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BALL-RING FRICTION AT LOW ROTATING SPEED

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Abstract: *The paper presents an experimental research of rolling friction between a ball and a ball bearing ring. An original computer assisted test rig was build in order to evaluate the rolling friction phenomenon, between balls and ball-bearing rings. Dry and lubricated contacts with three different lubricants were tested at very low rotating speed, starting from zero. Influences of kinematics and lubricant type and quantity upon friction were revealed. All experiments reveal a low increasing tendency of friction with speed. Conclusions about rolling friction phenomena and friction in lubricant presence are presented. Some considerations about film generation in ball-ring contact are presented, too.*

Keywords: *data acquisition, friction, rolling friction.*

1. INTRODUCTION

Friction is a very complex phenomenon that involves molecular, mechanical and thermal processes. This phenomenon is present in all mechanical coupling and is generated in presence of motion or in presence of the tendency of motion. Rolling friction accompanies pure rolling motion, when there are no relative tangential movements in the contact.

In the mechanical field rolling motion is present in many elements such as ball bearing, gears, variators etc. For these, the friction force has a rolling friction component and a study of the influences on friction can reduce the lost energy and improve the machines' efficiency.

This research aims to investigate the rolling friction between a ball and an external ball bearing ring, which it is the basic couple in a ball bearing. It is difficult to investigate this friction directly in a ball bearing because many different friction phenomena occur and the magnitude of this friction is also very small to be separated from a complex friction.

2. THEORETICAL ASPECTS

An ideal contact between a disk and a rigid plane is theoretically formed in a single point where the forces N and T are applied.

Standing balance system statement is:

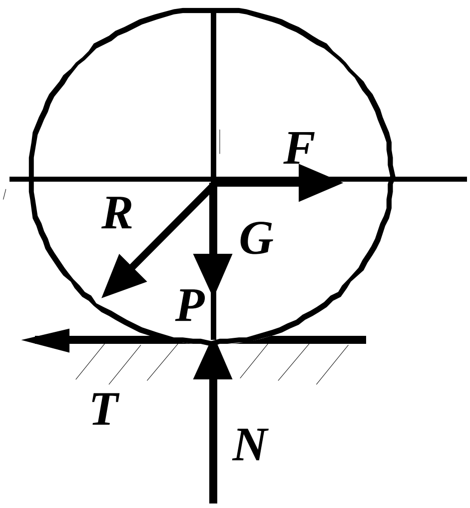

Figure 1. Ideal forces system

$$\begin{cases} F - T = 0 \\ N - G = 0. \\ -FR = 0 \end{cases} \quad (1)$$

The last equation involves F = 0. But the experiment reveals that this system can be in static equilibrium even in the presence of horizontal force F, when the value of this force is under a certain level.

The explanation of this fact is due to the changes in the form of bodies in the vicinity of the contact.

The bodies, near the theoretical point of the contact, *P*, develop a contact area. So, the reactivity force, *N*, is a cumulative of the distributed force on the contact area. Rolling tendency or the relative motion of the bodies involves an asymmetry of this normal distribution and a displacement, *s*, of the normal force support in the rolling direction occurs.

Standing balance system restatement is:

$$\begin{cases} F - T = 0 \\ N - G = 0. \\ Ns - FR = 0 \end{cases} \quad (2)$$

The term *Ns* is called rolling couple. The equilibrium involves:

$$\left|\overline{M}r\right| \leq s_{\max}\left|\overline{N}\right|. \quad (3)$$

The maximum value of *s* is called *rolling friction coefficient.*

3. TEST RIG PRINCIPLE

A test rig for the rolling friction coefficient evaluation between a ball in simple rolling motion and an outside ball bearing ring was built. The ball is free in the trough of the outside ring. When the ring is motionless, the ball is in a stationary position, corresponding to the minimum potential energy value. When the ring turns, the ball gets a position deviated with an angle, α, from the stationary position. This angle is directly correlated with rolling friction because only rolling friction is acting upon the ball.

