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Stiffness Calculation of Car Camber Link to Improve the Buckling Strength

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Abstract: ***The project is based on the stiffness of the camber link. Camber link plays vital role in suspension and steering system of the car. The main aim of the project is improve the stiffness and decrease the mass of camber link. Since camber link is subjected to different loads, like compression and tensile, it has to sustain that load without any deflection. In order to achieve this, the camber link must have sufficient stiffness. To increase stiffness different design iterations are carried out in this project. Another important aspect related to designing a new car is mass of the camber link. The camber link mass also adds to the whole weight of car. It adversely effects on the fuel consumption and decreases the fuel efficiency. Also it causes air pollution due to increasing mass. In this project the mass of camber link is decreased by replacing steel alloy material with the light weight aluminum alloy material. The experimental and theoretical analysis was carried out to determine the displacement, stiffness and buckling load of camber link. In preprocessing stage CATIA V5 and HYPERMESH software's were used to model and to mesh the model. In processing stage ABAQUS software was used as solver and post processing HYPERVEIW software was used to view the result. In this project the theoretical stress, displacement, stiffness and buckling loads were found to be in good agreement with the numerical values for steel alloy. Numerically four design iterations were carried out and finally best were selected among the four cases, by considering displacement, stress, natural frequency, mass, stiffness and buckling load. After selection of best case change the steel alloy material with the aluminum alloy material to decrease the mass of the link. Finally aluminum alloy camber link mass was 35% that of the steel alloy link mass. The fatigue analysis was carried out to selected steel alloy camber link, aluminum alloy camber link and existed or original steel alloy camber link to determine damage and life repeats by using nCode software. The selected camber links from design iterations was found to be less damage and high life repeats than the existed or original steel alloy camber link.***

Keywords: Camber link, stiffness, mass, buckling, fatigue.

1. Introduction

Camber link is one of the major components in steering and suspension system of the car. It is a rigid body of link. Its one end is connecting with knuckle arm and other end is connecting with cross member. Suspension links architecture is important in a vehicle. This controls the suspension and steering system of car. Camber link leads effect on camber angle of car. Lengthen the arm to add positive camber and shorten the arm to add negative camber. Over the past years, due to global competitive demands, the automobile industries are looking for low cost and reduced weight parts with increase in performance. Hence the optimization study plays a important role to help a manufacturer to define the mechanical parts that are lighter, reliable and lesser tendency to geometry variations.

Conventionally these parts are made by steel material. Which interacts not only with heavy mass, but also large in dimensions. The major contributor to operate a car is camber link that interacts the vehicle through steering rod Knuckle arm, which is a critical element of the power source. The link subjected to force from top of the vehicle, force existed from wheels and steering also. Hence links are subjected to both tensile and compression forces. The compression forces are mainly considered in suspension components design and analysis. Since the links must has good stiffness to predict displacement due to load. Otherwise the links will buckle take place. Buckle means lateral displacement due to compression loads. Therefore, the aim of the project is to analyze Stiffness of camber link for increasing strength.

To optimize the stiffness, the different parameters are considered like shape and size, material, and boundary conditions of components. If change boundary condition, obviously it will effect on other adjacent components. If change material, the cost and mass of component become major factor in design. If change size and shape, it do not give much effect on other components because there is a certain space between components. Figure 1.1 shows the arrangement of suspension components. Since size and shapes optimizations are commonly preferred. These parameters are leads major effect on the stiffness.

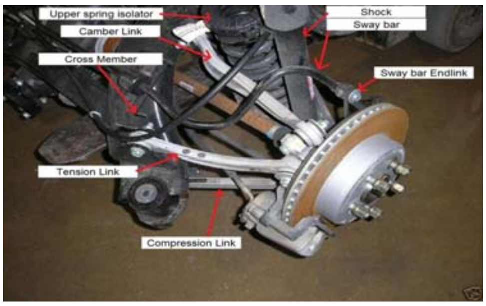

Figure 1.1: Arrangement of suspension components

In present study, the structure analysis was performed using computer aided engineering (CAE) to investigate how each design parameter makes an effect on weight, maximum von-

Misses stress and stiffness in order to obtain an optimal shape which satisfies the required reliability when applying the aluminum ally for lightweight of camber link component of vehicle.

Camber link has cyclic load during vehicle riding. Due to this fluctuating load component is fail before reaching its yield strength of the material. Hence it is necessary to analyze fatigue damage and life cycles. Fig. 1.2 shows the camber link.

Figure 1.2: Camber link

2. Experimental Analysis

The compression test is carried out in a Universal Testing Machine, and the plot of Load versus Cross head travel is obtained as shown in Figure 2.1. Where in for the maximum applied load of 6 KN and the deflection is 3 mm.

