Artur BEJGER
Maritime University, Szczecin

THE APPLICATION OF ACOUSTIC EMISSION SIGNAL TO THE INVESTIGATION OF DIESEL ENGINE FUEL INJECTION SYSTEMS

Key words

Acoustic emission, condition monitoring, fuel injection pump, injector.

Summary

The experimental results of acoustic emission signals application to the investigation of the fuel injection system of a medium-speed marine diesel engine are presented. The introduced studies were confined to the phenomenon of the injection process. The features extracted from the raw acoustic emission signal were used to condition the monitoring of the main process of the injection system. The advantage of AE application in comparison to traditional methods is that the non-intrusive nature of the sensors can result in reduced set up times and cost.

1. The idea of acoustic emission

Acoustic emission (AE), sometimes called Stress Wave Emission (SWE) can be defined as the elastic wave generated by the release of energy internally stored in a structure. The term AE is also used to describe the detection technology associated with phenomena.

Published research has included many papers in which acoustic emission monitoring has been applied as a means of process monitoring. The broad categories that these studies fall into include the following:

- machining and tribological processes: cutting start and consistency, tool wear and breakage, friction (also in fuel injection pump and injectors);
- fluid processes: leaks in seals, pipes and vessels;
- fabrication processes: welding, bond curing;
- forming processes and others.

The technology of acoustic emission as applied to non-destructive testing is very established, and highly sophisticated AE systems are commercially available. The unique feature of AE is its ability to simultaneously monitor an entire structure (e.g., bridge, dam, pressure vessel, pipeline, aircraft, etc.), often without talking it out of service [1].

Each condition monitoring technique has its own special advantages and, not surprisingly, its distinct disadvantages. The main advantages of acoustic emission condition monitoring are the following:

It is unaffected by typical environmental noise.

It provides good trending parameters.

It is more sensitive to activity from faults than from normal running.

The disadvantages of acoustic emission condition monitoring are that it requires highly specialized sensors, equipment and signal processing.

The digital analysis of stress waves consists of computing both the amplitude and the energy content of the detected stress waves. The amplitude (or peak level) of a stress wave is a function of the intensity of a single friction or shock event. However, Stress Wave Energy can be detected and analyzed early in the failure of an injection (fuel injection pump and injectors) process [2, 3].

2. Experimental investigations of fuel injection system conditions

The object of examination was a 6 cylinder 3960 kW four stroke type SW 380 Wartsila Diesel engine (Fig. 1), operating at a constant nominal speed of 600 revolutions per minute. The engine is designed for a centrally positioned fuel injector in the cylinder head. Acoustic emission signals were recorded on the stub inlet to the injector and on the stub outlet of the fuel pump for all six cylinders of the engine.

According to the Wartsila Engine Manual, the following timing occurs for the normal operation of the fuel supply and of the valve timing of the single cylinder:

- opening of the inlet valves [degrees before TDC] – 70°,
- closing of the inlet valves [degrees after BDC] – 37°,
- opening of the exhaust valves [degrees before BDC] – 69°,
- closing of the exhaust valves [degrees after TDC] – 64°,
- injection timing [degrees before TDC] – 12°30’.

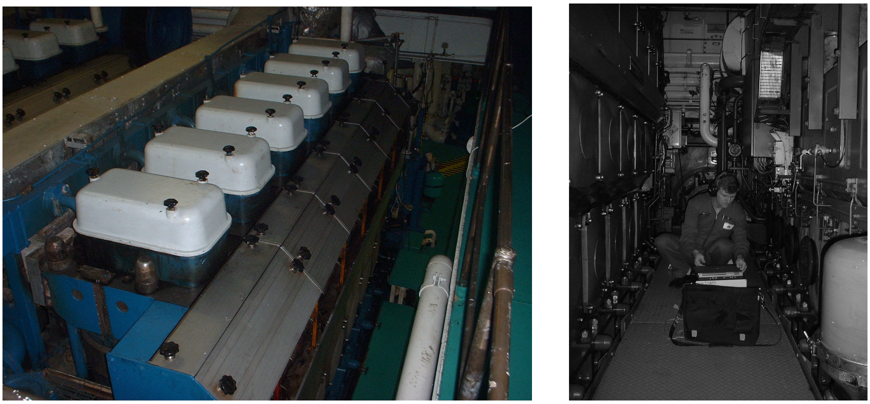

Fig. 1. The object of examination – four-stroke medium speed Wartsila SW 380 diesel engine

An acoustic emission signal AE was registered in three locations (Fig. 2): on the stub outlet of the injection pump (A) for monitoring the signals generated by the pump and on the stub inlet to the injector (B) for monitoring the signals generated by the operating injector.

