000000223PE

High Performance Ball Joint

Walter Bordon
Marcus Zucchini
Gustavo Simião
Dana Industrial Ltda.

Brian W. Cichoski
Nye Lubricants Inc.

ABSTRACT

In automobile steering and suspension systems, ball and socket joints are exposed to contaminants (water, sand salt, dirt and others) during their life span. Ball joints use a seal (also known as a boot or dust cover) to prevent these contaminants from penetrating into its housing.

Penetration by these contaminants will in most cases drastically reduce the useful life of a ball and socket joint. In order to avoid such a condition there have been several efforts made by ball and socket joint manufacturers to improve the performance and reliability of seals (dust covers).

This paper focuses on the development of a new ball and socket joint capable of performing adequately after the dust cover has failed and permitted the penetration of contaminants into the interior of the housing. It also includes experimental tests results that compare the new ball joint design to the conventional design currently used.

INTRODUCTION

Competition has motivated companies to constantly review their performance standards in search for better performing and longer lasting products. Therefore a research and development program was developed to study the tribology of ball and socket joints with the goal of developing a more durable ball joint.

The science of tribology studies friction, wear, and lubrication. Our previous studies have indicated that in order to improve the wear characteristics of the ball of the ball stud and the bearing on which it rides, it is necessary to improve both the contact surface between the ball stud and the bearing, and to improve the lubricating element placed in between these two surfaces.

In the study of the lubricating characteristics of a ball joint, several aspects of the lubrication element must be considered such as: viscosity index (how lubricant viscosity changes with low and high temperatures); compatibility with rubbers and plastics; thermal stability; and resistance to aggressive chemical products. The variation of these lubricant characteristics can increase the speed of degradation of the ball joint, therefore decreasing its life expectancy [1].

The present work was conducted with ball joints constructed with a plastic bearing design. Consequently several characteristics of plastic bearings must be considered in the design of the ball joint including: elasticity, surface roughness, resistance to temperature [2].

The goal of this work is to develop a lubricating system that will reduce the wear and improve the durability and life expectancy of ball and socket joints. In order to do so, it is necessary to maintain a stable ball joint torque level. This is achieved by controlling the wear characteristics of the contact surfaces with the goal of maintaining a stable ball joint torque level when the interior of the ball joint is exposed to contaminants such as water both in high and low temperatures.

Information about the products utilized

Several lubricants were evaluated in order to achieve the desired effect. Figure 1 displays the working temperature range of several synthetic lubricant bases.

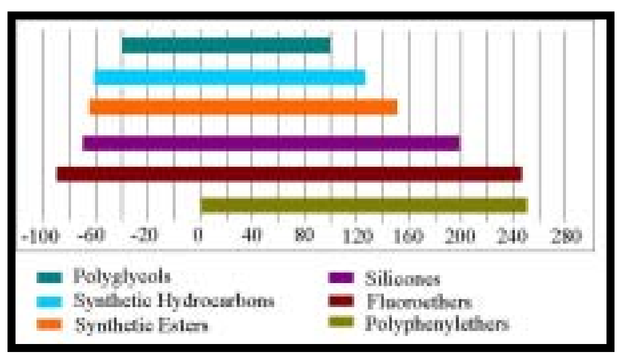

Figure 1: Working temperature of several lubricants (Degrees C)

Based on the working temperatures, it was decided to test the silicone-based (Lubricant A) and the synthetic hydrocarbon-based (Lubricant B) lubricants. These results were compared to conventional mineral grease currently used in production.

Lubricant A: Silicon-based synthetic grease thickened with polytetrafluoroethylene (PTFE), with a high viscosity index of 200 to 650, presents resistance to water and is mechanically stable at a wide temperature range (-40 to 200ºC), and is compatible with several plastics and elastomers.

Lubricant B: synthetic grease , with a PAO base (polyalphaolefin) oil thickened with PTFE, with viscosity index of 125 to 250, an operating temperature of -20 to 125ºC, and has good compatibility with most plastics, but must be used with caution with elastomers.

Lubricant C: Mineral base oil thickened with lithium soap, with the solid lubricant molybdenum disulfide, with corrosion and oxidation inhibitors, presents an operating temperature of -20 e (typically 0 to 100C)120ºC, and has limited compatibility with plastics and elastomers.

There were also two types of reinforcements to the plastic bearings tested in this study. Both bearings used a POM base material due to its high resistance to friction, abrasion and fatigue. They used two different concentrations of reinforcements in order to verify their performance [3].

Bearing A: POM bearing with a higher concentration of reinforcements had a hardness of 70 to 75 Shore D and resistance to tension greater than a 65 N/mm^2.

