Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 1, 2011, vol. LVII
article No. 1849

Martin KOTUS[*], Zuzana ANDRÁSSYOVÁ[**]

MEASUREMENT OF ADHESIVE WEAR SHARE IN LABORATORY CONDITIONS

MERANIE VEĽKOSTI ADHEZÍVNEHO OPOTREBENIA V LABORATÓRNYCH PODMIENKACH

Abstract

The study is focused on the one of possibilities of adhesive wear measurement in laboratory conditions. Adhesive wear share is defined on the basis of tribological quantity such as frictional force, radial wear and frictional temperature. Obtained results suggest the correct selected measuring succession for adhesive wear monitoring.

Abstrakt

V príspevku sme sa zaoberali jednou z možností merania adhezívneho opotrebenia v laboratórnych podmienkach. Veľkosť adhezívneho opotrebenie sme definovali na základe tribologických veličín, ako je trecia sila, radiálne opotrebenie a teplota vzniknutá trením. Na základe získaných poznatkov môžeme konštatovať správnosť zvoleného meracieho reťazca pre sledovanie adhezívneho opotrebenia.

1 INTRODUCTION

Tribology is technical science, that embraces friction and material wear, machine and mechanism components wear. Tribological attributes are necessary to consider for machines and devices design, which consist of moving parts.

Movement of these parts generate the force transfer, its changes and also its loss. This science analyzes processes that are in progress during reciprocal impact of surfaces and gives explanation about the actions in contact places. It allows affecting machine construction and their operation reliability. Tribotechnic interfere into very assembly and machine maintenance. Mainly it is lubricant usage and other preparations that contribute to wear resistance increment of function parts. The way of component surface machining also affects the tribological attributes significantly.

Object of the study is confirmation of measuring succession for the adhesive wear share determination in laboratory conditions. Tribological characteristics are evaluated within the adhesive wear of samples machined differently. Frictional force, radial wear and frictional temperature are the principal quantities that are determined. Weight and dimension changes of samples are assessed within tribological test. Samples surface roughness is defined on the basis of average arithmetic deviation R_a measurement.

2 MEASURING SUCCESSION CHARACTERISTICS AND DEVICE FOR ADHESIVE WEAR

Device allows continual measurement of the frictional force, radial wear and the contact temperature in tribological knot. The device (Fig. 1) consists of rotary shaft, on which the sample is fastened. Shaft drive is secured by electromotor, of which the rotations are transmission gradually by two systems of wedge belts. Normal force that impacts on sample is created by two pressing strings

[*] Ing. Martin KOTUS, PhD., Slovak University of Agriculture, Faculty of Engineering, Department of Quality and Engineering Technologies, Tr. A. Hlinku 2, 949 76 Nitra, E-mail: martin.kotus@uniag.sk
[**] Ing. Zuzana ANDRÁSSYOVÁ, Slovak University of Agriculture, Faculty of Engineering, Department of Quality and Engineering Technologies, Tr. A. Hlinku 2, 949 76 Nitra, E-mail: andrassy@student.uniag.sk

on both sides. Springs affect conduction, in which the replaceable frictional elements are fastened. They impact on sample by this force. Continual regulation of pressure (normal) force is secured by adjustable screws. Consol is shifting - sliding placed in socket in the motherboard for spread uniformity of pressure forces. Torque intensity of frictional force is registered by sensor of potentiometer with its compound lever. Continual measurement is assigned by optic-electric sensor. Thermo-sensor is used for running measurement of temperature in tribological knot. PVC pipe with regulator of flow drives and directs cooling medium from reservoir.

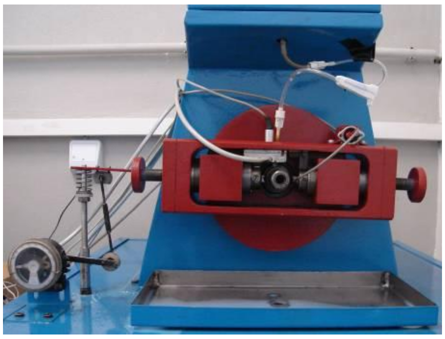


Fig. 1 Device for monitoring of tribological characteristics.

