Journal of POLISH CIMAC
Faculty of Ocean Engineering & Ship Technology
GDAŃSK UNIVERSITY OF TECHNOLOGY

ANALYSIS AND ASSESSMENT OF THE ACOUSTIC EMISSION SUITABILITY FOR DETERMINATION OF THE ENERGY STATES OF A TRIBOLOGICAL SYSTEM IN THE FORM OF A FOUR-BALL TESTER FRICTION NODE

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Abstract

The present operating safety and cost reduction requirements of the compression ignition engines make it necessary to search for new methods of detecting their defects, e.g. by the analysis of acoustic emission signals coming from the slide bearings. The paper presents non-destructive measurements of acoustic emission (AE) in order to obtain information on the processes taking place in a tribological system under the continuously increasing load.

Key words: tribological system, acoustic emission, energy state

1. Introduction

Ensuring safe sailing of a sea-going ship requires having sufficient amount of energy obtained from the chemical energy contained in the fuel combusted in compression ignition engines. That energy must be transmitted through many tribological systems to different receivers, e.g. to the screw propeller. The energy is then transformed and transmitted in the tribological systems. Therefore, it is justified to consider the tribological systems as energy expenditure devices. Operation is such an energy state of a tribological system when transformation and transmission of energy takes place [3, 4].

Maintaining a compression ignition engine in the operational state for as long a time as possible requires collecting sufficient information on the tribological system physical and chemical parameters. It is necessary to know the technical state of a tribological system for its proper operation, or for maintaining the energy state.

The paper deals with the assessment and analysis of the impact of release of the material accumulated energy by propagating micro-defects (increased micro-cracks) on the tribological system energy state. The object of investigation was a tribological system in the form of a four-ball tester friction node. Each ball has a primary distribution of the elastic energy (residual stresses) and a certain level of the structural defects and even micro and macro damage. The cause of change of the ball material state of equilibrium is the change of stress and temperature. If we assume that the bearing ball manufacturing stage structure of the external layer and the material interior was correct (i.e. in compliance with the respective standards) then acoustic emission should be considered a signal of degradation of properties of a given tribological system element.

Additionally the acoustic emission may be considered from the point of view of changes in the bearing ball material. These are, among others [2]:

- movement of vacancies and dislocations, grain boundary slip - possible in the high stress areas near the material yield point,

– connecting of dislocations, creation and development of cracks - a strong AE source.

It can be seen that AE may be a good tool for physical investigation of the material destruction process and on the other hand a tool for detecting internal defects reducing the tribological system strength.

The energy release impact investigations [1] were carried out on the T-02 four-ball tester with Vallen piezoelectric gauges (Fig.1), in the conditions defined in Section 2.

