loads are disappearing by Strut and Coil spring. If such bump loads acting on the vehicle repeatedly, it will causes an uncomfortable ride and same time it will damages the Coil spring and other components of suspension system.

As I Discussed earlier the entire road shocks are supported by Coil spring And Strut assembly in a vehicle under its Fatigue load conditions.so in my thesis I am trying to minimize the above stated problems by suggesting modified material, Designing a spring coil, model static and fatigue analysis under steady loading conditions.

3.1 OBJECTIVES:

- Designed a Spring Coil, such that it can withstand high static and fatigue loads.
- Simplify the model of McPherson Strut Suspension system to easy install or replace purpose.
- Static analysis is done for whole model under practical Boundary condition of Tata Indigo eCs model car.
- Predicted fatigue life and safety factor for whole McPherson Strut Suspension model, with help of fatigue analysis.

To achieve our aim we are using Mechanical core software's to create and analysis of McPherson Strut Suspension system. We used CATIA V5 for 3D model, Hypermesh for FE Modelling and ANSYS Workbench for Static and Fatigue analysis purpose.

III. MATERIAL STUDY

Material selection is the one of most important function for effective engineering design .As it determines the durability and reliability of the engineering design in terms of industrial and economic aspects.

SAE 9254:

SAE 9254 is a steel alloy material, recently using to manufacture a springs. These materials having good mechanical properties, high corrosion resistance property, have ability to manufacture any complicate design and less expensive.

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SAE 9254 spring steel is much suitable for fatigue loading conditions because its fatigue strength is high. In our project we used this material for coil spring design and after static and fatigue analysis we conclude that SAE 9254 material coil spring having good life and this material withstand the applied static and fatigue loads.

IV. ANALYTICAL SOLUTION

Design of Coil Spring:

Material Used:

SAE-9254 Spring Steel

Input:

Diameter of spring wire, $d=14.64$ mm

Outer diameter of spring, $D_{\text{outer}}=140$ mm

Free length of spring, $L_{\text{free}} = 280$ mm

Number of active coils, $n_a = 6$

Young's modulus of material, $E= 205.4$ Gpa

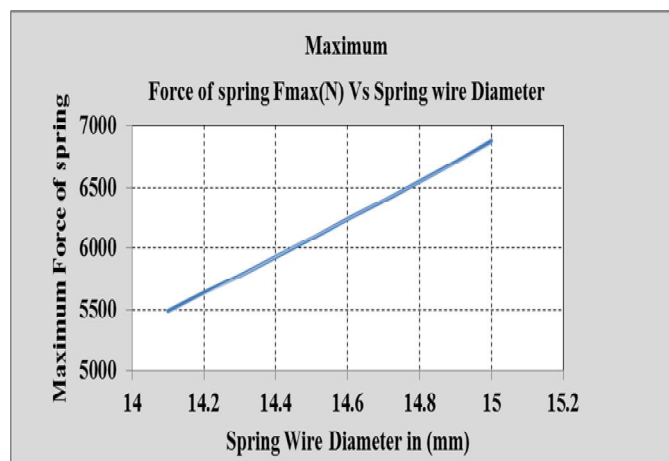
Poisson ratio of material $=0.29$

Density of material $= 7800$ Kg/m³

Output:

S NO	Descriptions	Calculated Value
1	Spring constant (K)	3.87×10^4 N/m
2	Coil Pitch (Pc)	46.667 mm
3	Maximum spring force (F_{max})	6300 N
4	Maximum Spring Shear stress (τ_{max})	750 Mpa
5	Mass of spring(m)	4.16 Kg

Table2. Design of spring calculation

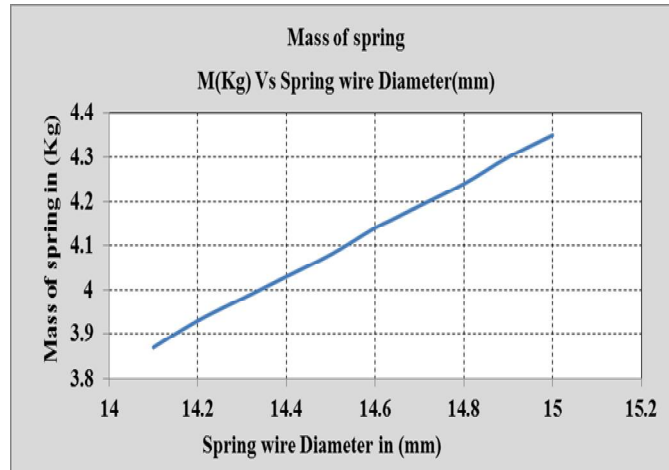


Graph1.1 Max Force of spring (N) Vs Spring wire diameter (mm)

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Graph1.2. Mass of spring (Kg) Vs Spring wire diameter (mm)

From above graphs we know that as we increase the spring wire diameter the maximum force carrying capacity of spring increases but as same time mass of spring also increases. If we use larger wire diameter, it decreases the vehicle efficiency due to weight of spring. so to avoid this I choose an optimum wire diameter as $d=16.64$ mm, this spring having capacity of 6300N and which is more suitable for car loading conditions.

