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THE POSSIBILITY OF APPLICATION OF THE ACOUSTIC EMISSION METHOD FOR MONITORING FRICTION PROCESSES

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Abstract

This article presents the methodology and research results of monitoring friction processes between couple of cooperating elements by acoustic emission method. The research was carried out at the lathing machine test stand of the Technische Hochschule Mittelhessen. The test stand included lathing machine Proxon PD 210, shaft, made of austenitic stainless steel X2CrNi18-9 and steel plate, made of S235. The Friction process was monitored by an acoustic emission set made by Physical Acoustics Corporation (PAC). The PAC system includes: preamplifier USB AE Node, type 1283 with bandpass 20 kHz – 1 MHz, AE signal measurement sensor type VS 150M, with a frequency range 100-450 kHz, computer with AE Win for USB Version E5.30 software. During the study, the acoustic emission (AE) generated by friction between shaft and steel plate was recorded. The load of the plate was 0, 1, 2, 3, 4, 5 and 10 N. The following parameters were determined: amplitude, number of events – hits, the effective value of the signal (RMS). The use of grease between the cooperating elements caused a significant reduction in friction and thus the power of the generated signal (10 to 30 times). In the case of dry friction, without grease, the maximum RMS value was recorded at 4 N load and at the lubricant between the pair cooperating at 1 N load. The research has shown that it is possible to monitor the friction process between cooperating elements using the acoustic emission method.

Keywords: *Acoustic Emission (AE), diagnostic, friction regimes*

1. Introduction

One of the methods for monitoring the technical condition of devices, machines and processes is the acoustic emission (AE) method. Acoustic emission is considered as a non-destructive method included in Standard PN-EN 473: 2008, described and defined in PN-EN 1330-9: 2009 and PN-EN 13554: 2011. According to the definition acoustic emission (AE) is an evanescent elastic wave, which is the result of rapid release of the energy stored in the material by propagating a micro-damage (increase in micro-cracks, the movement of groups of dislocations) in the material or by a process (friction, leakage, water flow, cavitation, etc.) [1-3, 7-10]. The typical frequency range of the acoustic emission is normally determined within 20 kHz – 2 MHz [5, 6].

Acoustic Emission is a passive non-destructive method. Its main advantages are:

– high sensitivity,
– the possibility of continuously research,
– the possibility to locate the source of the AE signals (damages, leaks, etc.),
– the possibility of carrying out research without having to shut down equipment out of service [2, 3].

The stimulus causing the release of energy and the formation of elastic waves can be: load operation, environment, temperature change, and the processes which are accompanied by AE changes both at the micro and the macro scale, such as: cracks, friction, plastic deformation, corrosion, leaks, structural and phase changes, chemical reactions, delamination, cracking of the fibres and matrix in composites, etc. [1, 5].

The acoustic waves propagate in all directions from the source, thus can be recorded by one or more sensors mounted on an object or component. During the propagation of the AE waves, they are damped by several physical effects. Therefore, the waves can only be detected within a limited distance. These distance dependents on many factors, mainly on properties of the material, the geometry of the object and the level of interference from background noise [8, 9]. An example of AE signal is shown in Fig. 1.

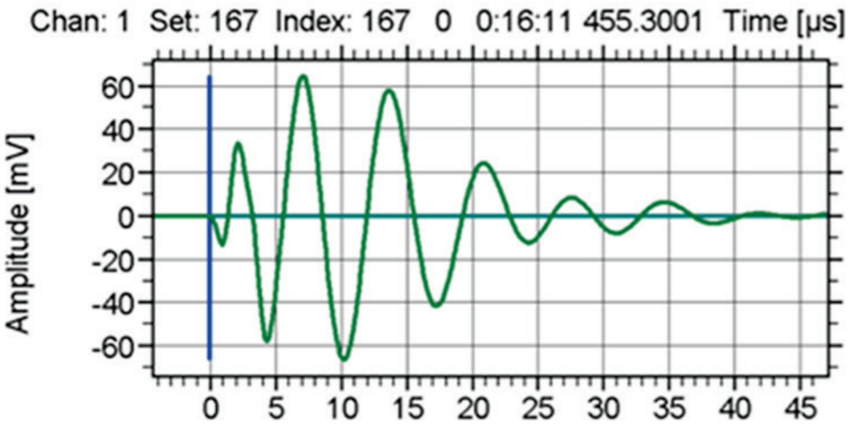


Fig. 1. An example of typical acoustic emission burst signal [6]