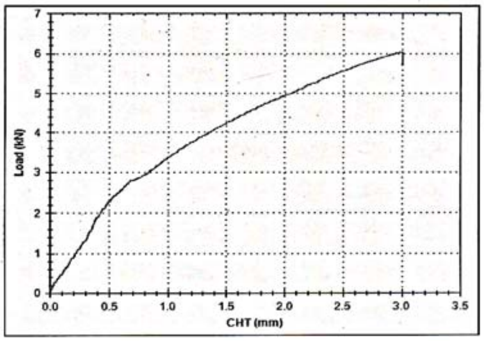

Figure 2.1: Load v/s displacements

Table 2.1: Load v/s displacements

Sl No.	*Applied load (p)in N*	*Recorded change in length(mm)*
1	1000	0.2
2	2000	0.4
3	3000	0.8
4	4000	1.3
5	5000	2.1
6	6000	3

3. Theoretical Calculations

The load, at which the column tends to have lateral displacement or tends to buckle, is called buckling load, critical load, or crippling load and the column is said to have developed an elastic instability. The buckling takes place about the axis having minimum radius of gyration or least moment of inertia.

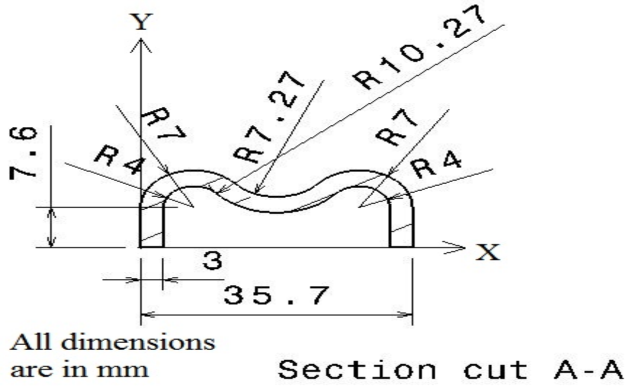

Figure 3.1: Cross sectional view of camber link

After substitution and calculations,
Centre of gravity of above cross section
X=17.85 mm
Y=9.054 mm
A=171.388 mm^2
Moment of inertia
Ixx= 7551.188 mm^4
Iyy= 40761.916 mm^4
Iyy > Ixx

Buckling load obtained from Euler's equation,

$$P_{cr} = (\pi^2 EI_{xx})/[L_{eff}]^2$$

= 73.607 KN
E = 2×10^5 MPa
Leff = effective length = 450 mm

Maximum deflection given by,

$$d_{max} = e[\sec[(\pi/2 \sqrt{(P/P_{cr})}) - 1]]$$

=2.946 mm
P = applied load = 6000 N
Pcr =buckling load = 73.607 KN
e = eccentricity = 26.85 mm

Stiffness of link is given by,
K = P/dmax
= 2036.659 N/mm

Total Stress is given by,

$$\sigma_{total} = 415.81 \text{ N}/[mm]^2$$

4. Geometrical configuration of the camber link

4.1 3D model of existed steel alloy camber link

The model is constructed by using CATIA V5R21, The explode view of the model as shown in Figure 4.1.

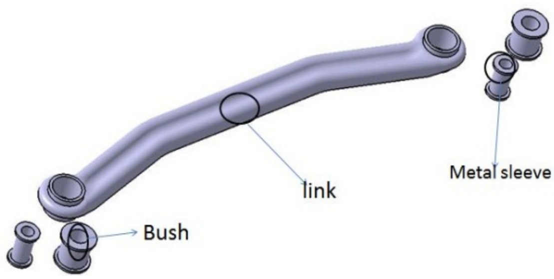

Figure 4.1: 3D Model

There are 3 parts in the camber link. Such as a link, two bushes and two sleeves at both end. The mass of link is 0.7453 kg.

4.2 Material properties

The mechanical properties of steel alloy material,
Type of material: STKM 14B
Properties: Young’s modulus= 2×10^5 MPa
Density=7.85×10^-6 kg/mm^3
Tensile strength= 500 MPa
Yield strength = 355 MPa
Poisson's ratio=0.3

5. Finite Element Method

Import the IGS file to Hypermesh and clean up the geometry. In meshing Rtria mesh was done on whole outer surface of the model and then tetra mesh (4 noded triangular elements) is obtained. Hexa (8 noded) solid meshing is made to bush and metal sleeve.

Figure 5.1: Meshed Model

6. Analysis of Existed Steel Alloy Camber Link

6.1 Loading and Boundary Condition

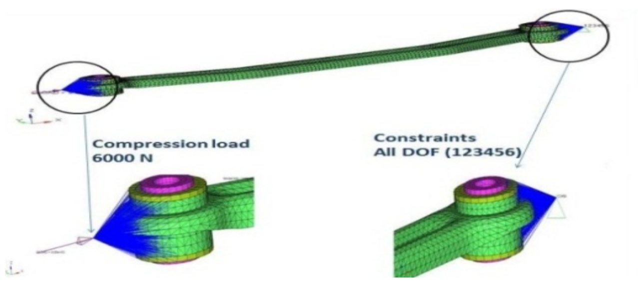

Figure 6.1: Loading and boundary condition

Figure 6.1 Shows that loading and boundary conditions. In suspension architecture camber link both end was hinged. But for numerical analysis one end is considered as fixed and other end is subjected to load. Also loads and constraints are applied at the end of link to compare the results with experimental values. Here rigid RBE2 elements are used to apply constraints and loads. Which elements are rigid, there is no motion between nodes. Which is not deformation take place and doesn’t transform to other elements. At one end is constrained in all degrees of freedom (DOF) that is three translations and three rotations. Other end is subjected to 6000 N compression axial load in X-direction.