V. MODELLING OF MCPHERSON STRUT SUSPENSION WITH COIL SPRING

Modified Design of “McPherson strut suspension with coil spring” is modelled with the help of CATIA V5 software.

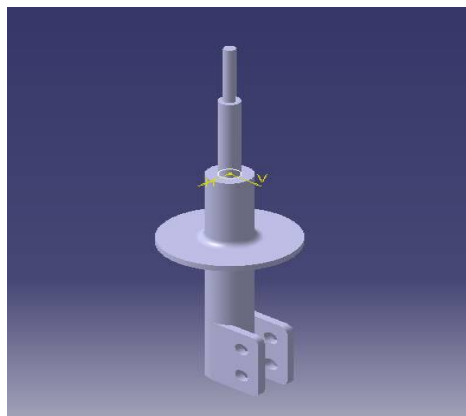


Fig 1. Shock Absorber model

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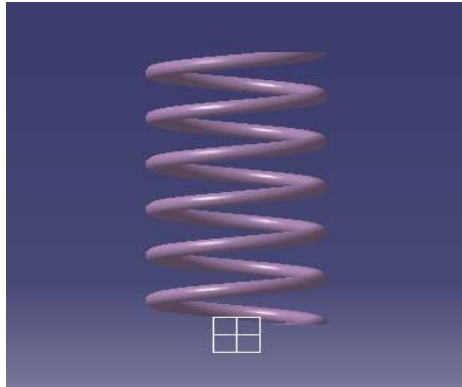


Fig 2. Coil spring

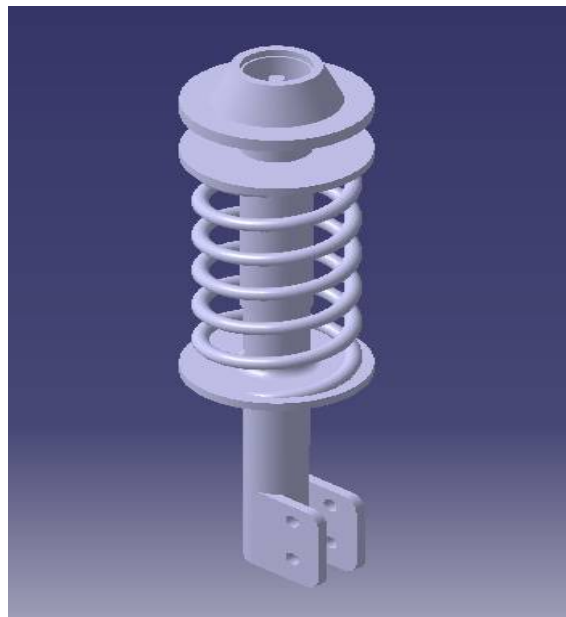


Fig 3. Total Assembly of McPherson Strut Suspension

VI. FINITE ELEMENT MODEL OF MCPHERSON STRUT SUSPENSION WITH COIL SPRING

Basic ideas of Finite Element Analysis is to make calculations at only limited number of points and then interpolate the results for entire surface or volume. But all practical objects have infinite degrees of freedoms and it's not possible to solve the problem in this format. Finite Element Method reduces the degrees of freedom from infinite to finite with the help of discretization or meshing.

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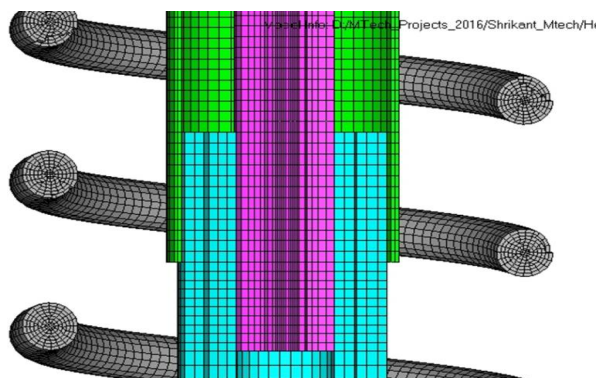


Fig 4. Middle section of FE model

Basically Geometry has a various entities like points, lines, Curves, Areas, Surfaces, Volume and Solids. But in the Finite element analysis we have only two entities they are nodes and Elements. FEA entities are built with respect to the geometric entities and for simulation only FEA entities are considered.

