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Preliminary study of friction in automotive ball joints

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Abstract. The present paper offers a brief description of the testing equipment, experimental methodology and some results regarding the motion resistive effort in automotive ball joints. The local ball joints manufacturers have difficulties in controlling the clamping force of the ball joints in the production process. Due to this, an original experimental device was conceived and built in order to evaluate the magnitude and evolution of internal friction between the joint's surfaces. The experimental setup's main advantage is the capacity of controlling and maintaining a constant clamping force and that it ensures a constant motion of the ball stud. The force magnitude was recorded using resistive transducers connected to a data acquisition system. The numerical values were recorded and used to analyse the mobility of the tested ball joints.

1. Introduction

Modern equipment often uses ball joints to maintain the relative position between constitutive elements. One of the most important applications of ball joints is in the steering system of road vehicles. This equipment must determine the steering of front wheels in direct proportionally to the steering wheel's position and also ensure minimum clearances and as little as possible needed effort from the driver. Also, the steering system elements have to allow vertical movement of the wheels so that the suspension system of the car can be efficient. Due to these requirements, the clamping force of the ball stud must ensure a minimum clearance fit as well as a limited friction force. In order to highlight the friction force in this type of joints and to estimate their reliability, experimental investigations are required. The most common structure of a ball joint consists of: ball stud, cap, bearing, socket and gasket.

A proper function of automotive ball joints depends on the behavior of the ball stud-bearing contact. If the clamping force is too high, the friction between the ball stud and the bearing is also very high, the spinning motion will be cumbersome loading additionally different parts of the vehicles steering system. If the ball joints are affected by wear, then in addition to the rotating motion, a translation displacement appears, which is undesirable for a proper function of the vehicles steering system.

This paper appears as a consequence of discussions with local automotive ball joints manufacturers, which found large differences of the clamping force level applied on the ball stud of the joint as a consequence of the manufacturing process. One of the manufacturing solutions used in ball joints production process consists in applying the clamping force through a closure cap. The closure cap and the joint socket are assembled by plastic deformation of the socket upper edge. The clamping force between ball stud and the bearing depends on technological parameters as, the dimension of the socket's upper edge, the strain magnitude, manufacturing errors etc.

By analysing the technical literature regarding ball joints tests it is noted that many machines were developed for testing, [1-4]. Those machines are capable to simulate the most difficult situations similar to those found during operation. Given that, the issue raised in this paper is to find the cause of these great variations between the minimum and the maximum motion resistant force of the joint ball stud. A special setup was proposed for this purpose.

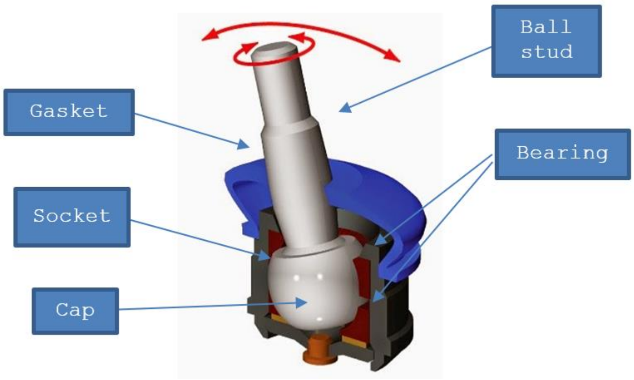

Figure 1. Ball joint structure, [5].

2. The experimental setup

An experimental setup was conceived and built. The experimental device must be capable to measure and to send further information regarding the clamping force level and the resistive motion force magnitude. The experimental setup has the following structure as is represented in Figure 2.

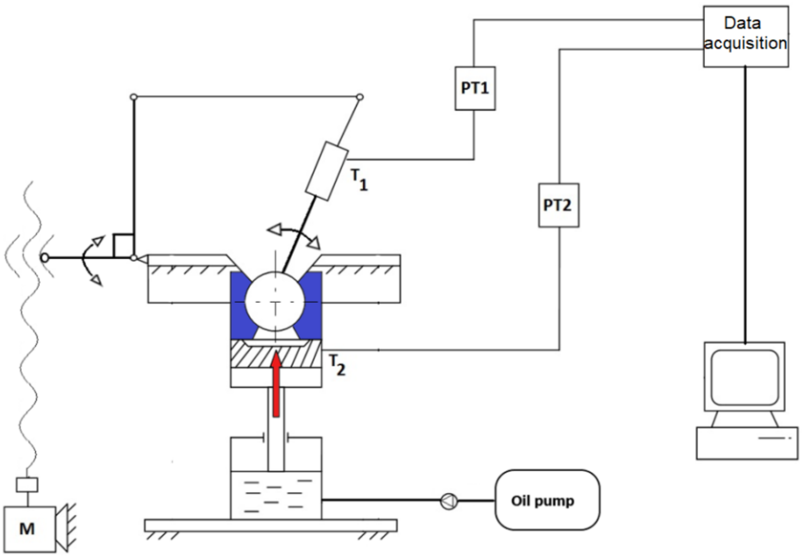

Figure 2. Schematic representation of the experimental setup, [6].

A DC motor is used to drive the experimental device at constant speed. The rotation motion generated by the motor is transformed into translation motion by means of a a screw - nut transmission. The translational motion of the nut is transmitted to a quadrilateral mechanism represented in Figure 2. The last element of the mechanism is connected firmly to the ball stud tail. The quadrilateral mechanism must provide a symmetrical alternating motion of the joint stud with constant speed.

The clamping force was generated using a hydraulic piston. The tested ball joints and the hydraulic piston were inserted in a rigid steel frame. In the upper region of the frame a hole was made to allow the pin to be connected with the transmission mechanism.