Bearing B: POM bearing with a lower concentration of reinforcements had a hardness inferior to 70 to 75 Shore D and resistance to tension greater than a 60 N/mm^2.

Consequently three lubricating systems were evaluated: system 1 with lubricant A and bearing A, system 2 with lubricant B and bearing A, and system three with lubricant C and bearing B. The determination of these combinations was established based on past experience and past studies.

EXPERIMENTAL PHASE

The test specifications and conditions used to test the ball joints are as follows. The test specimens were aged artificially at 70ºC for 168 hours in an air circulating chamber.

The durability test was conducted with an axial load (F1) of 0,2 ± 1,0 kN at a frequency of 0,33 ± 0,05 Hz. A radial load (F2) 2,0 ± 5,0 kN was also applied at a frequency of 0,33 ± 0,05 Hz. The oscillation movements (θ1) and rotation movements (θ2) were of ± 15 degrees for both movements at frequencies of 2,0 ± 0,33 Hz and 0,5 ± 0,1 Hz respectively (Figure 2).

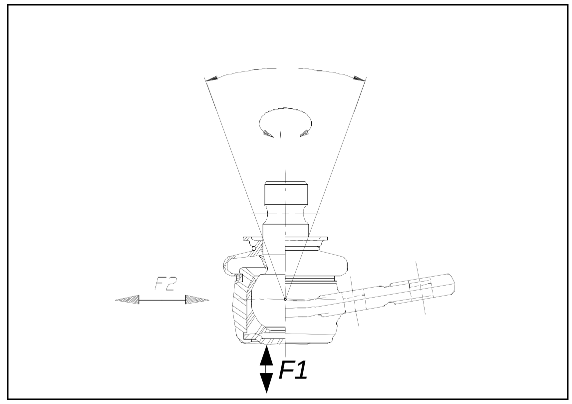

Figure 2: Ball and socket joint

Figure 3 and Figure 4 display test specimens in the testing apparatus. Water was sprayed into the ball joints, which were removed from the protective seal (dust cover) in order to verify the resistance of the lubrication element to water.

Figure 3: Test specimen in the test apparatus.

Figure 4: Test specimen in the test apparatus depicting the lack of the seal (dust cover)

The three lubricating constructions were tested. The test lasted 82,500 cycles of the radial load. The axial and radial elasticities of the test specimens were not to exceed 0.2 mm of their initial value before the test as displayed on Figure 5.

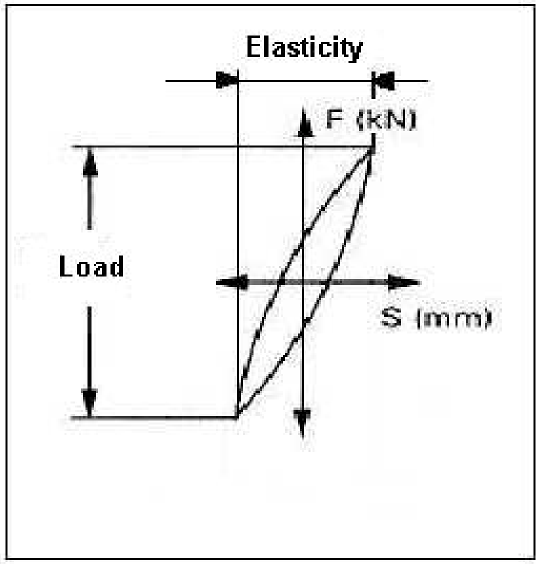

Figure 5: Elasticity measurement

The elasticity measurements were taken before and after the test as displayed on Table 1.

Table 1: Elasticity measurements

#	Lubricating System	Elasticity (mm)				# of Cycles
		Axial		Radial		
		Inicial	Final	Inicial	Final	
01	**3**	0,09	0,09	0,35	0,51	78.510
02		0,03	0,39	0,41	0,56	85.396
03		0,05	-	0,40	-	82.923
04		0,06	0,18	0,45	0,51	85.670
05		0,02	-	0,36	-	70.270
06		0,04	-	0,16	-	60.150
09	**2**	0,04	0,80	0,32	1,08	29.802
10		0,04	0,66	0,24	1,49	20.120
12	**1**	0,03	0,06	0,31	0,51	83.500
13		0,08	0,07	0,34	0,36	82.500
14		0,08	0,11	0,36	0,39	82.500
15		0,03	0,14	0,23	0,40	82.500

The test specimens that do not display final elasticity results failed before the conclusion of the test.

The test specimens that used lubricating system 3 lost almost all of its lubricating element at the conclusion of the test as displayed of Figure 6 and Figure 7. This occurred due to the low resistance of this lubricating element to water.

