Strength Evaluation and Slippage Study on Upper Control Arm

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Abstract- Suspension system is major part in a vehicle, the wishbone upper control arm is a type of a independent suspension used in passenger car. In this work it is mainly concentrated on stiffness, slippage and damage of upper control arm. The upper control arm is subjected to different type of loads such as static loads and cyclic loads. Stiffness is improved by changing shape and size of upper control arm this is achieved by static analysis. This analysis is carried out to find displacement, stress and stiffness. Due to some loading conditions, slippage occurs in between arm and bush. In this work slippage analysis carried out to check whether slippage occurs in the upper control arm. Fatigue analysis carried out to determine the damage and life of upper control arm.

Index Terms- Suspension system, Upper Control Arm, Stiffness, Slippage, Damage, Life.

1. INTRODUCTION

Suspension control arms are important parts in a vehicle. The Wishbone control arm is a type of independent suspension used in motor vehicles[1]. The function of control arms is to keep the wheels of a motor vehicle from uncontrollably swerving when the road conditions are not smooth. A control arm is a rigid body that has a pivot at both ends. Upper control arm plays vital role in suspension architecture of car. The car has several control arms, including the upper control arm and the lower control arm, which are arranged to form the letter A as shown in figure 1..

Fig. 1. Upper control arm

Since it leads effect on comfortable riding. In automotive suspension, a control arm is a hinged suspension link between the chassis and the suspension upright or hub that carries the wheel and manages the motion of the wheels so that it synchronizes with that of the body of the car. They work with bushings, which are cylindrical linings that reduce friction and restrain the auto parts from going every which way. As a result, the car must be able to go on joy rides without feeling sick and dizzy, as there is control and smoothness in the movement. Handling and steering could become erratic if the control arms are malfunctioning and the unsteady movements of car could take away from riding comfort

The upper control arm subjected various types of loads while riding on irregular surfaces and also forces exerted from steering. Since the upper control arm must be able to sustain those load without any deflection and slippage between bush and arm. The control arm takes most of the impact that the road has on the wheels of the motor vehicle. It either stores that impact or sends it to the connected suspension control arm depending on its shape.

During the actual working condition, the maximum load is transferred from upper wishbone arm to the lower arm which creates possibility of failure in the arm. Similarly impact loading produces the bending which is not desirable. Due to this loads the slippage happened and it cause accident. The present study will contribute in this problem by using finite element analysis approach[2-4].

The computer aided engineering (CAE) analysis was carried out to static analysis and slippage analysis, in order to determine maximum von misses stress, displacement and avoid slippage between bush and arm[5-7].

The control arm subjected to cyclic load also. Hence due to fatigue load the control arm failure take place before stress reaches the yield strength of the material. In this project road load data material data's are directly taken from experiment and those are input to the nCode software. Finally it gives damage and life repeats of the upper control arm. It helps to reduce damage and increase the life of the component by some design iteration[8-10].

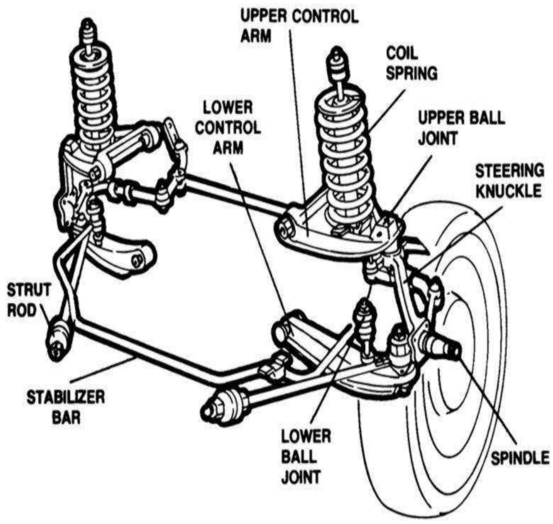

Fig. 2. Arrangement of suspension system

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 3. The displacement for 3KN load was found to be 10 mm that can be shown in graph.