Wear sensor - is optic-electric component that work on principal of one-way optical barrier. Transmitting element of sensor includes the infra-red diode, which illuminates photo-sensitive electronic element - receiver. It on the basis of lights intensity changes the amount of output voltage in range of ±1V. Area of photo-sensitive part of receiver is 3x3 mm. The amount of receiver lights is regulated by shutter that is thrust by adjustable touch. The sensor and touch are prepared on conduction. Frictional elements, which copy the worn sample surface, are also tightly fastened on conduction. On the basis of component wear it occurs the sample diameter change and also the illumination intensity of photo-sensitive element changes.

Thermal sensor - scans the temperature of tribological knot within sample wear running. Silicon thermal sensor KTY83A from Philips organization, which measures in range of -55 to +175 ºC, is used for measuring. It is built in one of frictional elements. Thermo-electric cell, which changes the surrounding thermal changes (internal resistance) to electric voltage changes, is used for measurement of temperature changes. Simple resistant bridge insures the resistance conversion to voltage, and output voltage is in range of ±1.5V.

Frictional force sensor - Potentiometric sensor of frictional force changes the value of output voltage in circuit on the basis of frictional force changes that affects reversible spring. The amount of this force gets stronger by motherboard arm and it is directed by compound lever. Power voltage value is 5V and output voltage changes in range of ±5V.

Tested material characteristics - Measurement is realised on five samples from steel 12 060 with surface hardening to hardness 655 HV, with minimum solidity in pull R_m=700-850 MPa, and min slide limit R_e=420 MPa.

Tab. 1 Initial chemical composition of basic sample material.

	C, %	**Mn, %**	**Si, %**	**Cu, %**	**Cr, %**	**Ni, %**
steel 12 060	0.52÷0.60	0.50÷0.80	0.15÷0.40	max 0.30	max 0.25	max 0.30

Samples preparation - Samples are turned on a lathe with needed addition before grinding. Plate of cutting ceramics DNGA 15 04 12T 010 20 is used as a material of lathe cutting tool. It is category of ceramics mixture on the basis of aluminium oxide and titanium carbide. This type of plate is mainly recommended for surface finishing of cast-iron, hardening steel and thermal resistant superb-alloy, where the combination of wear resistance and good thermal attributes are demanded. Dilution of 3 % of cooling emulsion EKOLEX 96 DN from Fusch Petrochema organization is used at grinding. One sparking process is realized after sample grinding. Prepared samples are grinded on the universal apical grinding machine with fixed points KUF 250/500 to final dimension using the grinding wheel J 50 20 STN 22 45 J 0 A 99 B 60 L9 V (13) consisting of 85÷98 % AL_2O_3 (white corundum). Shape of the wheel meets the standard STN 22 4510 with dimension 150×20 mm.

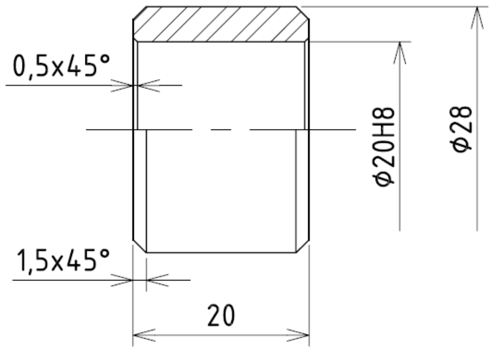


Fig. 2 Shape of normalized sample.

Samples are grinded with parameters:

- cutting speed: v_c = 33.9 m·s^{-1}
- work-piece speed: v_o = 11.1 m·min^{-1}
- feed: f = 0.05 mm·ot^{-1}
- in-feed - variable: a_{p1} = 0.01 mm, a_{p2} = 0.02 mm, a_{p3} = 0.03 mm, a_{p4} = 0.04 mm, a_{p5} = 0.05 mm

Roughness measurement - Measuring device SURFTEST 301 from Mitutoyo Kawasaki organization is used for analysis of sample surface hardness. Hardness is measured in three different places of each sample before and after wear.

