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Technical Note

Condition Assessment of the Conical Surface of Atomizer Needles and Seats of Marine Diesel Engines by Acoustic Emission – Preliminary Research

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The condition of the conical surface of the needle and seat in a fuel atomizer can be assessed by using the acoustic emission method. The assessment of this conical tribological pair can be performed by up-to-date measurement methods that substantially enhance the quality of evaluating the technical condition of conical surfaces of the atomizer needle and seat.

Keywords: fuel atomizer, assessment, conical tribological pair, acoustic emission.

1. Introduction

Today the quality of diesel engine fuel atomizers is assessed:

- in operational conditions by diagnostic methods,
- at the manufacturing stage or during repairs by using traditional workshop measurements and examining the micro- and macrostructure of the material.

A new supplementary method is herein proposed for assessing the conical tribological pair (needle-seat) by using the acoustic emission (AE). The atomizers used in experimental measurements were those of marine engines Stork-Wärstilä SW38, which are the main propulsion units of the ferry *Polonia*. The engine manufacturer recommends using atomizers from L'Orange of VVO-U953G/E type. This work describes the choice of the transducer location and the technique of its mounting on the examined atomizer as well as the checks whether the measures of the acoustic emission signals are sensitive to the condition of the conical surface of the atomizer needle and seat.

2. Characteristics of the examined atomizers

The geometric requirements (Fig. 1) for a new atomizer and the hardness distribution in the surface layer (Fig. 2) of its tribological pair indicate the atomizer belongs to products of high accuracy. The hardness of the surface is the most important factor having influence on the durability of the tribological pair. For example: if the surface hardness decreases by approx. 30%, an accelerated material waste occurs resulting in a permanent damage.

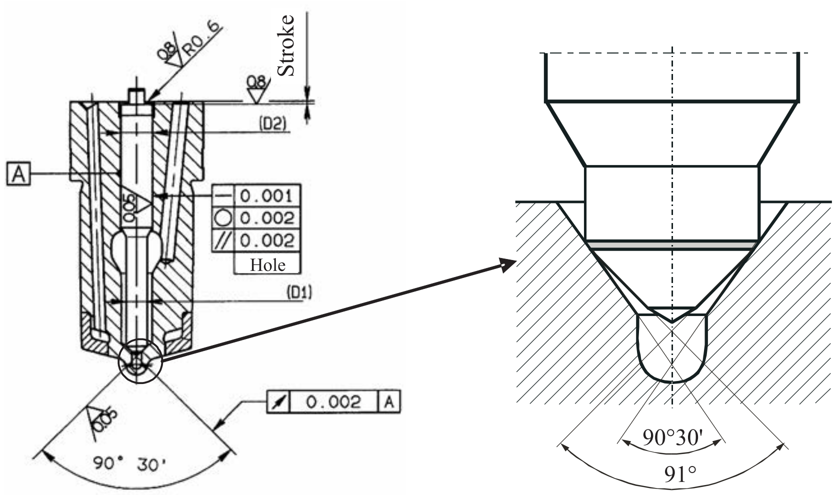
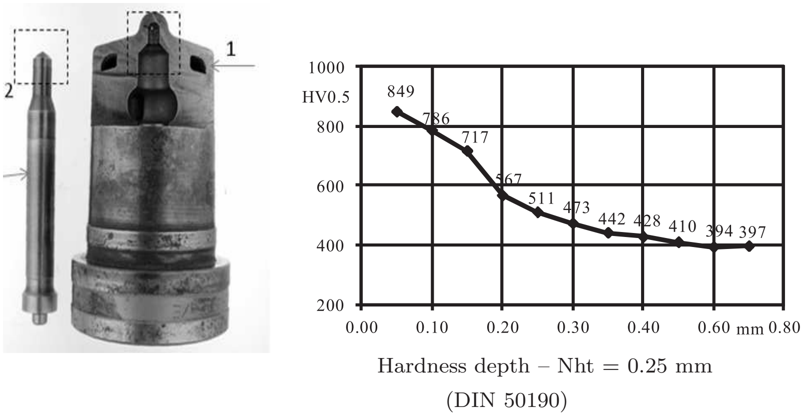


Fig. 1. Geometry of the examined atomizers; a) atomizer cross-section, b) conical tribological pair of a new or repaired atomizer.