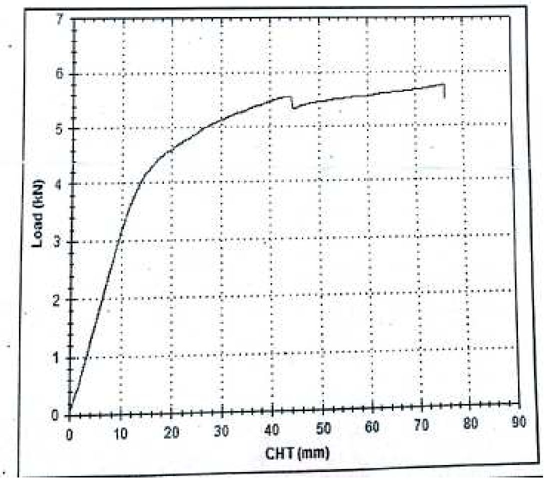

Fig. 3. Graph of Displacement v/s Load

From the above graph displacement values can be recorded for corresponding load, that can be clearly showing in fallowing table

Table.1 Displacement v/s Load

Sl No.	Applied load (p)in Newton	Recorded change in length(mm)
1	1000	4
2	2000	8
3	3000	10
4	4000	14

3. GEOMETRICAL MODELING

3.1 3D Modeling

The model is constructed by using CATIA V5R21, The explode view of the model as shown in Figure 4.

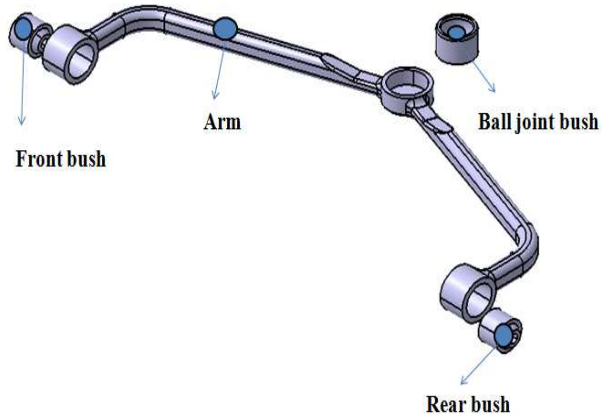

Fig.4. 3D modeling of upper control arm

3.2 Mechanical properties of gray cast iron

Table.2 Mechanical properties of gray cast iron used in Upper Control Arm

Sl No.	Mechanical properties of gray Cast iron	Value
1	Young's Modulus(E)	1.57x10^5 N/mm^2
2	Poisson's Ratio(ϑ)	0.26
3	Density(ρ)	7.1x10^-9 Ton/mm^3
4	Yield Strength(σy)	276 N/mm^2
5	Ultimate Strength(σu)	370 N/mm^2

4. 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.

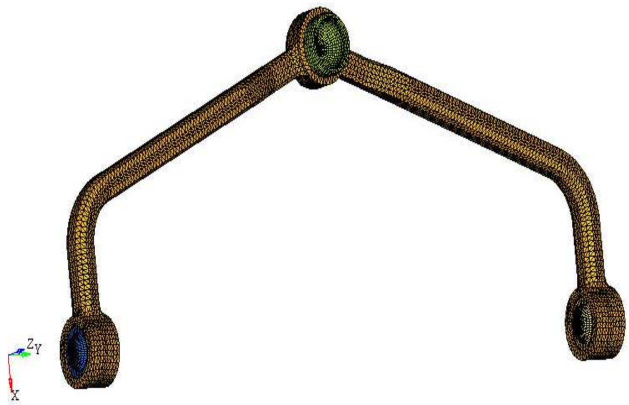

Fig. 5. Meshed model

Table.3 Mesh details

Sl No.	Type of element	No of element
1	Hexa/C3D8	8850
2	Tetra/C3D4	52106

	Total	60956

5. RESULT AND DISCUSSIONS OF STATIC ANALYSIS

5.1 Displacement results

5.1.1Displacement of existed design upper control arm of gray cast iron material by numerically

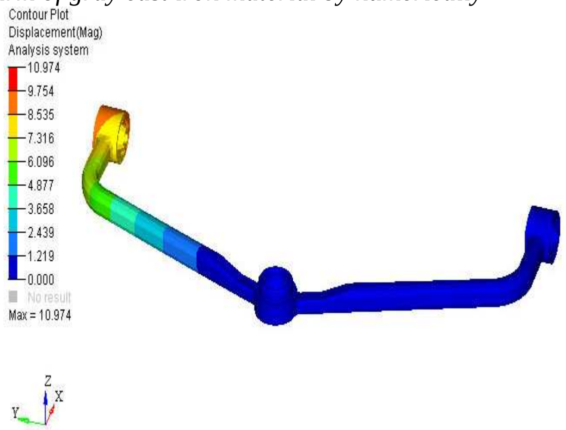

Fig. 6. Displacement of existed design upper control arm of gray cast iron

5.1.2Displacement of first modified upper control arm of gray cast iron material by numerically