6.2 Results of Existed Steel Alloy Camber Link

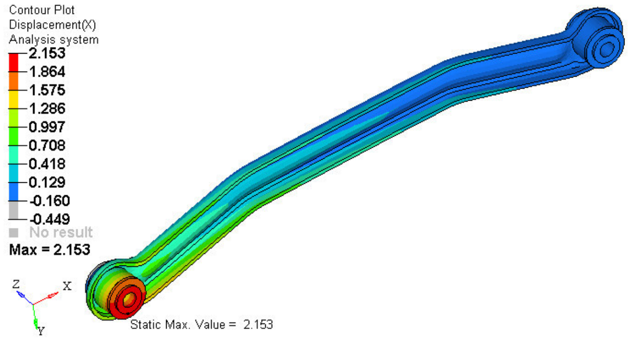

Figure 6.2: Displacement of existed steel alloy camber link

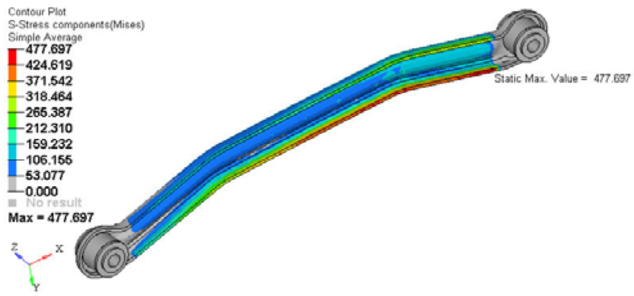

Figure 6.3: Maximum von-misses stress of existed steel alloy camber link

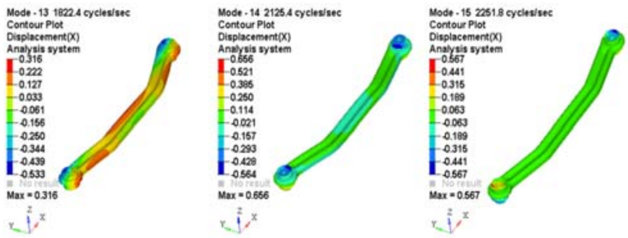

Figure 6.4: Modal analysis mode shapes of existed steel alloy camber link

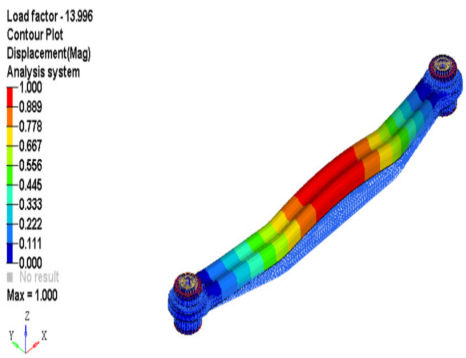

Figure 6.5: Buckling mode shape of existed steel alloy camber link

7 Design Iterations

7.1 Elongated hole steel alloy camber link

7.1.13D model

The mass of link is 0.7251 kg.

