Design and Analysis of Lower Wishbone ARM using Finite Element Analysis and its Experimental Validation

Mr. Ruturaj Rajesh Varpe[1], Asst. Prof. B. S. Kamble[2]

[1] M.Tech. (CAD/CAM/CAE), Department of Mechanical Engineering, KITCOEK, Kolhapur, Maharashtra, India.
[2]Asst. Professor, Department of Mechanical Engineering, KITCOEK, Kolhapur, Maharashtra, India.

Abstract - *Lower Wishbone arm in automotive vehicle acts as a linkage between sprung and unsprang mass of vehicle. Lower wishbone arm is subjected to various loads. Due to this type of loading, there are chances of bending of wishbone arm. Hence failure of lower wishbone arm occurs. The aim of the project is to analyze and optimize the lower wishbone arm using finite element analysis. The model of lower wishbone arm is done in CATIA software. Static analysis of lower wishbone arm is carried out in ANSYS software.*

In this project we have overcome various physical properties like strength, yield strength, weldability of lower wishbone arm by changing the material .The material is changed from EN18D steel to Extra Deep Drawn steel by which we got better improvement in the wishbone arm.

Key Words*: *lower wishbone arm, lower control arm, finite element analysis.

1. INTRODUCTION

In suspension system, the wishbone arm is very important component. The double wishbone suspension system contains lower wishbone arm and upper wishbone arm. The McPherson structural suspension system contains only lower wishbone arm between wheel assembly and vehicle chassis the wishbone arm is rigidly placed. The wishbone arm is connected to the chassis with the help of bush which is placed in pivot joints. The wishbone arm receptacle is adapted to cooperate with a wishbone arm assembly and may include a wishbone arm housing integrally formed with the wishbone arm. Typical modern wishbone arm incorporates a separate wishbone arm housing which is inserted in to the apex of wishbone arm. The bushing apertures are designed to retain pipe housings for mating engagement with a pivot bar assembly forming a portion of the vehicle suspension system. The pivot bar typically extends through both bushing apertures allowing the wishbone arm to pivot about the assembly in response to road conditions affecting the vehicle suspension system. Wishbone arm consist of modulus section which is between the apex and pivot points. The lower suspension arm is connected to the vehicle frame with bushing and permits the wheel to go up and down in response to the road surface. Wishbone arm is the most crucial part of the suspensions system. Suspension arm is very important for the all vehicles on the road, if there is no suspension arm in suspension system, then it is expected that it can result in annoying vibrations and unwanted driving irregularities that could sometimes lead to road accidents like collisions with another car or obstruction on the road. Suspension arm is one of the most important component in the suspension system. It is fitted in various types of the suspensions like Macpherson strut or double wishbone suspensions. During actual working conditions the maximum load is transferred from tire to the wishbone arm in Macpherson strut system and in double wishbone maximum load is transferred from upper arm to the lower arm. Hence it essential to focus on the stress and deformation study of lower suspension arm. The finite element analysis approach is used for analysis of wishbone arm.

2. LITERATURE REVIEW

This chapter focuses on literature reviews done by researcher till dates. Conclusions of literature review are given below.

C. Kavitha et al. [1] determined that a method for improving handling characteristics of the vehicle by controlling camber and toe angle using double wishbone suspension arms in an adaptive manner. This is accomplished by two telescopic arms with actuators which changes camber and toe angle of the wheel dynamically to deliver best possible traction and maneuverability. Active suspension controllers are employed to trigger the actuators based on the camber and toe angle from sensors for reducing the existing error. Hence the arms are driven by the actuators in a closed loop feedback manner with help of a separate PID controller. A quarter car physical models with double wishbone suspension is modelled in SolidWorks and simulated using MATLAB for analysis. Further, the prototype was able to achieve 89% of camber reduction and 45% of toe reduction with respect to the simulation.

