MODIFICATION OF THE BALL-JOINT FOR NISSAN PICK UP CAR

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ABSTRACT

A Nissan pickup car shown in Fig.1 is widely used car in Iraq. In spite of its being sturdy, this car has a problem regarding to failure of their suspending ball joints. Nowadays , 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. The modification has depended on the results obtained from the numerical analysis of the loaded ball-joint in two situations (forms), the first situation (form) when its angle is negligible and second situation (form) when this angle is considerable. Measurements of parts of ball joint of Nissan pickup car have been made and these parts have been drawn in two forms (situations) by using CATIA software. Also, Measurements of parts' lengths of suspension system of Nissan pickup car has been made and an approach model of its suspension system has been created by using MSC ADAMS software to view the angle of ball-joint with Max.travel of suspension system., all drawn forms have been imported to ANSYS WORKBENCH software where a three- dimensional model was created and maximum load is applied to ball-joint Then, solution had been done and the results were obtained. Then, a modification is created and drawn by CATIA software, after that it is imported to ANSYS WORKBENCH software to check it ability for supporting the results.

الخلاصة:-

إن سيارة نيسان البيك اب المبينة في (الشكل.1) هي سيارة واسعة الانتشار في الشوارع العراقية، وبالرغم من متانتها إلا أنها تمتلك مشكلة متمثلة باستهلاكها الكبير للمفاصل الكروية المتواجدة في نظام إسناد السيارة (الصدر) والتي تسمى محليا بال(طوبا). من الملاحظ إن المفاصل الكروية لهذه السيارة تفشل بشكل مفاجئ في هذه الأيام بدون أي استشعار مسبق لاستهلاكها وهذه حالة خطرة ومزعجة للمرور. لذلك لابد من وجود شئ ما يسند السيارة عند فشل هذا المفصل، لهذا الغرض يتضمن هذا البحث تطوير للمفصل الكروي وهذا التطوير يعتمد على النتائج المستحصلة من التحليل العددي للمفصل الكروي المحمَّل بوضعين :- الأول عندما تُهم ل زاوية المفصل والثاني عندما تؤخذ تلك الزاوية بنظر الاعتبار. حيث تم اخذ مقاسات أجزاء مفصل الكرة لهذه السيارة ورسمها باستخدام برنامج CATIA software بوضعين، وتم أيضا قياس إبعاد أجزاء نظام الإسناد (الصدر) في السيارة وعُمل نموذج تقريبي لهذا النظام باستخدام برنامج MSC ADAMS software لقياس اكبر زاوية يبلغها مفصل الكرة عند أقصى إزاحة لنظام الإسناد في السيارة. بعد ذلك، تم نقل جميع الرسومات إلى برنامج التحليل العددي ANSYS WORKBENCH حيث حوَّلت هناك إلى نموذج رياضي ثلاثي الأبعاد وعُرِّفت مناطق التلامس المختلفة بين أجزاء المفصل وسُلِّط أعظم حمل إلى المفصل وبذلك اجري الحل وتم الحصول على النتائج، وأُعتمدت هذه النتائج في تطوير المفصل حيث تم رسمه بواسطة CATIA ومن ثم نُقل إلى برنامج التحليل العددي ANSYS WORKBENCH للتأكد من قابليته على الإسناد.

1-INTRODUCTION:-

Ball joints are used on the front end of almost every car, truc and minivan. Ball joint is an important part of car's 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 [Matt Keegan, 2006]. Ball joint of any car eventually wears and becomes loose so it needs to be replaced because the failure of worn ball joint of car such as shown in Fig.2 is dangerous as well as disturbing factor for driver and traffic. General signs of consumption or loose of ball joint are usually misalignment , uneven tire wear, sometimes a steering pull to one side , and/or suspension noise such as clicking or snapping sound when the wheel is turned[Auto Repair Tips & Advice,2011]. Nissan Pickup car has conventional suspending system type which uses an upper and lower ball joint such as shown in Fig.3. One type of ball joints used in this car is a tension-loaded lower type which has the most inclination to be worn as a compare with other types [Andrew Markel, 2007]. Nowadays, it is sometimes seen the ball joint of this car suddenly fails without any sign of consumption which was mentioned above.

2-BALL JOINT WORK AND STRUCTURE:-

Ball-joint operates something like the ball–and–socket joint in human hip. It has a round–head part that swivels in a cuplike cavity [Matt Keegan, 2006]. A lower ball joint used in Nissan Pick-Up car is a loaded joint designed to support the weight of the vehicle and to resist impacts. While the upper ball joint is a follower joint that positions the control arm or strut assembly and helps set the alignment. A lower ball joint subjects to a more wear and tear than an upper ball joint because it has more loads , so in a daily life , it is noted that the lower ball joint is always failed and the knuckle(on which the tire is bonded) is connected alone by the upper ball joint. Consequently, the lower ball joint will only be considered in this work. A lower ball joint in Nissan Pick Up car is described as tension-loaded ball joints where the force of the load tends to pull the ball out of the socket [Bureau of Automotive Repair, 2010]. Fig.4A shows the outside apparent of this ball-joint, Fig.4B shows the structure as well as cross section of this joint and the Fig.4C shows the parts of the ball joint individually.

