STUDY OF FRICTION COEFFICIENT BETWEEN PARTS OF ALUMINUM AND IRON CONTAINING ALLOYS

Georgi KADIKYANOV – Vasil STOYANOV – Daniel BEKANA – Emil MARINOV
University of Ruse, Bulgaria

Summary: The high coefficient of friction increases wear, temperature, roughness of the sliding surfaces of parts. These side effects due to the increased friction coefficient are usually enabled in the break-in. In this work the possibilities for reducing the coefficient of friction in brake-in of the sliding surfaces are considered. To reduce the coefficient of friction various coatings on the surface of parts made of aluminum alloy are used.

INTRODUCTION

The Al–Si alloy/iron containing alloy pair is widely used in automotive industries and agricultural machinery. Iron containing alloy used in engine shaft (crank shaft, camshaft, pump shaft). Al–Si alloys, with lighter weight and better heat conductivity than iron, have been increasingly used in engine rod for small agricultural machine.

Al–Si alloy/iron containing alloy pair scuffing is one of the major failure mechanisms in engines. Scuffing is a complicated phenomenon. It involves mechanical, thermal, physical and chemical interactions among the contacting bodies, the environment, the lubricant, and other species at a sliding interface. Nautiyal and Schey [3] found that the transfer of aluminum to a steel surface might occur even in the presence of a substantial amount of lubricant. Cocks [1] studied the interaction of sliding metallic surfaces and found that scuffing happened when wear particles deposited on the rubbing surface, and created a high tendency of adhesion. Reddy et al. [4] reported that scuffing loads increased with the increase of silicon content and decreased with the increase of sliding speed. He proposed a scuffing criterion for this type of contact, stating that scuffing would occur if the traction force is larger than the allowable shear stress of the surface materials. Guo [2] reported that micro scuffing could self - heal in further running, otherwise macro scuffing might occur. In unlubricated Al–Si alloy/iron containing alloy contact, the transition from severe wear to scuffing was related to the surface temperature. The coefficient of friction increased with the increase of load in severe wear regions [4,5].

One of major phenomenon of tribological behavior is friction coefficient. The purpose of this research is to study friction coefficient between Al–Si alloy/iron containing alloy pair.

MATERIAL AND METHODS

In this research, tester of tribologicul performance was used to simulate the contact and lubrication conditions between the shaft and bearing. The tester consists of three major parts: driving system, loading system and lubrication system, as shown in Fig. 1. The tester provides a rotating motion of shaft sample. A horizontal adjustable load (normal load) is applied through a mechanical actuator to push a bearing sample against the shaft sample.

Three parameters are measured during the test: the normal load, the frictional force between the Al–Si alloy bearing sample and the iron containing alloy shaft sample shown on Fig. 2, and the temperature of the contact surfaces. The normal load is measured using an analog gauge. When the shaft sample rotates against the bearing sample, the frictional torque between them is measured by torque sensor on the driving shaft. In order to simulate the real working condition lubricant is used.

University of Ruse, Faculty of Automotive and Transport Engineering and Faculty of Agricultural Mechanization, Bulgaria, 7017 Ruse, 8, Studentska str., e-mail: gkadikyanov @uni-ruse.bg