Figure 6: Remains of lubricant C on the bearing

Figure 7: Loss of lubricant C on test specimen 05.

After the disassembly of the ball joints that used lubricating system 3, it was verified that the plastic bearings did not present wear as displayed on Figure 8. This is a result of the correct selection of the bearing material that didn’t display wear even though the lubricating element was washed out by the sprayed water.

Figure 8: Plastic bearing of test specimen 02

Both test specimens tested using lubricating system 2 presented an elasticity increase greater than the maximum elasticity accepted after approximately 30% of the cycles of the test had been concluded.

Lubricating system 1 obtained the best performance. The elasticity increase results were within the specification and there was no wear of the bearing as displayed in Figure 9. Figure 6 displays the lubricating element removed from the test specimen after the completion of the test demonstrating the resistance of this lubricating element to the conditions imposed by the test.

Figure 9: Plastic bearing A of test specimen 12

Figure 10: Lubricant A removed from test specimen 12

Aspects verified in this study other than the elasticity values were the breakaway and movement torque values. The graph below displays the variation of torque values as a function of time.

Figure 11 displays the graph obtained from lubricating system 2 and Figure 12 displays the graph obtained from lubricating system 1. The higher values are breakaway torques and the lower values are movement torques.

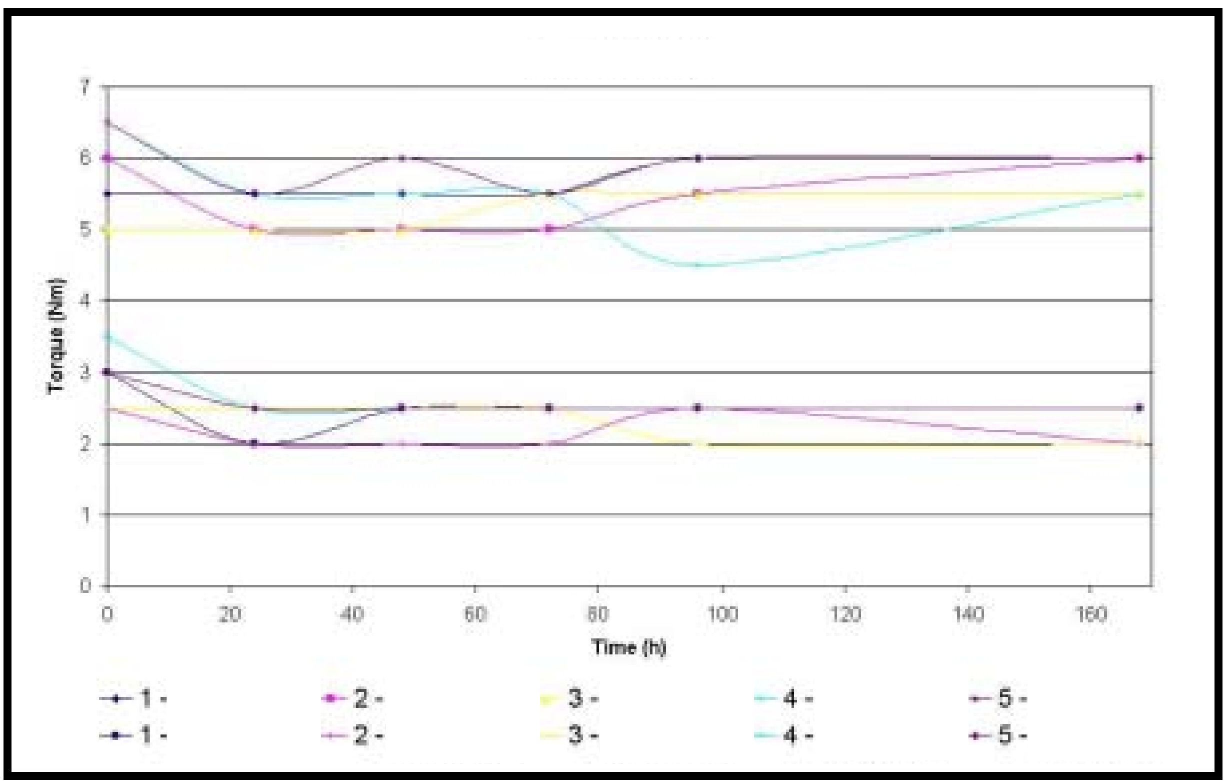

Figure 11: Lubricating system 2

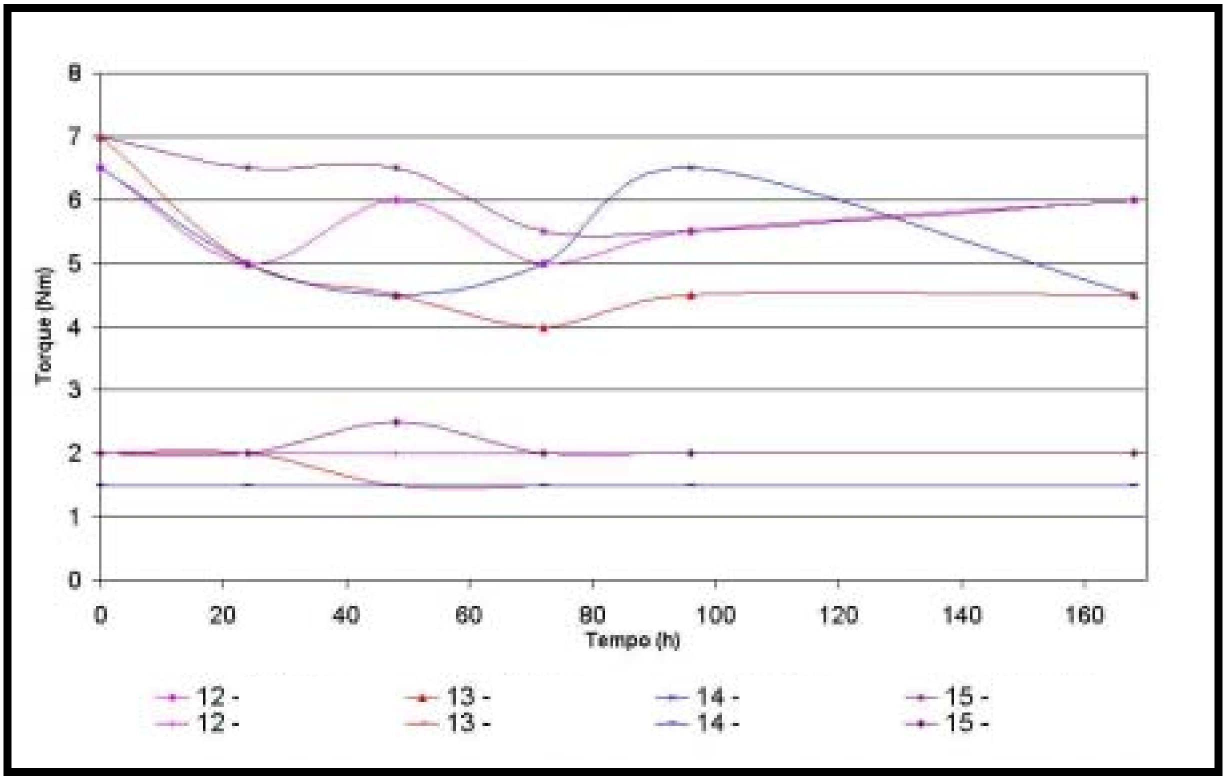

Figure 12: Lubricating system 1

