

Design modification and Analysis of Suspension Ball Joint Using Finite Element Analysis

Jitendra Shinde¹, Sunil Kadam², Amol Patil³, Shamuvel Pandit⁴

P.G. Student, Department of Mechanical Engineering, Bharati Vidyapeeth's CO Engg, Kandalgaon, Kolhapur, India¹

Associate Professor, Department of Mechanical Engineering, Bharati Vidyapeeth's CO Engg, Kandalgaon,
Kolhapur, India²

Asst. Professor, Department of Mechanical Engineering, Bharati Vidyapeeth's CO Engg, Kandalgaon, Kolhapur, India³

Asst. Professor, Department of Mechanical Engineering, Bharati Vidyapeeth's CO Engg, Kandalgaon, Kolhapur,
India⁴

ABSTRACT: This study describes the analysis and investigation of the causes of the sudden failure of a suspension system ball joint. The axis of the ball joint element showed a complete fracture which occurred midway between the top and bottom section changes of the element. It is seen the ball joint of this car fails suddenly without any sign of consumption and this case is a dangerous as well as disturbing factor for traffic and driver. So there should be something else supports car when the ball-joint fails. This research has a modification of this ball joint for this purpose. Design of ball joint is modified and stress raisers are removed from the previous design of ball joint. Design of the present ball joint has been improved and from obtained results we can say that the design of ball joint is modified and within safety limit.

KEYWORDS: Ball joint, Modeling, Stress and Fatigue analysis, Design modification

I. INTRODUCTION

Ball joints are used on the front end of almost every car, truck and minivan. Ball joint is an important part of car suspension system. Ball joints act as the pivot point between two parts: the suspension and car's tires. Ball joints help support car's weight and, as is the case with some vehicles, ball joints may be used to help set the alignment. The ball joint is one moveable part of a control arm assembly. It is steel bearing stud and socket enclosed in a steel casing. The socket enclosed in steel casing is connected to the control arm. The bearing stud is tapered and threaded so that it fits into a tapered hole in the steering knuckle and the latter connects the tire. Ball joints are a critical part of any car's suspension and steering. They attach the wheel hub, which the wheel and tire are mounted to the rest of the suspension. This connection needs to be able to rotate horizontally for steering and vertically for shock absorption, hence the use of ball joints that can move in all directions. While ball joints last for a long time, they do wear. The polished metal ball rides in a polished metal cage. Space between the two is filled with grease to reduce wear. However, if the grease leaks out of the ball joint or any dirt and impurities get into the grease, the ball joint may become worn or damaged. There is a rubber boot over the joint to help keep dirt out, but that does not mean that there is no way in which dirt can enter. In an automobile, ball joints are spherical bearings that connect the control

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

arms to the steering knuckles. They are used on virtually every automobile made and work similarly to the ball-and-socket design of the human hip joint.[5]

The front suspension system ball joint fails due to many of the parameters so it is necessary to study the exact reasons for the failure of ball joint in this it intended to observe these failures with the different tests. This projected study is an overall revive of existing ball joint failure and to minimize this failures by improving some failure parameters. So that it will helps to maximize life of ball joint and resulting minimizing road accidents.

II.RELATED WORK

From the literature review following possibilities are drawn because of the existing scenario of geometrical condition of suspension ball joint, boundary conditions and nonlinearity of material properties and some other parameters are required to study in detail.

II. MODELLING AND ANALYSIS OF SUSPENSION BALL JOINT

The measurements of main parts of ball joint 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. Initially the 3D drawing of ball joint is done by using CATIA according to dimensions specified in the Table:

Diameter	Dimension in mm
D1	30
D2	20
D3	15

Table No.1 Dimensions of Suspension Ball Joint

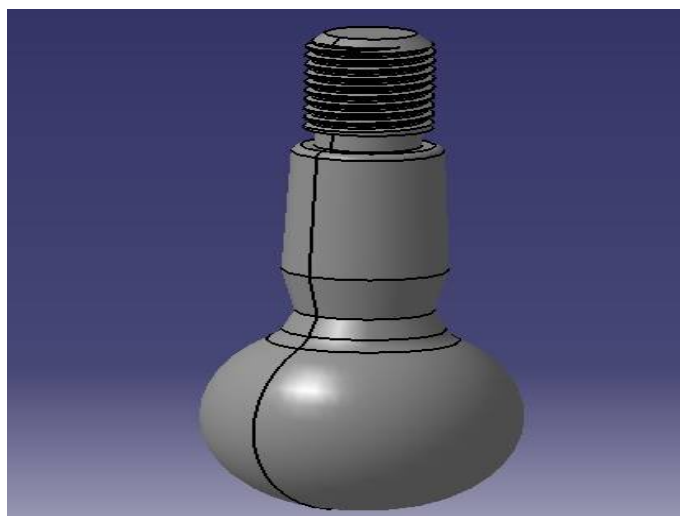


Fig. 1. 3D-Model

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

III. MATERIAL

According to chemical composition analysis by OES[5], the ball joint was manufactured using an EN 18D steel alloy.

EN 18D Steel Alloy properties:

- Young's modulus (E) =190 GPa
- Yield stress=565MPa
- Ultimate tensile strength=887 MPa
- Density =7.85g/cm³
- Poisson's ratio = 0.29

IV. MESHING GENERATION

Meshing of a given model will be done depending on geometry of the model, it is better to have more degrees of freedom hence more number of elements so that results obtained will be closure to analytical results. In two bay panel analyses, crack region is meshed with more number of elements when compared with other parts of fuselage, for obtaining a converged solution which in turn a better solution.

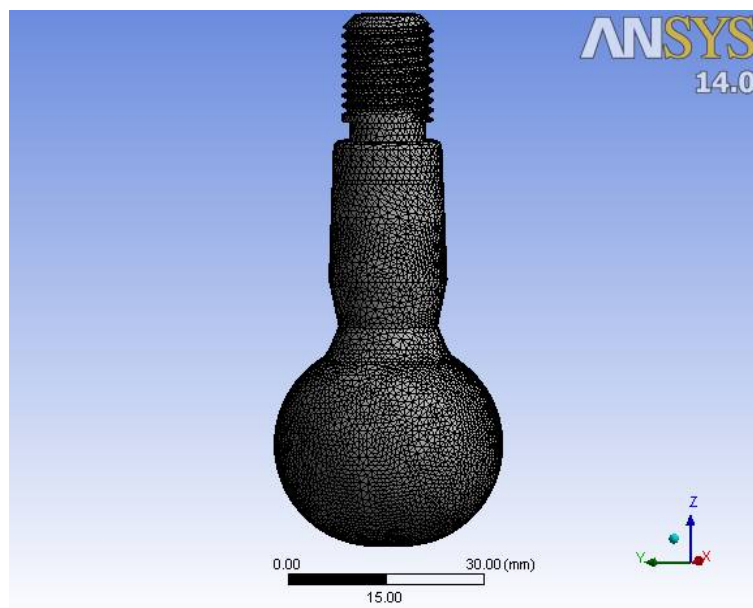


Fig. 2. Meshing of ball joint

V. LOADING AND BOUNDARY CONDITION

Each tire of this vehicle has a share of the car's weight, gross weight and weights of persons riding the car. The centroid of this car under its full static load is located at the a point of intersection of its diagonal axes, consequently, each tire has a share of quarter of that full static load, If the car has a gross weight of 2300 kg and the weight of its passengers and luggage is 620 kg as well as each passenger is assumed to weight of 100 kg, the total static load will be 2300 kg .So each tire will have a share of 575 kg. when the a car has an impact within the motion, ball joint subjects to longitudinal load equals nearly to double of its tire share static load as well as horizontal load equals to that longitudinal one but it directs a horizontally along the length of car.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

A load of $(2 \times 575 \times 9.81) \text{ N}$ is applied downward to stud at the thread place in its longitudinal direction while other load of $(2 \times 575 \times 9.81) \text{ N}$ is applied horizontally at a place where it is in contact with knuckle, also a general joint is added to this region to keep only linear motion. A fixed boundary condition is applied to the socket at a place where it's bonded to the lower control arm.