Figure 7.1: 3D model of elongated hole steel alloy camber link

7.1.2 Analysis results of existed steel alloy camber link

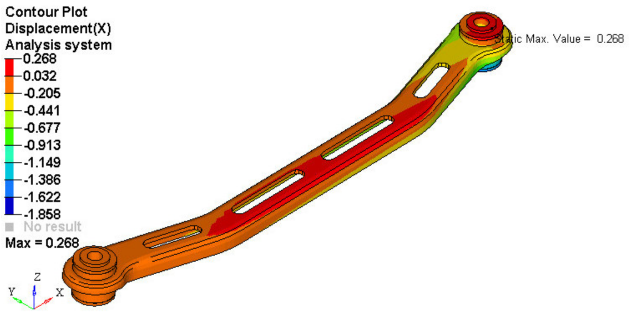

Figure 7.2: Displacement of elongated hole steel alloy camber link

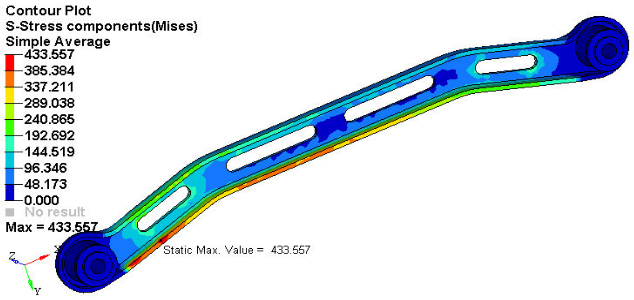

Figure 7.3: Maximum von-misses stress of elongated hole steel alloy camber link

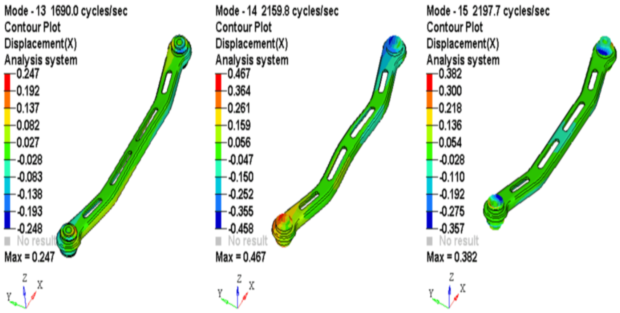

Figure 7.4: Modal analysis mode shapes of elongated hole steel alloy camber link

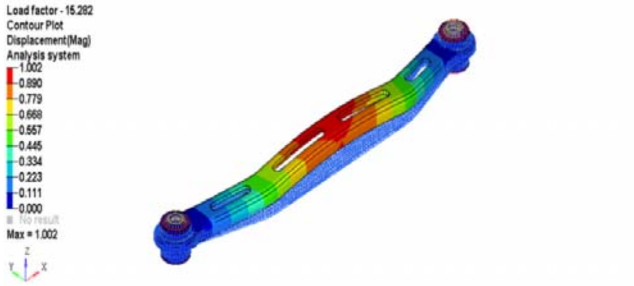

Figure 7.5: Buckling mode shape of elongated hole steel alloy camber link

7.2 Circular hole steel alloy camber link

7.2.13D model

The mass of link is 0.7427 kg.

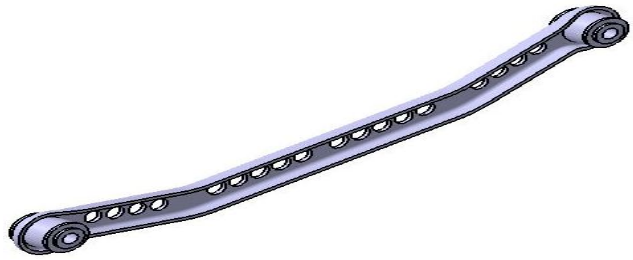

Figure 7.6: 3D model of circular hole steel alloy camber link

7.2.2 Analysis results of circular hole steel alloy camber link

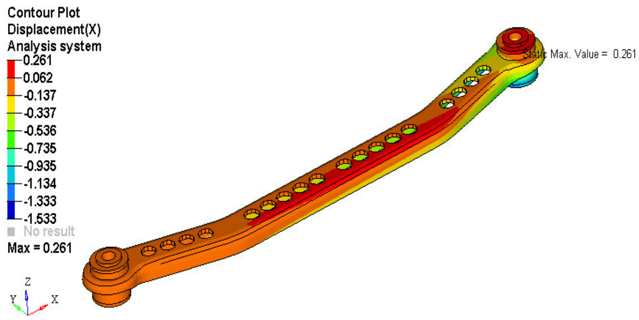

Figure 7.7: Displacement of circular hole steel alloy camber link

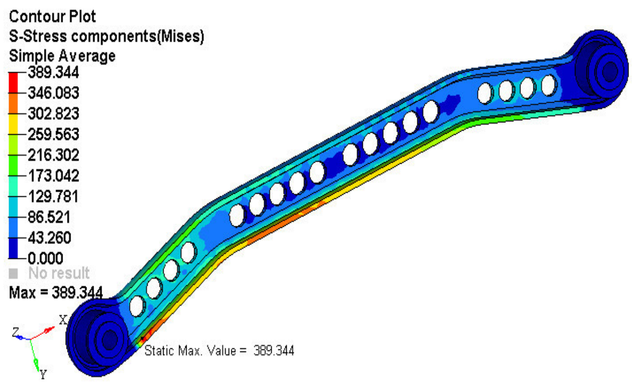

Figure 7.8: Maximum von-misses stress of circular hole steel alloy camber link

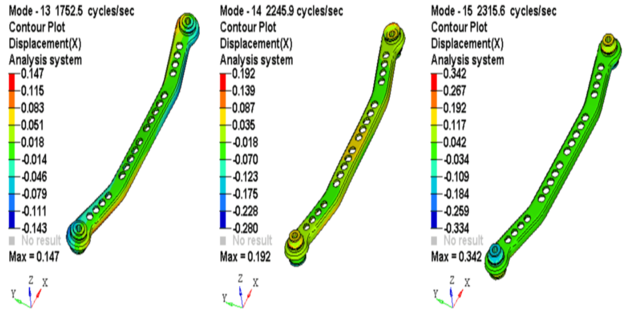

Figure 7.9: Modal analysis mode shapes of circular hole steel alloy camber link

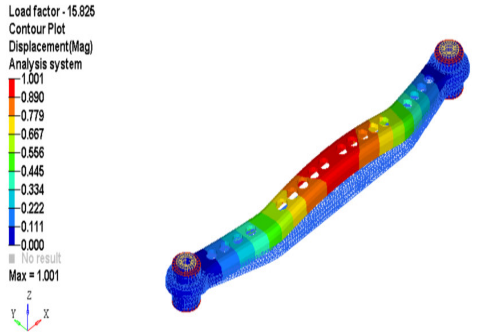

Figure 7.10: Buckling mode shape of circular hole steel alloy camber link

7.3 I-section steel alloy camber link

7.3.1 3D model

The mass of link is 0.7427 kg.