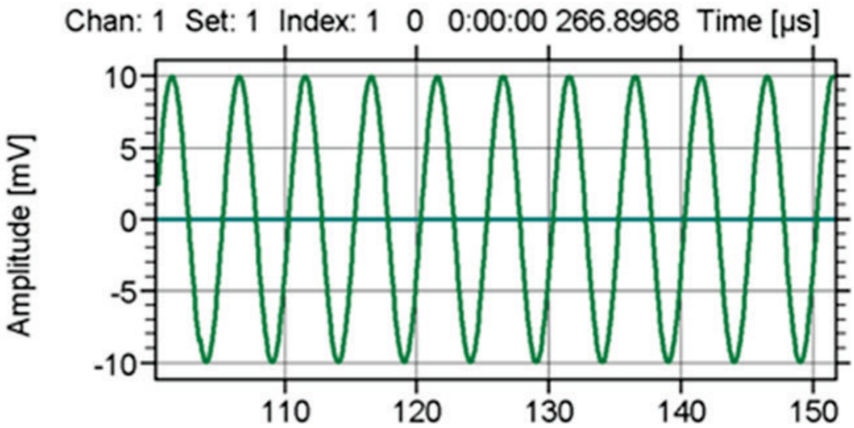


Fig. 2. An example of typical acoustic emission continuous signal [6]

According to PN-EN 1330-9: 2009, an AE signal can be characterized by parameters such as: amplitude, frequency, energy, rise time, duration, number of exceedances of the threshold of discrimination – hits, RMS of the signal, etc.

The article presents the possibility of using acoustic emission method for monitoring friction process between rotating shaft and metal plate in order of its load. That should simulate slide-bearing operations in different conditions.

2. Research methodology

The research was carried out at the lathing machine test stand of the Technische Hochschule Mittelhessen, Faculty of Mechanical Engineering, Laboratory of Diagnostics. The friction couple were shaft, made of austenitic stainless steel X2CrNi18-9 and steel plate, made of S235 steel covered by chromated zinc. These materials are shown in Fig. 3.

The test stand included small lathing machine Proxon PD 210, shaft and plate. General view of laboratory stand is presented in Fig. 4.