Hardness distribution	
[mm]	HV0.5
0.05	849
0.10	786
0.15	717
0.20	567
0.25	511
0.30	473
0.35	442
0.40	428
0.50	410
0.60	394
0.70	397
core	390

Fig. 2. Hardness distribution in the nitrided layer; 1 – fuel atomizer, 2 – needle.

3. Concept of the assessment method of the conical tribological pair of marine diesel engine fuel atomizers

The measuring stand was built on the basis of the author's research and information found in the available written sources (Brüel&Kjær; PN-EN, 2002; Ranachowski, 2006; Ranachowski, Bejger, 2005; Raunmiagi, 2008; Trevor, 2000). The stand is equipped with devices enabling an analysis of the acoustic emission signals generated by the examined tribological pair of the atomizer.

Measurements at the stand were performed as follows (Fig. 3): weight (*1*) with a mass $m = 0.5$ kg was moving affected by gravitational force in a special guide from a height H, the same for all measurements, towards the needle surface (*3*). The needle transferred its pulse energy onto the conical surface of the needle-seat contacting the surface of the atomizer (Fig. 1b). As the internal energy in the form of an elastic wave was released on the external surface of the atomizer, the piezoelectric transducer (*7*) of 4371 V type from B&K transformed the impact pulse into an electric signal (Brüel&Kjær). Then the electric signal was amplified in an amplifier (*8*), and the analogue signal was digitized in a 24-bit Sound Blaster card (*9*) and recorded as a computer file. Each digital recording of the pulse measurement was processed by using the Wave Studio software from Creative Labs. The amplifier (*8*) and software for the AE analysis are standardized. They were designed by IPPT PAN in Warsaw. Their detailed description can be found in (Bejger, 2004; Malecki, Ranachowski, 1991; Ranachowski, 2008).

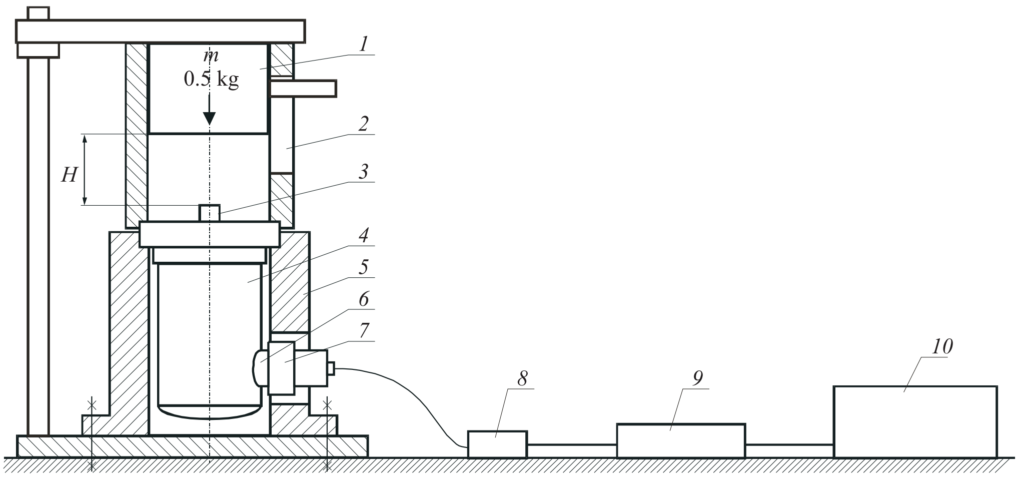


Fig. 3. The measuring stand diagram; *1* – weight, *2* – guide, *3* – atomizer needle, *4* – atomizer, *5* – tripod, *6* – profiled rod, *7* – piezoelectric transducer 4371 V, *8* – amplifier, *9* – sound card, *10* – laptop computer.