The parts of ball-joint are divided into two groups depending on their functions:- the main parts group and the auxiliary parts group. Main parts are stud and socket. Auxiliary parts are the rest. The main parts are the most important because they support as well as resist the loads so they are always failing while the auxiliary parts(spring, washer, cover) are working together in keeping the lower part of stud in contact always with the socket[Automotive Diagnostic & Repair Help ,2011]. Therefore, the main parts will be only taken in consideration in this research.

Note:- Ball joint subjects to a lot of wear and tear, so to properly protect them ,ball joint is housed in an enclosed boot called dust cover to keep dirt away from the joint assembly[Journal of Vehicle and Engine Technology,2010].

3-MODEL DESCRIPTION:-

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. Before going on with description the model, there is a need to know two terms:-

- Travel: - Travel is the measure of distance from the bottom of the suspension stroke (such as when the vehicle is on a jack and the wheel hangs freely) to the top of the suspension stroke (such as when the vehicle's wheel can no longer travel in an upward direction toward the vehicle) [Wikipedia, 2012].

- Angle of ball joint:- is defined as the angle between the longitudinal axis of the stud and the longitudinal axis of socket[B. Longhurst, 2010].

The angle of ball joint changes with the travel. When the car hits a bump ,the travel will proportionally increase with the amount of impact[S. A. Kesulai,2009]. So, this angle must be taken in consideration during the analysis of stresses. Consequently, the stud and socket of ball joint have been drawn by CATIA software with consideration of this angle. So, The main parts of ball-joint must be drawn in two situations (forms):-

1. In the first form, the main parts of ball-joint are drawn normally by CATIA software regardless of joint's angle, then the model (geometry) has been imported to ANSYS workbench software

2. In the second form, the main parts of ball-joint are drawn by CATIA software under consideration to joint's angle, then the model (geometry) has been imported to ANSYS workbench software.

To view the change in this angle with the change in travel, another software called MSC ADAMS software has been used where an approached model of the suspension system of this car was created after measuring the lengths of suspension system's parts. The magnitude of joint's angle (when the car is loaded statically by its weight, freight's weight and weights of persons riding the car) has been measured. Fig.5 shows the suspension system of this car when it is loaded statically. The angle of ball joint is zero when the car is statically loaded and the position of suspension system under the effect of static load is called stable position [J. GARDULSKI, 2007]. The suspension's stable position is taken as a reference and the measurement of the suspension's distance will be from the stable position to the top of the suspension stroke i.e. the whole travel will not be taken in consideration because the maximum loads on the suspension system's parts including ball joint is at the stable position and at the top of the suspension stroke [J. GARDULSKI, 2007]. It is noted that when the suspension system is at the top of the suspension stroke, the travel has a maximum value (Maximum travel is),

Geometry:-

A real ball joint with some simplifications has been used as test case. The simplifications introduced are aimed at keeping the model "simple" without affecting the significance of the obtained results. To avoid unnecessary complexity of the model (i.e. to keep the number of degrees of freedom of the mesh as small as possible), most of the outside and inside geometric features of the stud and socket have been removed such as the threads and the entire of margins. Also , the auxiliary parts of the ball joint (spring, washer, cover) have been ignored because they don't play an important role of supporting the loads [Automotive Diagnostic & Repair Help, 2011]. The stud and socket are only the parts which have been considered. Fig.6 shows the ball joint with its two parts in CATIA Window after simplification.

In the second situation (form), where MSC ADAM software has been used, an approached model of the suspension system of this car was created, Fig.7 shows this model in MSC ADAMS window. A marker which is belong to lower control arm has been created in knuckle part of this model, the measurement of angle of ball joint with the distance from the stable position was done, the maximum angle is about 11.5° for upward maximum distance of the suspending system from its stable position as shown in Fig.8.

Materials:-

In real lower tension load ball joints, each component has its specific material (high-performance steels) and its specific heat treatment [Roadsafe, 2009], generally, induction hardening for Socket and Case hardening for stud is used. But iIn this model, a unique uniform isotropic material (a "generic steel") has been used for all joint components, without taking into account any hardening-induced pre-stress. Table (1) below [American standard,2008] shows the specification of the metal used in the model:-

Meshing Generation:-

The mesh must be homogenous. The elements must have equal sizes as far as possible and their numbers must be enough to get accurate results. Also the elements must be dense at a sensitive region such as the contacts, margins…etc. So, different options for meshing process have been used in each part of the joint to get the desired accuracy [Moaveni, 2006]. The mesh of each part of the ball-joint is shown in the Fig. 9

Constraints and Loads :-

Each tire of this vehicle has a share of the car's weight, freight's weight and weights of five 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 [Nissan Pick Up Guide, 2003], consequently, each tire has a share of quarter of that full static load, If the car has a weight of 1 ton and the weight of its freight is 1 ton too [Nissan Pick Up Guide, 2003] as well as each passenger is assumed to weight of 100 kg [Kur,2005] , the total static load will be 2500 kg .So each tire will have a share of 625 kg. According to reference [Gorsich,2009], 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. A load of (2*625*9.81) N is applied upward to stud at the thread place in its longitudinal direction while other load of(2*625*9.81)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 as shown in Fig.10. Also, Contact Pairs have been created between the lower part of stud (master) and inner surface of the socket (slave) [Yoshimoto, 2006]. It is known that ball joint is packed with grease, so an equivalent coefficient of friction of 0.01 has been used in this model [Erich Aucktor, 2006]. 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.