Finite Element Modelling of McPherson Strut Suspension with Coil Spring is done in **Hypermesh** 11 Software. This software is powerful tool to create the FE Model for any complexity of the structure. And today many of the automotive industry are preferred this software.

VII. STATIC ANALYSIS RESULT

Static analysis is the type of Finite element analysis, from this analysis we determined the stress, strain and displacement of the model in its practical boundary conditions. And Static analysis does not dependent on time.

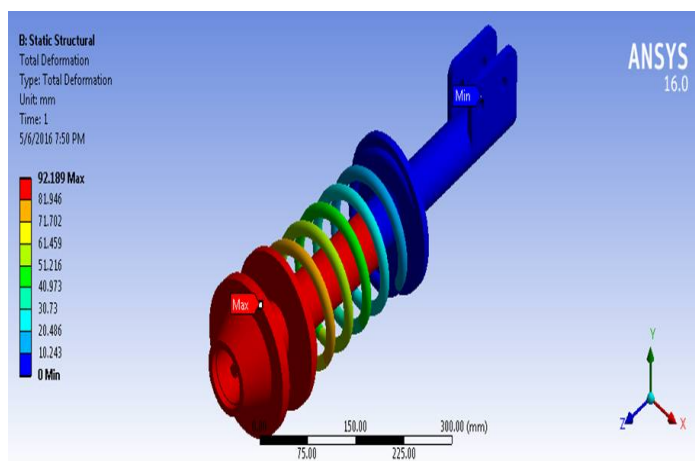


Fig5. Total Deformation

For 3465 N force, we get total deformation 92.189 mm in top cap and 81.946 mm in Coil spring which is 50.27% of overall deformation of modified Coil Spring. And convergence graph represents the no of iterations to converge the FE Model Solutions.

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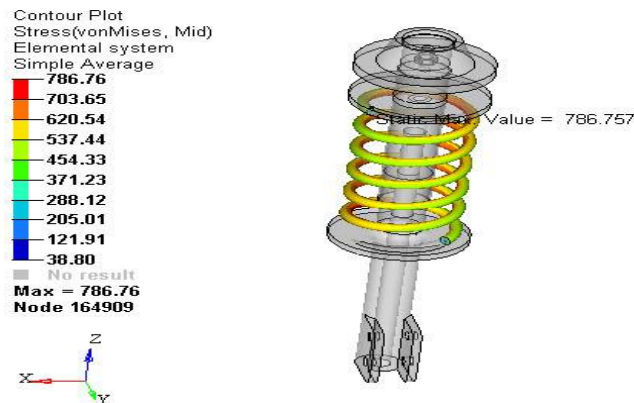


Fig6. Von-Mises Stress

Von-Mises stress is popularly used by design engineers to check whether the design is withstand the given loading conditions or not. For design engineer Von-Mises stress are considered to be safe haven. Using this information one can say that design is safe or not.

“If Maximum value of Von-Mises stress induced in the material is less than strength of material then design is safe” this theory works well for all designs, especially when material is ductile in nature.

In our design for McPherson Strut Assembly Coil spring we got maximum Von-Mises stress is 786.76 Mpa. And Yield strength of Coil spring material SAE 9254 is 2270 Mpa.

Hence

Von-Mises Stress < Yield Strength of Material 9254

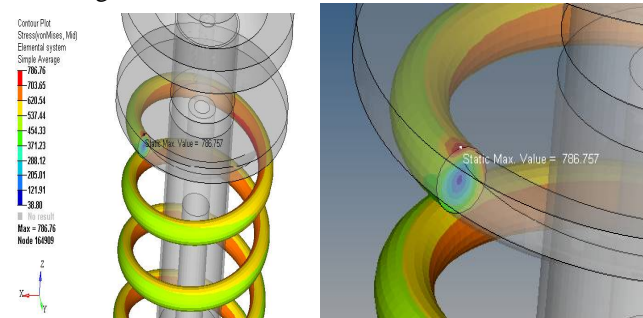
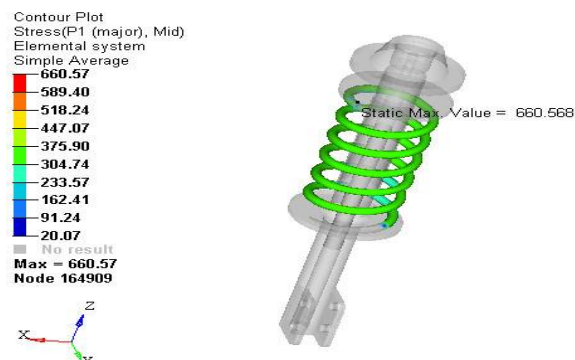