The fatigue stress and its safety factor have been created in these two forms of numerical analysis, the load on ball-joint is fluctuating between its maximum (where the ball-joint faces an impact) and the static load which only includes the weights of car, freight and persons.

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

$W = (0.50 \times \text{WG}) / 2$

$= (0.50 \times 2300) / 2$

$W = 575 \text{ Kg}$

So, the reaction force,

$P = W \times g$

$= 575 \times 9.81$

$P = 5640.75 \text{ N}$

$P = 5700 \text{ N Appx.}$

Assumed condition is of bump, in which the extremity of load is present.

The load considerations are Double Gravity (2g acceleration)

$P = 11400 \text{ N (taken for Analysis)}$

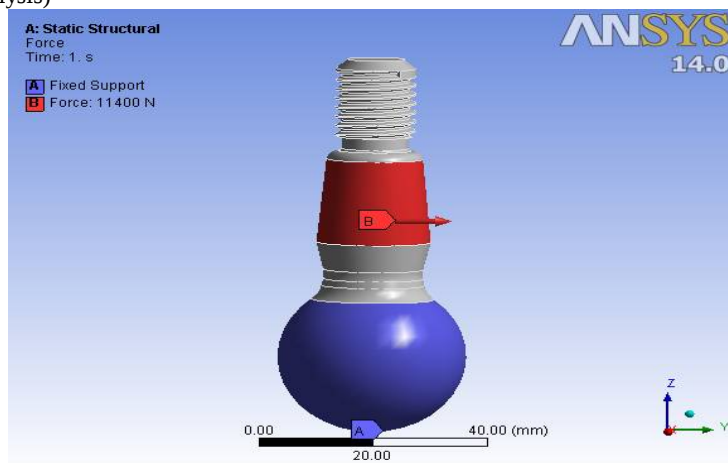


Fig. 3.loading and boundary conditions

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

VI. RESULTS FOR ORIGINAL GEOMETRY

From the above loading and boundary condition following results are obtained.