Following values are registered by this device:

- R_a – average arithmetic deviation, µm
- R_q – average quadratic deviation, µm
- R_m – maximal profile height, µm
- R_z – height of profile protrusion from ten points, µm
- t_p – carrier profile curve, %
- P_c – number of extrusions, cm^{-1}

Cooling fluid characteristics - emulsion H is mixed product of petroleum oil, synthetic emulsifier and effective bactericidal additives. It is used as cutting fluid within metal machining and also as pressure fluid in undemanding hydraulic systems. Emulsion H is modern type of emulsive oil without chlorine, nitrites, PCB and heavy metals. Emulsion H in concentration of 3÷5 % belongs to middle biological irritant materials (category II. B) according to biological efficacious degree.

Dimensioned measurement - is measured by screw micro-meter with precision of 0.01mm.

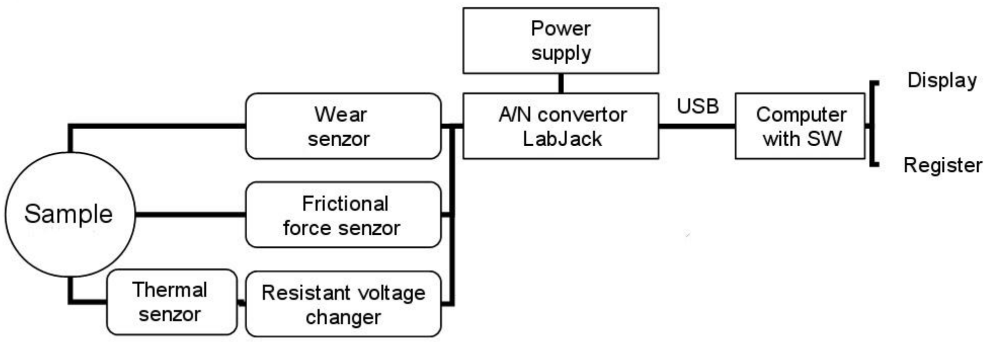


Fig. 3 Connection of measuring succession – flow chart.

Measurement conditions **-** for measuring process are following:

- intensity of lubrication 0.05 $l \cdot min^{-1}$
- frictional speed 0,578 $m \cdot s^{-1}$
- pressure force 500 N
- time of test duration 18 000 s

Evaluation of measuring succession and monitoring of adhesive wear share are carried out with regard to technical conditions of device and samples preparation. The main selected criterions are precision, cost and measuring elements availability. We mostly aim to thermal measurement and radial wear as well as to selection of suitable numerical/analogical converter. Each sample is machined with constant variability of in-feed motion. The wear is defined as unfavourable change of surface or dimension of solid bodies. It is caused by the interaction of functional surfaces or of functional surface and medium, which cause the wear by their interaction in relative motion. It is shown as removal or transference of material elements from functional surface by mechanical influence, possibly accompanied with other affects, such as chemical, electro-chemical, electrical.

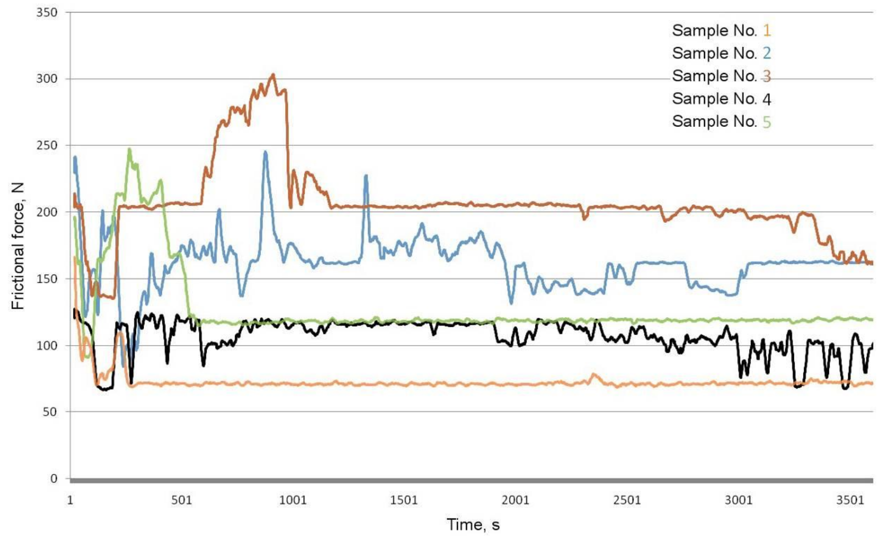
3 RESULTS OF MEASUREMENT

Measured average values of monitored parameters before and after test are shown in table 2, such as the differences of diameter, weight sample and hardness R_a.