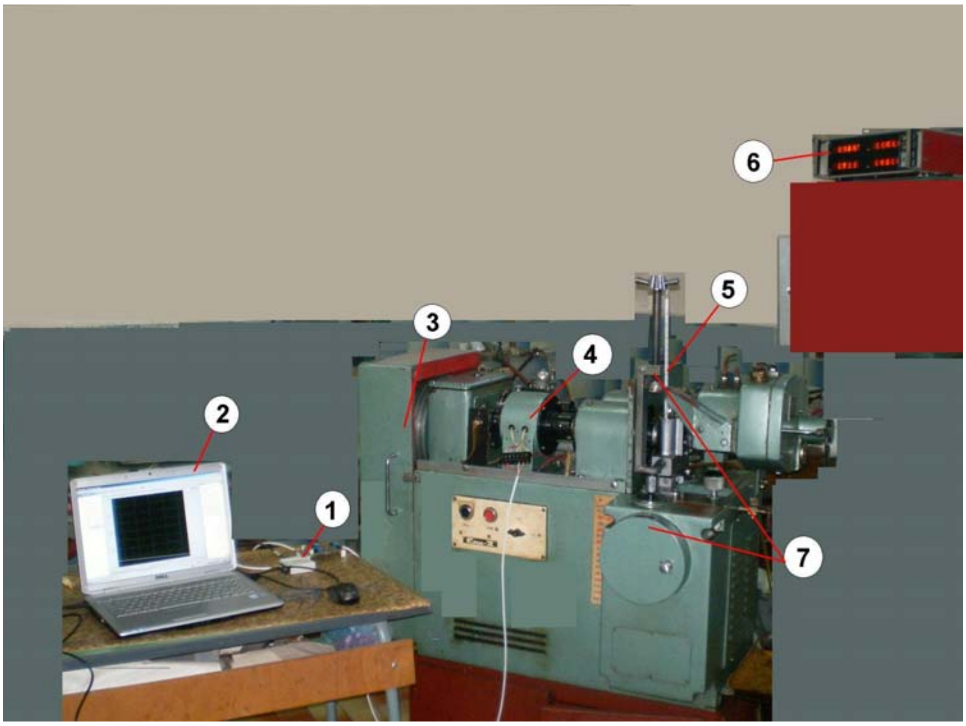

Fig. 1. Tester of tribologicul performance: 1 - NI DAQ USB-6009; 2 – mobile computer; 3 – driving system; 4 – torque sensor; 5 – thermometer; 6 – impulse counter; 7 – normal loading system.

A K-type thermocouple is set inside the bearing sample just behind the rubbing surface to measure the temperature in the area of interest. These measured analog signals from torque sensor input into a computer through a NI DAQ USB-6009 data acquisition unit. By using VI Logger software, signals are collected. After finishing of the experiment the data was transferred in program MS EXCEL. Some simple calculations were done and final graphic is shown on Fig.3.

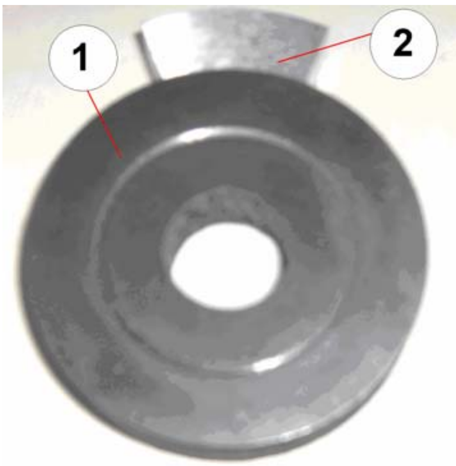

Fig. 2. Al–Si alloy/iron containing alloy pair: 1 - iron containing alloy shaft sample; 2 - Al–Si alloy bearing sample.

All bearing samples specimens are made from the same eutectic Al–Si alloy with or without surface coatings. Coated bearing samples surface include those with Al_2O_3 plating or chemical treatment surface plating (CTUP), or with an Al_2O_3 plating and chemical treatment surface plating on it, which are referred[8,9]. The coating thickness is about 15µm for Al_2O_3 plating, and about 5µm for chemical treatment surface plating. The combination plating thickness is about 20µm totally. The shaft samples were cut from material used for production of crank shaft, camshaft or pump shaft (iron or cast iron).

RESULTS AND DISCUSSION

During testing, all real time data were automatically recorded and a typical plot showing data curves of friction torque versus time is shown in Fig.3.