Figure 7.11 3D Model of I-section steel alloy camber link

7.3.2 Analysis results of I-section steel alloy camber link

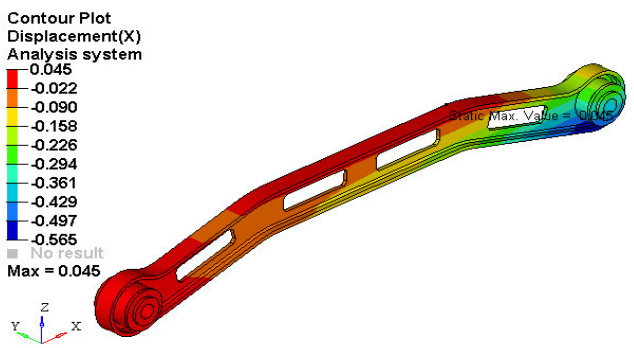

Figure 7.12: Displacement of I-section steel alloy camber link

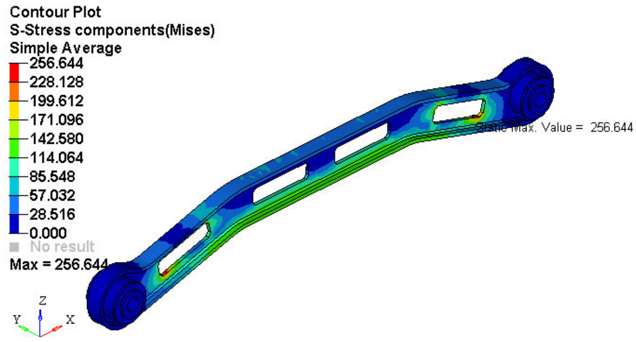

Figure 7.13: Maximum von-misses stress of I-section steel alloy camber link

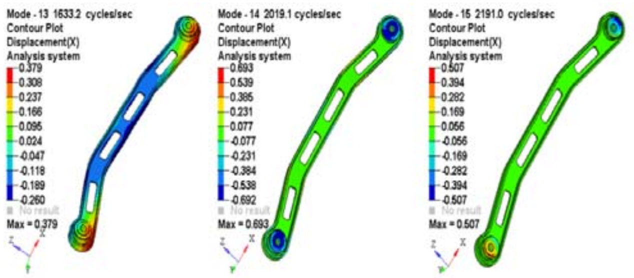

Figure 7.14: Modal analysis mode shapes of decreased eccentric steel alloy camber link

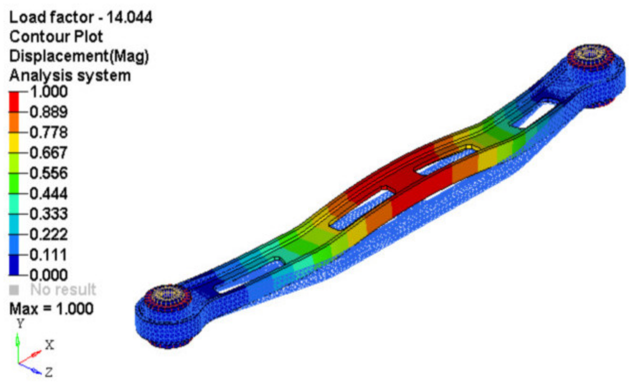

Figure 7.15: Buckling mode shape of decreased eccentric steel alloy camber link

7.4 Decreased eccentric steel alloy camber link

7.4.1 3D model

The mass of link is 0.7393 kg.