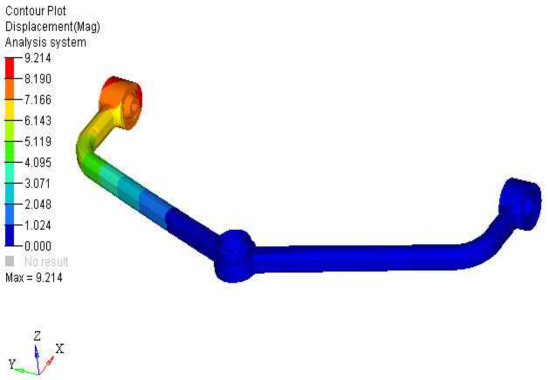

Fig. 7. Displacement of first modified design upper control arm of gray cast iron

5.2 Stress results

5.2.1 Stress (Misses) of existed design upper control arm of gray cast iron material by numerically

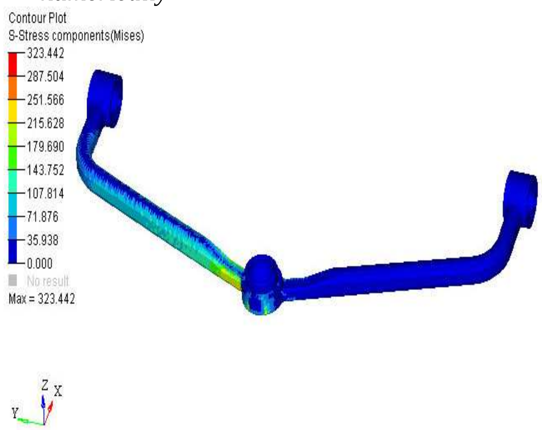

Fig. 8. Stress (Misses) of existed design upper control arm of gray cast iron.

5.2.2 Stress (Misses) of first modified upper control arm of gray cast iron material by numerically

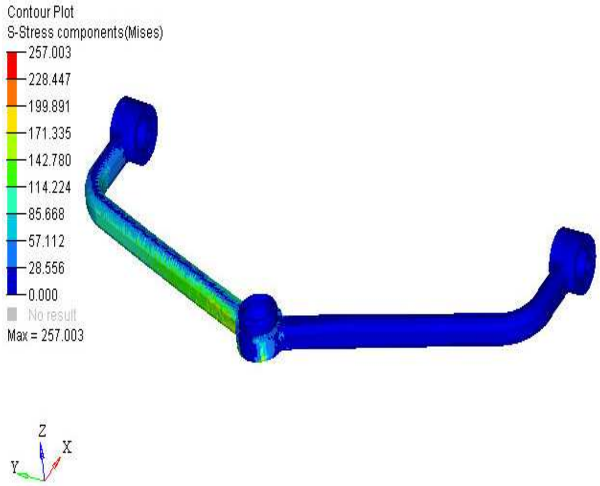

Fig. 9. Stress (Misses) of first modified upper control arm of gray cast iron.

5.3 Discussions

From the above results the displacement obtained experimentally is 10mm and by numerically obtained displacement for existed design of gray cast iron is 10.974 mm and for first modified design of gray cast iron is 9.214 mm. Hence first modified design of grey cast iron has less displacement as compare to existed upper control arm.

From the above results Stress (Misses) for existed design of gray cast iron obtained to be 323.442 N/mm^2 and for first modified design of gray cast iron obtained to be 257.003 N/mm^2 and yield stress of gray cast iron is 276 N/mm^2.hence first modified design of upper control arm of gray cast iron Stress (Misses) is lesser than yield stress and hence it is safe.