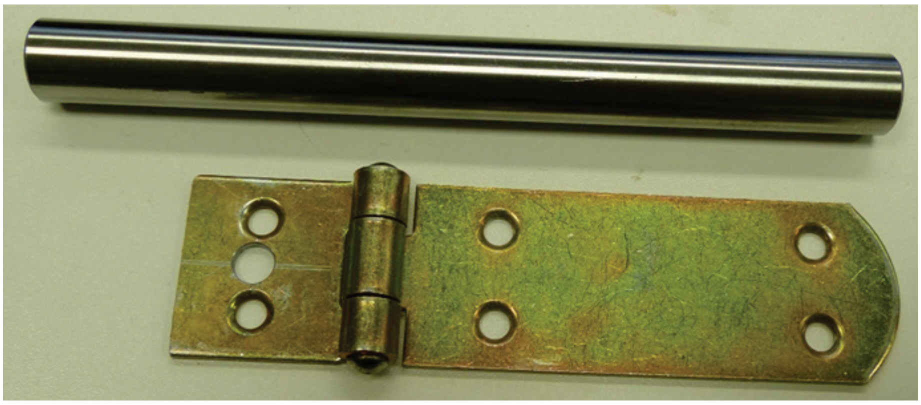


Fig. 3. Friction couple – shaft and plate used in research

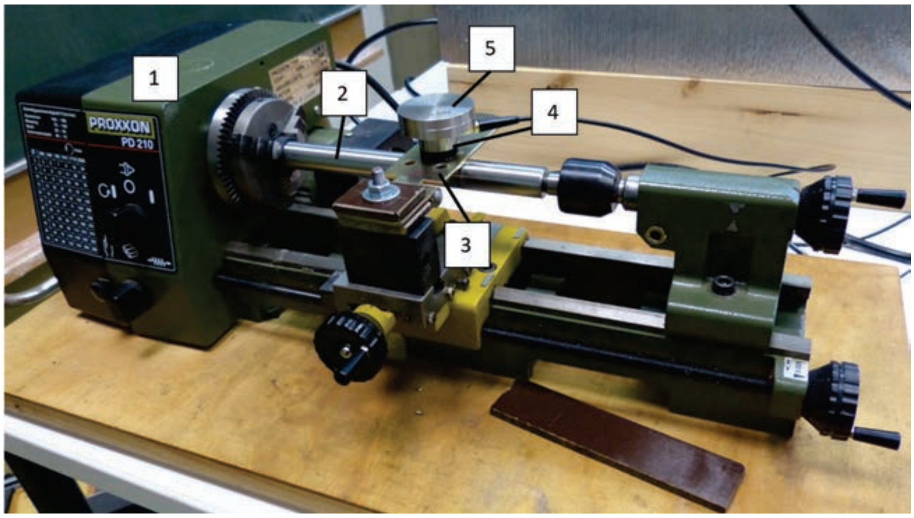


Fig. 4. Over view of the laboratory test stand: 1 – lathing machine, 2 – shaft, 3 – plate, 4 – AE sensor 5 – standard blocks used for loading

For diagnosis of the friction process between couple of chosen materials, Physical Acoustics Company (PAC) acoustic emission system was used.

For isolating tested materials against noise and vibrations from lathing, machine-dumping materials were used. In case of the shaft, these isolating elements were rubber O-rings. The metal plate, which was the friction-partner of the shaft, was fixed at the machine's support and dumped by "Pertinax". The details of fixing the shaft and plate are shown in Fig. 5.

a) *b)*

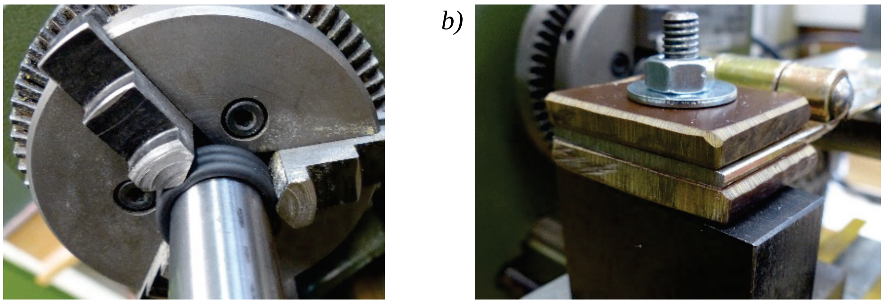


Fig. 5. Dumping materials used for isolating tested materials against noise from lathing machine a) rubber O-rings on the shaft, b) "Pertinax" used for fixing the plate

The AE Research-Set, that received the AE-waves, which were generated by friction between rotating shaft and steel plate simulating slide bearing, was performed using set by Physical Acoustic Corporation (PAC). That set consisted of: single channel system USB AE Node, type 1283 with bandpass 20 kHz – 1 MHz, preamplifier with bandpass 75 kHz – 1.1 MHz, AE-Sensor VS 150M (with a frequency range of 100-450 kHz), computer with AE Win for USB Version E5.30 software for recording and analysing AE data.

Between the sensors and the surface of the steel plate, a coupling fluid was used.

The research was carried out with constant revolution of the shaft of 895 rpm. The measurements of acoustic emission were recorded while the load of the plate was 0, 1, 2, 3, 4, 5 and 10 N. The load was achieved by using standard blocks.

During the study, the AE generated by friction carried out on a test stand, recorded a number of parameters, which were analysed afterwards. These parameters were e.g.: amplitude, number of events – hits, energy, RMS of the signal. To compare continuous AE, which is chiefly stochastic, an energy equivalent parameter is needed. For comparing these results, which were obtained at different loads, the parameter Root – Means – Square (RMS) was chosen.

3. Research results

An example of a chart recorded during the laboratory tests illustrating the change in the RMS value as a function of time as shown in Fig. 6. That signal was recorded at 3 different load values of the plate.