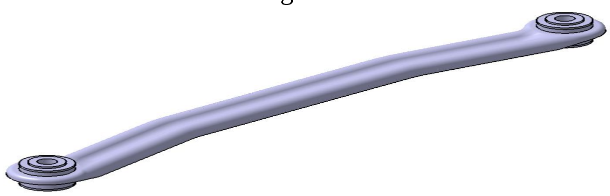

Figure 7.16: 3D model of decreased eccentric steel alloy camber link

7.4.2 Analysis results of decreased eccentric steel alloy camber link

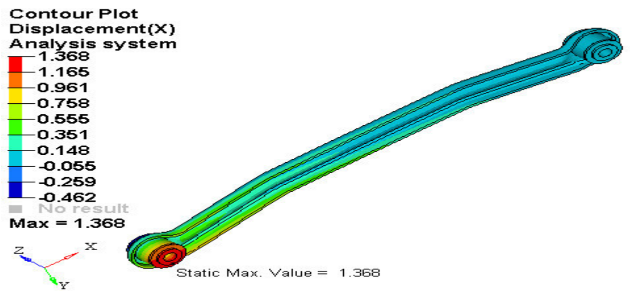

Figure 7.17: Displacement of decreased eccentric steel alloy camber link

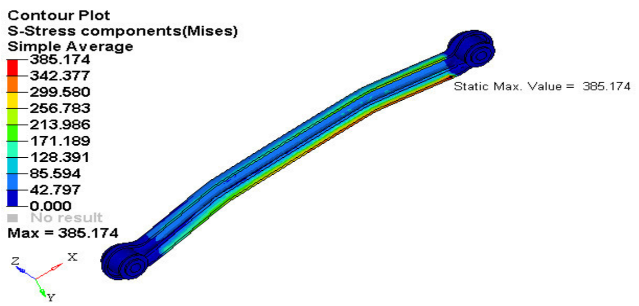

Figure 7.18: Maximum von-misses stress of decreased eccentric steel alloy camber link

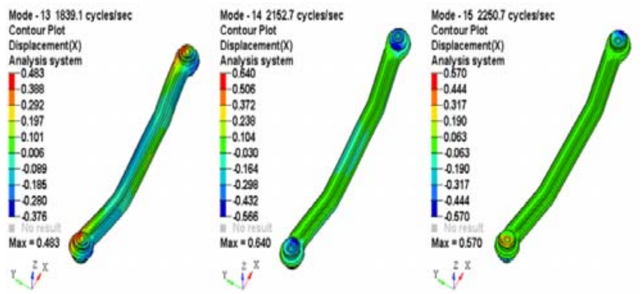

Figure 7.19: Modal analysis mode shapes of decreased eccentric steel alloy camber link

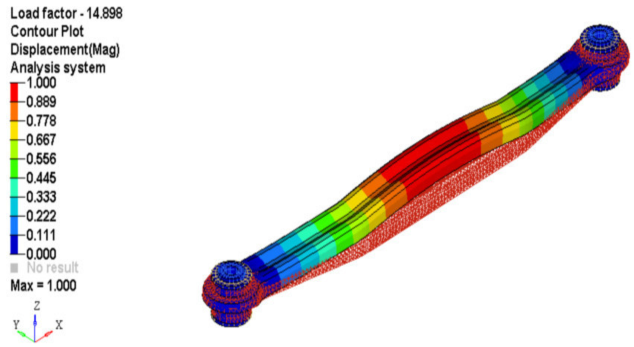

Figure 7.20: Buckling mode shape of decreased eccentric steel alloy camber link

7.5 Discussions

From above results, I-section steel alloy camber link has;

- Less displacement (0.199 mm)
- Less stress (256.664 N/mm^2)
- Maximum stiffness (133333.4 N/mm)
- Less mass (0.7427 kg) compare to existed steel alloy camber link. And save 0.348% of that existed design.
- Frequency and buckling loads are nearer to existed steel alloy camber link.

Hence I-section steel alloy camber link is better as compare to existed steel alloy camber link.

8 Replacement of steel alloy material with aluminum alloy material

The replacement of material process is carried to I-section steel alloy camber link. Because it satisfied all conditions like displacement, stress, stiffness etc. The link has steel alloy (STKM 14B) material and replace with the aluminum alloy material to reduce mass of the component. The bush and metal sleeve materials are same as existed steel alloy camber link. After replacement of material the mass of link becomes 0.258 kg. The 3D model and mesh model are same as I-section steel alloy camber link.

Type of material: Aluminum alloy A16082M
Properties: Young's modulus = 72000 MPa
Density= 2.71 × 10^-6 kg/mm^3
Tensile strength= 380 MPa
Yield strength = 340 MPa
Poisson's ratio=0.3