4-RESULTS AND DISCUSSION OF THE TWO SITUATIONS:-

Numerical analyses of the ball joint had been made in two forms:-

1- A normal ball joint without consideration to ball-joint's angle
2- A ball-joint with consideration to its angle (at the top of the suspension stroke).

There is noticeable difference in results in contact pressure (bearing stress) between the first form and the second form of the situation of ball-joint. The contact pressure shown in Fig.12b in the second case (where suspension is at the top of the suspension stroke) is higher than that in the first case (Fig.11b). Consequently, more wear and consumption will occur in the ball joint when the car has an impact and suspension system is at the top of the suspension stroke. But the case is opposite with Von Mises stresses, their values in the second situation, Fig. 12a, are a little lowerthan those in the first situation Fig. 11a and they concentrate at the upper region of the socket. In analysis of the fatigue, the results show that the fatigue's life and the minimum fatigue's safety factor of the second form{Fig. 12c & Fig. 12d} (where maximum travel is) are higher than those of the first form{Fig.11c & Fig.11d }. Also, their values are concentrated at the upper region of the socket. It is noted that maximum contact pressure occurs at the place of the contact and maximum fatigue stresses occur at the socket part of the ball joint.

The speech above supports what is being seen on the daily life that this ball-joint will have more wear and consumption when the suspension system has maximum travel, so general signs of consumption or loose of ball joint (such as misalignment, uneven tire wear) can be clearly noted after time of usage. But, in the case of fatigue and Von Mises stress, their highest magnitudes are when the suspension system is just to be moved upward (the travel is still zero).Consequently, if the ball-joint has not been manufactured well, the ball-joint suddenly fails as a result of fatigue. The failure resulting from fatigue will be more earlier than wear causing by high contact pressure so, ball joint fails without any sign of consumption. Nowadays, The spare parts (including ball-joints) are not genuine in Iraqi markets i.e are not manufacturing well, therefore a sudden failure resulting from fatigue is occurring.
First form:-

The modification:-

The whole purpose of this modification is for safety not for usage. Depending on the results obtained from the numerical analysis above, the modification includes a simple small secondary semi ball-socket assembly added to the ball joint at the bottom because the upper part subjects to maximum fatigue. So, the stud is modified, as well as a simple change (modification) has been made to the socket part of ball-joint in order to fit the new added parts, Fig.13 shows the modified parts. This assembly supports car when the ball-joint fails so, they are not for permanent usage but merely for temporary usage i.e they are impossible to be operated as a ball joint. The modification has been made in such a form that all effects, including movement of suspension system (travel) and the change in ball joints' angle, have been considered as shown in Fig.14a, moreover been taken into account the easiest and simplest way in the manufacture and assembly of the new parts of ball-joint. Fig.13 shows the new parts of ball-joint.

Note:- The thin-ring is new part and it does not exist among the modified parts in Fig.13 because thin-ring has a simple geometry and it is clearly shown in Fig.14b. the function of thin ring is to support and fix the safety socket.

It is clearly seen that in Fig.14a, the stud doesn't touch any other part of the modified ball-joint when its angle pass the Max. Limit (11.5°). In the Fig.14b above, the safety socket is first interred to the stud through its groove and the stud with the safety socket will be inserted together to the main socket, then the thin-ring follows to be inserted to the main socket too. The main socket is modified that it has certain several internal diameters in order to fit all the inserted parts.

Mesh Generation , Constraints and Loads:-

They follow the same steps and notes as for unmodified one, except several contact pairs has been created:-

1. Between the safety ring(safety socket) (slave) and the safety ball Fig.13c (master), this type of pair is frictional with same specifications as unmodified one.

2. Between the safety ring(safety socket) (master) and the modified socket, this type of pair is bonded type because it is inserted strongly[ANSYS WORKBENCH 11 help].

3. Between the safety ball (master) and the modified socket, this type of pair is bonded type because it is inserted strongly too[ANSYS WORKBENCH 11 help].

4. Between the thin-ring (slave) and the safety ball Fig.13c (master), this type of pair is frictional with same specifications as unmodified one.

Note:- when sudden failure occurs, secondary or safety ball will hit the safety socket. This hit has been taken in to consideration within the numerical analysis.

5-RESULTS , DISCUSSION AND CONCLUSION:-

In Fig.16, The results show that the lower region of the stud (between the main ball and the safety ball) has the maximum fatigue stresses and this stresses are higher than those for the ball-joint before failure. For fatigue's safety factor and life , the results indicate that the new loaded parts are not for permanent usage but merely for temporary usage.

In the case of sudden failure, the lower part of stud (secondary or safety ball) will hit and be in contact with the safety socket after failure. So, the stud will move up from its position causing a loose in balance in suspension system. This loose in balance will cause misalignment, steering pull to side on which the failing ball-joint is and difficulty to rotate the steering tool of car. These signs as well as other signs of ball-joint's failure will be a very noticeable indicator for a driver. Therefore when a driver notes these signs within driving, he must lower car's speed and go as soon as possible to nearest service center to replace the ball-joint.

Note:- the auxiliary parts of the modified ball joint is modified too. But they are outside of the size of this paper. Their modifications are too simple to be mentioned.

