# CONSIDERATIONS REGARDING LUBRICANTS TESTING ON FOUR BALLS MACHINES

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**Abstract:** *The paper presents several research studies developed on the four balls testing machine to evaluate the best method which can be used in a future study. Tests conducted by the authors of this paper and others were presented and the results were represented graphically and compared. Also, different testing methodologies were presented and the results obtained. The evolution of the wear scar dimensions reflects the quality of the tested lubricant.*

**Keywords:** *lubricant, contact, four balls test, scuffing, wear*

## 1.Introduction

Lubricants were and remain one of the most important factors which affect friction between surfaces with relative motion between them. The quality of the lubricant influences the extreme pressure, load capacity of the contact and the occurrence of scuffing. To determine the quality of lubricants over the time, several testing methodologies were developed, [Dongare,2012]. Also, special equipment was conceived and built for this scope. One of them is the four balls testing machine, usually used in the contact mechanics and tribology laboratory to test the lubricants and contact loading. Using this type of machine, the quality of lubricants can be evaluated by following standardized procedures, [Dongare,2014]. Some typical properties of lubricants can be highlighted by experiments such as: extreme pressure, weld point and wear magnitude. Also, the influence of the different additives to the lubricant quality can be evaluated, [Dongare,2012].

## 2.Testing procedures used to evaluate greases quality

In order to evaluate the quality of greases several testing procedures were elaborated. Some of those procedures were generalized and became international standard.

One of them is the ISO 20623:2003, developed to determine the extreme pressure and anti-wear capacity of greases, [ISO20623]. For testing, only 12.7mm bearing balls must be used, manufactured by SKF. The testing procedure consists of loading the contact in 100N steps and running the test during 10 seconds for each loading step. The testing machine must provide 1600rpm spinning velocity. After testing, the obtained wear scar is washed with a solvent and the dimension of the scar is measured. The test ends when the complete welding between contact bodies occurs.

ASTM D2596 and ASTM D 2783 present the detailed procedure to evaluate the greases and oils, [ASTM D2596, ASTM D2783]. The testing methodology is similar to ISO20623, differences appears at the spinning velocity of the loading shaft. The ASTM D2596 and ASTM D2783 require 1770 rpm spinning velocity of the loading shaft. The above methodologies recommend for finish the tests the loading level corresponding to the occurrence of the weld point.

## 3. Experimental testing machines used for greases evaluation

To evaluate greases quality, typical testing equipment's must be used. The equipment must ensure constant spinning velocity and loading. Also, the testing running periods have to be constant and the loading device has to ensure identical loading levels on all three contacts.

The tested grease must completely cover the contacts and to remain between balls during testing. After each test, the testing equipment loading device must be able to be cleaned and the obtained wear scars must be possible to be measured without changing the relative position of the balls.

**Figure 1:** *Falex testing equipment [Falex]*

Several testing equipment that satisfies the above presented requests are described in literature. One of them was conceived by Falex, [Falex]. This experimental test rig was conceived to run four ball tests following standard procedures such as ASTM D2596 and ASTM D 2783. Using the test rig in Fig.1, the temperature of the lower ball cage and the loading can be controlled.

An original testing equipment was presented by Couțun and Muscă [Coutun,2015]. Their equipment was conceived to use a bench drilling machine as loading device as is shown in Fig.2. The drilling machine's feed mechanism was used to generate constant loading by attaching deadweights on the lever arm. In order to ensure constant testing periods, an electronic timer was used for turning off the drilling machine's electric motor.

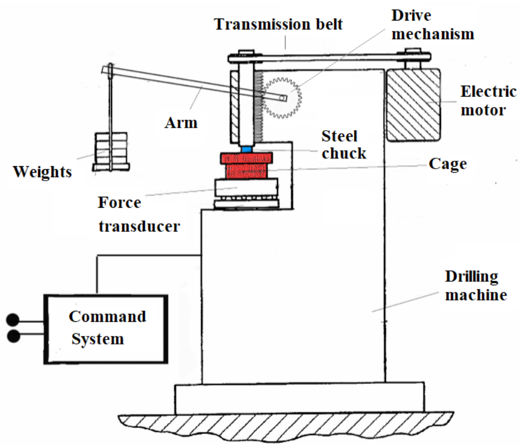


**Figure 2:** *Grease testing equipment [Romanu,2016]*

In order to obtain identical contacts between balls, a special device was conceived and used. The loading device is represented in Fig.3.