6. RESULT AND DISCUSSIONS OF SLIPPAGE ANALYSIS

6.1 Slippage results

6.1.1Contact normal force for slippage of front bush and UCA

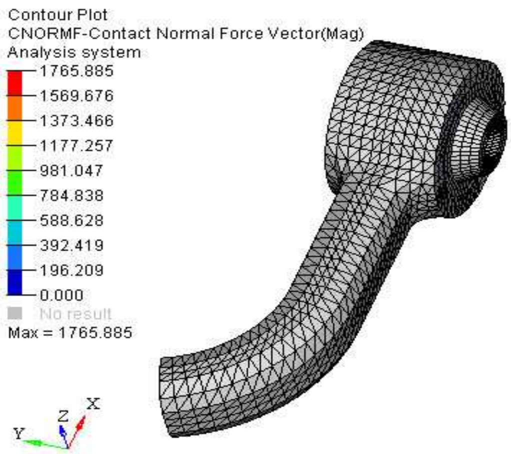

Fig. 10. CNFM for slippage of front bush and upper control arm

6.1.2Contact shear force for slippage of front bush and UCA

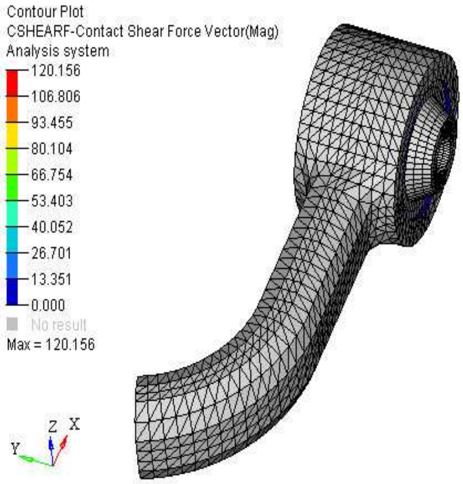

Fig. 11. CFSM for slippage of front bush and upper control arm

6.1.3Contact normal force for slippage of rear bush and UCA

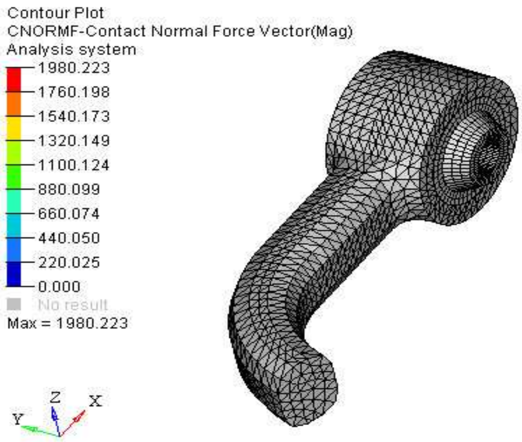

Fig. 12. CNFM for slippage of rear bush and upper control arm

6.1.4 *Contact shear force for slippage of rear bush and UCA*

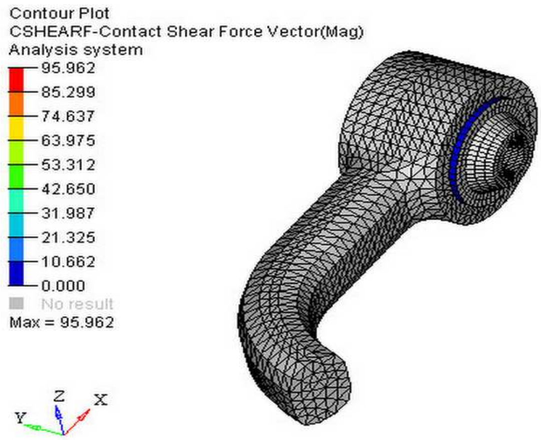

Fig. 13. CFSM for Slippage of rear bush and upper control arm

6.1.5 Contact normal force for slippage of upper ball joint bush and UCA

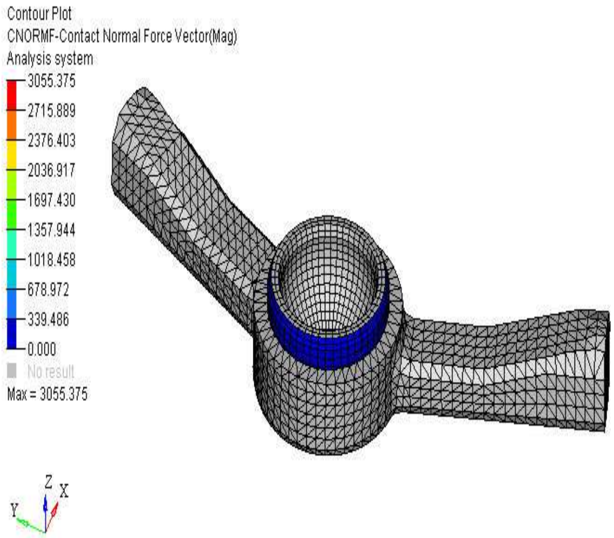

Fig. 14. CNFM for slippage of upper ball joint bush and Upper control arm

6.1.6 Contact shear force for slippage of upper ball joint bush and UCA

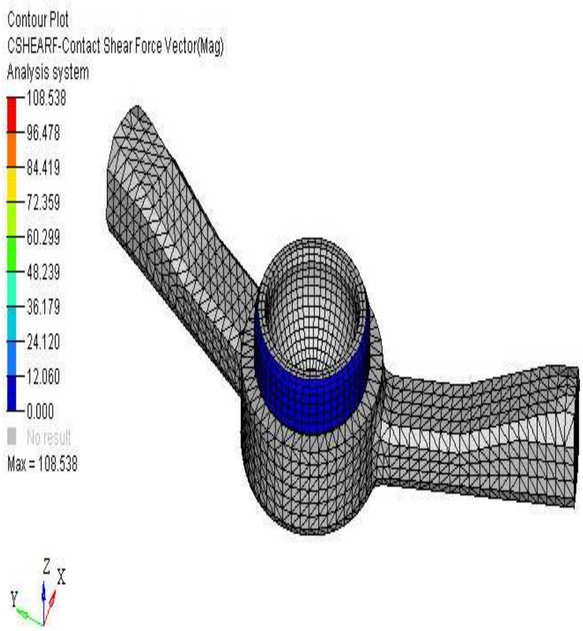

Fig. 15. CFSM for slippage of upper ball joint bush and upper control arm

6.2 Discussion

Due to some load conditions slippage occurring between arm and bush. This analysis is carried out to check whether bush is slipping from arm, that can be obtained by obtaining the output like CNFM and CFSM by numerically, Fatigue strength can be obtained by multiplying friction coefficient to CNFM .If fatigue strength is greater than CFSM means its No Slipping similarly if fatigue strength is lesser than CFSM means it's slipping.

6.2.1Front bush and arm slippage analysis:

Slippage analysis is carried out for front bush and arm, from the analysis CNFM obtained is 1765.898 N/mm^2 and CFSM obtained is 120.156N/mm^2 that shown in above plots

Frictional strength = Friction coefficient X CNFM

Friction coefficient=0.15

Frictional strength = 0.15 X 1765.898

=264.8847 N/mm^2.

If Frictional strength > CFSM = No slippage

i.e. 264.8847 > 120.156 = No slippage.

No slippage occurs between front bush and upper control arm, hence it is safe.

6.2.2Rear bush and arm slippage analysis:

Slippage analysis is carried out for rear bush and arm, from the analysis CNFM obtained is 1980.822 N/mm^2 and CFSM obtained is 95.962 N/mm^2 that shown in above plots

Frictional strength = Friction coefficient X CNFM

Friction coefficient=0.15

Frictional strength = 0.15 X 1980.822

=297.1233 N/mm^2.

If Frictional strength > CFSM = No slippage

i.e. 297.1233 > 95.962 = No slippage.

No slippage occurs between rear bush and upper control arm, hence it is safe.

6.2.3Upper ball joint bush and arm slippage analysis:

Slippage analysis was carried out for upper ball joint bush and arm, from the analysis CNFM obtained is 3055.375 N/mm^2 and CFSM obtained is 108.538 N/mm^2 that shown in above plots

Frictional strength = Friction coefficient X CNFM

Friction coefficient = 0.15

Frictional strength = 0.15 X 3055.375

=458.306 N/mm^2.

If Frictional strength > CFSM = No slippage

i.e. 458.306 > 108.538 = No slippage, Hence it's safe

7 FATIGUE ANALYSIS

7.1Loading and boundary conditions

For fatigue analysis unit load was applied in each direction (X, Y, Z direction) at bush centre by using rigid KINGKOUP elements. 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 .odb and .inp files were input o the nCode designlife software.