The fixing of the converter was preceded by an analysis of the atomizer design (Fig. 1), bearing in mind a slight influence of the material discontinuities (fuel and cooling channels, cooling space etc.) and the fact that the converter should be close to the examined conical pair of elements. The selected point 1 (Fig. 4a) was located in the way of the atomizer as shown in Fig. 4b.

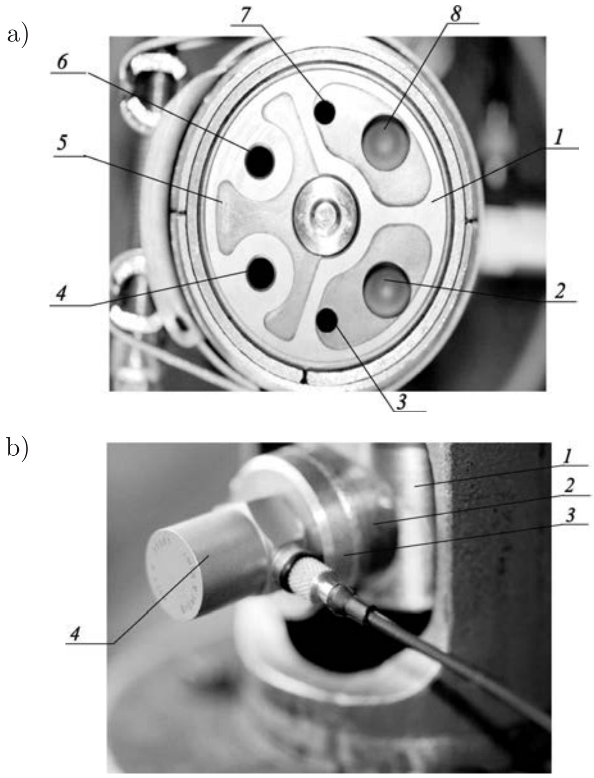


Fig. 4. The location and method of fixing the transducer: a) the view from weight top (Fig. 3): *1* – measuring position, *2* and *8* – holes for dowels, *3* and *7* – cooling channels, *4* and *6* – fuel channels; b) the place of fixing the transducer: *1* – atomizer, *2* – profiled connector, *3* – fixing magnesium, *4* – transducer (sensor).

4. Experimental results

Two groups of randomly selected atomizers were examined at the measuring stand as shown in Fig. 3. There were two atomizers in each group. Each atomizer underwent 30 measurements in two series: a) for new atomizers: $2 \times 30 \times 2$ series = 120 measurements, b) for defective atomizers: $2 \times 30 \times 2$ series = 120 measurements. Three measures of the acoustic emission signals (mean number of events, mean energy of events, mean amplitude value) were used for the analysis of the obtained results (Table 1).

Table 1. Mean values from an analysis of partial signals for various source signals.

Source signal	Measurement series	Mean number of events			Mean energy of AE events			Mean amplitude value			Remarks
		Mean value	Δ [%]	Standard deviation	Mean value [mJ]	Δ [%]	Standard deviation [mJ]	Mean value [mV]	Δ [%]	Standard deviation [mV]	
R1	I	182 (4.9%)	−22	9.0	24 076 (3.0%)	1.9	729	3072 (2.1%)	−0.0	66	new
	II	222 (5.0%)		11.2	23 620 (6.0%)		1438	3073 (6.0%)		185	
R2	I	188 (3.8%)	−6.9	7.3	20 088 (5.1%)	−21	1044	2479 (4.3%)	−32	107	new
	II	201 (3.8%)		7.7	24 342 (2.3%)		574	3289 (4.6%)		154	
R12	I	250 (5.0%)	20	12.5	17 702 (5.0%)	3.8	891	2714 (3.5%)	4.6	96	defective, worn needle
	II	199.6 (8.0%)		16	17 016 (2.9%)		502	2589 (2.5%)		67	
R15	I	254 (7.0%)	−15	17.9	20 176 (2.7%)	−5.2	553	2964 (2.0%)	−10	60	defective, natural wear
	II	292 (2.6%)		7.7	21 232 (2.3%)		490	3289 (1.9%)		62.9	