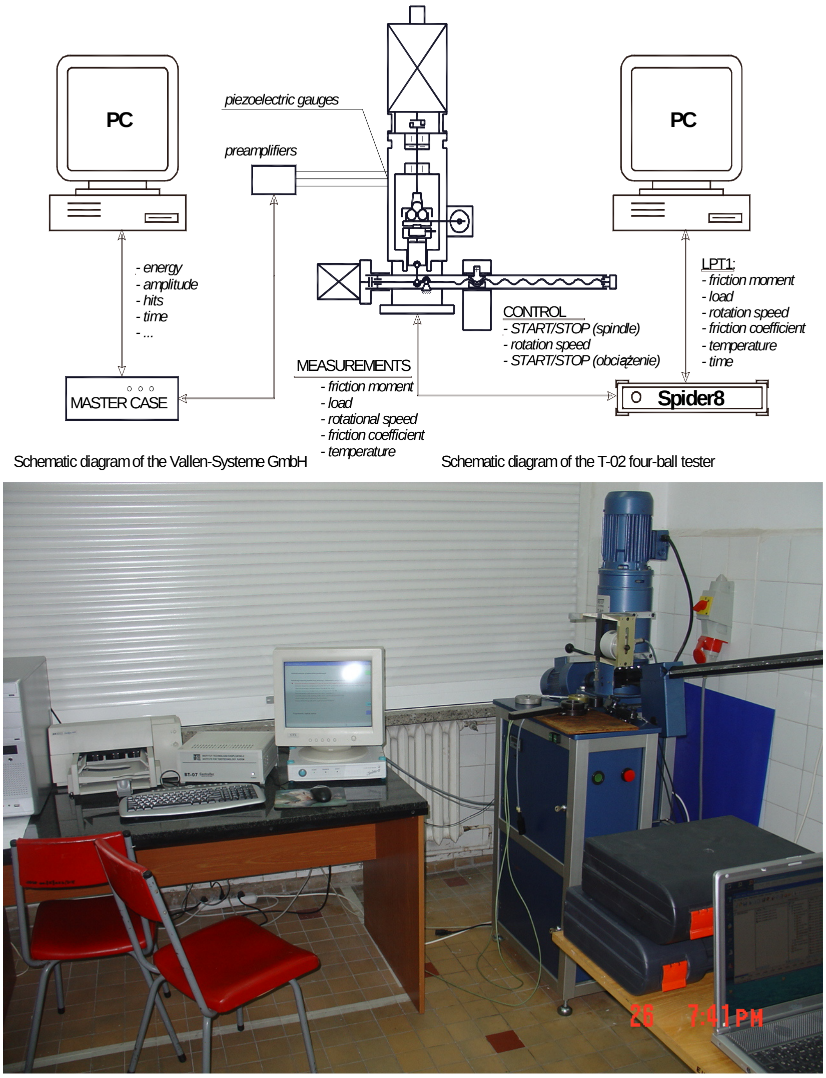

Fig.1 Schematic diagram of the ITeE Radom company four-ball tester and the Vallen-Systeme GmbH AMSY-5 apparatus measurement and control systems[1]

2. Investigation methodology

The investigations were carried out in four stages on the Marinol RG1240 lubricating oil of a Cegielski-Sulzer 8S20UD-H engine:

- clean oil (not used for lubrication),
- used oil,
- used oil with a 5% content of the MDO fuel that the engine is fed with,
- used oil with a 5% content of distilled water.

In order to obtain a broad picture of the impact of forcing intensity on the tribological characteristics, the following testing parameters were adopted [1,5]:

– spindle roational speed: 500 rpm, 1000 rpm, 1500 rpm
– load escalation rate: 409 N/s
– initial load: 0 N
– maximum load: 7400 ± 100 N
– lubricating oil temperature: 60°C

The friction node constituted dia. 12.7 mm bearing balls from the LH15 steel (iron alloy with an average content of 1% C, 0.02% S, 0.3% Ni, 0.3% Cu), accuracy class 16 in accordance with the PN-83/M-86452 standard, dipped in the tested lubricating oil.

Altogether 12 different tests were carried out and each one was additionally analysed by the AE gauges (Fig. 2).

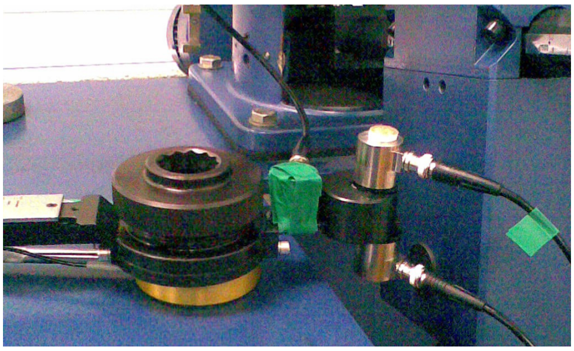

Fig. 2. Positioning of three piezoelectric gauges in the T-02 four-ball tester friction node [1]

During the AE measurements, the most often used measure of the phenomenon is the impulse (event) count or the AE rate (number of events in a time unit). Also the AE energy may be used, i.e. area under the envelope of the squared amplitude. These quantities are illustrated in Fig. 3, an example of one AE impulse.