The correlation is expressed by:

$$s = Rtg\alpha. \quad (4)$$

In order to evaluate the values of the rolling friction a test rig was designed. Figure 3 presents the principle schema. The motor 2 drives the disk support for the optical transducer (1) and (2). The first transducer is activated when the ball reflects the light and the second one by a zero angle position element.

The disk and the ring turn at low rotational speed. A computer controls all parameters and also evaluates the time between the zero position and the ball position signal. Then, the angle, α, can be calculated.

4. ELECTRONIC SYSTEM

The electronic system is formed by:

- Electronic touring regulator for the ring driver motor (M1);
- Disk driver motor (M2);
- Transducer 1 (ball position transducer);
- Transducer 2 (angular zero position transducer);
- Tact generator and computer interface.

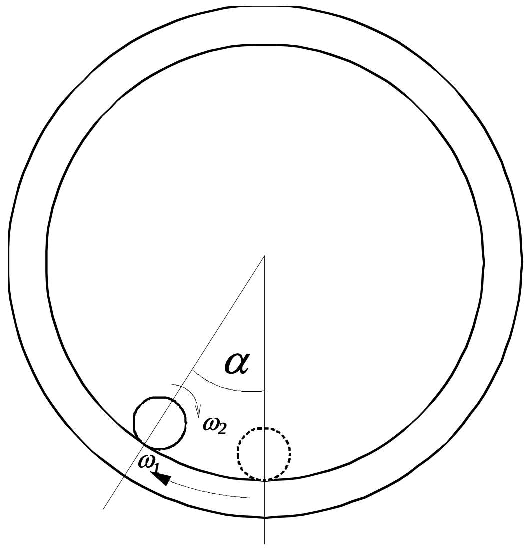

Figure 2. Test rig principle.

The motor 1, managed by an electronic touring regulator, rotates the ring. The rotational speed transducer is based on an IR transducer and, a 60-holes disk, rigidly assembled with the shaft and a counting system.

The signal generated by the rotational speed transducer was adapted to be interpreted by the computer in order to evaluate rotating speed and to perform data acquisition.

A converter frequency-tension based on MMC 4013 is used to obtain a 0-5V tension for a frequency between 0-150Hz. This represents the negative reaction tension for the revolution speed regulator, based on LM324 integrated circuit.

Software in C code was created to acquire on the PC's parallel port information on rotating speed of the ring and ball position. This information is written in a file.

5. EXPERIMENTAL RESULTS

Rolling friction experiments were done in dry and lubricated conditions. A large experimental program was perfected in order to study the influence of rotating speed, in dry and lubricated conditions using three different lubricants (15W-40, T90 and 80W-90) in two different quantities (1 and 2 drops). Some rotations of the ball-ring system were made before starting the measurements for uniform distribution of the oil in the rolling way.