M. Mahmoodi-Kaleibar et al. [2] examined that the geometric parameters of suspension system were optimized using genetic algorithm (GA) in a way that ride comfort, parameters due to road roughness and different steering angles were presented in ADAMS and the results of optimized and conventional suspension systems during various driving maneuvers were compared. The simulation results indicate that the camber handling and stability of vehicle were improved. The results of optimized suspension system and variations of geometric angle variations decrease by the optimized suspension system, resulting in improved handling and ride comfort characteristics. The geometric parameters of suspension system were optimized using genetic algorithm (GA) in a way that ride comfort, handling and stability of vehicle were improved. The results of optimized suspension system and variations of geometric parameters due to road roughness and different steering angles were presented in ADAMS and the results of optimized and conventional suspension systems during various driving maneuvers were compared. The simulation results indicate that the camber angle variations decrease by the optimized suspension system, resulting in improved handling and ride comfort characteristics.

Samant Saurabh Y et al. [3] carried out the design procedure of the front double A-arm push rod suspension system for a formula student race car. The type of suspension systems used generally are reviewed. The CAD models of the components in the suspension system are made using SolidWorks® and the Finite element analysis of the components is done using ANSYS® Workbench. Both kinematic and dynamic analysis of the designed suspension system is performed. The results of vibration or ride analysis and roll steer analysis are also presented for the designed suspension system. The method for spring design is elucidated. This work emphasizes the method for designing and analyzing the suspension system for a race car in various aspects.

Jagwinder Singh et al. [4] carried out optimization approach to increase the structural strength of the component and found stress analysis, the stresses of material for the given loading condition fall well in within the yield stress i.e. 211.06 MPA. The total deformation due to the force applied on the suspension arm was 0.65515 mm which is maximum was at the ball bearing of the suspension arm. The minimum safety factor was 1.1845 which shows the component is safe.

A.M. Patil et al. [5] examined that the static load conditions deflection and stresses of steel lower wishbone arm and composite lower wishbone arm are found with the great difference. Carbon fiber suspension wishbone arm that meet the same static requirements of the steel ones they replace. Deflection of Composite lower wishbone arm is high as compared to steel lower wishbone arm with the same loading condition. The redesigned suspension arms achieve an average weight saving of 27% with respect to the baseline steel arms. The natural frequency of composite material lower wishbone arm is higher than steel wishbone arm.

Manishkumar Manjhi et al. [6] described about designing and analyzing suspension of an All-Terrain Vehicle (ATV) and their integration in the whole vehicle. The ATV has been designed and analyzed based on the facts of vehicle dynamics. The primary objective of this work was to identify the design parameters of a vehicle with a proper study of vehicle dynamics. This work also helps us to study and analyze the procedure of vehicle suspension designing and to identify the performance affecting parameters. It also helps to understand and overcome the theoretical difficulties of vehicle design.

P. B. Patil et al. [7] carried out FEA analysis of existing lower wishbone arm. Lower wishbone arm is meshed in Hyper mesh and solver deck for modal analysis is prepared. Then this total data was incorporated into Ansys software which gives the natural frequencies of exciting lower wishbone arm. By using the topology optimization technique, lower wishbone arm is optimized and natural frequencies are extracted. After that the comparative study of existing and optimized lower wishbone arm is undergone. Then optimized lower wishbone arm is fabricated and tested using FFT analyzer. The experimental outcomes and FEA results shows a closure resembleance.

Vinayak Kulkarni et al. [8] determined, the forces acting on lower wishbone arm of wishbone has been calculated while vehicle subjected to critical loading. The CAD model of lower wishbone arm has been carried out using Pro-E software packages. The static and modal analysis as well as optimization of lower wishbone arm has been carried out in Hyperworks. From the analyzed results, it is found that the values obtained for the maximum von mises stress and maximum displacement are lower than safe limit. On strength basis, aluminium alloy is good material than Mild Steel whereas on strain basis, Mild Steel is good material than aluminium alloy. Modes and mode shapes of lower wishbone arm contingent on material properties. Hence change in material leads to change in resonance condition. Modes are used as a simple and efficient means of characterizing resonant vibration. The higher factor of safety leads to optimization of component. Topology optimization generates an optimized material distribution for a set of loads and constraints within a given design space. Optimization reduces weight, product design cycle time and cost.