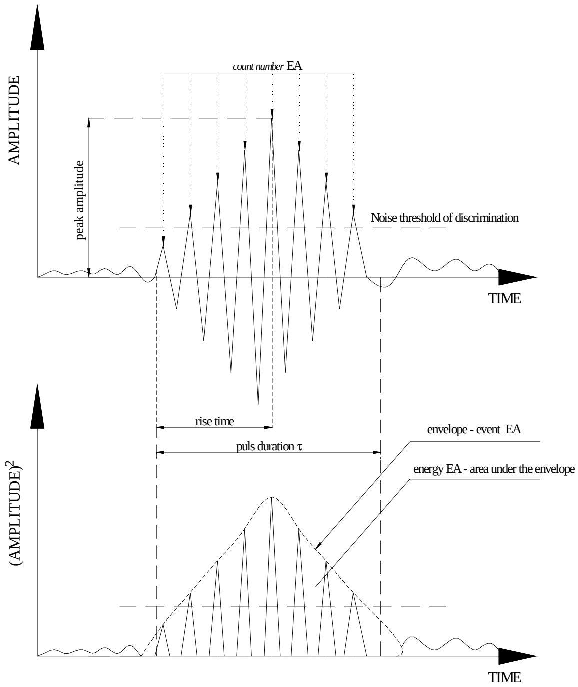

Fig.3. The AE phenomenon main description and valuation parameters, Σ = count number, event, event energy in V^2 sec [2]

3. Analysis of the investigation results

Based on the results of measurements performed by the T-02 four-ball tester and the AMSY-5 apparatus measurement and control system, an analysis was carried out of which diagnostic parameters may be useful (Table 1 and Figs. 4 to7).

Table 1. Values of the calculated diagnostic parameters

l	P_t	f_t	A_t	E_t
Clean oil: measurement at 500 rpm	1604		51	503
Clean oil: measurement at 1000 rpm	1610		48,5	193
Clean oil: measurement at 1500 rpm	1621		47,9	185
Used oil: measurement at 500 rpm	1237,2	0,72	54,7	202
Used oil: measurement at 1000 rpm	1351,2	0,66	49	200
Used oil: measurement at 1500 rpm	1380	0,62	48,7	208
Used oil + 5% MDO: measurement at 500 rpm	1156,8	0,72	55,8	8080
Used oil +5% MDO: measurement at 1000 rpm	1244,4	0,64	76,9	1970000
Used oil +5% MDO: measurement at 1500 rpm	1294,8	0,63	76,9	1970000
Used oil + 5% H_2O: measurement at 500 rpm	949,2	0,77	85,2	36900000
Used oil +5% H_2O: measurement at 1000 rpm	1017,6	0,66	72	2070000
Used oil +5% H_2O: measurement at 1500 rpm	1114,8	0,65	75,4	5090000

where:

- P_t – seizing load [N],
- f_t – maximum value of the kinematic friction coefficient [-],
- A_t – peak amplitude at the seizing load [dB],
- E_t – seizing load energy [eU].