Table (1) Material's properties of the Model

Young's Modulus	2.e+011 Pa	Tensile Yield Strength	2.5e+008 Pa
Poisson's Ratio	0.3	Compressive Yield Strength	2.5e+008 Pa
Density	7850. kg/m³	Tensile Ultimate Strength	4.6e+008 Pa
Thermal Expansion	1.2e-005 1/°C	Compressive Ultimate Strength	0. Pa

Fig.1 Nissan Pick Up Car

Fig.2 Ball-joint's failure

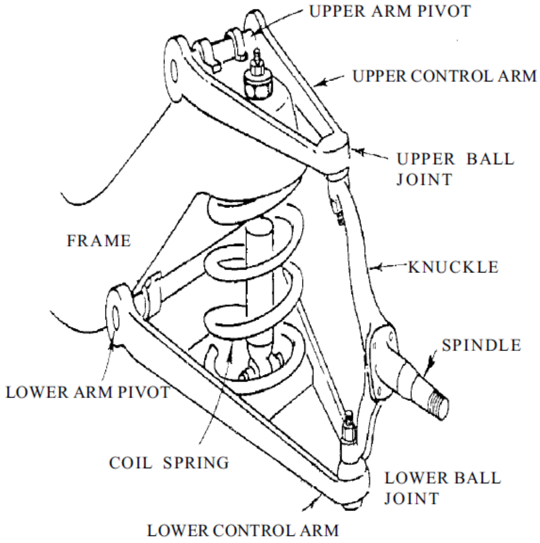


Fig.3 Conventional suspending system

Fig.4 Ball-joint of Nissan Pickup Car

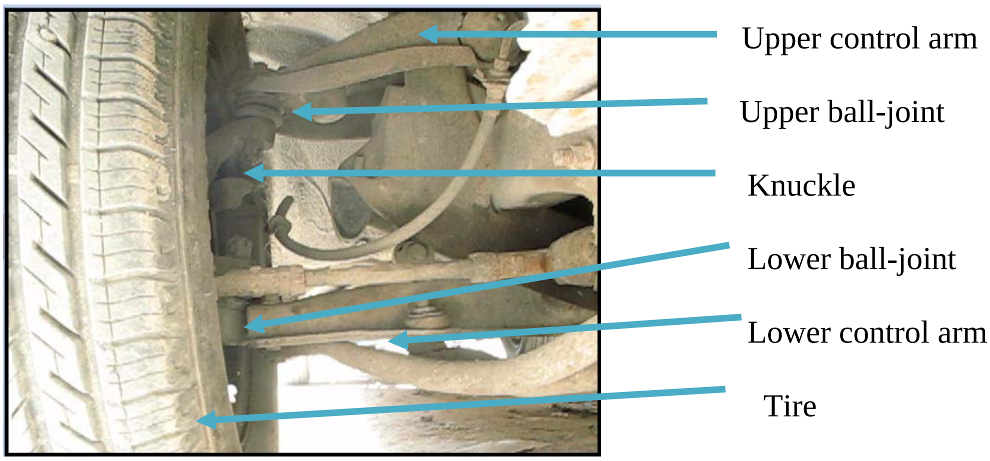
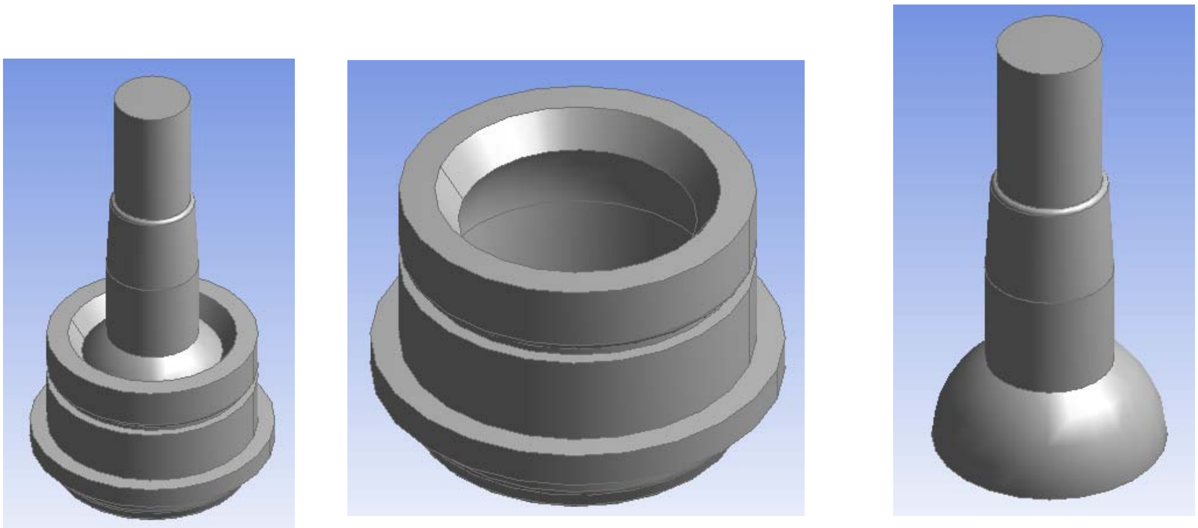


