INVESTIGATIONS OF SEIZURE AND SCUFFING OF MACHINE PARTS

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Abstract: *The usual failures of heavy loaded metallic sliding surfaces are scuffing, seizure etc. Many of these processes can be originated from adhesive bounds formed between the contacting peaks of rough sliding surfaces. The surfaces have to be prevented from these failures, by hindering the adhesive bounds. Presented paper submits the results of investigations, aims of which were to determine the reasons of surface damages of rubbing pairs. Laboratory experiments were made on steel ball/steel disk sliding pairs under heavy load. During the tests the friction force and load were measured, after that, the form and size of the wear marks and the condition of the worn surfaces were investigated. The results of the experiments demonstrate the differences of the tests performed by lubrication and without lubrication.*

Keywords: *friction coefficient, pin-on-disk machine, damages of surfaces, seizure, preventive layers.*

1. INTRODUCTION

Rubbing machine parts are often made of metals owing to its beneficial mechanical and physical properties in spite of the fact that many nonmetallic new materials were developed in the last years to improve the tribological properties of heavy loaded sliding surfaces. Except at very low velocity the mating metal surfaces are not able to slide on each other without lubrication, because high friction and wear rate or sever adhesion (scuffing, scoring, seizure). Severe damages of sliding metal surfaces are caused mainly by heavy load and/or high temperature. Heavy load brakes through the oxide film and the adsorbed molecular layers at the peak of surface roughness making virgin metal area, which tends to adhere to the counter face. High temperature softens the metal surface and desorbs the molecular surface layers also creating virgin metal spots, which leads to develop severe adhesion. Kosteckii [1], Kragelskii [2], Vinogradov [3], and others distinguished some types of surfaces damages (cold seizure, hot seizure, severe abrasion etc.), and gave some explanation the cause of their development. Markov and Kelly made a very good discussion on the catastrophic wear, initiated by adhesion and classified this type of damages in four class referring to the earlier theories of sever failure of rubbing steel surfaces [4].

At the same time both load and friction heat help to create a special surface layer (second phase, tribological transformed layer) protecting the subsurface material (bulk material) from damages. The physical and chemical properties of this layer enormously differ of the properties of bulk material: the hardness is much higher; the plasticity is lower, etc. The second phase develops only is a range of loads or temperatures, between their critical (threshold) values, where the coefficient of friction and wear rate is nearly constant. The protective surface layer wears away but also is created maintaining the steady state condition of friction and wear. Overstep the threshold values of load or temperature severe surface damages will arise.

Many works proved the existence of such protective surface layer [2], but not too much attention was given to investigation of its development and factors influencing it. The main influencing factors are the form and the composition of the mating surfaces, treatments, the properties of the surrounding media, the lubricants, the load, the speed and the temperature [4]. But, to develop a second phase in the surface layer it is necessary to have some energy (passivating energy), which derives from the friction, and also some time. In the investigations, results of which are presented here, the aims were to find the characteristics of the periods of developing second phase at low sliding speed, where high temperature does not arise. In this case the main factor influencing the development and the destruction of second phase is the load deforming plastically the surface layer, cleaving its structure, increasing its hardness, etc.

2. INVESTIGATION OF EFFECTIVENESS OF PREVENTIVE LAYERS

Determining of relationship between load carrying capacity of the rubbing surfaces and stresses, arise by applied loads, and effectiveness of preventive layers at low speeds, we made a test rig, and worked a measurement method out. The test rig was presented in a former paper. [5, 6].

The test machine is a Pin-on-Disk machine. The disk can be fastened horizontal at the top end of a cyclo-drive’s shaft (axis of rotation of that is vertical). The ball can be fixed in a clamp at the end of a pin, what can be moved in a vertical linear bearing. At the top of that pin can be fastened the weights, which press the ball to the disks surface. (Maximal load: ~300N).

V-belt drive and an electric motor rotate the shaft of the cyclo-drive. Distance can be changed between the axis of linear bearing and the axis of disk holder in order to adjust the sliding speed. During the tests, balls slid on surfaces of mild C45 steel disks rotating at low speed. The rubbing surfaces were ground and degreased with alcohol before the tests.

