TRIBOLOGICAL EFFECTS OF DISCONTINUOUS BLOCK-ON-RING TEST

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Abstract

In many research articles dealing with tribological characteristics of sliding couples measured by Block-on-Ring test, the discontinuous course of the test appears in order to evaluate cumulative mass loss during the test. According to the ASTM G-77-05, the wear rate is supposed to be determine after the end of the test without interrupting, by evaluation of volume loss based on the measurements of wear scars geometrical characteristics. The question of the influence of the discontinuity of the test remains usually unanswered. Therefore, this paper studies experimentally the effects of a discontinuous course test on the tribological properties of the material in comparison with continuous course test. Tests were carried out by a Block-on-Ring test according to ASTM G77-05 and according to modified testing methodology with discontinuities, using the tribometer CETR-UMT3 with equal settings of other test parameters. Furthermore, except of usually measured characteristic such as coefficient of friction and wear, the experimental evaluation of temperature characteristics of sample pairs: ring and block is presented in the paper. For determining of the thermal properties, a thermal camera με TIM was used. In these tests was captured the processes and maximum temperatures in the contact area, and the measured results was correlated with the results of friction measurements.

Keywords: Block_on_Ring Test, Wear Test, tribological properties, temperature characteristics

1. INTRODUCTION

Block-on-ring method covers laboratory procedures for determining the resistance of materials to sliding wear. The test utilizes a block-on-ring friction and wear testing machine to rank pairs of materials according to their sliding wear characteristics under various conditions [1].

An important attribute of this test is that it is very flexible. One can use a combination of different kinds of materials, variable load and sliding speed settings. The tests can be performed with a lubricant, liquid or air. Settings of the testing conditions should be done according the required operating conditions [1]. In the case of laboratory test, the settings are limited by the possibilities of available testing equipment. In our case, we can set the load in the range 1-750N.

The principle of the test is as follows:

The block is loaded with a constant force while the ring rotates at a specific rate. Scheme test block-on-ring is shown in **Fig. 1**. Scar volume of block is calculated from a scar width on the test block, and scar volume of the ring is calculated from weight loss of the ring. The friction force required to keep the block in place is continuously measured during the test with a load

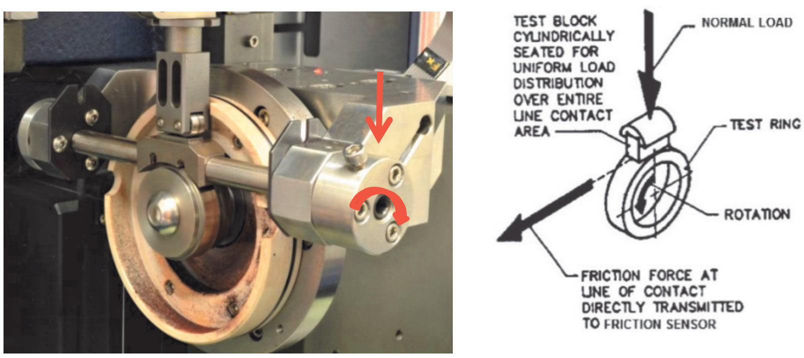


Fig. 1 Schema of the test ,,block-on-ring“ [1]

cell. These data, combined with normal force data, are converted to coefficient of friction values and reported. [1]

2. EXPERIMENT

As the test material was selected Cr-Mn-Si steel DIN 100CrMnSi6-4 (numerical designation 1.3520) for the block, which is used for roller bearings. In our case, the steel block has 59.7 HRC hardness and surface roughness of Ra = 0,4 μm. Dimensions of the block are 6.35 x 10.16 x 15.75mm according to ASTM G77-05. Chemical composition of steel was verified by elemental analysis and shown in **Table 1**. Material of the ring is the same as its counterpart block thus steel DIN 100CrMnSi6-4 with the measured hardness of 64.3 HRC and surface roughness Ra = 0.4 μm to this part. Diameter of the ring was 34,98 mm and thickness of 8.74 mm according to ASTM G77-05. The chemical composition of the steel was also verified using the elemental analysis and shown in **Table 2**. More detailed information on the chemical composition the steel DIN 100CrMnSi6-4 according to EN ISO 683-17: 2006 in **Table 3**.