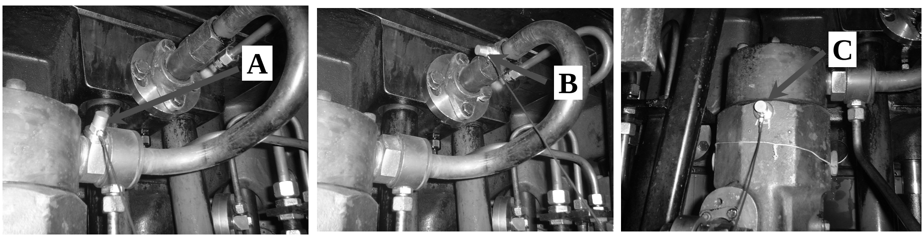

Fig. 2. Placement of the acoustic emission sensor for monitoring the signal generated by the fuel injection pump (A) and the injector (B) and the 2nd point of the fuel injection pump (C)

The results on the raw acoustic emission waveforms of the registered signals are shown in Figure 3A. Figure 3B illustrates the wavelet decomposition of AE signal measured on the stub outlet of the fuel injection pump.

Figure 4 presents the acoustic emission signal registered in location (A). In this situation, the fuel injection pump was out of trim, and the injector had insufficient fuel volume. The voltage reading is in accordance with injection pressure – the opening pressure of the injector, and the maximum injection pressure [4].

Figures 5 and 6 present the acoustic emission signal registered on the stub inlet to the injector working correctly. Two pulses are indicated from the opening (IO) and from the closing (IC) of injector. The distance between them gives us the time of the injection process.

The highest of pulses and the kind of pulses (Fig. 5 and 6) describe wear in the needle-slideway, spring, needle, and seat of the injector valve.

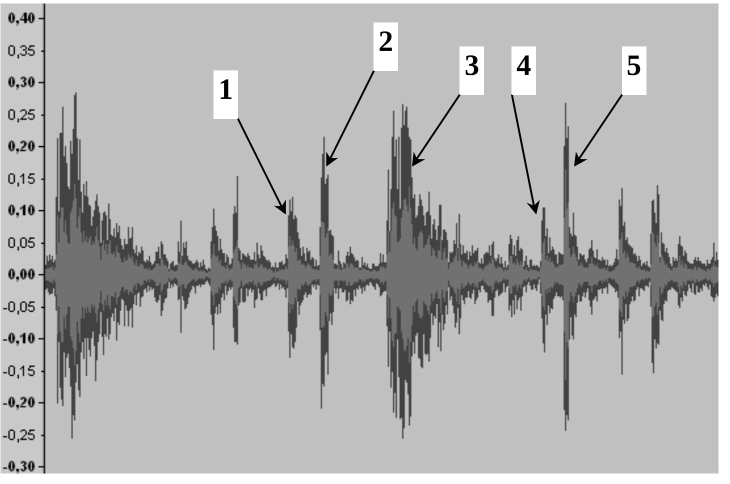

Fig. 3A. Raw acoustic emission signal with normal operation of valve timing and the injection timing: *1* – opening of the inlet valves, *2* – closing of the exhaust valve, *3* – injection process, *4* – closing of inlet valve, *5* – opening of exhaust valve