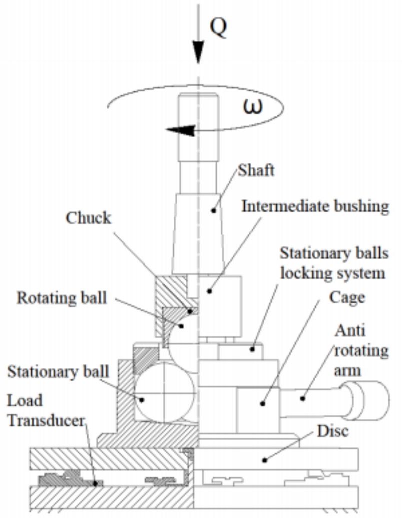


**Figure 3:** *Loading device [Hangan,2020]*

## 4. Typical results obtained on four balls testing machine

Many testing machines were presented in literature designed to evaluate grease quality. All have similar working principles and parameters.

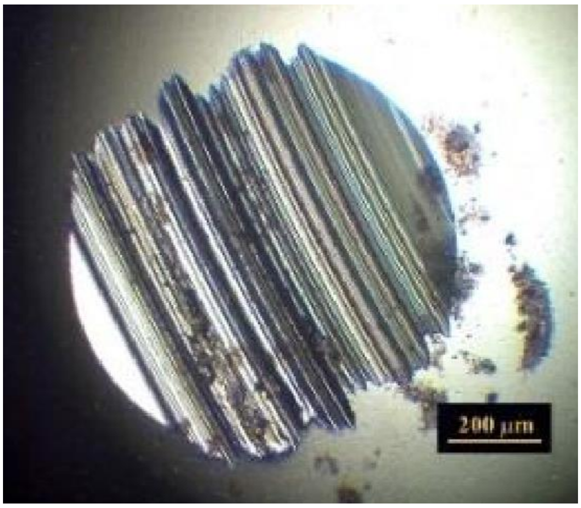


**Figure 4:** Typical example of wear scar obtained in a four balls test *[Ionescu,2019]*

Over the years, many research studies conducted on four balls machines using various lubricants obtained from mineral fluids, animal fat and vegetal oil. Some of the results presented in those studies were compared and were used to evaluate lubrication capacity of lubricants.

A typical example of the wear scar resulted from a four ball test, found in literature, [Ionescu,2019], is shown in Fig.4.

Another example of such results was presented by Hills, [Hills,1995], shown in Fig.5. He tested such fluids as: synovial liquid, milk, oils, etc. After testing, the mean scar dimension was measured and evaluated by aid of a microscope. His results show that in the tests with fresh milk between contact balls, the wear scar dimension has the highest value, while in oil tests the wear scar dimension is the smallest. This evolution is predictable due to the respective viscosity of investigated fluids.

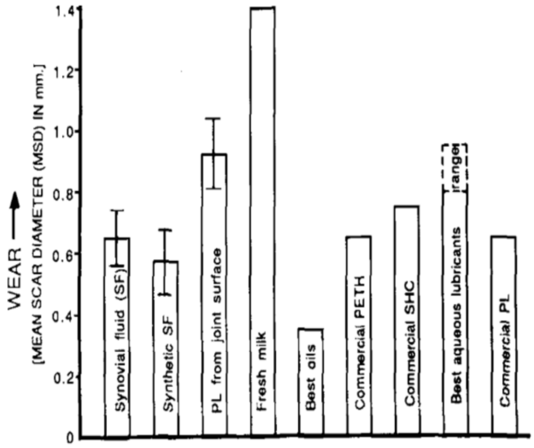


**Figure 5:** *The dimension of mean scar diameter obtained in four balls test for different lubricants.[Hills,1995]*

Another study conducted on four balls testing machine was presented by Shahabuddin, [Shahabuddin,2020]. He manages to use the four balls testing machine for different lubricants and to measure the wear scar obtained at several loading levels. From the correlation shown in Fig.6, it can be observed that the wear scar dimension has an important growth in all tests near the 100N loading level. This growth can be attributed to the scuffing phenomenon initiation.

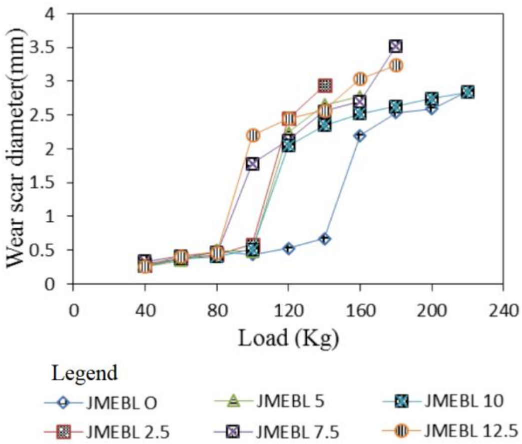


**Figure 6:** *Wear scar dimension - loading correlation obtained for different lubricants.[Shahabuddin,2020]*

ISO20623 documentation presents as typical results obtained using a four balls testing machine the values shown in Fig.7.