Table 1 Chemical composition of the block

Element	Fe	Mn	Cr	Si
Wt %	92.67	1.23	0.53	0.52

Table 2 Chemical composition of the ring

Element	Fe	Mn	Cr	Si
Wt %	91.62	0.91	0.75	0.52

Table 3 Chemical composition of the steel DIN 100CrMnSi6-4

Element	C	Si	Mn	P	S	Cr	Mo	Al	Cu	O
Wt % EN ISO 683-17:2006	0.93 — 1.05	0.45 — 0.75	1.00 — 1.20	max 0.025	max 0.015	1.40 — 1.65	max 0.10	max 0.05	max 0.30	max 0.0015

Tribological measurements were performed using a standard test method for ranking the resistance of materials to sliding wear using block-on-ring wear test without lubricant at room temperature in according to ASTM G77-05 (reapproved 2010).

For this test parameters were selected:

- Test load 75N,
- Speed of ring rotation 1.37 m/s,
- Test sliding distance 7 000 m,
- Ambient temperature 22 ± 2°C,
- Relative humidity 40 - 60 %.

Measurements were performed on tribometer CETR-UMT3. During the measurement, the dependence of the sensed instantaneous coefficient of friction on the polished surface of the material against a piece of steel to the sliding track was scanned. Two kinds of testing methodology were compared: the measurement without the interruptions and the discontinuous course of the test. While the first is recommended by ASTM G-77, the second is often used in the literature. [2]

For discontinuous measurements, the he total sliding distance was divided into 4 sections, after each the weight loss of the block was measured (after 1 000 m, 3 000 m further after 5 000 m and finally after 7 000 m). For continuous measurement, the weight loss after all 7 000 m was measured.

Except of the weight loss, the range and mechanism of wear of the block were further examined. Wear of the block was documented using a scanning electron microscope FEI Quanta 200. The wear scar dimensions were measured using the profilometer KLA-Tencor P-6 and volumetric wear was calculated according ASTM G77-05 standard.

Thermoanalysis of during the measurement Block-on-ring test were performed using the infrared camera με TIM, which was directed perpendicular to the ring face. That is, the temperature characteristics were recorded at the spot of contact friction pair in a point. In these tests was captured the processes and maximum temperatures in the contact area, and the measured results was correlated with the results of friction measurements.

3. RESULTS AND DISCUSSION

The running of the friction coefficient Block-on-ring wear test is shown in **Fig. 2**. One complete wear test consisting of 7 000 m sliding distance is shown in this figure. The yellow curve represents the COF values measured at continuous wear test. The second gray curve represents the COF values measured at test duration of each test step (1000 m, 1 000 - 3 000 m, 3 000 - 5 000 m and finally 5 000 - 7 000 m sliding distance). The mean stable coefficient of friction is given in **Table 4**.

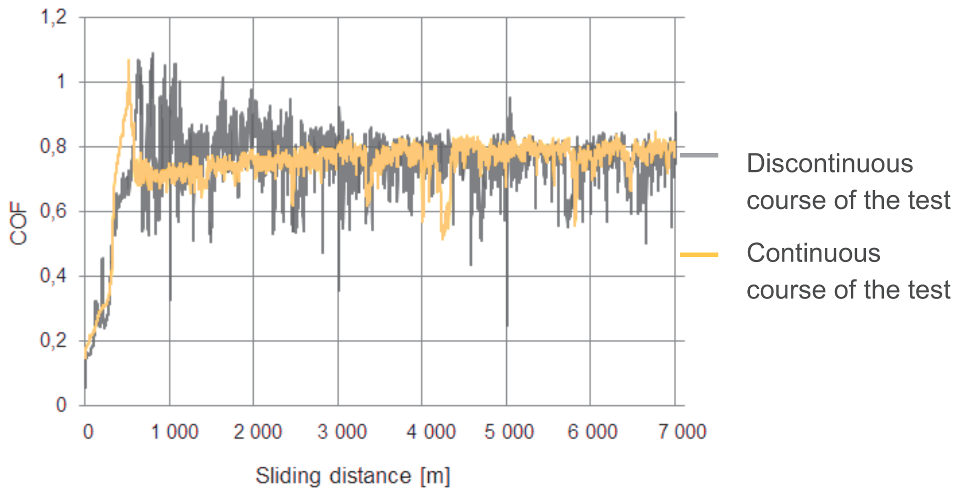


Fig. 2 Course of the coefficient of friction

The mean measured values of friction coefficient aren´t significantly different for the two compared types of used testing methodology. At the beginning of the test the measured COF presents high unstable values due to the run-up process. This run-up process is caused by the initial roughness of the two surfaces, which are removed under steady-state wear contact as a result of a loss of material or plastic deformation. [2]