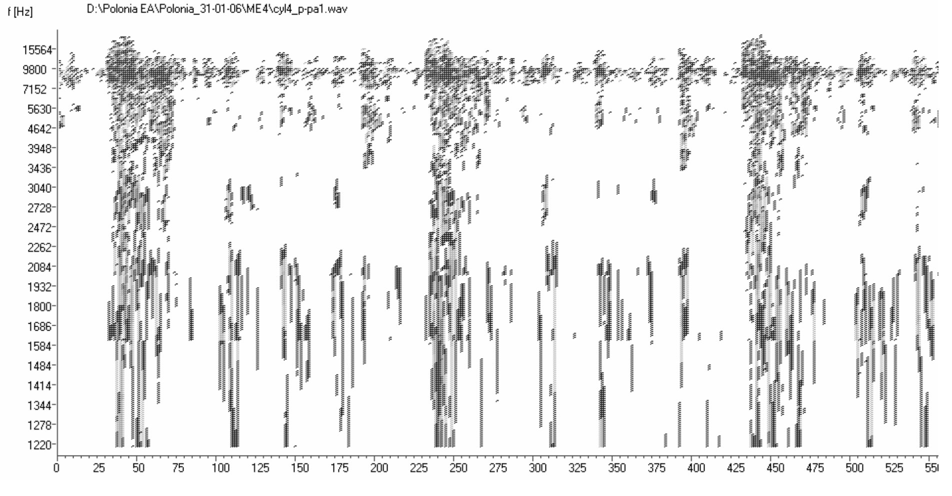

Fig. 3B. Wavelet decomposition AE signal showed in Fig. 3A [2]

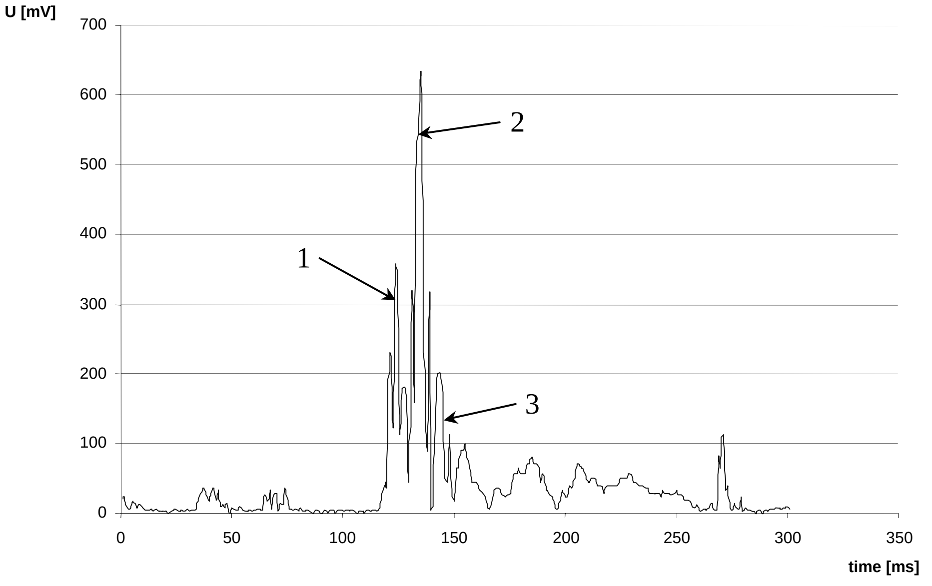

Fig. 4. Acoustic emission signal from fuel injection pump: *1* – opening pressure of injector, *2* – maximum injection pressure, *3* – closing of relief valve

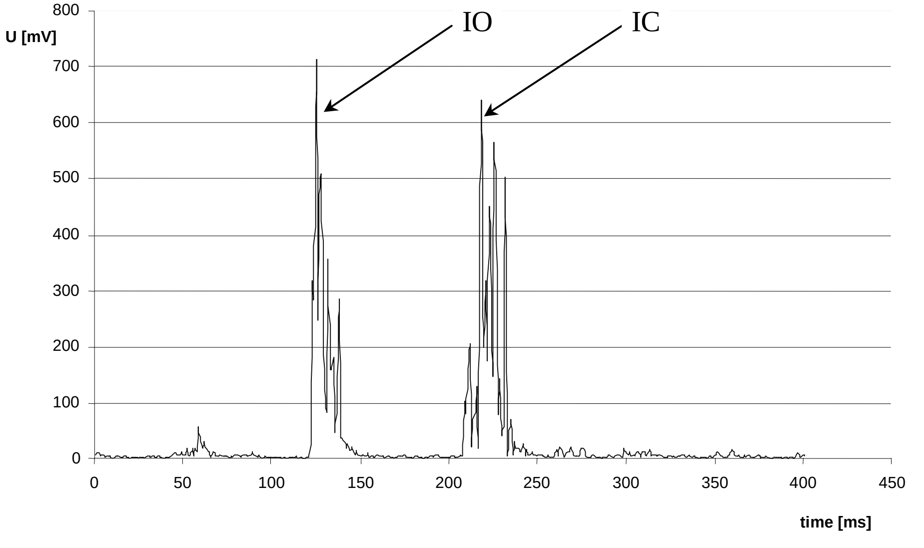

Fig. 5. Acoustic emission signal registered in the inlet to the injector: IO – injector opening, IC – injector closing