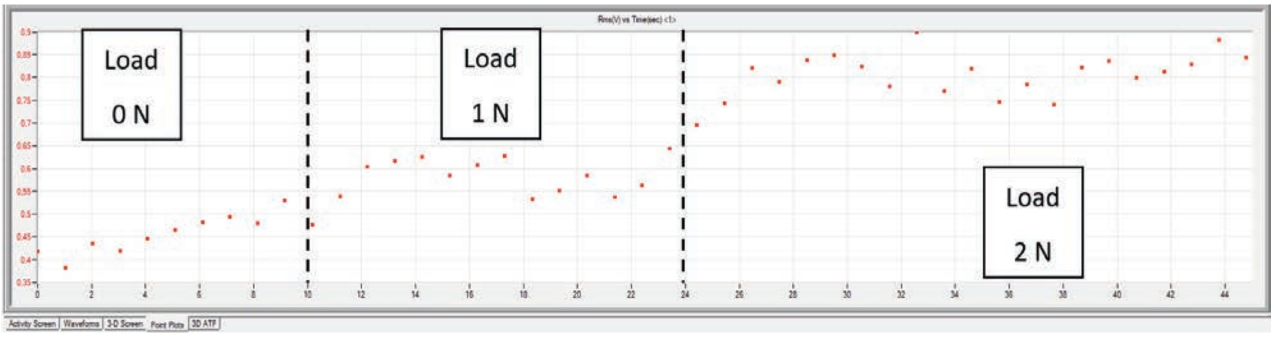


Fig. 6. An example of a chart recorded during the research showing RMS of the signal as a function of time

RMS values of acoustic emission generated by friction between the shaft and plate were presented in Tab. 1. These results were obtained by using different loads on the steel plate in two different tribological situations – with and without lubricant between shaft and plate.

Tab. 1. RMS average values of acoustic emission depending on the load of the plate

RMS of AE signal [V]	Load on steel plate [N]						
	0	1	2	3	4	5	10
Friction without lubricant	0.412	0.657	1.195	1.466	1.583	1.544	1.103
Friction with lubricant	0.041	0.051	0.046	0.043	0.042	0.041	0.015

The change in RMS value of the signal generated by the friction between the shaft and the plate is presented graphically in the chart shown in Fig. 7. Fig. 8 represents the nature of the signal change depending on the load on the plate. Fig. 8a figures out the waveform recorded for the dry shaft and Fig. 8b for the tribological system with lubricant.

In both cases – with and without the lubricant – the character of the signal changes has a similar course. In the first phase at a relatively low load, the RMS of the signal increases followed by its decrease. For the dry shaft, the probable reason is the clash of the tops of roughness of cooperating surfaces in the first phase [4]. In the second phase, the strength of the RMS-signal generated by the friction, decreases. Therefore, one can conclude, that the coefficient of the friction decreases too. In the case of a shaft with lubrication applied (Fig. 8b), the RMS signal is many times smaller. An increase in low loads is noticeable, after which the dry friction turns into a smooth one, which results in the decrease in the power of the generated signal.

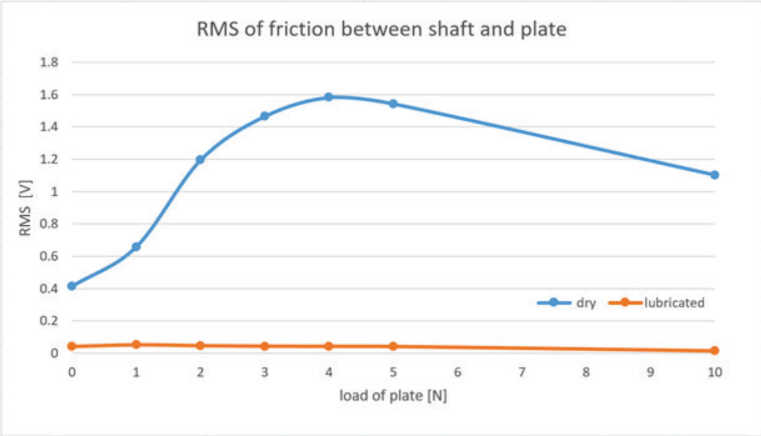
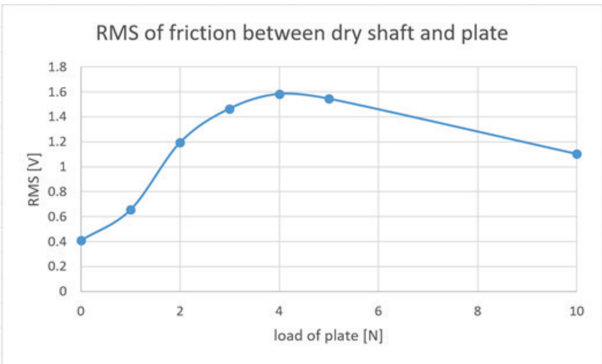


Fig. 7. Changes of RMS of AE signal in subject to the load on the plate with and without grease between friction couple

a)



b)