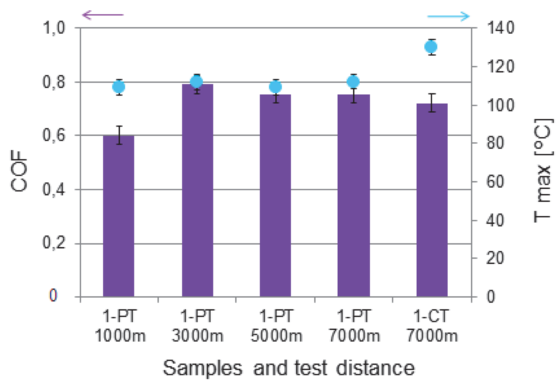
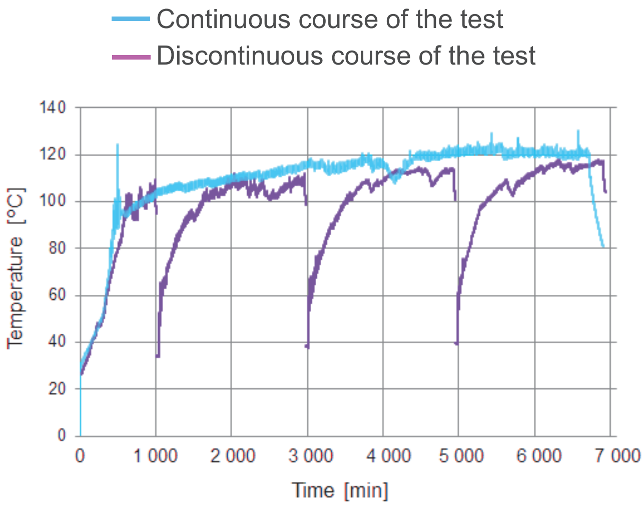


Fig. 3 Dependance COF and T max. on test distance

At the beginning of each test, the temperature of the specimens was around 20°C (room conditions). During the test, the contact area temperature increases up to 130°C (continuous test) and 112°C (discontinuous test). The maximum temperature of each measured test is shown the **Table 4**. In all the cycles of discontinuous test is maximum temperature very similar. At the continuous wear test is maximum temperature higher about 20°C than maximum temperature of the discontinuous wear test. This is consistent with expectations, because the temperature doesn´t decreases in duration of all test. While at the discontinuous test, the block is put out of the tribometer and weighed; in the meantime the block lost its temperature to the value about 40°C, then the contact area temperature repeatedly increased up to approximately 110°C. This is captured in **Fig. 4**. At the beginning of continuous wear test, the contact area temperature rapidly increased up to approximately 100°C. After the 500 m sliding distance the contact area temperature slowly increased up to 130°C. On the **Fig. 5** is shown thermogram of contact area the friction pair. The temperature is increased during each test due to the thermal conductivity of the ring, block and holder in tribometer.

Table 4 Measured values of COF and T max

Sliding distance [m]	COF	T max [°C]
2-PT 1000m	0.6021	109.2
2-PT 3000m	0.7904	112.2
2-PT 5000m	0.7554	109.5
2-PT 7000m	0.7555	112.3
1-CT 7000m	0.7217	130.2



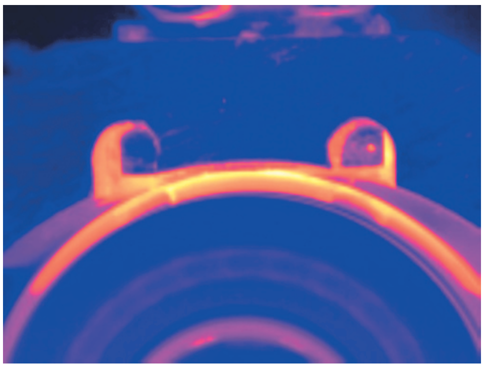


Fig. 4 Course of the temperature

Fig. 5 Thermogram of the contact area

From the measured geometrical data describing the size of the wear grooves the wear rates of block material were calculated according to ASTM G77. The results are summarized in **Table 5**.