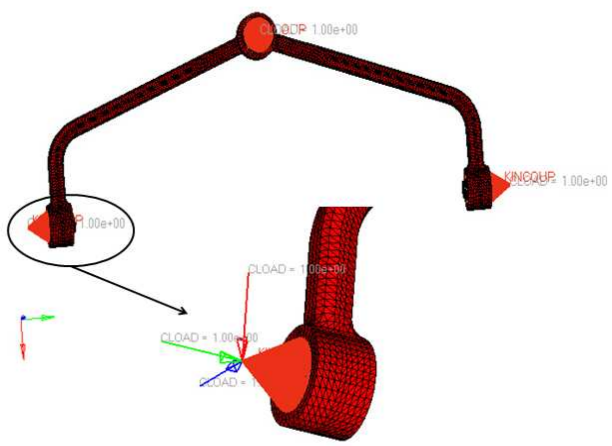

Fig. 16. Loading and boundary conditions for fatigue analysis

7.2 RESULT AND DISCUSSIONS OF FATIGUE ANALYSIS

7.2.1Damage results

1) *Damage of existed design upper control arm of cast iron alloy*

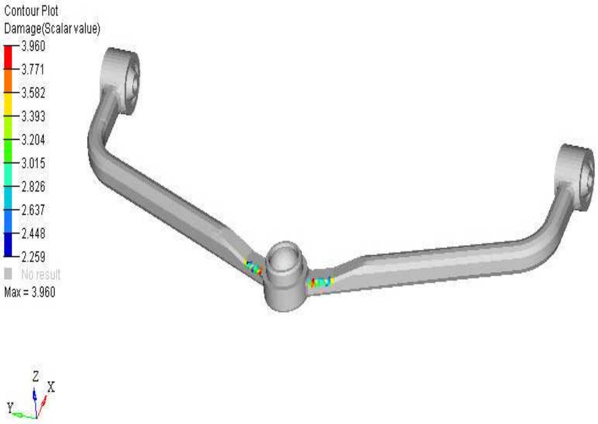

Fig. 17. Damage of existed design upper control arm of cast iron alloy

2) *Damage of existed design upper control arm of aluminum alloy*

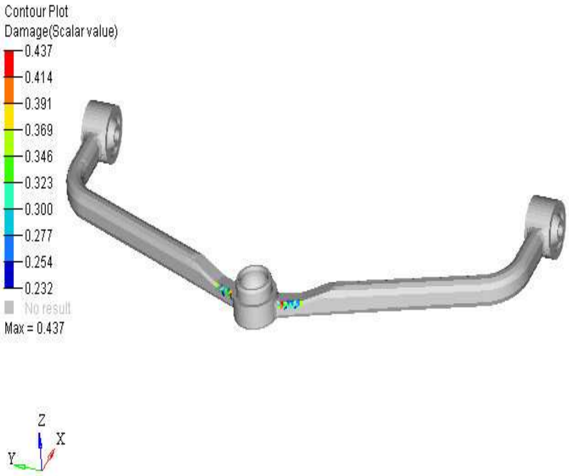

Fig. 18. Damage of existed design upper control arm of cast iron alloy

3) *Damage of existed design upper control arm of steel alloy*

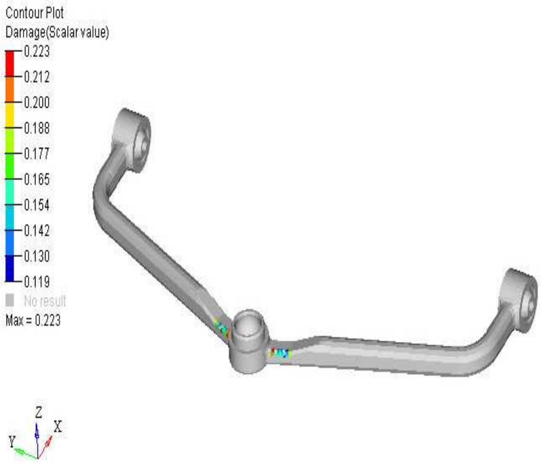

Fig. 19. Damage of existed design upper control arm of steel alloy

4) *Damage of first modified design upper control arm of cast iron alloy*

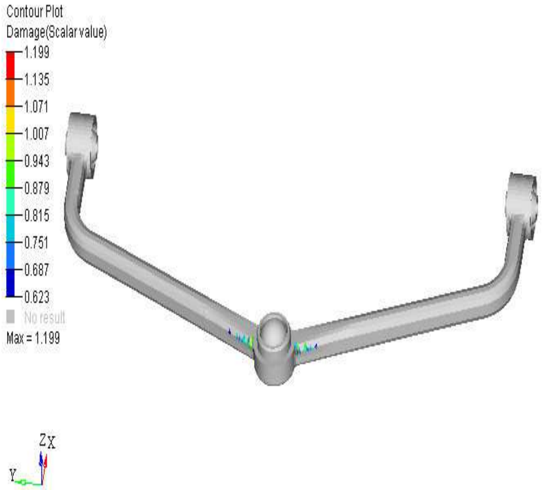

Fig. 20. Damage of first modified upper control arm of cast iron alloy

5) *Damage of first modified upper control arm of aluminum alloy*

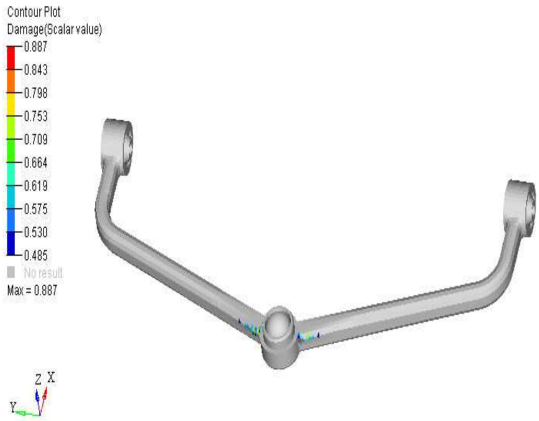

Fig. 21. Damage of first modified upper control arm of aluminum alloy

6) *Damage of first modified upper control arm of steel alloy*

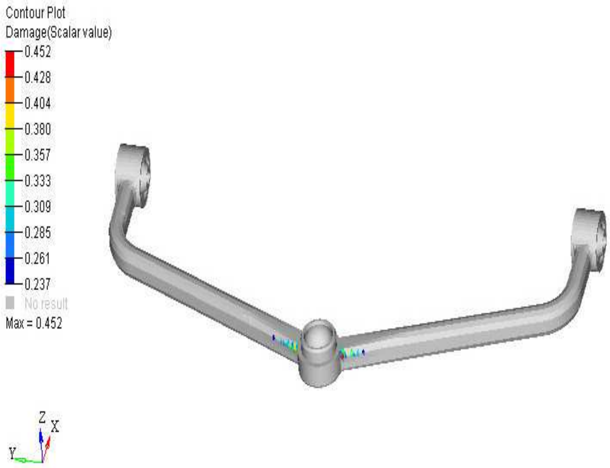

Fig. 22. Damage of first modified upper control arm of steel alloy

7) *Damage of second modified upper control arm of cast iron alloy*

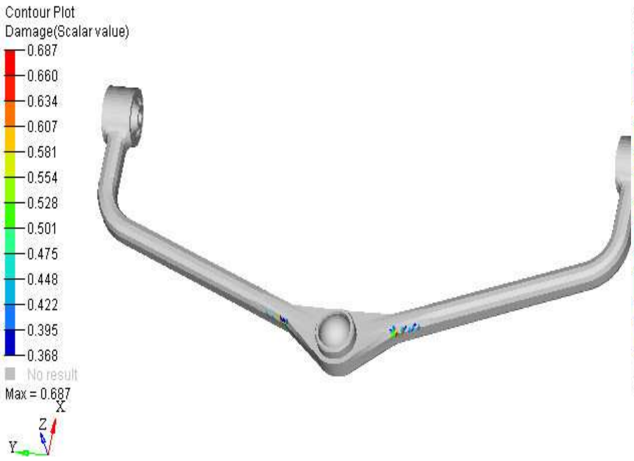

Fig. 23. Damage of second modified upper control arm of cast iron alloy

8) *Damage of second modified upper control arm of aluminum alloy*

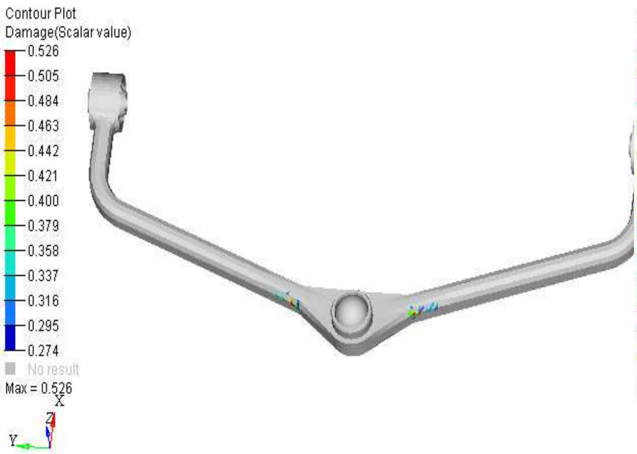

Fig. 24. Damage of second modified upper control arm of aluminum alloy

9) *Damage of second modified upper control arm of steel alloy*

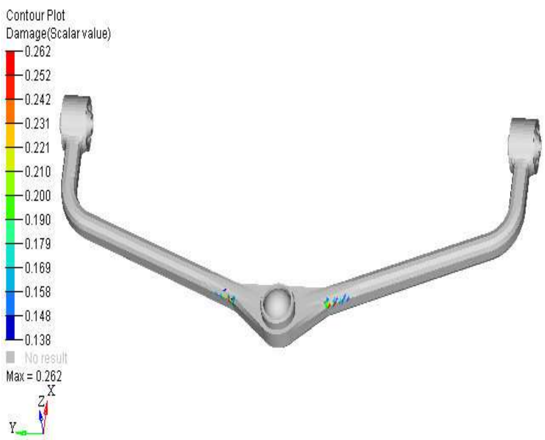