8.1 Analysis results of I-section aluminum alloy camber link

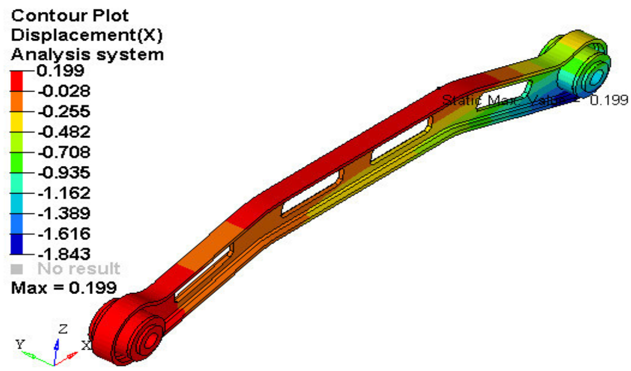

Figure 8.1: Displacement of I-section aluminum camber link

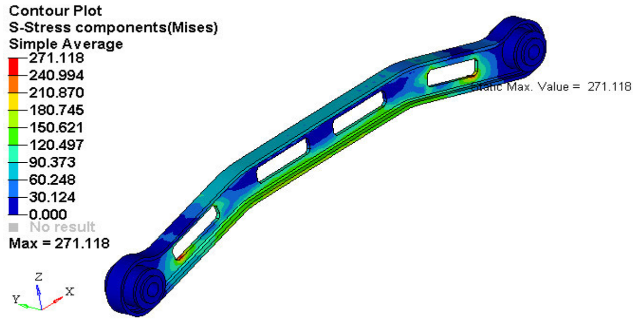

Figure 8.2: Maximum von-misses stress of I-section aluminum camber link

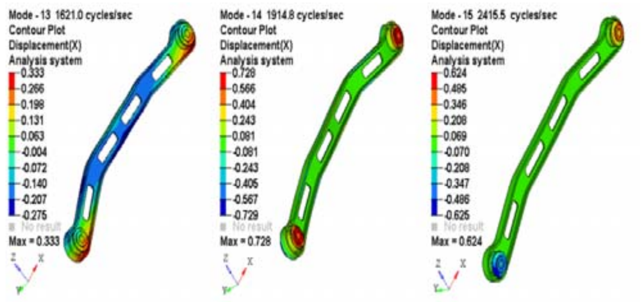

Figure 8.3: Modal analysis mode shapes of I-section aluminum alloy link

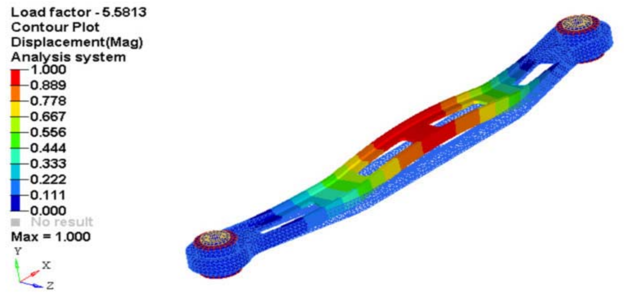

Figure 8.4: Buckling mode shape of I-section aluminum alloy link

8.2 Discussions

From above results I-section aluminum alloy camber link has

- Less displacement (0.199mm)
- Less mass (0.258 kg)
- Large frequency (2415.5 cycles/sec)
- Less stress compare to material yield strength (271.118 N/mm^2)
- I-section aluminum alloy link has less buckling load as compared to existed steel alloy camber link and I-section steel alloy camber link.

9 Fatigue Analysis

Camber link has subjected to cyclic load during vehicle riding. This fluctuating load leads adverse effect on component and it fails before reaching its yield strength of material. Hence the link must be less damage and more life cycles. In this project for fatigue analysis nCode software has used.

9.1 Boundary and loading conditions for fatigue analysis

For fatigue analysis unit load was applied in each direction (X, Y, Z direction) at bush centre by using rigid RBE2 elements at both end of link. Before applying load, take face of the 3D solids of each component. Because in fatigue analysis, it was consider inside of the solid also but always crack was initiated from outside surface. Since first take face of the solid and apply rigid and load. In Hypermesh, deck was prepared with unit load and solved in Abaqus. Finally road load data, material data and Abaqus output files like .OBD and .inp files were input to the nCode designlife software to get damage and life, repeats.