The results show that the measured volume loss and consequent wear rates and coefficients of wear resistance are different for each type of test. Graphically it is shown in the **Fig. 6**.

When assessing the cumulative weight loss, the fact occurs that at discontinuous course of the test is the wear is the two times higher comparing to continuous course. The significantly higher values of cumulative weight loss are caused probably by disassembling the block-ring sliding couple and its cleaning before checking block weight loss, removing the wear debris. This procedure was repeated 4 times. In the **Table 6**, the cumulative weigh loss of both discontinuous and continuous course of measurement is shown.

Table 5 Calculated values of wear characteristic

	1-CT discontinuous	**2-PT continuous**
Volume loss [mm^3]	2.12E-01 ± 3.29E-02	3.88E-01 ± 3.59E-02
Wear rate W [mm^3/m]	3.02E-05 ± 4.69E-06	5.54E-05 ± 5.13E-06
Coefficient of wear resistance K [mm^3/Nm]	4.03E-07 ± 6.29E-08	7.39E-07 ± 6.83E-08

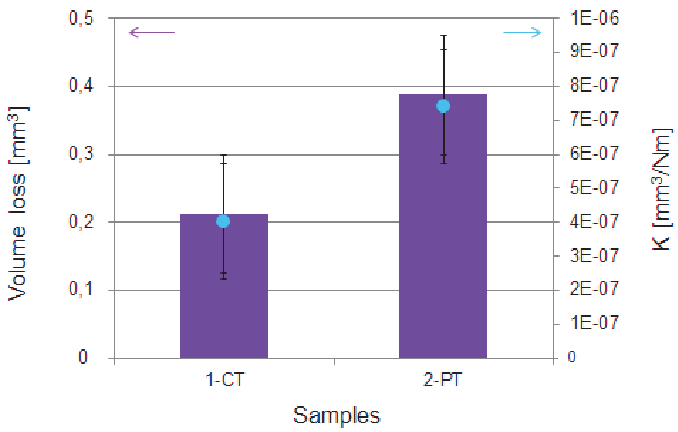


Fig. 6 Measured values volume loss and K for each sample

Table 6 Values of the cumulative weight loss

Sliding distance [m]	**Cumulative weight loss [g]**	
	Discontinuous	**Continuous**
Before	-	-
1000	0.0007	-
3000	0.0020	-
5000	0.0024	-
7000	0.0029	0.0012

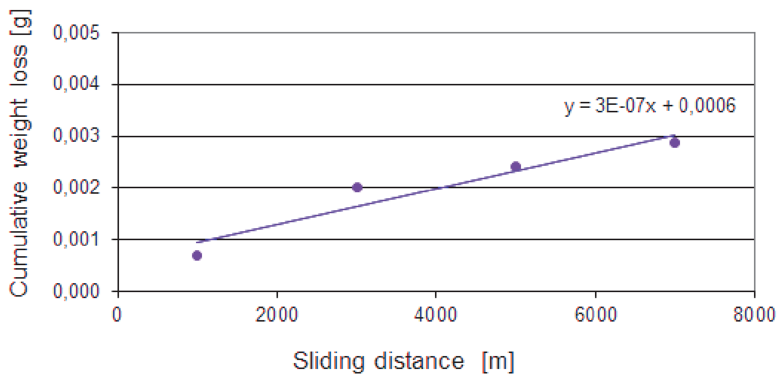


Fig. 7 Course of the cumulative weight loss of discontinuous course of the test

The wear mechanism, observed by SEM, is shown in the **Fig. 8**. The deeper groves were observed for continuous course of the test, which confirm the results of wear rate measurements.