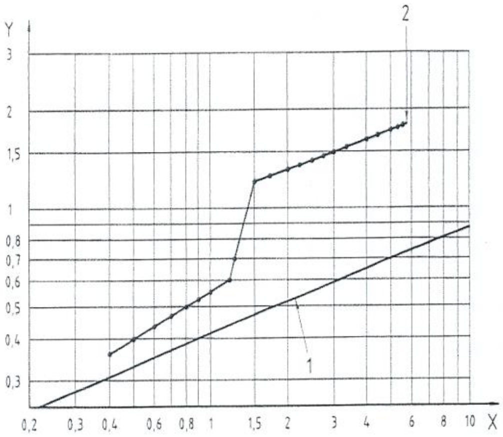


**Figure 7:** *The correlation wear scar dimension – loading, where: X –loading [kN], Y –wear scar dimension [mm], 1 –Hertz, 2 -experiment. [ISO 20623]*

The test was conducted using general purpose grease placed between balls. These experimental results were compared with those obtained by calculus using Hertz's equations corresponding to similar loading levels. At low loading levels, the experimental values of the wear scar have close values to those obtained by applying Hertz's equations. At high loadings, the interpolation curve which approximates the evolution of wear scar dimensions has a different slope. This evolution can be attributed to the cumulative effect of the wear, which conducts to high contact surface and scuffing initiation. This wear scar evolution is similar to that obtained by Shahabuddin, [Shahabuddin,2020].

Dongare [Dongare,2014], presents some results obtained on the four balls testing machine using: SAE 20, SAE 90, SAE140 mineral oils between contact bodies. The last loading level in his tests was the moment when the welding point occurs. In Fig.8, his results were represented graphically and those obtained by Hangan using U90Ca3 grease between contact bodies, [Hangan,2020]. From the below representation, Fig.8, it can be concluded that the loading capacity of the lubricant is dependent on the viscosity. The wear scars obtained in U90Ca3 test are close to those obtained with SAE 20. This reveals that this type of grease has a low loading capacity.

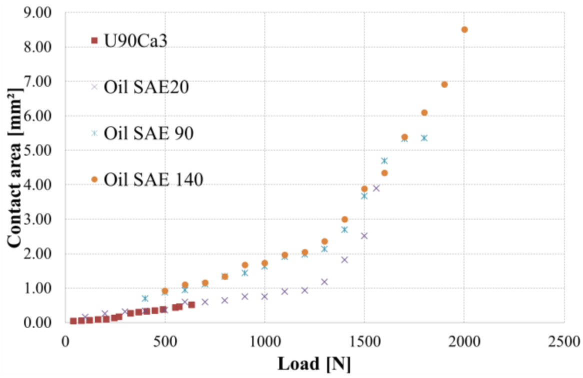


**Figure 8:** *Correlation wear scar dimension – loading*

## 5. Conclusions

Lubricants were and remain one of the most important factors which influence the occurrence of scuffing. Due to this reason, the qualitative evaluation of lubricants is very important in order to determine the maximum loading capacity of contacts.

Over time, several procedures were elaborated to evaluate lubricants ability to separate contact surfaces. Some of those procedures became international standards. The ISO 20623:2003 international standard requires greases testing in 100N loading steps and testing during 10 seconds for each loading step. The testing equipment must ensure 1600rpm spinning velocity and constant loading. After each loading step, the contact bodies are cleaned from the remaining grease and the wear scar is evaluated. The obtained wear scar dimension – loading correlation can be used to determine the loading capacity of the lubricated contact and to evaluate the quality of greases. Using this procedure several tests were conducted by researchers and the results can be applied to evaluate the lubricant quality.

ASTM D2596 and ASTM D 2783 have similar procedures. Differences appear with regards to the spinning velocity of the loading shaft and running period of the test for each loading level.

The four balls machine can be used to evaluate the loading capacity of contacts immersed in lubricants or other liquids. Using this type of equipment, tests with milk, honey, animal fat, vegetable oil etc. can be conducted in order to highlight the influence of the contamination of bearings with those fluids.

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