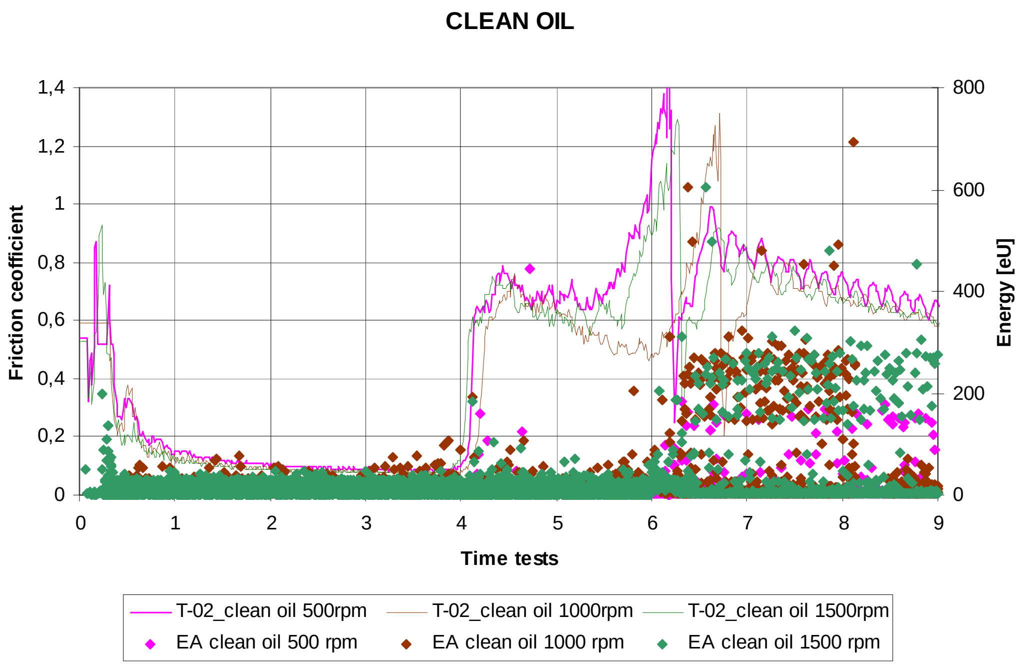

Fig. 4. Changes of the AE energy caused by the kinematic friction in the friction node dipped in clean oil, where: T-02_clean oil 500 rpm – friction coefficient change at 500 rpm curve; AE clean oil 500 rpm – AE energy distribution at 500 rpm curve; T-02_clean oil 1000 rpm – friction coefficient change at 1000 rpm curve; AE clean oil 1000 rpm – AE energy distribution at 1000 rpm curve; T-02_clean oil 1500 rpm – friction coefficient change at 1500 rpm curve; AE clean oil 1500 rpm – AE energy distribution at 1500 rpm curve;

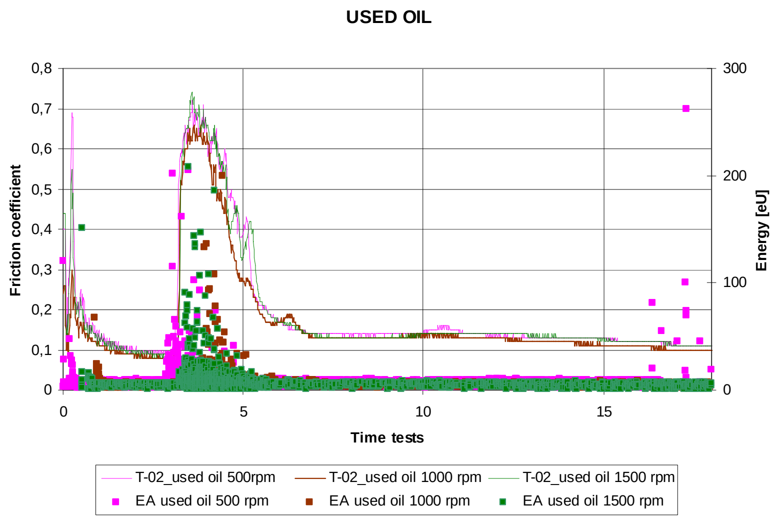

Fig. 5. Changes of the AE energy caused by the kinematic friction in the friction node dipped in used oil, (curve designations as in Fig. 4)