Fig.5 The Suspending System



Outside apparent **Socket** **Stud**

Fig.6 Ball joint with its two parts in CATIA Window

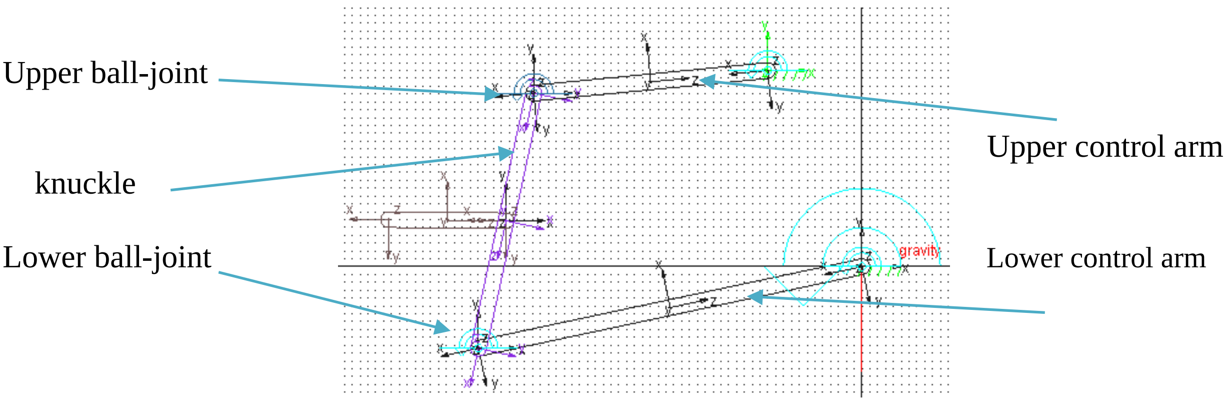


Fig.7 Model of the Suspension System in MSC ADAMS

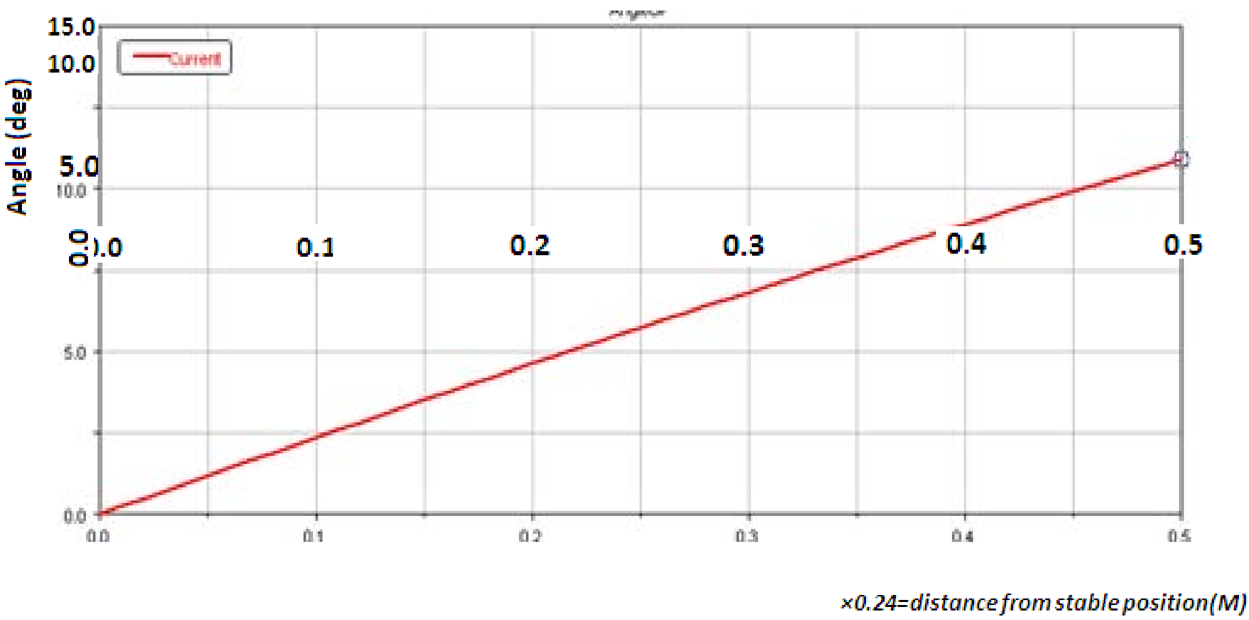
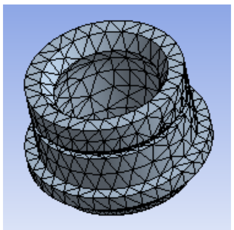
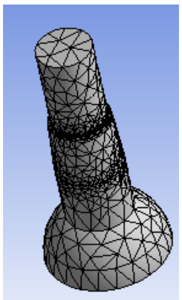