The tips of pins were rolling bearing balls fixed in clamps. Their diameters were 5 mm, hardness 63-64 HRC, surface roughness (CLA) Ra<0,1 μm.

The running surfaces of the disks were ground. Their surface roughness was (CLA) Ra = 0,3-0,4 μm.

The experiments were carried out with or without lubrication. In lubricated cases was a low viscosity pure mineral oil (ISO VG 10) used.

In experiments with lubrication the running surfaces of the disks were covered with thin oil film only at the start. During running oil was not get to the surface any more. The applied load was: 20N, 50N, 100N, 300N, and 1200N. The sliding speed can be adjusted in the range of 0,025-0,1m/s. Length of tests were 31 minutes (in dry cases) and 61 minutes (with lubrication). During the experiments the load and the friction force were measured, in the first minute in every 0,0075 s, after that only in every 1 s. The measured values were stored and computerized by a PC.

3. RESULTS OF INVESTIGATIONS

The huge amount of measured values made it possible to present the variation of the coefficient of friction from the beginning of the experiments correctly. The variation of coefficient of friction characterized the friction processes and also the evolvement of the

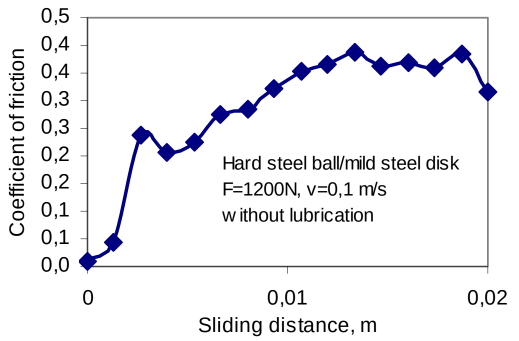

Fig. 1. Variation of the coefficient of friction of hard steel ball/mild steel disk at the beginning of experiments (F=1200N)

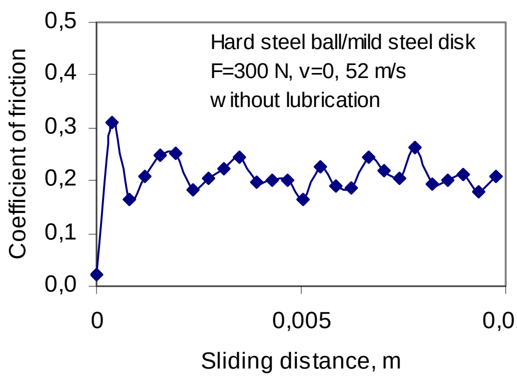

Fig. 2: Variation of the coefficient of friction of hard steel ball/mild steel disk at the beginning of experiments (F=300N)

surface structure. The following figures show some examples of the test results. In Figure 1 and 2 can be seen the variation of coefficient of friction under very high load (1200N and 300N respectively) at the very beginning of the experiments.

At load of 1200 N the coefficient of friction increased very sharply and the surface showed intensive plastic deformation (Figure 3).

At load of 300 N at the beginning of the investigation the coefficient of friction stabilized for a while, but later, owing to sever adhesion the coefficient of friction override the value of 1 (Figure 4).

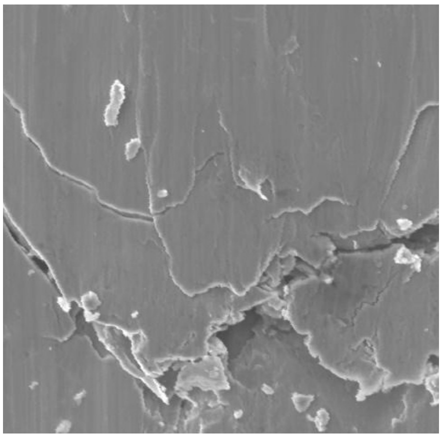

Fig. 3. Intensive plastic deformation in the middle of the wear track under load of 1200N.