Himanshu Pachauri et al. [9] focused on the topic, design and analysis of independent suspension system for an all-terrain vehicle. The purpose of this study was to design an independent type suspension system which can rely on any type of off road conditions. The focus of the study was to provide comfort to driver by reducing the effects of bumps and also improving the dynamic parameters of the vehicle. Here calculated the various aspects of vehicle dynamics such as wheel rate, roll rate, spring stiffness, roll gradient etc. which are helpful during the stimulation process and some assumptions also been taken during the calculations which are based on SAE standards. From the study it has been concluded that suspension system is resisting all types of bump forces so that ride quality does not affected and driver's comfort also not exhausted.

Mr. Sushilumar et al. [10] analysed that the stress analysis for considering lower arm deformation, von-Misses Stress and Max shear stress and also using different lower arm materials were tested and it was observed that Fe410 material was much better than the EN 24 material. The stress analysis is done with the help of ANSYS 13.0 software. The stress and deformation effect on suspension lower arm was investigated under vehicle loading.

H.S.Deore et al. [11] designed the double wishbone suspension and analyzed it on CATIAV5R20 software where and found the safe result to desired condition of ride. Authors have calculated dimensions of upper and lower arm also calculated roll center of ATV by geometry of double wishbone suspension system and predicted result of analysis of lower arm. After performance trial maximum suspension travel, better performance and reduce cost and weight of suspension assembly; have been achieved.

Prashanthasamy R.M. et al. [12] attempted to work existing design with aluminium alloy. The 3D model will be generated by Catia V5, the FE model will be generated by HyperMesh and the static and dynamic analysis will be conducted by Abaqus. In the new design 1 and new design 2 of aluminum alloy, the stresses are almost reduced to 30% compare to existing design. The deformation in the new design 1 and new design 2 is almost reduced to 10% existing design. Finally, it can be concluded that from the FEA analysis the new design 1 and new design 2 can be replaced with aluminum alloy existing design with AISI 1040 for wishbone suspension arm.

Dayanand J. Mahamuni et al. [13] presented a weight reduction of chassis by weight optimization of wishbone arm. Weight of wishbone arm is optimized using topology optimization and analysed using Ansys. Stress analysis is performed using finite element method. For Static analysis on wishbone arm, HyperMesh and Radioss applied to conduct the static simulations, optimization and the fatigue analysis. The FEA model of lower wishbone arm in this study is constructed based on the geometry. According to design theoretical calculation, weight of wishbone arm can be reduced by 13%. This saves material cost, reduce weight on chassis and fuel consumption and indirectly reduce pollution also.

Prashant Gunjan et al. [14] analyzed the lower wishbone arm, ANSYS FEA software is used. The standard modeled analyzes and optimized using ANSYS topology optimization tool which is give most useful result in present. Using the topology shape optimization technique, the total deformation, von mises stress, maximum shear stress and mass will be reduced as compared to previous work. By reducing mass of the object and by suggesting the suitable material and design the production cost of lower wishbone arm is reduced. This leads to cost saving and improved material quality of the product.

As these all references says that of the Lower Wishbone arm fails due to many of the parameters so it is necessary to study the exact reasons for the failure of Lower Wishbone arm in this it intended to observe these failures with the different tests. This projected study is an overall revive of existing Lower Wishbone arm failure and to minimize this failures by improving some failure parameters. So that it will helps to maximize life of Lower Wishbone arm and resulting minimizing road accidents.

2.2 Concluding Remarks

In this topic we discuss about the papers findings and the remarks of that literature review.

1. Literature survey gives the information regarding lower wishbone arm.
2. The literature survey provides useful information of analysis of control arm of different vehicles.
3. In the literature review work done by different researches in the area of Design, finite element analysis and modifications carried out to improve structural strength of the component and found stress analysis, the stresses of material for the given loading condition fall well in within the yield stress.
4. Information about structural analysis of lower control arm with different material is given by many researchers but analysis of lower wishbone arm of Mahindra bolero car is not given by any researcher.
5. Insufficient work on the Mahindra Bolero lower wishbone arm is found.