Fig.8 Ball-joint's angle with Distance from Stable Position





Socket **Stud**

Fig.9 Meshed Model

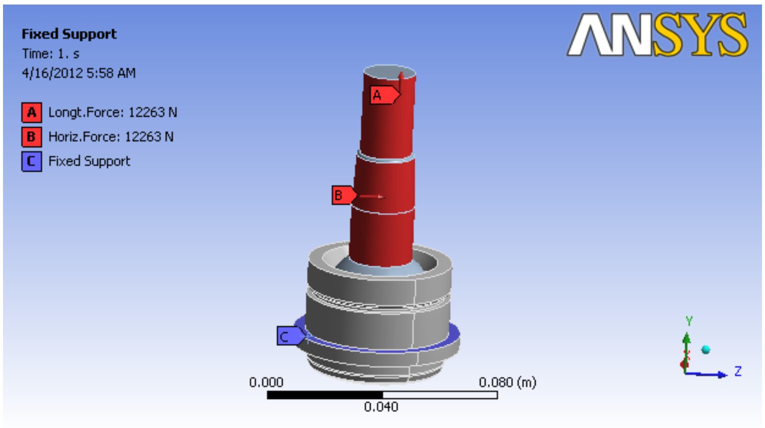
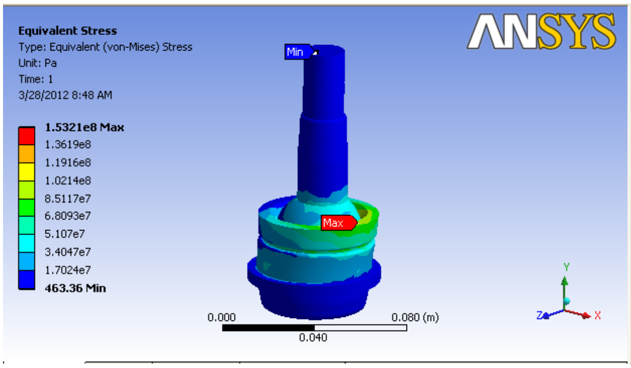


Fig.10 Boundary Conditions

First form:-



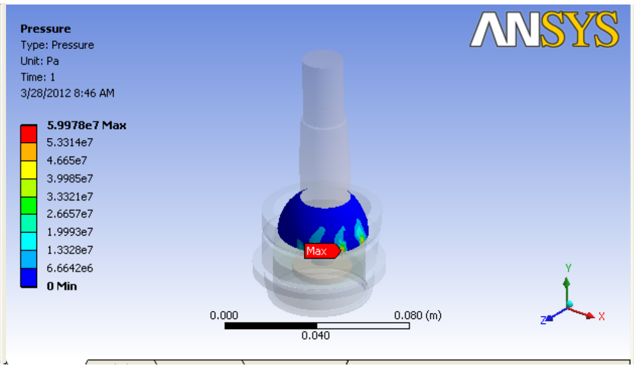
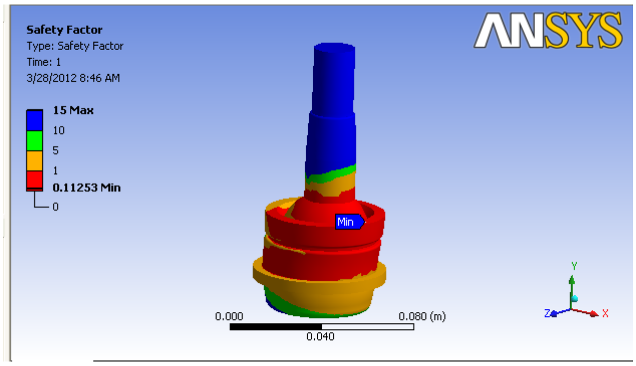


Fig.11a Von Mises stresses **Fig.11b Contact pressure**



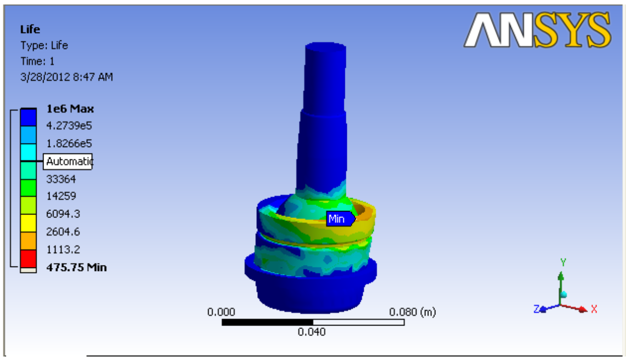
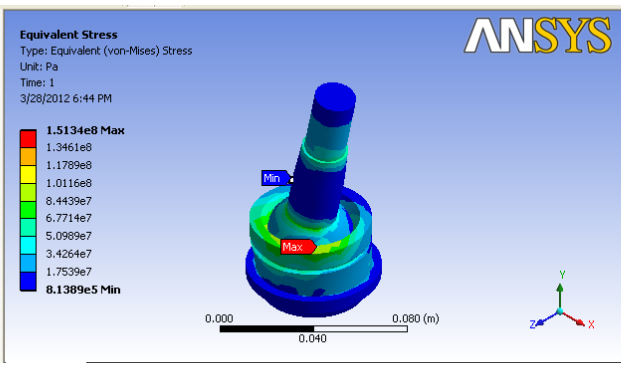