Fig7. Critical Areas of Coil Spring



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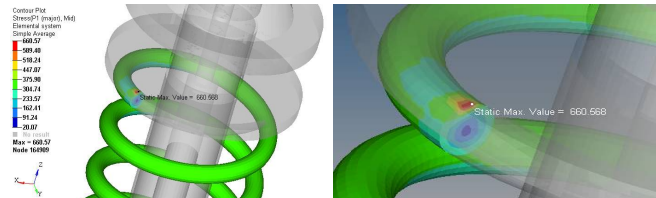


Fig8. Critical Area for Maximum Principle

The Maximum Principle Stress for designed model is 660.57 Mpa which is less than the Maximum strength of material at elastic limit. So we decide that failure will not occur in our design.

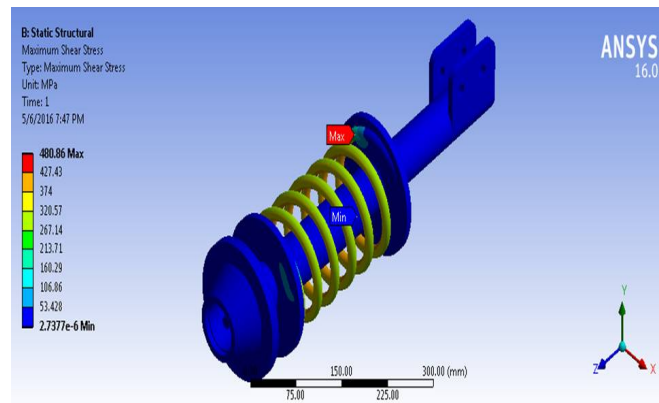


Fig 9. Maximum Shear Stress

S No	Description	Maximum(Mpa)	Minimum(Mpa)
1	Equivalent Von-Mises Stress	786.76	38.80
2	Maximum Principle Stress	660.57	20.07
3	Minimum Principle Stress	-19.65	-608.69
4	Maximum Shear Stress	480.86	2.7377×10^{-6}
5	Strain Energy Stored in Coil Spring	22.194 mJ	4.5×10^{-17} mJ

Table 4.Static Stress Results

VIII. FATIGUE ANALYSIS RESULT

For fatigue analysis, we are the use of Static evaluation outcomes as a input data and there's no resonance effect within the changed version. From those conditions it's far clean that we are done a static fatigue analysis.

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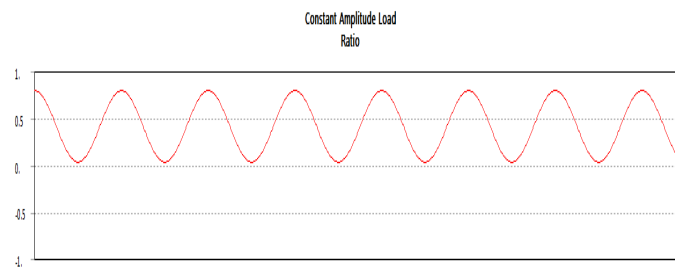


Fig10. Constant Amplitude Load Ratio for fatigue analysis

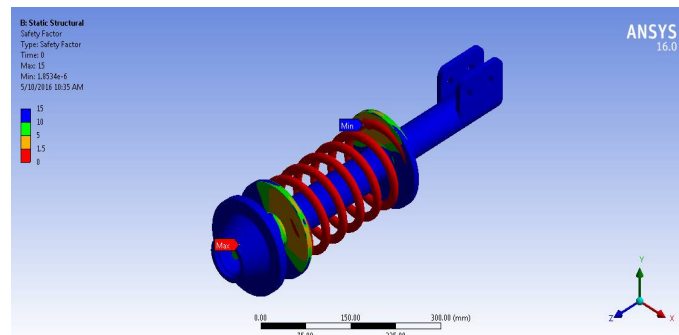


Fig11. Factor of safety for McPherson Strut Suspension System

From Finite Element Analysis we get Factor of safety value of Coil spring is 1.5 which is greater than 1 and it shows that our fatigue analysis of coil spring belongs to safe zone.