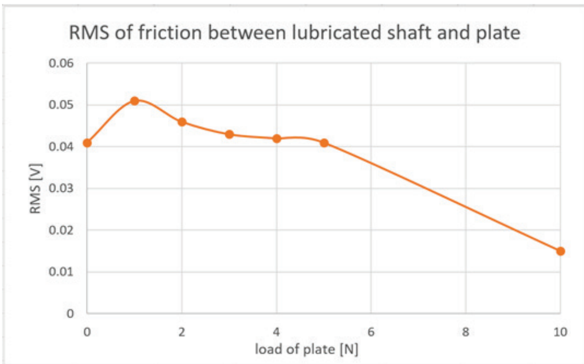
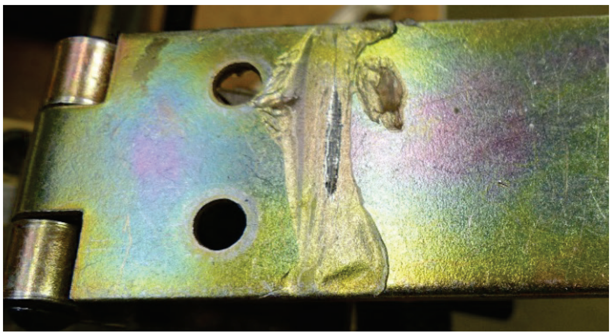


Fig. 8. RMS of AE signal recorded during research depend on load on plate: a) without grease, b) with grease

The view of the friction surfaces of the cooperating elements – shaft and plate – is shown in Fig. 9. Fig. 9a shows the view of the plate, which has an anti-corrosive coating of chromated zinc, with visible wear caused by abrasion. The applied grease is still visible on the damaged plate surface. Fig. 9b shows the shaft's surfaces with visible signs of wear at the points of contact with the plate.

a)



b)

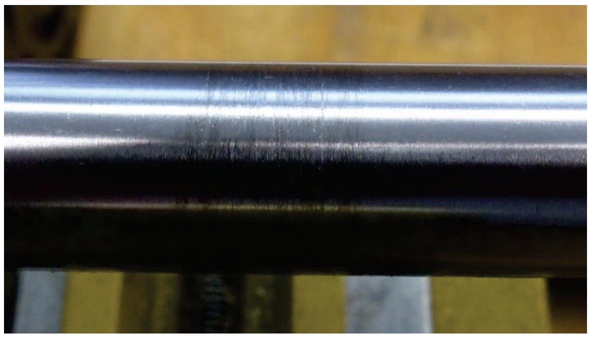


Fig. 9. The views of surfaces of cooperating couple after the test: a) plate, b) shaft

4. Summary

In the research, a couple of materials were used (shaft and a plate). This couple simulates common materials that cooperate in diverse machines and devices, e.g. in a slide bearing.

The monitoring of friction processes between cooperating elements (Tribological Systems) allows avoiding damage and expansive repairs of devices.

Common applied measurement methods for the selection of friction parameters are for e.g.: temperature distribution, thermography methods, low frequent vibrations, lubricant analysis, etc.

In this research, the acoustic emission method was used.

It allows measuring the actual strength of the friction between the cooperating couple of chosen materials. One advantage of the Acoustic Emission Method is the measurement without any delay, in contrast to e.g. temperature measurement caused of heat capacity.

AE is a possibility to control the process continuously and enables the operator to be informed about additional circumstances for example the danger of occurring damage of parts of the machine.

The application of acoustic emission for monitoring friction process allowed determining the strength of the signal, which is characteristic in normal or abnormal work. In this research, the acoustic emission system made by Physical Acoustics Company was used. The most useful parameter within the range of all parameters recorded during the test was the RMS value of the AE signal.

The use of grease between the cooperating elements caused a significant reduction in friction and thus the power of the generated signal (10 to 30 times). It is characteristic that there is a maximum RMS value of the signal for certain loads, both in the case of dry friction and with grease. In the case of dry friction (without grease), the maximum RMS value was recorded at 4 N load. In the case of the lubricated friction partners, the maximum was at 1 N load. The Decrease in the RMS values of the signals generated by friction in the case of dry shaft may be caused by clashing the roughness tops of cooperating surfaces, which reduced the coefficient of friction. In contrast, a certain load is required to ensure the transition from dry or semi-dry to liquid lubrication in case of using grease.

The research has shown that it is possible to monitor, by means of the acoustic emission method, the friction process between cooperating elements. On this basis, it is possible to determine the characteristic values of the signal generated by friction, which inform the operator about the malfunction of monitored devices.

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