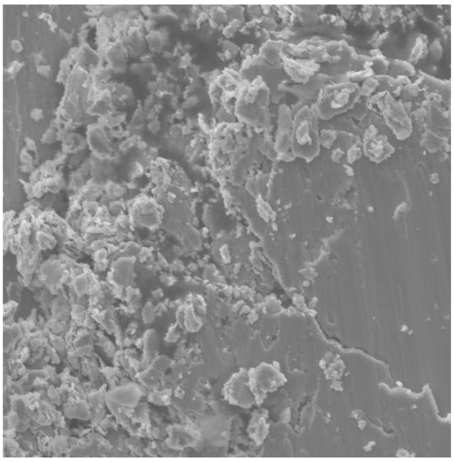

Fig. 4. Wear fragments in the middle of the wear track under load of 300 N.

In this case, at the beginning of the investigation a protective surface layer developed on the disk surface in spite of the intensive plastic deformation of the material around of the wear track. The cross section of the wear track made by a profilometer presents the amount of plastic flow. (Figure 5 and 6)

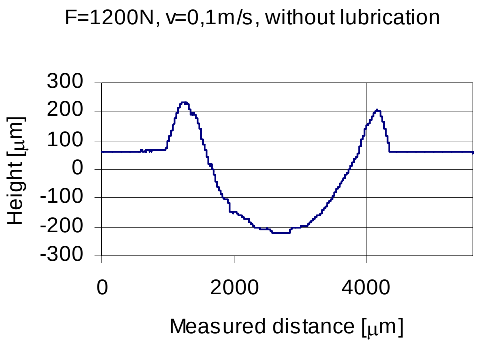

Fig. 5. Cross-section of wear track under load of 1200N.

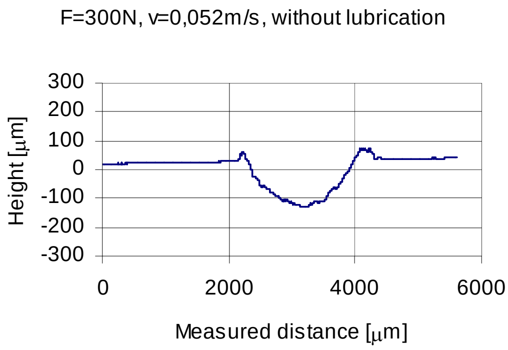

Fig. 6. Cross-section of wear track under load of 300 N.

The developed protective surface layer later was broken through leading to increase the coefficient of friction. The wear fragments of the broken layer can be seen in Figure 6. The second phase was not able to develop again.

In the beginning, at load of 100 N the coefficient of friction increased quickly but after a while began to decrease showing the developing some protective layer on the surface of mild steel disk. Owing to the high load it needs a longer time (Figure 7).

Investigation with load of 50 N presented a typical process of developing a second phase on the disk surface. In the beginning the coefficient of friction increased quickly but later decreased and stabilized at a level of 0.35 (Figure 8).

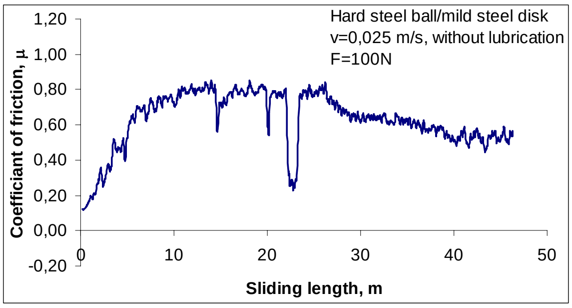

Fig. 7: Variation of the coefficient of friction of hard steel ball/mild steel disk (F=100 N, in dry case)

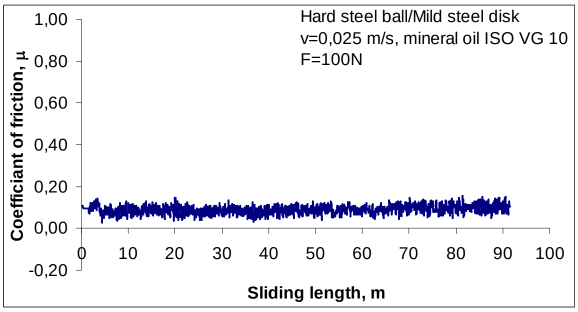

Fig. 10: Variation of the coefficient of friction of hard steel ball/mild steel disk (F=100 N, with lubrication)