2.3 Objectives

1. To study existing scenario of selected Lower Wishbone arm.
2. Design and Analysis of the existing Lower Wishbone arm using ANSYS software.
3. Validation of Finite Element Analysis results with Experimentation.
4. Identify the cause and recommend modification.
5. Optimize the material of lower wishbone arm
6. Analysis of Lower Wishbone arm of changed material

3. METHODOLOGY

1. Detailed theoretical study Lower Wishbone arm presently used in car.
2. Modelling of Lower Wishbone arm in CATIA by taking actual dimension from actual Lower Wishbone arm which was in application and import into ANSYS for further analysis.
3. Validation of Finite Element Analysis results with Experimentation.
4. Identify the cause and recommend modification.

5. To optimize the material of Lower Wishbone arm.
6. Carry out Finite element analysis for new changed material Lower Wishbone arm using ANSYS.

3.1 Problem definition

Lower Wishbone arm is undergoing complex complication of stresses and hence failing to perform its function. To minimize the stresses on Lower Wishbone arm by changing material to achieve maximum performance. Hence, we are performing this activity in order to identify the cause of failure and suggest or recommend the counteracting material modification.

3.2 Modelling

The measurements of main parts of wishbone arm have been made in order to create a three-dimensional geometry by CATIA software. Then the model (geometry) has been imported to ANSYS workbench software.

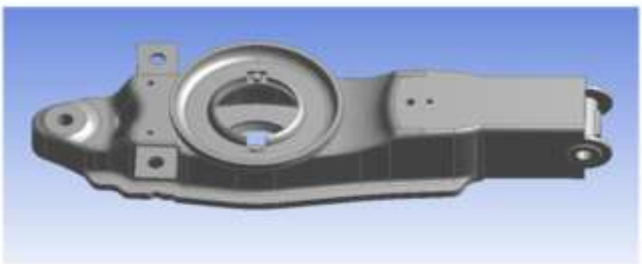

Fig. 3.1 Model of Wishbone Arm

3.3 Meshed Model

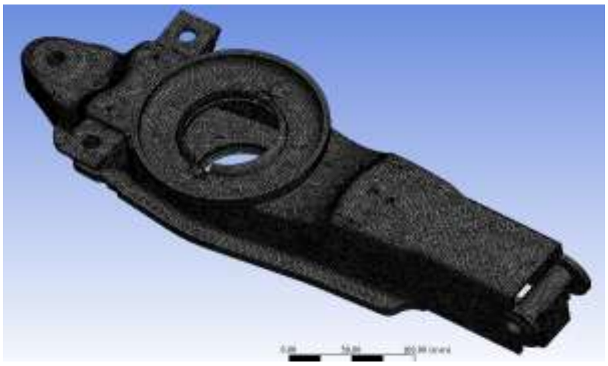

Fig. 3.2 Meshed Model

3.3 Constraints and Loads

Calculations for weight distribution on each wheel:
Kerb Weight: 1680 Kgs
Seating Capacity: 7
Gross Weight = Kerb Weight + Passenger weight + Luggage weight
WG = 2300 Kgs

From standard,
The ratio of weight distribution is F/R: 49/51
Weight acting on each front wheel
W = (0.50 X WG)/2
= (0.50 X 2300)/2
W = 575 Kg
For the considered event,
Vehicle is passing with 20kmph through assumed bump,
Hence,
Force component acting on wishbone are,
1. Fv = 575 x 9.81 x 2 x 9.81 = 17100N
2. Fh = {(575 x 9.81 x [[20 x1000) / 3600]^2])/ 2}
= 8500N

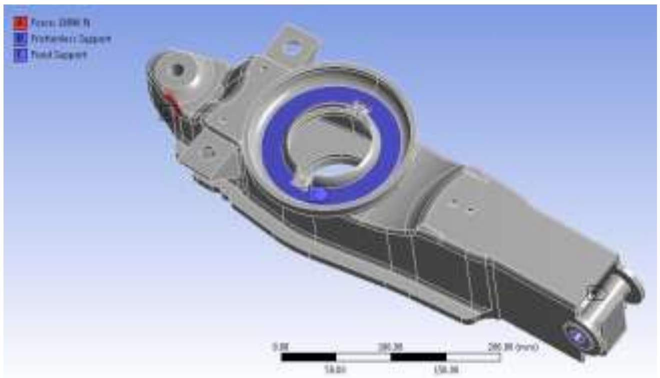

Fig. 3.3 Loading and Boundary Conditions

3.4 Mechanical Properties of EN18D steel

Table No. 3.1 Material Properties

Density (kg/m3)	Young's Modulus (Pa)	Poisson's Ratio	Bulk Modulus (Pa)	Shear Modulus (Pa)	Yield strength (Mpa)
7850	2e11	0.3	1.6667e11	7.6923e	250