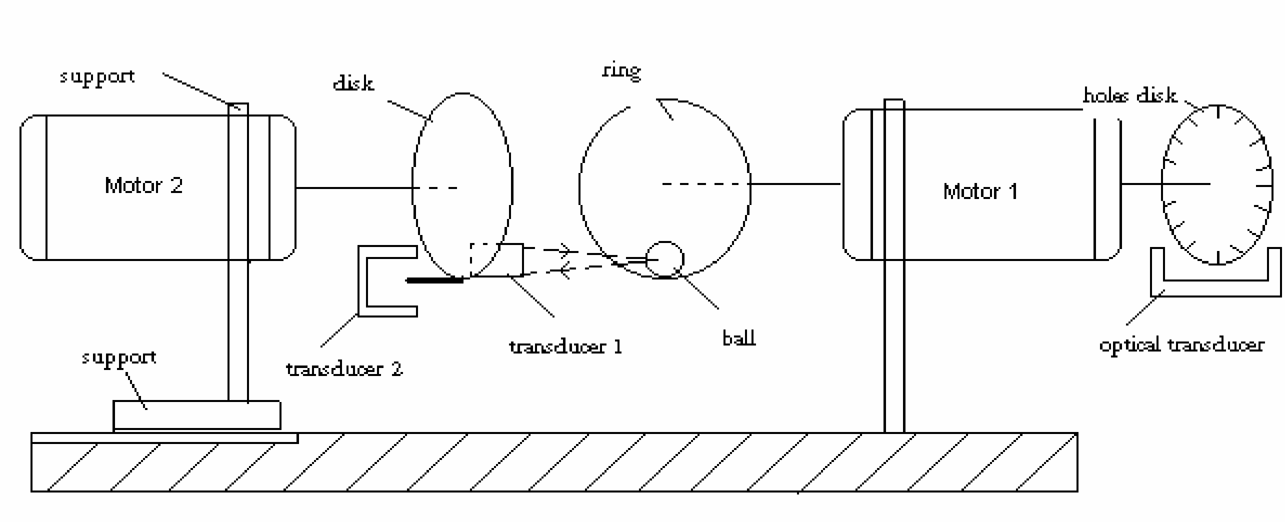

Figure 3. Test rig.

Some experimental results are presented in the following figures:

- figure 4 - Ball ring friction in dry conditions.
- figure 5 - Ball ring friction, 15W-40 oil, 1 drop.
- figure 6 - Ball ring friction, 15W-40 oil, 2 drops.
- figure 7 - Ball ring friction, 80W-90 oil, 1 drop.
- figure 8 - Ball ring friction, 80W-90 oil, 2 drops,
- figure 9 - Ball ring friction, T90 oil, 1 drop,
- figure 10 - Ball ring friction, T90 oil, 2 drops,

The diagrams present the angular ball deviation (grd) under friction effect during experiments and rotating speed (rpm).

6. CONCLUSIONS

In dry experiments noise and important ball oscillations were observed. This motion was dependent on rotational speed. No important angular deviations were observed.

Larger values of the deviation angle were found in lubricated rolling experiments. All values were acquired beginning with the start time, from the beginning of the motion. These values are larger than dry rolling values. This can be explained by the oil adherence on surfaces.

Rolling friction increases with rotating speed and oils viscosity.

Rotating speed gives a slow variation of friction. In lubricated conditions it can be observed a large angle increment at the beginning of the motion. This deviation is determined by the oil presence. A large oil quantity involves more energy for expelling it and in consequence large resistance energy consumed for.

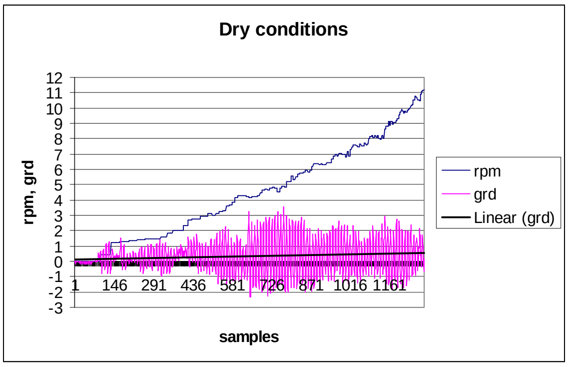

Figure 4. Ball ring friction in dry conditions.

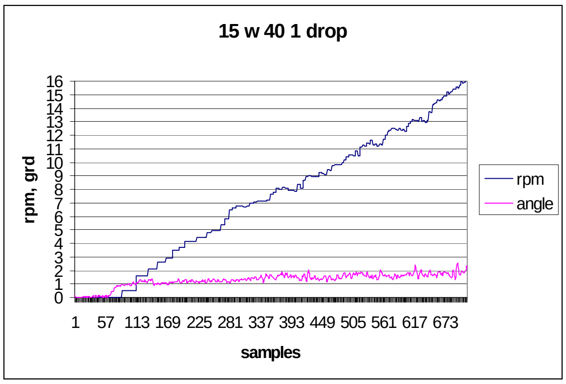

Figure 5. Ball ring friction, 15W-40 oil, 1 drop.