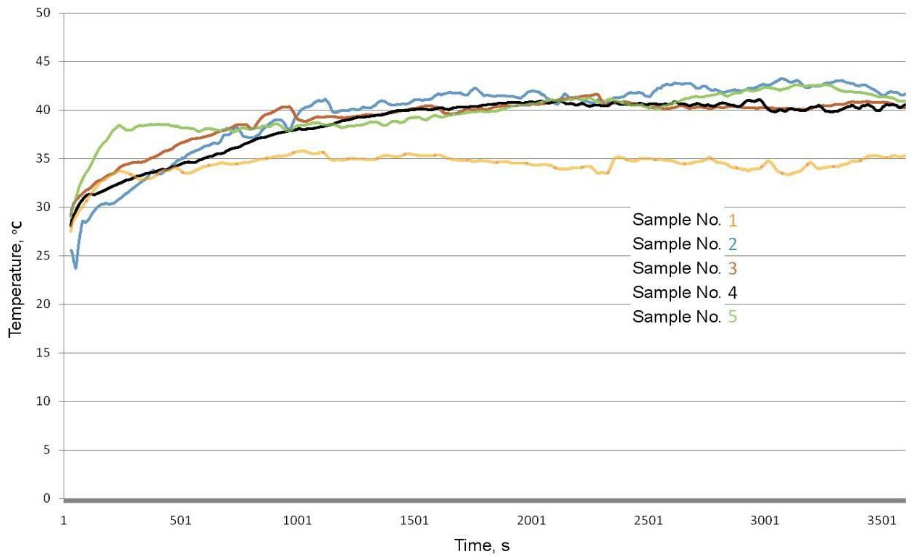
Graphic dependence of principal tribological characteristic of adhesive wear in time is pictured in graphs 1 to 3.

Tab. 2 Average surface roughness, outer dimension and weight of samples.

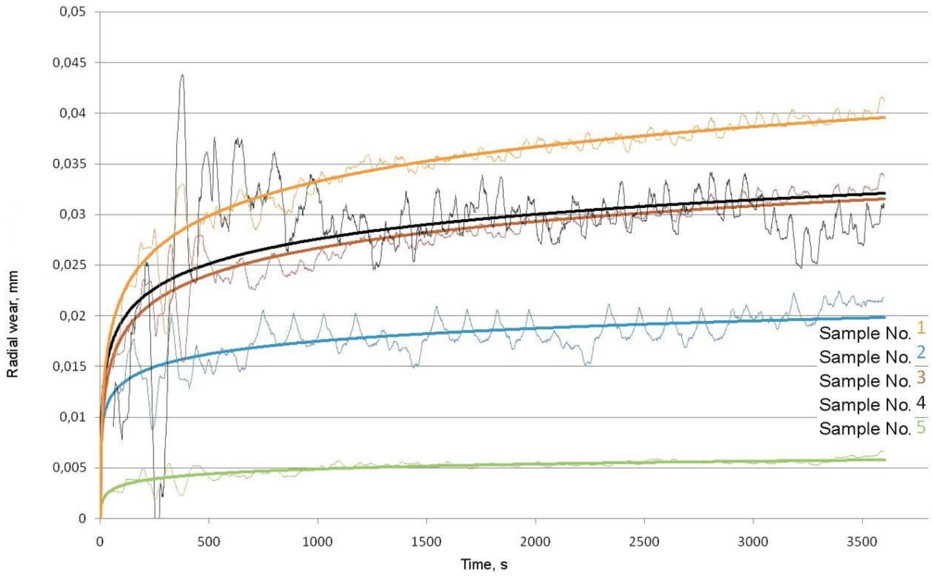
Sample	**Diameter Ø, mm**			**Weight, g**			**Average hardness R_a, µm**		
	Before wear	After wear	Difference	Before wear	After wear	Difference	Before wear	After wear	Difference
No.1	28.017	27.970	0.047	46.5879	46.4097	0.1782	0.59	0.90	-0.31
No.2	27.699	27.657	0.042	45.0062	44.7311	0.2751	0.50	1.03	-0.53
No.3	28.890	28.853	0.037	46.3445	46.2623	0.0822	0.51	0.67	-0.16
No.4	27.915	27.905	0.010	45.9113	45.8599	0.0514	0.39	0.69	-0.30
No.5	27.911	27.902	0.009	45.5229	45.4739	0.0490	0.41	0.75	-0.34