3.5 RESULTS FOR EN18D STEEL

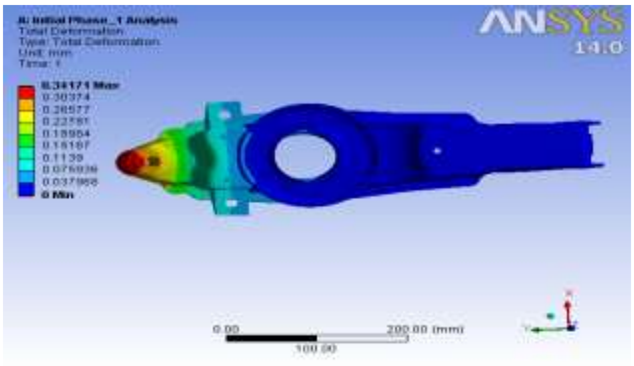

Fig. 34 Total Deformation

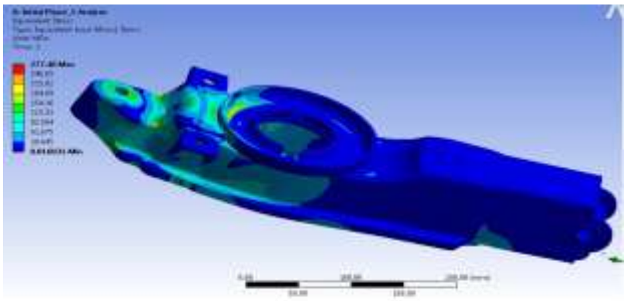

Fig. 3.5 Equivalent Stress Plot

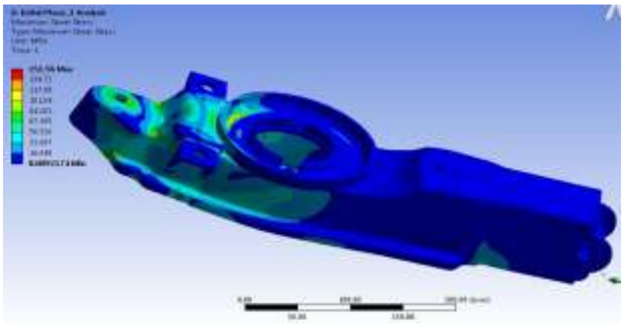

Fig. 3.6 Max. Shear Stress Plot

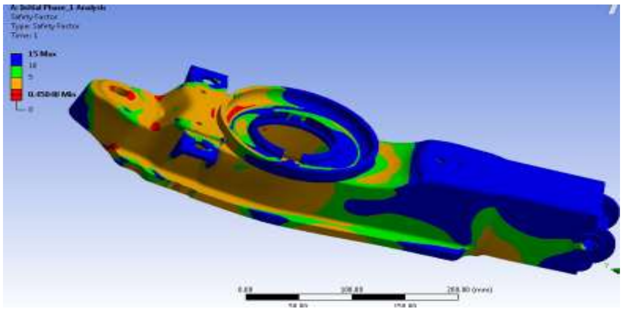

Fig. 3.7 Factor of Safety

Table No. 3.2 Result analysis

Sr. No	Components	Value
1	Total Deformation	0.34171 mm
2	Equivalent Stress Plot	277.48 MPa
3	Max Shear Stress	151.56 MPa
4	Factor of Safety	0.45

From the above table von misses stress is 277.48mpa which is higher than yield stress of the material.