Fig.11c Fatigue's safety factor **Fig.11d Fatigue's life**

Fig.11 Results on Joint without Angle's Consideration

Second form



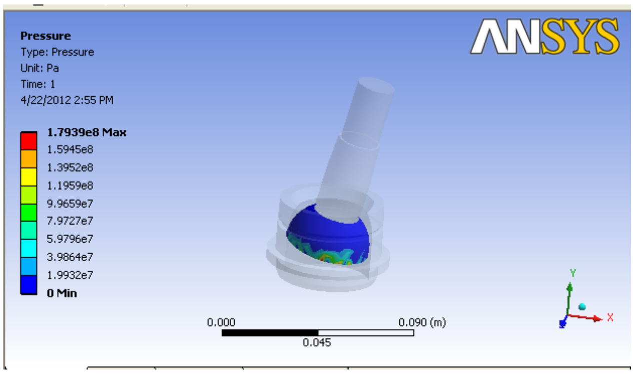
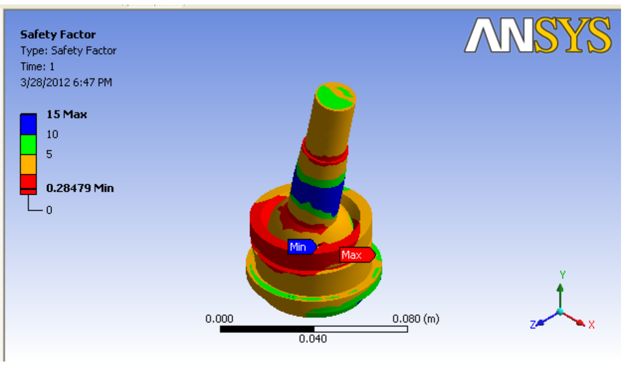