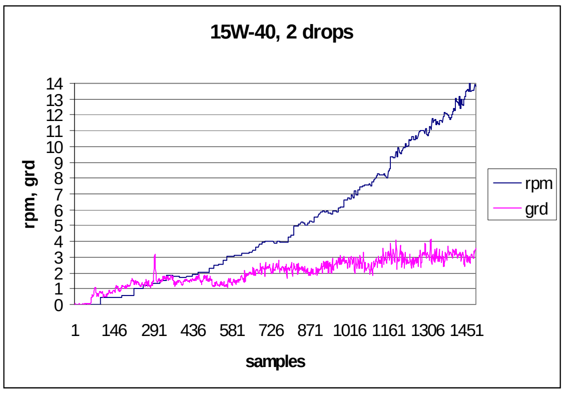

Figure 6. Ball ring friction, 15W-40 oil, 2 drop.

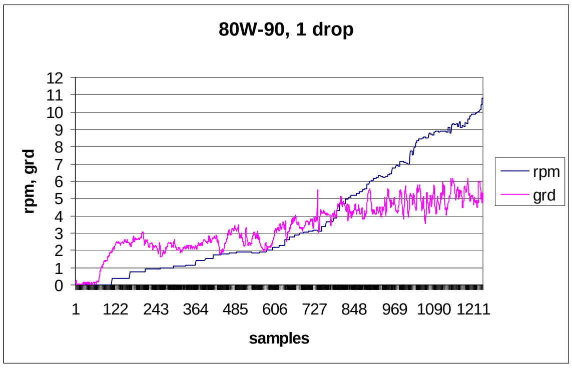

Figure 7. Ball ring friction, 80W-90 oil, 1 drops.

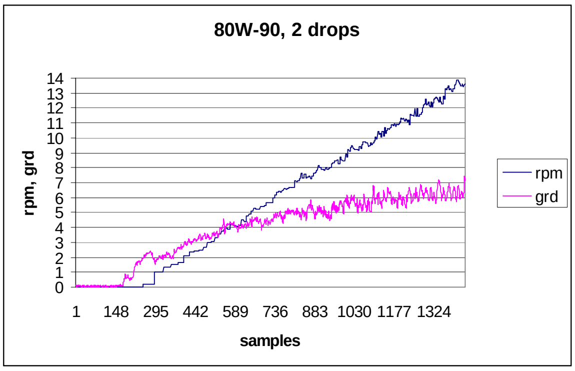

Figure 8. Ball ring friction, 80W-90 oil, 2 drops.

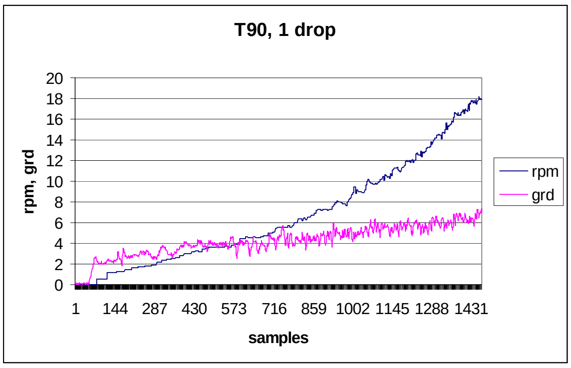

Figure 9. Ball ring friction, T90 oil, 1 drop.

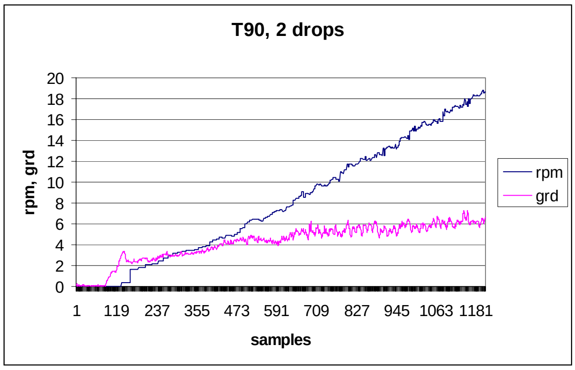

Figure 10. Ball ring friction, T90 oil, 2 drops.

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