Additionally, the parameter Δ was introduced in Table 1, informing about the proportional relative error of the two measuring series.

The amplitude-time graphs of the AE signal for new atomizers are characterized by close similarity. In other words, the AE signals from new atomizers feature repeatability (Fig. 5). However, the shapes of the AE signals and their maximum amplitudes are clearly different for the faulty atomizer, as seen in Fig. 6.

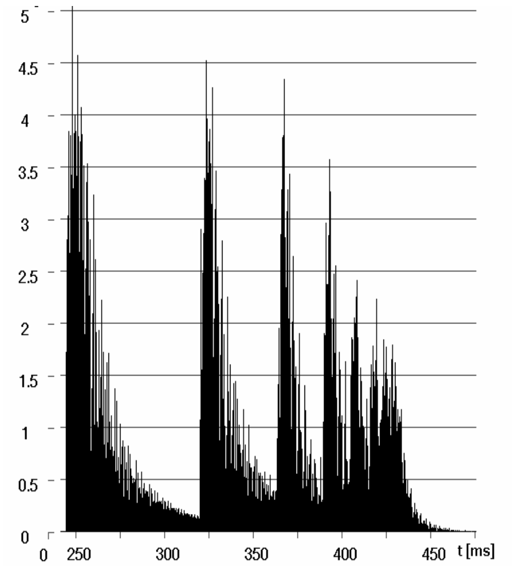


Fig. 5. The acoustic emission signal amplitude versus time for a new atomizer.

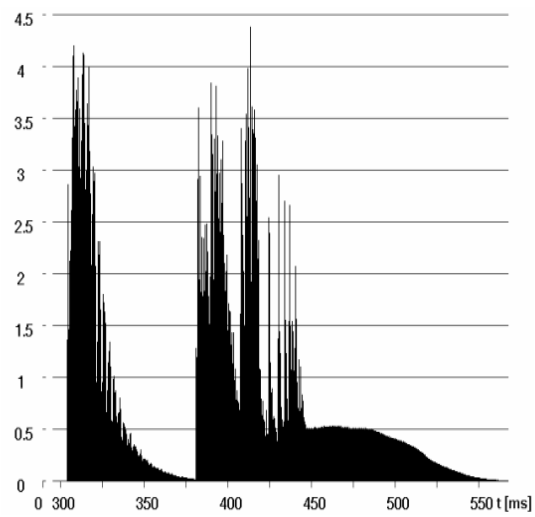


Fig. 6. The acoustic emission signal amplitude versus time for a faulty atomizer.

5. Conclusions

From the results presented in Table 1it may be concluded that:

1) all three measures of the acoustic emission signal are sensitive to the condition of the conical needle and seat of the atomizer;
2) the descriptor of the mean energy of AE events seems to be useful for classifying atomizers as operational;
3) it may be tentatively assumed that the value of the descriptor 'mean energy of AE events' for new atomizers oscillated around 23,000 plus minus 1,000;
4) the mean value of this descriptor measured for naturally worn atomizers and leaking atomizers is about 21,000 or less, varying by plus minus 1,000;
5) further tests should be done again for a larger number of atomizers;
6) it seems purposeful to change the method of fixing the transducer to minimize the influence of the material discontinuity of the atomizer body (fuel and cooling channels).

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