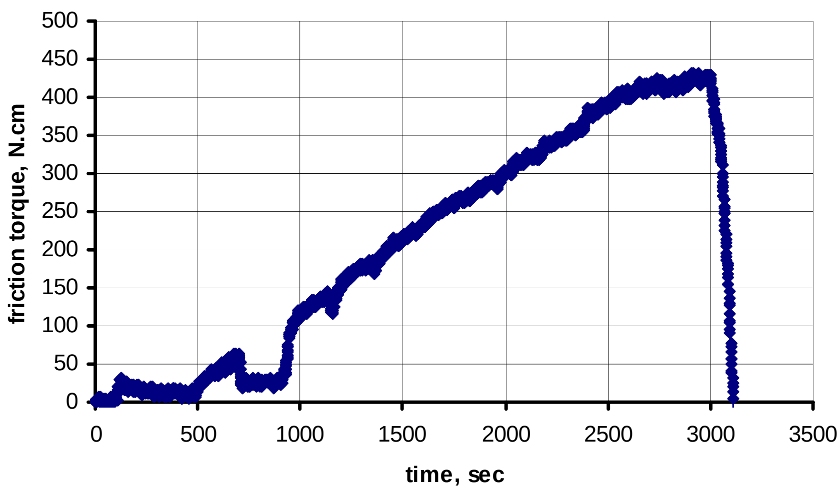

Fig.3. A plot showing the friction torque as a function of testing time for one of tests.

Coefficient of friction can be obtained by the data acquisition system simply by calculating the ratio of– friction force (measured friction torque) to the normal load. The value of coefficient of friction varies not only within each test cycle but also from shaft sample/bearing sample combination to combination. Final graphic is shown on Fig.4. A typical coefficient of friction curve generally has two stages, as shown in Fig. 4: (1) the break-in stage, where the coefficient of friction increases with the normal load; (2) the steady stage, where it remains almost constant.

When the shaft sample and bearing sample first contact with each other under the load, the peaks of machining marks start to become flattened due to wear, and the actual contact area becomes larger. This polishing process had also been observed by Ludema [6]. At this stage, the oil film pressure is large enough to partially support the normal load, and the shaft sample/bearing sample contact is in the mixed lubrication regime. The coefficient of friction increases with the increase of load during the break-in stage.

Wanga et al. [7] reported that after break-in, due to the increase of normal load and contacting temperature, the lubrication condition gradually turns into the boundary lubrication regime. The coefficient of friction remains at a steady level even though load increases periodically. In these tests scuffing is not occurs.

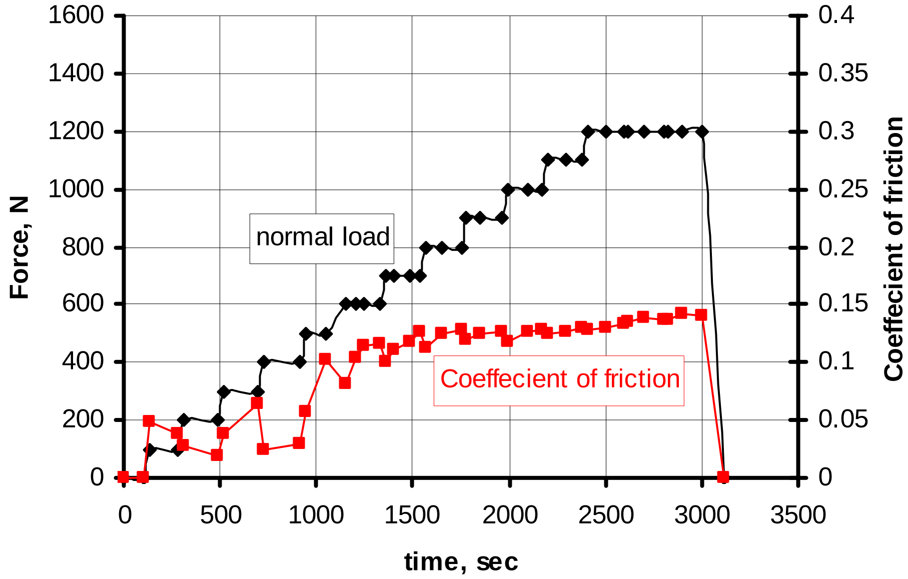

Fig. 4. A plot showing the friction coefficient and normal load as a function of testing time for one of tests.