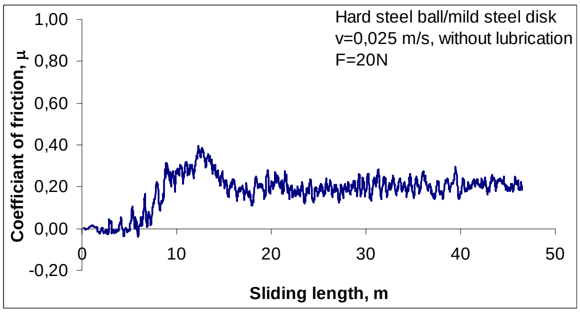

Fig. 8. Variation of the coefficient of friction of hard steel ball/mild steel disk (F=50 N, in dry case)

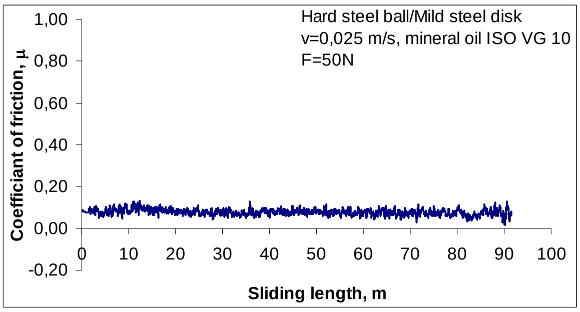

Fig. 11. Variation of the coefficient of friction of hard steel ball/mild steel disk (F=50 N, with lubrication)

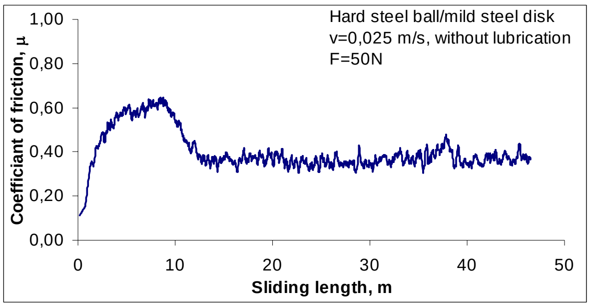

Fig. 9. Variation of the coefficient of friction of hard steel ball/mild steel disk (F=20 N, in dry case)

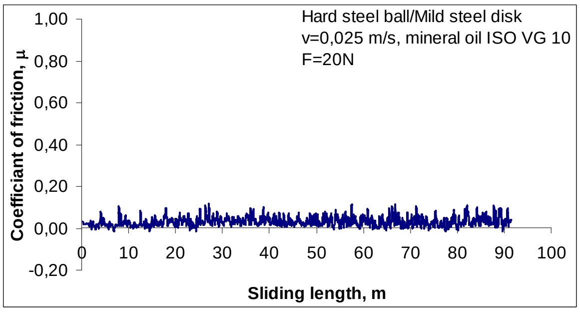

Fig. 12. Variation of the coefficient of friction of hard steel ball/mild steel disk (F=20 N, with lubrication)

More typical development of second phase in investigation with load of 20 N is presented the Figure 9.

At low load of 50 N and 20 N in the beginning the adsorbed surface layer maintained a low coefficient of friction and only later began to create a modified surface layer.

Despite of the large plastic deformation the unalloyed, low viscosity mineral base oil (ISO VG-10) can effectively reduce the coefficient of friction at the same loads and the speeds as in the dry cases.

The lubricants decreased the coefficient of friction at every load levels, and influenced also the deformation on the rubbing surface of mild steel disk. At 20 N load, also the hydrodynamic effect can be considerable resulted in the lowest coefficient of friction values (Figure 10).

At higher load the boundary lubrication determined the values of the coefficient of friction, which seems to be independent of the load. However the scatter of values of coefficient of friction is higher at higher load showing the larger influence of solid contacts on the friction (Figure 11 and 12).

4. CONCLUSION

The presented results of experiments proved that the variation of coefficient of friction characterizes the process of surfaces damages, and helps to identify the boundary of normal friction and wear, where a protective surface layer existence on the mating surfaces. Studying the worn surface helps to reveal the cause of the surface damages.

5. ACKNOWLEDGEMENTS

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