Fig. 25. Damage of second modified upper control arm of steel alloy

7.2.2Life, repeats results

10) *Life, repeats of existed design upper control arm of steel alloy*

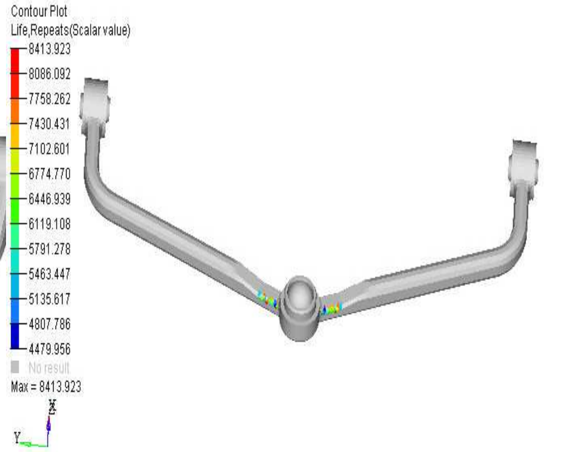

Fig. 26. Life, repeats of existed design upper control arm of steel alloy

11) *Life, repeats of first modified upper control arm of steel alloy*

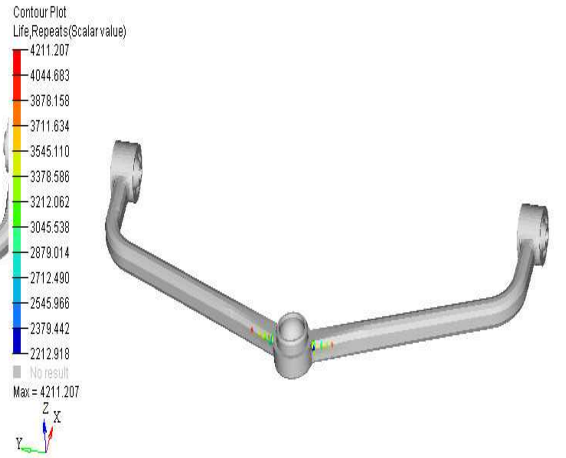

Fig. 27. Life, repeats of first modified upper control arm of steel alloy

12) *Life, repeats of second modified upper control arm of steel alloy*

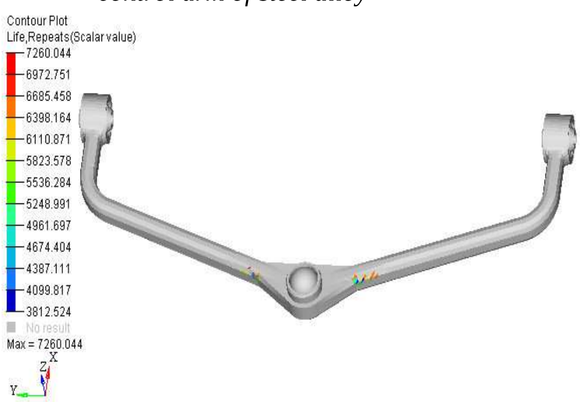

Fig. 28. Life, repeats of second modified upper control arm of steel alloy

7.3Discussions

Damage of existed design upper control arm for cast iron alloy is found to be 3.960 it is greater than one. Since this upper control arm was going to fail and for aluminum alloy is found to be 0.437 It is less than one. Since this upper control arm is going to safe similarly for steel alloy is found to be 0.223 it is lesser than one. Since this upper control arm is going to safe.

Damage of first modified upper control arm for cast iron alloy is found to be 1.199 it is greater than one. Since this upper control arm is going to fail and for aluminum alloy is found to be 0.887 It is less than one. Since this upper control arm is going to safe similarly for Steel alloy is found to be 0.452 it is lesser than one. Since this upper control arm is going to safe.

Damage of second modified upper control arm for cast iron alloy is found to be 0.657 it is lesser than one. Since this upper control arm is going to safe and for aluminum alloy is found to be 0.526 It is less than one. Since this upper control arm is going to safe similarly for steel alloy is found to be 0.262 it is lesser than one. Since this upper control arm is going to safe.