To determine the clamping force level and the resistive motion effort, two force transducers were used. One of them was inserted between the end of the hydraulic piston and the ball joint cap and the other was connected to the last element of the mechanism.

3. Testing methodology and results

Unpacked ball joints with 25 mm ball stud radius were used for tests. The ball stud was manufactured from C12E steel and the joint bearing was made from polyethylene. The experimental setup was connected to a DC power supply which provided constant DC voltage.

The force transducers were connected to a data acquisition system in order to record the numerical values. The recording rate was 50Hz. From the oil pump the clamping force was adjusted by reading the indication of the T1 transducer. After the clamping force adjustment, the electric motor was connected to the power supply. The numerical values recorded from the second transducer were recorded and processed.

The experimental values obtained by using those two force transducers were recorded and represented graphically. The following evolution of the motion effort of the ball joint corresponding to a 440N clamping force was obtained.

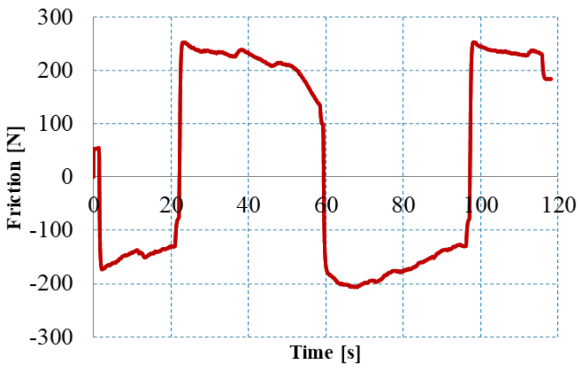

Figure 3. Ball joint friction evolution corresponding to 440N clamping force.

Several tests for different clamping forces (440N, 620N, 870N, 1080N) were conducted and the results were represented graphically on the same chart as shown in Figure 4.

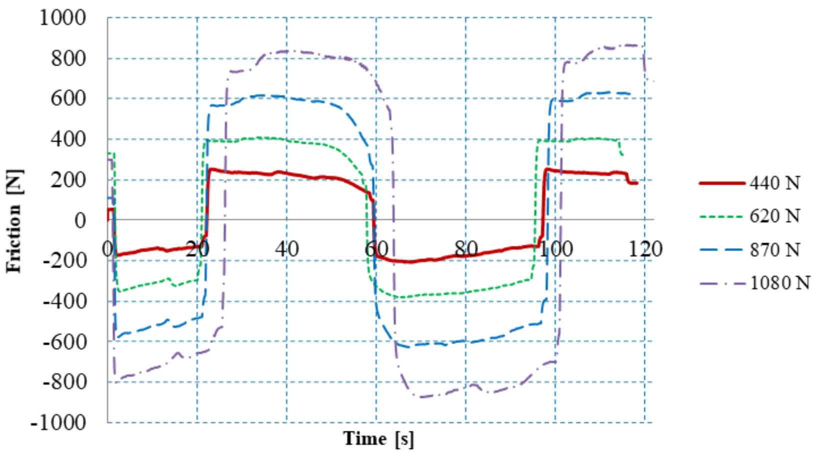

Figure 4. Ball joint friction evolution at different clamping levels.

To validate the reliability of the measurements, two tests were made at the same clamping loading level in different contact conditions. The evolution of the friction force corresponding to 650N clamping force with and without oil between contact surfaces was obtained and represented in the chart below. From the representation shown in Figure 5, it can be observed that the friction in the lubricated contact case is much smaller. The results show an evolution similar to those presented in the literature, [7].

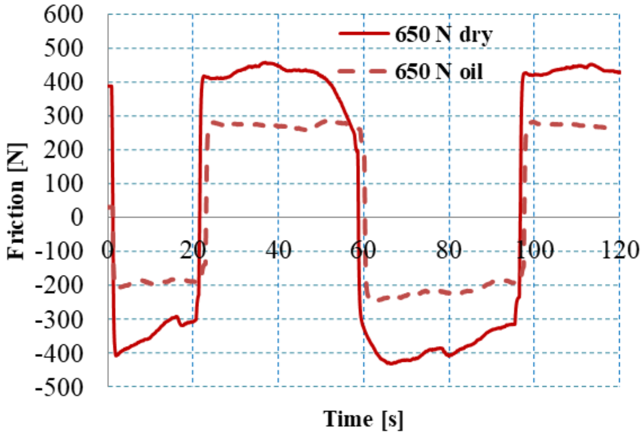

Figure 5. Ball joint friction evolution with and without oil between surfaces at 650N clamping force.

4. Conclusions

For the abovementioned experiments, an experimental equipment was conceived and built at the "Ştefan cel Mare" University of Suceava, in the Tribology Laboratory. The experimental setup permits to impose a planar oscillatory motion to a spherical joint, while applying a controlled clamping force by means of an original loading system. By aid of a special measuring device, the evolution of friction force in this type of ball joints was highlighted for different clamping force levels. Several tests were conducted with and without presence of lubricant in the ball joint.

Results obtained at low clamping force levels applied to the tested ball joints reveal that the static friction force under dry conditions has higher values than those obtained for kinetic friction. At high clamping force levels, the differences between the static and kinetic friction are increased.

Results obtained at 650N clamping force with and without oil between contact surfaces show a low magnitude of the friction force in the joint. This can be caused by the attenuation of the adhesion effects between surfaces due to presence of a thin film of oil and the thin oil film formed between contact surfaces. The magnitude of the friction decreases with approximately 50 % when the contact is lubricated.

Own results were compared to those obtained by Baroiu, [8]. Baroiu has made some tests on automotive ball joints and he determine the magnitude of the force necessary to tilt alternant a joint ball stud. His work shows a similar evolution of the friction force in the ball joint near the ends of the stroke.

5. References

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