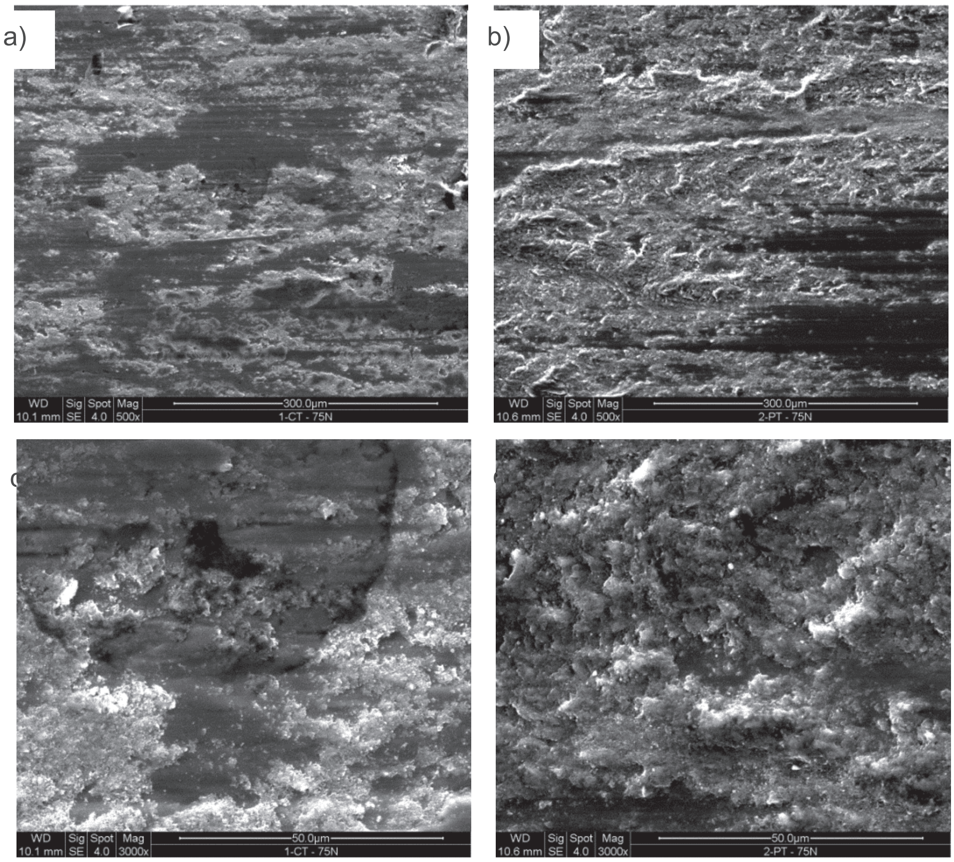


Fig. 8 Figures of the block wear track a, b) continuous course of the test, c, d) discontinuous course of the test

SUMMARY

The aim of this paper was to determine the difference of tribological characteristics of the sliding materials pair using the test Block-on-Ring with two types of testing methodologies - continuous and discontinuous course of the test. Furthermore, the possibility of implementation of the thermo analysis into the tribological testing according to ASTM G77 was verified.

Comparing the two testing methodologies, it was found that discontinuous course of the wear test has little effect on the coefficient of friction. The course of the friction coefficient of individual test progress is comparable to the average values and their friction coefficients as well.

On the other hand, the difference between the wear was significant. The discontinuous testing methodology led to a almost two times higher volume loss then continuous. Removing and cleaning of the sample caused the removal of tribological film slot of the block as well as the wear debris. This has changed the conditions for measurements between the tests. This observation is crucial and has to be taken into account, comparing the results of tribological test of different kinds of material.

The using of thermoanalysis of Block-on-Ring Test showed to be possible and useful for obtaining the additional information. Thermal analysis in tribology could be used to substantiate the mechanism of oxidation under practical conditions and to characterize and improve the thermal and oxidative properties of a pair of sliding materials [3]. In our case, its results showed that the maximum temperature of the contact between friction pair which reached 112°C at discontinuous course of the test and 130 °C at continuous course of the test. After the sudden increase during the running-in period, the temperature in the contact area increases slowly and without sudden changes. Temperature variation correlates with the process of the friction coefficient for each test.

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