3.6 Experimentation

UTM test is carried out on lower wishbone arm. For holding lower wishbone arm we have taken nut, bolt and plate. The size of bolt is M20x200. The length of bolt is 200mm and diameter is 20mm. The length of plate is 250mm, width is 50mm and height is 25mm. The lower wishbone arm is hold in with this assembly so that it can resist while testing.

Fig. 3.8 Testing wishbone arm on UTM

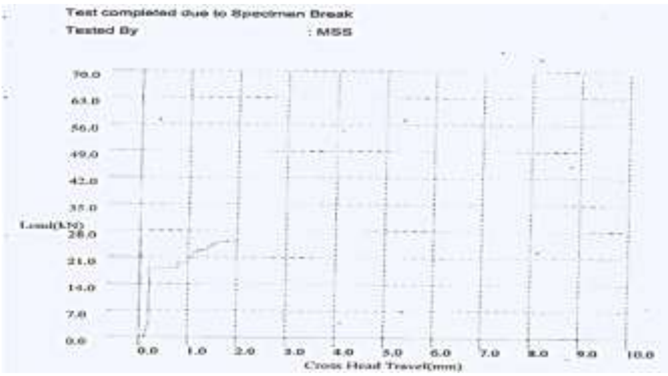

Fig.3.9 Load vs deformation graph

From the experimental results we found that the 0.2mm – 0.3mm deformation started at 17KN -18KN load. And then total deformation of 2mm occurred at 25KN to 26KN.

3.7 Material selection

Selection of materials is based on following criteria:
1. Mechanical properties
2. Wear of materials
3. Corrosion
4. Cost
5. Safety
6. Recycling

3.8 Extra Deep Drawing Steel (EDDS)

This grade is for really severe drawing applications. EDDS really only allows for the product to be hit with a one or two hit draw.
Properties of High strength EDDS
1. High Compressive Strength.
2. Good Weld ability.

3. Corrosive Resistance.
4. Good Susceptible to Denting
5. Low Yield Strength.
6. Maximum Fatigue Life.

Table No. 3.3 Mechanical Properties of EDDS

Density (kg/m3)	Young's Modulus (Pa)	Poisson's Ratio	Bulk Modulus (Pa)	Shear Modulus (Pa)	Yield strength (Mpa)
7850	2e11	0.35	2.22e11	7.4e10	250