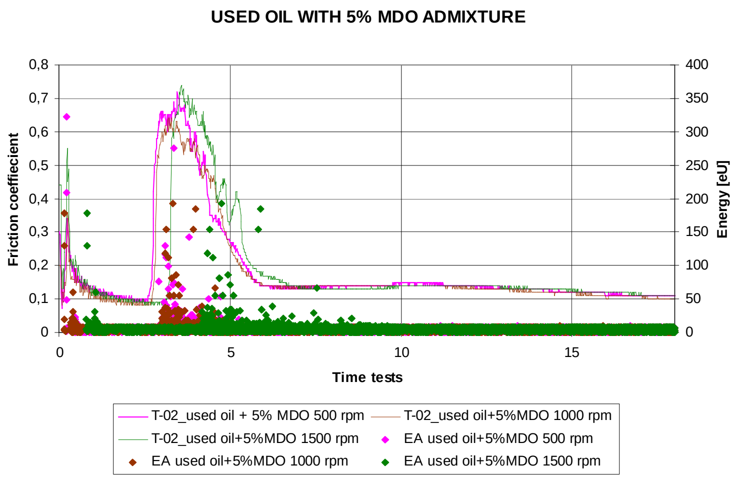

Fig. 6. Changes of the AE energy caused by the kinematic friction in the friction node dipped in used oil with 5% MDO admixture, (curve designations as in Fig. 4)

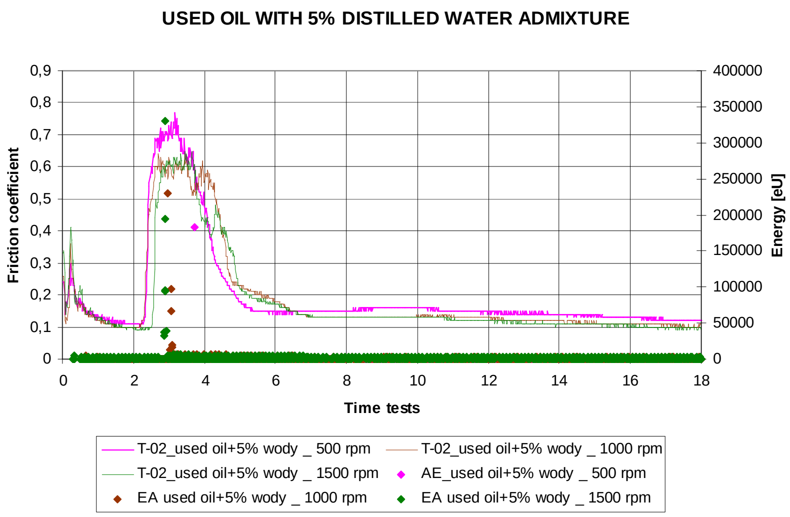

Fig. 7. Changes of the AE energy caused by the kinematic friction in the friction node dipped in used oil with 5% distilled water admixture, (curve designations as in Fig. 4)

During clean Marinol RG1240 oil testing (Fig. 4) the ball seizure and welding together occurred, therefore the maximum value of the kinematic friction coefficient is missing (Table 1).

4. Final remarks and conclusions

The compression ignition engine tribological system boundary layer action is understood as transmission of the friction node load energy in a given time, in the form of work dependent on the friction node tribological parameters. The work value may indicate the energy states of tested tribological systems, corresponding to specific technical states (i.e. fully operational, partially operational and nonoperational state).

Results of the tests carried out by the authors of reference [4] should be treated as a pilot study. The results pertain to the acoustic emission of friction node in the T-02 four-ball tester with the Vallen-Systeme GmbH company AMSY-5 apparatus set connected to it. The main purpose of the tests was analysing the lubricant interaction with the friction surface by the acoustic emission signals.

The tests indicate a significant probability of strong correlation between the kinematic friction coefficients defining the friction node technical state, and the AE signals defining the friction node energy state. The following requirements should be met in order to improve the reliability of the T-02 four-ball tester results and to facilitate the energy state separation:

- sample the lubricating oil in the whole period of a compression ignition engine operation and compile a test result biography,
- the four-ball tester friction node balls should have the same overlay structure as e.g. the main slide bearing liners,
- install in the four-ball tester friction node a number of different piezoelectric gauges in order to determine the energy released during the boundary layer destruction process.

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