Graph 1 Dependence of frictional force on time.



Graph 2 Dependence of temperature on time.



Graph 3 Dependence of wear on time.

Significant amplitude of measured values of radial wear was caused by sample ovality and internal noise of photo-sensitive sensor. During the normal operational wear after the finishing of inrun we registered stable dispersion of measured values.

Thermal duration was affected by the wear process. Frictional temperature depending on time was increased until the maximum values and then it was fluently stabilized on the certain values with gradual wear. All samples except for the sample 1 (measurement was realized within lower temperature in laboratory) had the same registered characteristics of thermal behaviour. This information pointed out the great sensitiveness of selected thermal sensor.

Values of frictional forces were changing more dynamically during the measurement. This fault was caused by cumulating cooling emulsion on the consol of tribo-tester. It was eliminated by down-gradation and drilling the sluice outlet into the bottom part of consol. Measured values referred to decrement of surface hardness during the machining by in-feed increment. It was also affecting the frictional force and radial wear behaviour. Samples 4 and 5 showed the lowest amount of wear during the inrun, what could be caused by lower beginning surface hardness. Sample 1 regarding to its highest beginning hardness showed the highest amount of wear, what has already been confirmed by knowledge history.

3 CONCLUSIONS

Progress in development of new elements of testing machines such as sensitive sensor, plotters, analysers, micro-processors by PC usage creates conditions for progression of new universal devices for frictional process parameters monitoring. Character of sample wear changes, wear amount, precision of selected method, as well as practical usage of results are important to be considered for selection of measuring succession.

Tribological characteristics, which are measured within tribo-tests, must allow characterizing the process of friction and wear. Interpretation of results should be presented with regard to fact that the obtained wear values are not material constants but values dependent on system, where the operational variables and structure of considered tribological system are reflected.

Increment of measuring precision of monitored tribological quantities can be reached by using the modern techniques. These can be possibilities for deduction the others, more illustrative and more effective quantities. Confrontation of achieved results and current state of solving problematic suggests that selected measuring succession for measurement of adhesive wear resistance has justification with regard to obtained data quality.

In chapter were used researches results within the frameworks of statutory researches VEGA 1/0576/09 (2009-2011) – "*The quality improvement of agricultural machines and production systems*"

REFERENCES

[1] BALLA, J. *Tribologia a tribotechnika.* Nitra: SPU, 1989. 134 s. ISBN 80-85175-25-8.

[2] BALLA, J. – BÁTORA, B. – DRAHOŠ, Š. – TOLNAI, R. – ŠKARBALA, A. *Opotrebenie prvkov poľnohospodárskych strojov (Záverečná správa)*. Nitra: SPU, 1990. 119s.

[3] CHRASTINA, J. – KOTUS, M. Inovácia zariadenia na adhezívne opotrebenie. In *Najnovšie trendy v poľnohospodárstve, v strojárstve a v odpadovom hospodárstve*. Nitra: SPU, 2009. s. 144-149. ISBN 978-80-552-0208-2.

[4] FRIES, J. Analyse of together catching profiles of chainless haulage systems. *Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava*, 2004, roč.49, p. 61-66. ISSN 1210-0471.

[5] KOTUS, M. – CHRASTINA, J. – PLÁNKA, M. Hodnotenie adhezívneho opotrebenia v laboratórnych podmienkach. In *Kvalita a spoľahlivosť technických systémov 2010*. Nitra: SPU, 2010. ISBN 97880-552-0390-4.