3.9 RESULT FOR EDDS

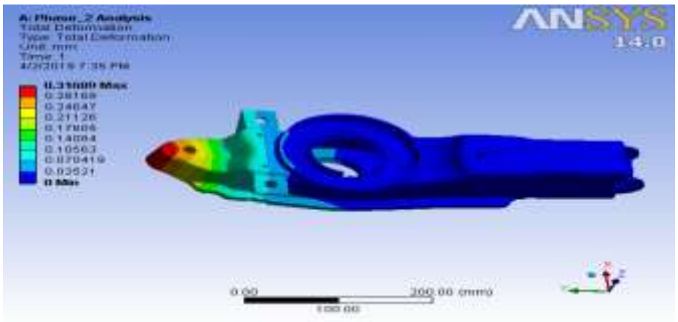

Fig. 3.10 Total Deformation

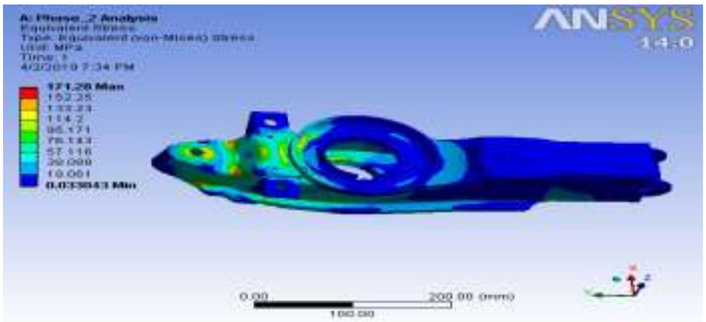

Fig. 3.11 Equivalent (Von Misses) Stress

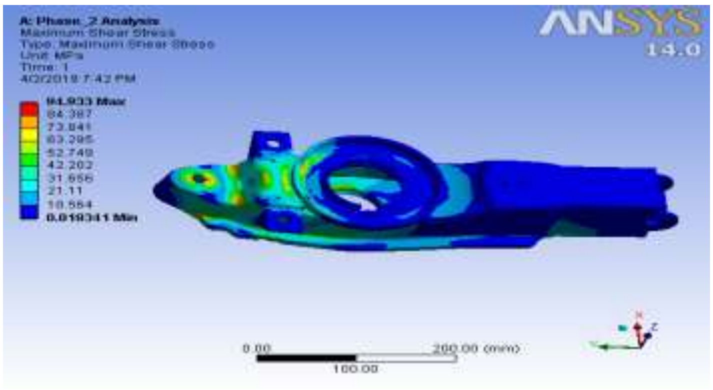

Fig. 3.12 Maximum Shear Stress

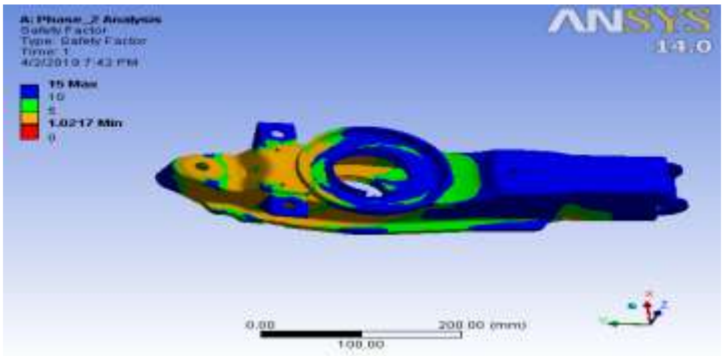

Fig. 3.13 Safety Factor

Table No. 3.4 Result analysis

Sr. No	parameters	Value
1	Total Deformation	0.31 mm
2	Equivalent Stress Plot	171.28 MPa
3	Max Shear Stress	94.93 MPa
4	Factor of Safety	1.02

From the above table von misses stress is 171.28mpa which is within the yield stress of the material.

3.10 RESULT COMPARISON

The results for EN18D STEEL and EDDS are compared below:

Table No. 3.5 Result analysis

Sr. No	parameters	Before	After
1	Total Deformation	0.34 mm	0.31mm
2	Equivalent Stress Plot	277.48Mpa	171.28Mpa
3	Max Shear Stress	151.56MPa	94.93MPa
4	Factor of Safety	0.45	1.02

The above table shows the comparison of parameters of both the materials.

4. CONCLUSIONS

From the result we change the material of the lower wishbone arm from EN18D Steel to High Strength Extra Deep Drawing Steel which have better strength than that of EN18D Steel.

From the results of analysis on the lower wishbone arm it is observed that change in material is serving the purpose and bringing in the stresses within safety limit and hence we have completed the objectives.

5. REFERENCES

[1] C. Kavitha, S. Abinav Shankar, K. Karthika, B. Ashok, S. Denis Ashok. "Active camber and toe control strategy for the double wishbone suspension system", Journal of King Saud University – Engineering Sciences-direct, 2018.

[2] M. Mahmoodi-Kaleibar, I. Javanshir, K. Asadi, A. Afkar, A. Paykani, "Optimization of suspension system of off-road vehicle for vehicle performance improvement", Central South University Press and Springer-Verlag Berlin Heidelberg 2013.

[3] Samant Saurabh Y., Santosh Kumar, Kaushal Kamal Jain, Sudhanshu Kumar Behera, "Design of Suspension System for Formula Student Race Car", Science-Direct , IIT Guwahati, Guwahati, Assam-781039, India.

[4] Jagwinder Singh and Siddhartha Saha, "Static Structural Analysis of Suspension Arm Using Finite Element Method Jagwinder", International Journal of Research in Engineering and Technology, ISSN: 2319-1163, pp , Volume: 04 Issue: July-2015.

[5] A.M.Patil,A.S. Todkar, R. S .Mithari and V. V. Patil , "Experimental & Finite Element Analysis of Left Side Lower Wishbone Arm of Independent Suspension System", (IOSR-JMCE) ISSN: 2320-334X, Volume 7, Issue 2 (May. - Jun. 2013), PP 43-48.