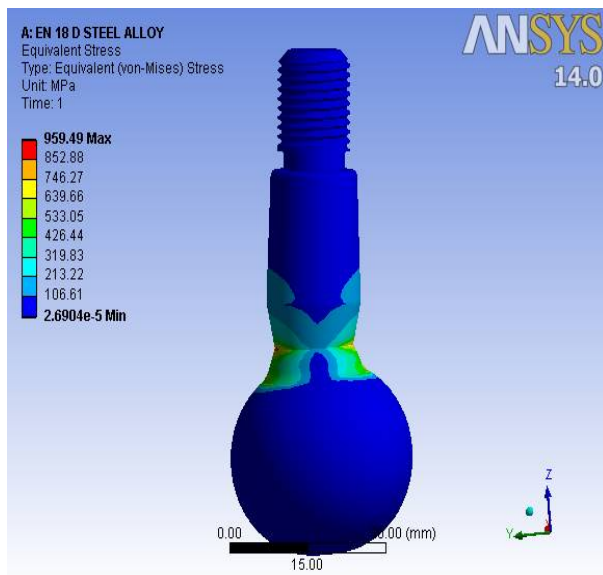


Fig.4. Equivalent Von-Mises stress

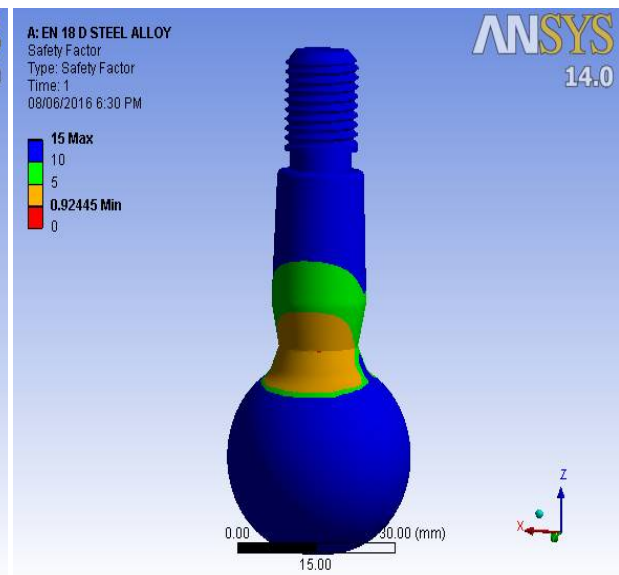


Fig. 5. Factor of safety

According to the von Mises's theory, a ductile solid will yield when the distortion energy density reaches a critical value for that material. Since this should be true for uniaxial stress state also, the critical value of the distortional energy can be estimated from the uniaxial test.

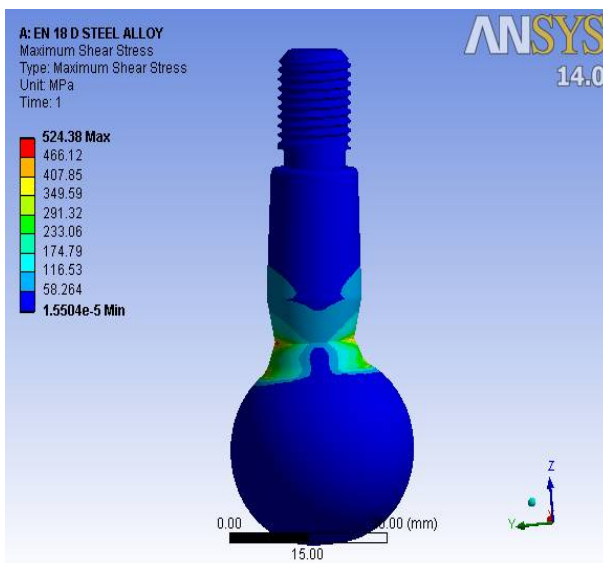


Fig. 6.Maximum shear stress

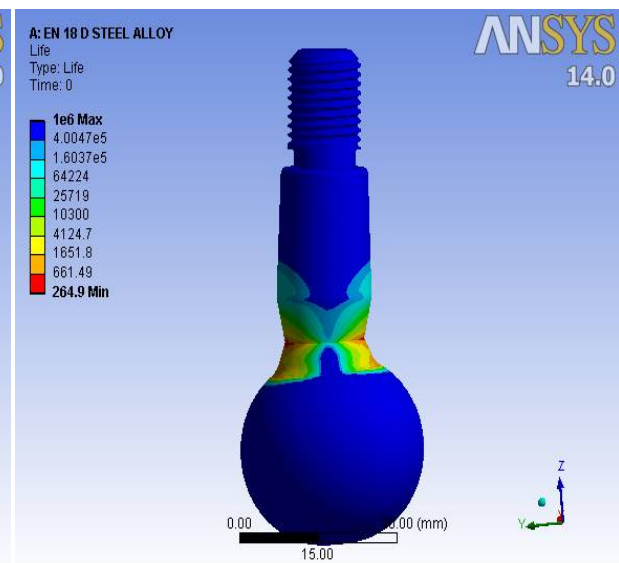


Fig. 7. Fatigue life

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

It is since observed that from the results, We came to know that, equivalent von-mises stress goes beyond ultimate tensile strength of the material and hence there is crack initiation in the ball joint at the specified loading conditions and that crack leads towards the fatigue failure of the ball joint as the ball joint is under cyclic loading as per the description given in the problem definition.

After the knowing results, it is need to increase diameter of ball joint at failure section from 15 mm to 17.5 mm and revise the design to get the desired results.

VII. RESULTS FOR MODIFIED BALL JOINT

For the same loading and boundary condition after design modification improved results for ball joint shown below.