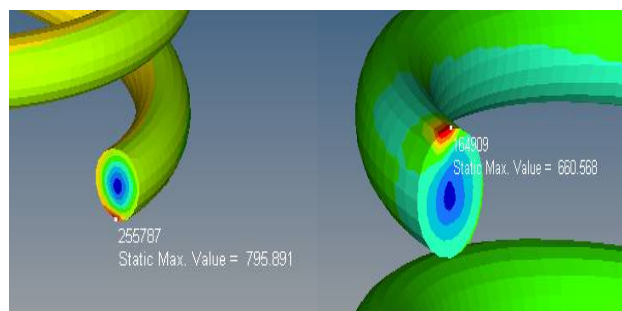


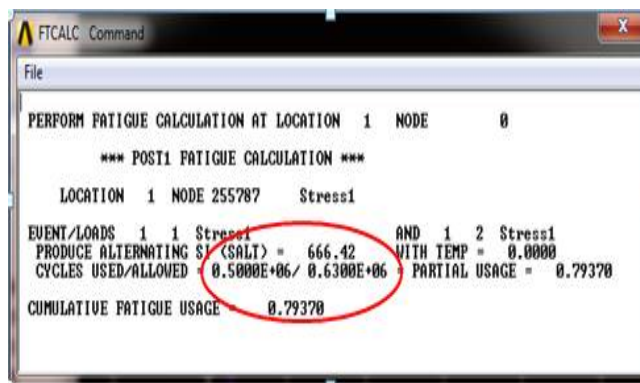
Fig13. Fatigue Result for Location 1 and Location 2

- Location 1 at node 255787 and Location 2 at node 164909 are the two critical areas, where fatigue failure occurs. Hence we considered these two areas for fatigue life prediction of Modified Model.
- For applied boundary condition, it is clear that the First failure component in the McPherson Strut Assembly is Coil Spring.

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The Combination of event 1, load 1 and event 2, load 2 produces a stress intensity of 660.57 Mpa. Subjected to 1×10^7 Cycles while from the S-N Table, the Maximum Number of cycles allowed at that stress intensity is 6.3×10^5 Cycles for Location 1. And the Partial Usage value is 0.79370 is the ratio of cycles used to the maximum cycles allowed. Similarly at location 2 the no of cycles allowed 10×10^5 Cycles and now used cycles are 5×10^5 Cycles.

S NO	Type	Analytical Result	Analysis Result
1	Factor of Safety	1.5616	1.5
2	Fatigue Life	6.5986×10^5 Cycles	6.3×10^5 Cycles

Table5. Comparison Table For Analytical and FE Analysis **Result:**

S NO	Description	Present Design	Modified Design
1	Von-Mises Stress(Mpa)	1478	786.76
2	Maximum Principle(Map)	778.24	660.57
3	Wire Diameter(mm)	15	14.64
4	Spring Mass(Kg)	4.35	4.16

Table6.Comparison Table for Present and Modified Design

IX. CONCLUSION

We have designed a Coil Spring and Modified McPherson Strut Suspension System used in “TATA Indigo eCs Model”. We modelled McPherson Strut Suspension with Coil Spring using CATIA V5 software, and We Done FE Model in Hypermesh tool using specific Meshing Parameters. Finally we did the static and fatigue analysis in ANSYS.

a. We Designed a Coil Spring for McPherson Strut Suspension Assembly; it can withstand both static and fatigue loads, under practical Loading and Boundary conditions.

b. According to Von-Mises Criteria it proves that our design is safe and Maximum Stress is acting on spring coil, Hence we Conclude that we concentrated area of whole assembly is in right path.

c. From Fatigue analysis we found that the fatigue life of model is 10×10^5 cycles, which means that, this model having longer life.

d. In design of Coil Spring we chosen an optimum wire diameter ($d=14.64\text{mm}$) of spring coil. This is lesser than existing wire diameter hence we achieved material optimization.

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- e. The total deformation of the Coil spring is equal to 81.946 mm. This is 50.12% of overall Deformation of the Coil Spring.
- f. The Von-Misses and Maximum Principle stress values are lesser in our designed model than in the original model.
- g. The modified McPherson Strut Suspension is simple in Design and it is easy to install, replacement.

FUTURE SCOPE OF THE PROJECT

McPherson Strut Suspension System is more popular in all European and Indian cars. But main Drawback of this suspension system is a long and Vertical Assembly. Hence we would encounter difficulties. If our car is lower height they may be collision with structure of our car. Thus this type of suspension is not used in racing car.

- a. In Future we need to Change the Suspension Vertical Height so this suspension can used in lower height cars also.
- b. Future Vibrational and Kinematics analysis are carried out to this model.
- c. Dynamic analysis of McPherson Strut Suspension can be done in Future.

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