A normal load, when boundary regime starts for various bearing sample\shaft sample combination is shown on Fig 5. The same figure shows normal load when boundary regime starts for bearing sample\iron shaft sample is greater than that of bearing sample\cast iron shaft sample. The normal load when boundary regime starts is greater for chemical treatment surface plating bearing sample\shaft sample. Chemical treated surface on Al_2O_3 plating does not change the normal load, when boundary regime starts. Plating of Al_2O_3 increases slightly normal load in comparison than without coating, when boundary regime starts.

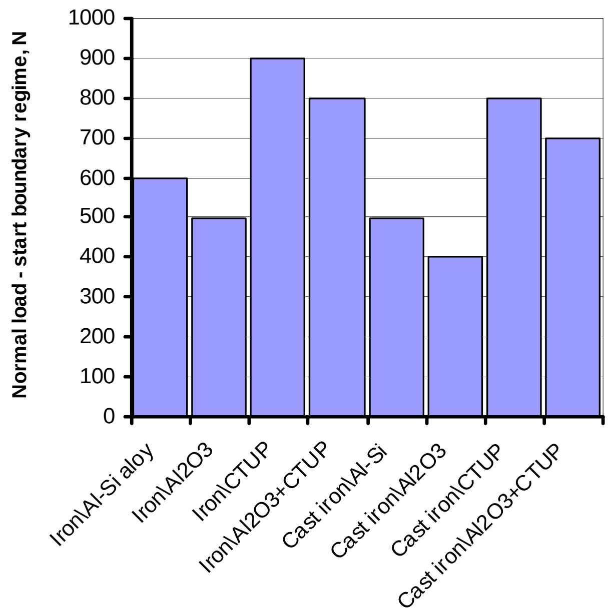

Fig.5. Normal load, when boundary regime starts for various bearing sample\shaft sample combination: Al – Si Alloy – without plating; Al2O3 – Al_2O_3 plating; CTUP - chemical treatment surface plating; Al2O3+CTUP - Al_2O_3 plating and chemical treatment surface plating on it.

CONCLUSION

A normal load, when boundary regime starts shows (characterizes) the load capacity of the lubrication film. The dimension of load capacity depends on the combination of the friction pairs. Load capacity of the lubrication for bearing sample\iron shaft sample is greater than that of bearing sample\cast iron shaft sample. Load capacity of the oil film is greater for chemical treatment surface plating bearing sample\shaft sample. Chemical treated surface on Al_2O_3 plating does not change significantly the load capacity of oil film. Plating of Al_2O_3 increases slightly the load capacity of oil film.

For Al–Si alloy/iron containing alloy pair can be used successfully chemical treated surface plating and Al_2O_3 coated and chemical surface plating on it.

ACKNOWLEDGMENTS

The study was supported by contract № BG051PO001-3.3.04/28, "Support for the Scientific Staff Development in the Field of Engineering Research and Innovation". The project is funded with support from the Operational Programme "Human Resources Development" 2007-2013, financed by the European Social Fund of the European Union.

REFERENCES

1. COCKS M., Interaction of sliding metal surfaces, J. Appl. Phys. 33 (7) (2000) 2152–2161.
2. GUO X.Z., Scuffing Failure Under High Speed Lubricated Counterformal Contacts, Ph. D. Dissertation, Northwestern University, 1992.
3. NAUTIYAL P.C., J.A. SCHEY, Transfer of aluminum to steel in sliding contact, J. Tribol. 112 (1990) 282–287.
4. REDDY A.S., B.N.P. BAI, K.S.S. MURTHY, S.K. BISWAS, Wear and seizure of binary Al–Si alloys, Wear 171 (1994) 115–127.
5. REDDY A.S., B.N.P. BAI, K.S.S. MURTHY, S.K. BISWAS, Mechanism of seizure of binary Al–Si alloys dry sliding against steel, Wear 181–183 (1995) 658–667.
6. LUDEMA K.C., A review of scuffing and running-in of lubricated surfaces, with asperities and oxides in perspective, Wear 100 (1984) 315–331.
7. WANGA Y., C. YAOB, G.C. BARBERB, B. ZHOUA, Q. ZOUB, Scuffing resistance of coated piston skirts run against cylinder bores, Wear 259 (2005) 1041–1047.
8. US Patent 6562223 B2.
9. US Patent 6951691.