Life, repeats of the existed design upper control arm were found to be 8413.923 cycles.

Life, repeats of the first modified upper control arm were found to be 4211.207 cycles.

Life, repeats of the second modified is found to be 7260.049 cycles

8 CONCLUSION

In this work numerical stiffness for existed and first modified design of upper control arm were found to be 273.37 N/mm and 325.59 N/mm respectively with a marginal error of 16% and experimental stiffness of gray cast iron alloy is found to be 300 N/mm and an error of 8.877% and 7.86% respectively.

Considering slippage analysis of front bush and upper control, CFSM found to be 120.156N and fatigue strength is found to be 264.884N it was more than CFSM hence no slippage.

Considering slippage analysis of rear bush and upper control arm,CFSM found to be 95.962N and fatigue strength is found to be 297.123N it is more than CFSM hence no slippage.

Considering slippage analysis of upper ball joint bush and upper control arm, CFSM found to be 108.538N and fatigue strength is found to be 458.306N it is more than CFSM hence no slippage.

From the fatigue analysis on upper control arm, damage for existed design of steel alloy is found that 0.223 it is less than one,hence upper control arm is safe similarly life,repeats is found that 8413.923 cycles,hence it has more life compared to other design and materials. By considering damage and life,repeats factors existed design upper control arm of steel alloy had better values than different design and materials.

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