[6] Manishkumar Manjhi, Shaktiprasanna Khadanga, Bibhutibhusan Sahoo, SusarthakRath, Karankumar Guru and P. Murarji , "Design And Analysis Of Suspension System Of An Off Road Vehicle (All Terrain Vehicle) ", April 2017 IJIRT, Volume 3 Issue 11,ISSN: 2349-6002,PP.134-141.

[7] P. B. Patil and M. V. Kharade, " Finite Element Analysis and Experimental Validation of Lower Wishbone arm ", IJEDR, Volume 4, Issue 2,ISSN: 2321-9939, , April 2016.

[8] Vinayak Kulkarni, Anil Jadhav and P. Basker, "Finite Element Analysis and Topology Optimization of Lower Arm of Double Wishbone Suspensionusing RADIOSS and Optistruct", IJSR, ISSN 2319-7064, Volume 3 Issue 5, PP.639-643, May 2014.

[9] Himanshu Pachauri, Dr. V. K. Saini, Sunil Kumar and Bhavyakant Bhardwaj, "Design and Analysis of Independent Suspension System for an All-Terrain Vehicle", IJRASET, ISSN: 2321-9653, Volume 5 Issue V, May 2017.

[10] Sushilkumar P.Taksande and A.V.Vanalkar, "Design, Modeling and Failure Analysis of Car Front Suspension Lower Arm", IJSTE Volume 2, Issue 01, ISSN 2349-784X, PP.235-249, July 2015.

[11] H.S.Deore , Shivani Aware, Chetan Wani and Dhiraj Sonawane,"Design and Analysis of Double Wishbone Suspension System For an ATV", 6th International Conference on Recent Trends in Engineering & Technology (ICRTET) , ISSN : 2454-9150 PP.571-574 Feb-2018.

[12] Prashanthasamy R.M.T, Sathisha, Imran Ali M.R and Mr. Jnanesh. K ,"Design and Modal Analysis of Lower Wishbone Suspension Arm Using FE Approach", (IJIR) ISSN: 2454-1362, Vol-2, Issue-9, PP.858-863, 2016

[13] Dayanand J. Mahamuni and T. R. Shinde," Weight Reduction of Chassis By Weight Optimization of Wishbone Arm", (IERJ), ISSN 2395-1621, PP.1-4, November2015.

[14] Prashant Gunjan and Amit Sarda ,"Design and Analysis of Front Lower Wishbone arm by Using Topology Optimization", IJARIIE, ISSN 2395-4396, Vol-4 Issue-2, PP.1982-1986, 2018.

[15] G.Dhanu and Kattimani, "Comparision Study Of Lower Wishbone arm With Different Material", (IRJET), Volume: 03 Issue: 10, PP.702-708, Oct -2016.

[16] Savan Thacker, "Research paper on Design and analysis Double Wishbone Suspension system using Finite Element Analysis", (IJAREST), ISSN(P): 2394-2444, Volume 2, Issue 7, July – 2015.

[17] M.Sridharan and Dr.S.Balamurugan ,"Design and Analysis of Lower Wishbone arm ", IJIRSET, ISSN : 2347-6710, Vol. 5, Issue 4, April 2016.

[18] Asst. Prof. N.Vivekanandan1, Abhilash Gunaki , Chinmaya Acharya, Savio Gilbert and Rushikesh Bodake, "Design, Analysis And Simulation Of Double Wishbone Suspension System", Volume 2, Issue 6, PP.1-7, June 2014.

[19] Prashant Gunjan and Amit Sarda," Optimization Approach of Front Lower Wishbone Suspension Arm",IJARIIE, ISSN 2395-4396 Vol-4 Issue-2 PP. 305-308, 2018.

[20] Mr. Dibya Narayan Behera, Rajesh Kumar, Kunal Abhishek, Sunil Kumar Panda, "Design, Static and Dynamic analysis of an All- Terrain Vehicle Chassis and Suspension System", IJEDR, ISSN: 2321-9939 , Volume 4, Issue 2, PP.120-128, 2016.