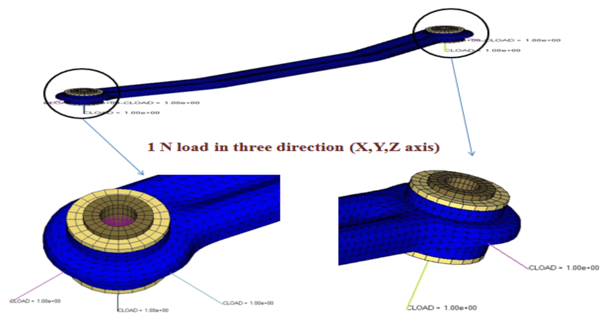

Figure 9.1: Boundary and loading conditions for fatigue analysis

9.2 Results and Discussions

9.2.1 Damage Results

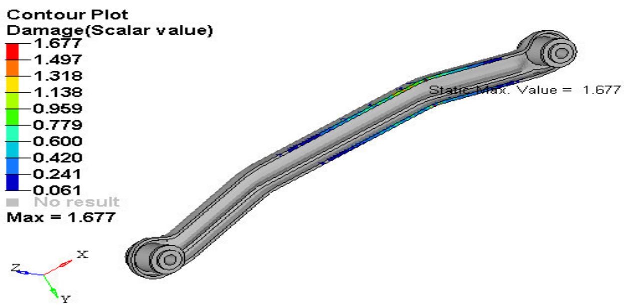

Figure 9.2: Damage of existed steel alloy camber link

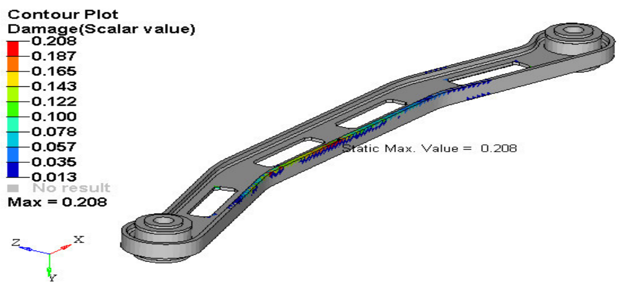

Figure 9.3: Damage of I-section steel alloy camber link

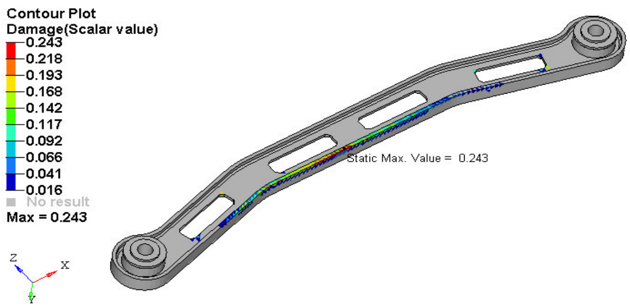

Figure 9.4: Damage of I-section aluminum alloy camber link

9.2.2 Life, Repeats Results

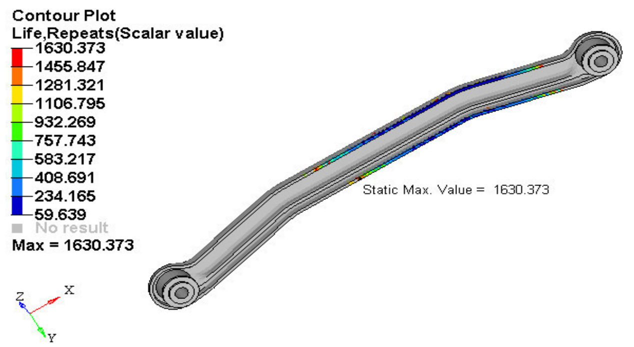

Figure 9.5: Life, repeats of existed steel alloy camber link

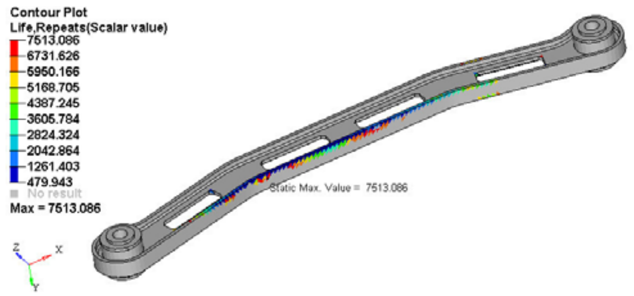

Figure 9.6: Life, repeats of I-section steel alloy camber link

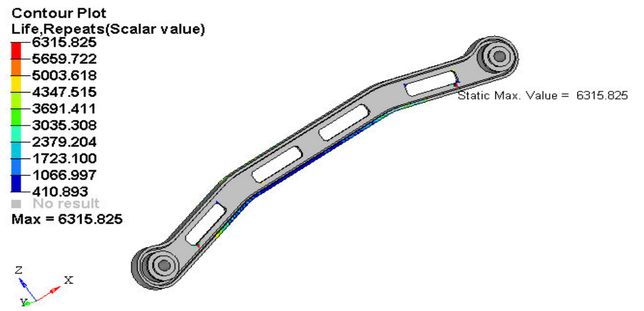

Figure 9.7: Life, repeats of I-section aluminum alloy camber link

9.3 Discussions of Fatigue Analysis

From above results

- The damage of the I-section steel alloy camber link has less as compare to other camber links. The I-section aluminum alloy camber link has less damage as compare to existed steel alloy camber link.
- The life, repeats of the I-section steel alloy camber link has high as compare to other camber links. The I-section aluminum alloy camber link has high life, repeats as compare to existed steel alloy camber link.

10 Conclusion

The experimental value of displacement of existed steel alloy camber link was found to be 3mm. While the theoretical and numerical values were 2.946 mm and 2.153 mm respectively under a compression load of 6000N. The experimental and numerical values had an error of 28.233%. The theoretical and numerical stiffness of existed steel alloy camber link was fond to be 2036.66 N/mm and 2786.809 N/mm respectively with an error of 26.91%.The theoretical and numerical buckling load of existed steel alloy camber link was found to be 73607.148 N and 81600 N respectively with an error of 9.79%.

In design iterations the I-section camber link was suggested. Because it has high stiffness of 133333.4 N/mm. The mass of I-section steel alloy camber link and existed steel alloy camber link was found to be 0.7427 kg and 0.7453 kg respectively. Since I-section camber link was save 0.348% of the mass. I-section steel alloy camber link was improved 3.16% of buckling load.

Steel alloy was replaced with the aluminum alloy (A16082M) to I-section steel alloy camber link. Hence around 65.38% of mass of material was saved from existed steel alloy camber link. The damage of the I-section steel alloy was found to be 0.204. Which is less than one, hence design is safe and the damage of existed steel alloy camber link was found to be 1.677. The life, repeats of the I-section steel alloy camber link was found to be 7513.086 cycles and the life, repeats of existed steel alloy camber was found to be 1630.373 cycles.

11 Scope for future work

Some other design iterations can carried out by adding stiffener or changing shape and size, to optimize the camber link in order to improve the stiffness and decreasing mass.

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