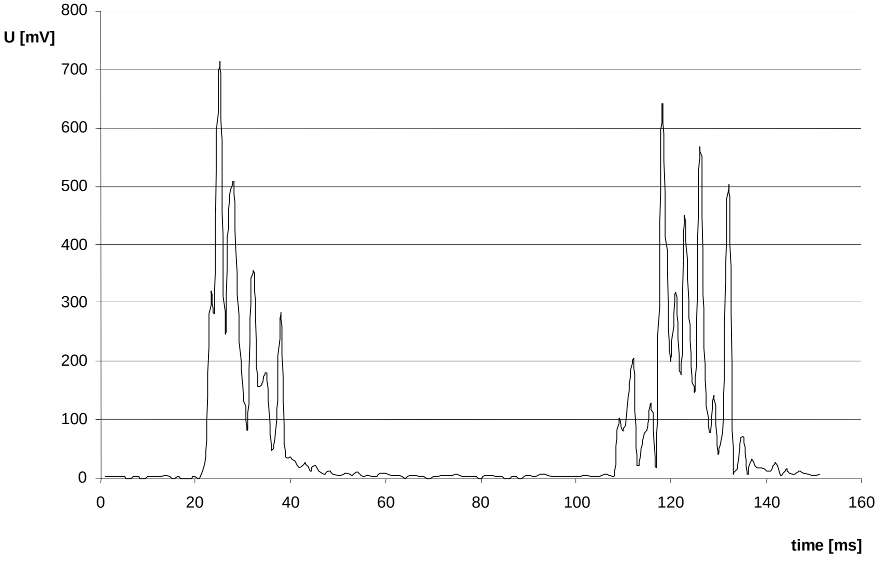

Fig. 6. The same figure as Fig. 5 but with a magnified time axis

Conclusions

The objective of this research work was the partial study of the injection process in the injection system of a medium-speed diesel engine. In this study it has been shown that there is a relationship between acoustic emission signal energy and the condition of fuel injection system.

References

1. Horloyd T. J.: Machine & Systems Condition Monitoring Series Acoustic Emission & Ultrasonics. Coxmoor Publishing Company's, Oxford 2000.
2. Ranachowski Z., Bejger A.: Application of wavelet transform for monitoring of operation of high-power Diesel engine. 35th Winter School of Wave and Quantum Acoustics, 2006.
3. Bejger A.: Zużycie i możliwość diagnozowania wybranych elementów układu wtryskowego silników okrętowych. Diagnostyka Nr 4(40), 2006, s. 47–50.
4. Ranachowski Z., Bejger A., Fault diagnostics of the fuel injection system of a medium power maritime diesel engine with application of acoustic signal, Archives of Acoustic, Vol. 30, No 4, 2005, p. 465–472.

Reviewer:
Zbigniew RANACHOWSKI

Zastosowanie sygnałów emisji akustycznej do badania układów wtryskowych silników wysokoprężnych

Słowa kluczowe

Emisja akustyczna, monitorowanie warunków, wtryskowa pompa paliwowa, wtryskiwacz.

Streszczenie

W artykule zaprezentowano fragment prowadzonych przez autora badań układów wtryskowych silników okrętowych średnich mocy. Badano zjawiska zachodzące w układzie wtryskowym z wykorzystaniem sygnałów emisji akustycznej EA (znanej w lit. ang. jako *acoustic emission lub stress wave emission*). Za pomocą „czystego sygnału źródłowego” EA można w dokładny sposób określić procesy związane z pracą układu wtryskowego oraz układu wymiany czynnika roboczego (np. otwieranie/zamykanie zaworów dolotowego i wydechowego). Analizując sygnał pochodzący z układu wtryskowego (pulsacje I zmiany sygnału EA) wnioskować można o stanie układu iglica–prowadnica wtryskiwacza, początkach zacierania się iglicy, zmianie ciśnienia podiglicowego we wtryskiwaczu, a także o niewłaściwej pracy pompy wtryskowej. Istotną zaletą stosowanej przez autora metody jest to, że podłączenie czujnika do układu odbywa się bez jakiejkolwiek ingerencji w proces.