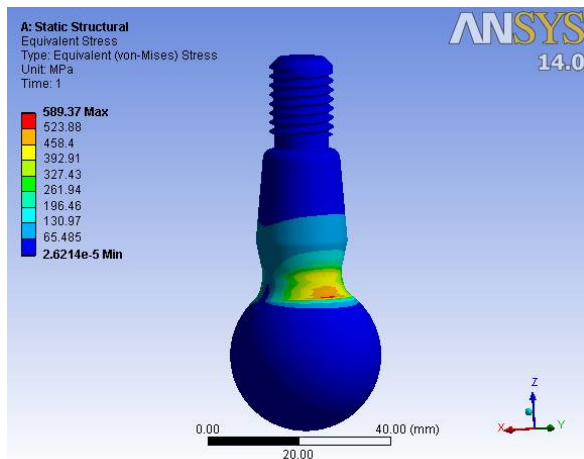


Fig. 8.Equivalent Von-Mises stress

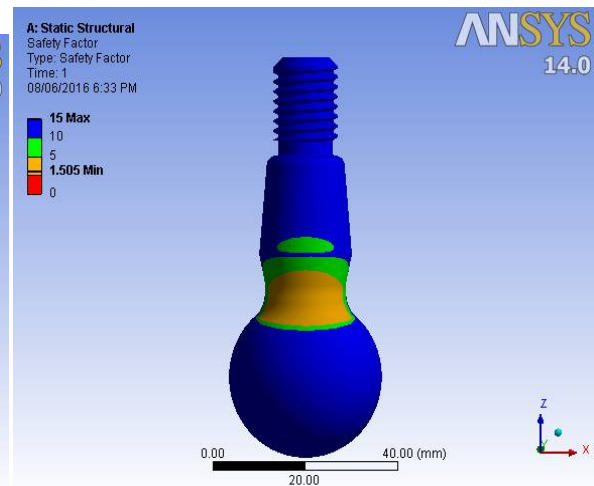


Fig. 9.Factor of safety

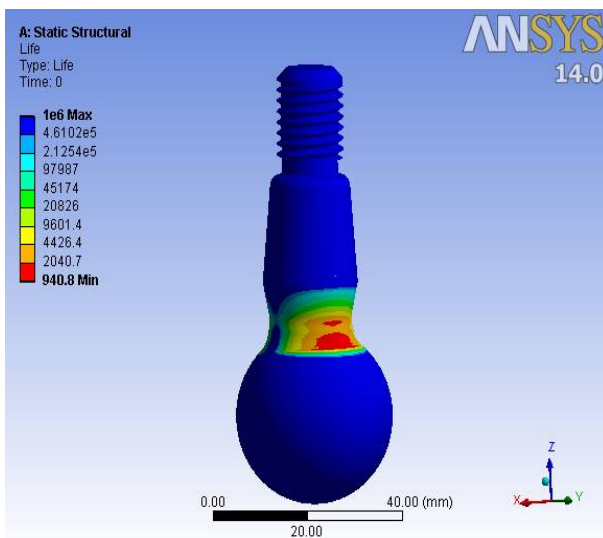


Fig. 10.Maximum shear stress

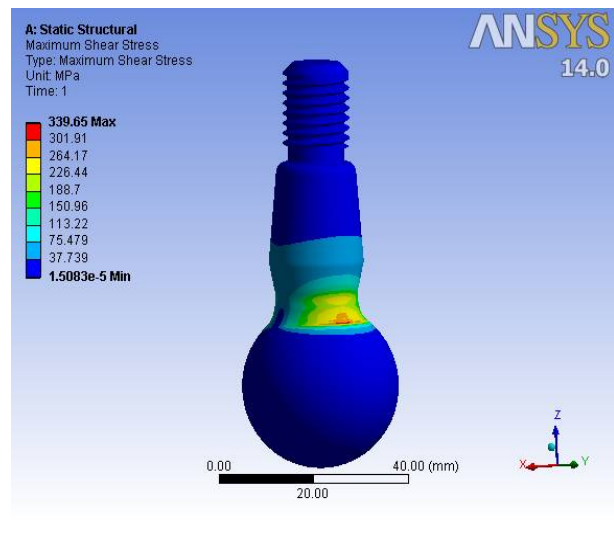


Fig. 11.Fatigue life

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

We worked on the stress raiser in the previous design of ball joint and required design modification are done and results of stress and fatigue analysis of modified ball joint shows that stress value has been brought to the safety limit.