Fig.12a Von Mises stresses **Fig.12b Contact pressure**



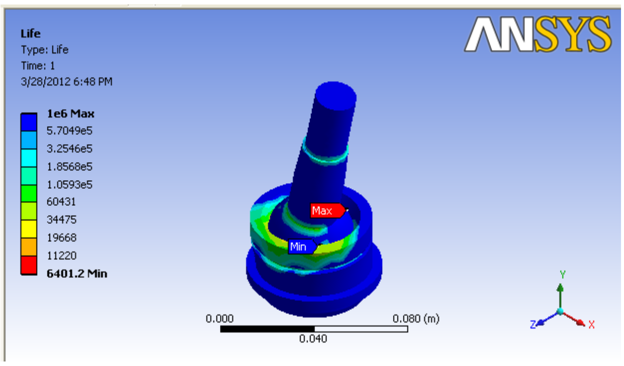


Fig.12c Fatigue's safety factor **Fig.12d Fatigue's life**

Fig.12 Results on Joint under its Angle's Consideration

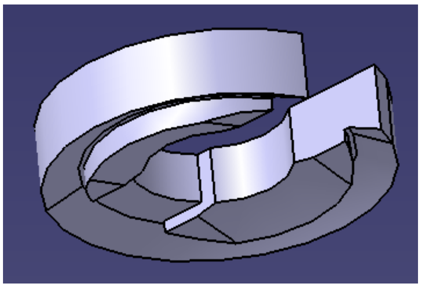


Fig.13a Safety socket

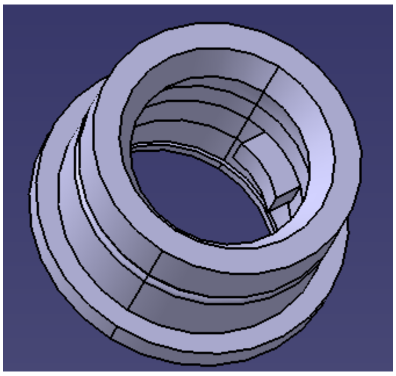


Fig.13b modified socket

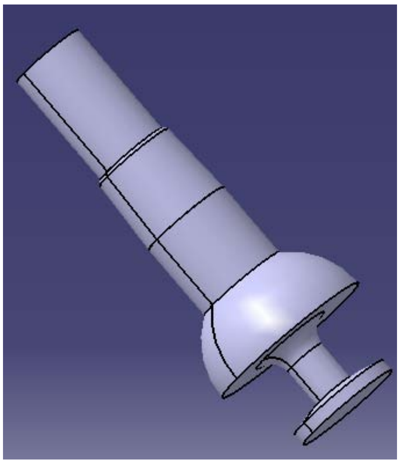


Fig.13c Modified stud

Fig.13 Modified parts of Ball-joint

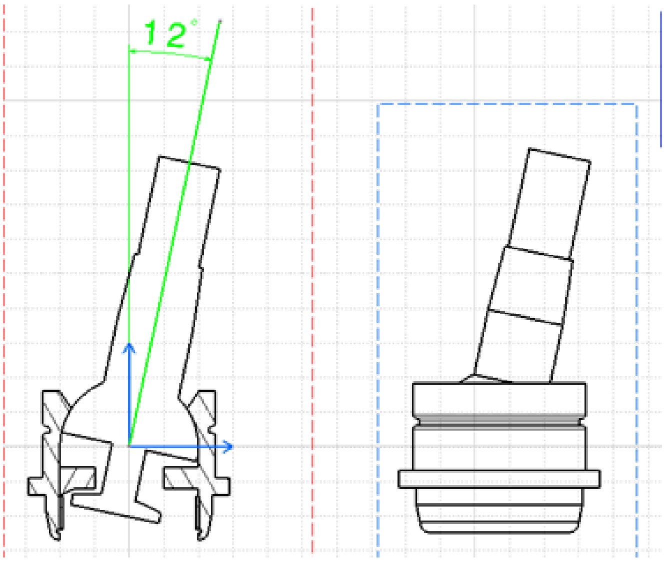


Fig.14a Cross-section of the modified ball-joint

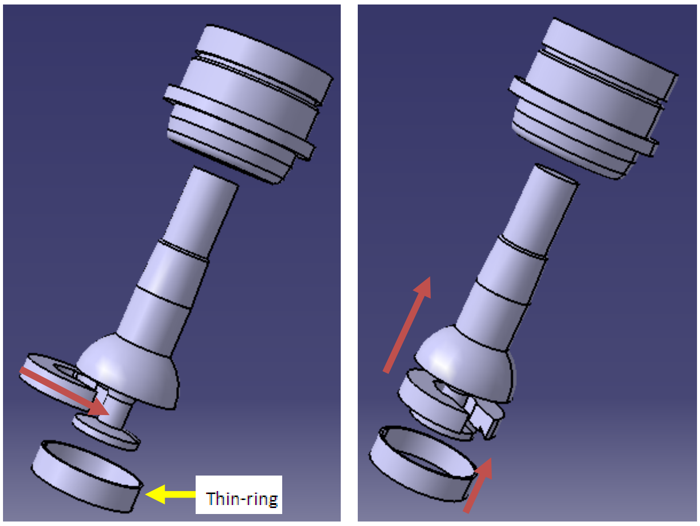


Fig.14b How to assemble the modified ball-joint

Fig.14 Modified Ball-joint

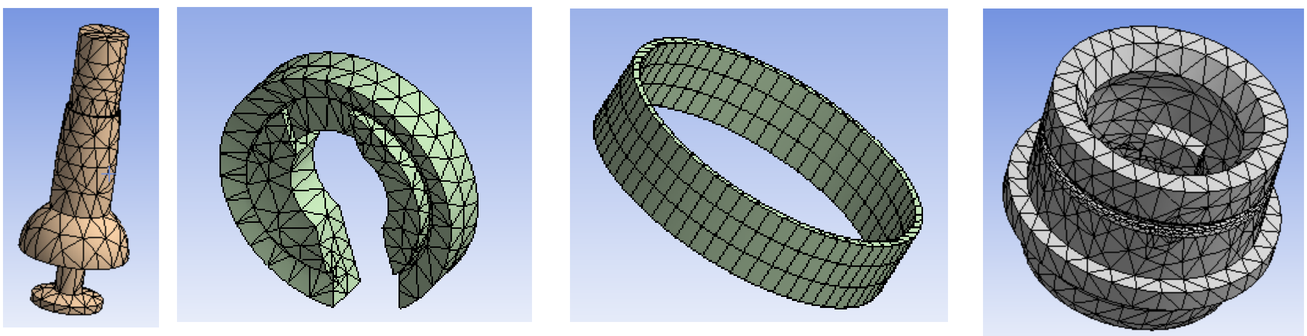


Fig.15 Meshed Modified Parts

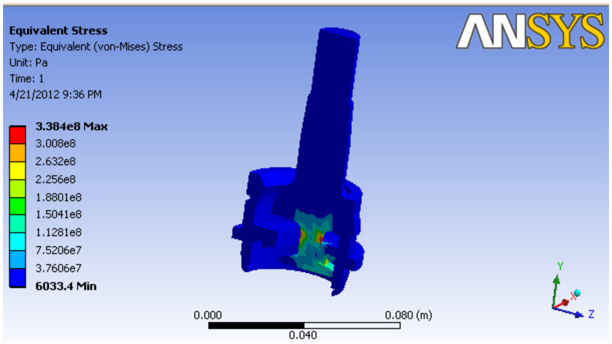


Fig.16a Von mises stress

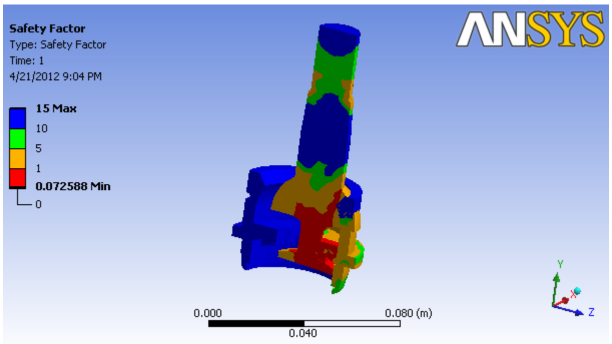


Fig.16b Fatigue's safety factor

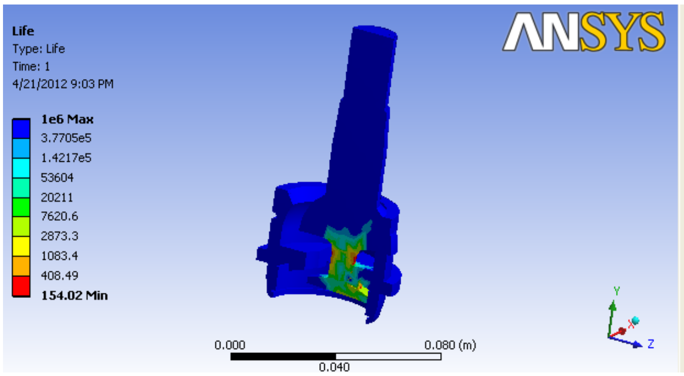


Fig.16c Fatigue's life

Fig.16 Results on Modified Ball-joint

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