These results confirm the importance of the use of the correct lubricant and bearing material. It is worth noting that the roughness of the bearing and the ball stud must be compatible with the materials used (bearing material and lubricant). Previous studies indicate that the roughness of the ball studs must be different when using lubricants with synthetic or mineral bases.

CONCLUSION

The results indicate that the careful selection of the bearing material in conjunction with the choice of the lubricant can significantly improve the durability/wear life of a ball and socket joint after the protective seal (dust cover) has failed to protect the internal components located in the housing of the ball joint.

Considering that vehicles are submitted to a wide range of temperatures, it would be beneficial to conduct this same test at the high and low temperature ranges suitable for the application in question. This will aid in further understanding the behavior of the lubricating system under such conditions.

The present paper has demonstrated that it is only possible to obtain improvement if the lubrication regime is known. The modification of the lubricant led us to modify the bearing material, dimensions and surface conditions, so that a new stable regime was achieved.

This new bearing package design improved the performance of a ball joint. The final results pointed to a ball joint able to withstand higher loads, due to the plastic bearing improvement; improved the torque stability, due to the characteristics of the lubricant as well as the dimension modifications; and improved the resistance of contaminants, due to the characteristics of the lubricant.

BIOGRAPHY

[1] LAY, Jeffrey & WEIKEL, Jay. Gaining a competitive advantage with synthetic lubricants. Appliance Magazine, 2001.

[2] CALLISTER, William D. Jr. Material Science and Engineering: an Introduction. 5ª ed., John Wiley & Sons, 1999.

[3] MANO, Eloísa B. Polímeros como materiais de engenharia. Ed. Edgard Blüncher, 2000.