VIII. COMPARISON OF RESULTS

SR. NO.	COMPONENTS	BEFORE MODIFICATION	AFTER MODIFICATION
1	Total Deformation	2.1 MM	0.2 MM
2	Equivalent Stress Plot	959.49 MPa	589.37 MPa
3	Major Principal Stress Plot	916.64 MPa	493.75 MPa
4	Equivalent Elastic Strain Plot	0.0048	0.0111
5	Max Shear Stress	524.38 MPa	339.65 MPa
6	Factor of Safety	0.9289	1.505

Table No. 2. Stress Analysis Results

SR. NO	FATIGUE COMPONENTS	STRESSS CYCLE	STRESS CYCLE
1	Fatigue life	264 (min) cycle/s	941 (min) cycle/s

Table No.3. Fatigue Analysis Results

IX. CONCLUSION

The results for stress and fatigue analysis of ball joint with boundary condition for the previous ball joint tests shows that stress limit was crossed and the stress value is much higher than the ultimate tensile strength of the material, Also because of this there is no safe fatigue life to the ball joint .

To modify the design of ball joint to make it safe, reliable and durable. We worked on the stress raiser in the previous design of ball joint and required design modification are done and results of stress and fatigue analysis of modified ball joint shows that stress value has been brought to the safety limit, the component is now have considerably good fatigue life. Hence design of ball joint is modified and stress raisers are removed from the previous design of ball joint. Design of the present ball joint has been improved and from obtained results we can say that the design of ball joint is modified and within safety limit.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

REFERENCES

1. Agah Uguz and S. Hakan Oka, Bursa, "Finite Element modeling of ball joints under dynamic loading" Material prufungJahrg. 46 (2004) 10.
2. Bong-Su Sin, " Process Design of a Ball Joint, Considering Caulking and Pull-Out Strength", Department of Mechanical Engineering, Dong-A University, Busan 604-714, Republic of Korea, 2014.
3. Byung-Hyun Jang and Kwon-Hee Lee, "Analysis and design of a ball joint, considering manufacturing process", J Mechanical Engineering Science, Vol 228, 2014.
4. Chen A., "Investigating the behavior of ball joint sealing boots using a 3D Finite Element Model ", 2nd Worldwide Automotive Conference, 2010.
5. E.A. Ossa, C.C. Palacio and M.A. Paniagua, "Failure analysis of a car suspension system ball joint"Materials Engineering Research Group, Colombia, 2011.
6. Fischer, I. S., "Numerical analysis of displacement in spatial mechanisms with ball joints", Mechanism and Machine Theory,35 (2000) p. 1623-1640.
7. Fischer, I. S., "Velocity analysis of mechanisms with ball joints", Mechanics Research Communications, 30 (2003)69-78.
8. K. Baynal, M. Makaraci, K. Gulbudak, "solution for failure analysis of automotive axle knuckle pull-out"International Journal of Automotive Technology 54-11
9. K. H. Lee and S. C. Hwang, "Structural dynamic analysis of a ball joint," AIP Conference Proceedings, vol. 1499, pp. 394-398, 2012.
10. Krzysztof Siczek, Piotr Jóźwiak, "The existence of boron nitride existence in grease and how it influences the motion resistance of the stud of steering rod". Technical University, 90-924 Lodz.2004.
11. Ryu YI, Kang DO, Heo SJ, Yim HJ, Jeon JI., "Development of analytical process to reduce side load in strut-type suspension". J MechSci Technol2010; 24:351-6.