Artur BEJGER, Jan DRZEWIENIECKI
Maritime Academy, Szczecin

APPLICATION OF ACOUSTIC EMISSION IN RESEARCH OF PHENOMENON OCCURRING IN HIGH PRESSURE FUEL OIL PIPES OF MARINE DIESEL ENGINES

Key words

Acoustic emission signal, diagnosis, marine diesel engine, injection system, injection process.

Summary

This article presents the possibilities of AE signal application in the diagnosis of the technical condition of marine diesel engines, while taking into consideration injection systems in the range of the evaluation of the repeatability of fuel injection pressure. It describes the phenomenon and characterized disturbances in the injection pipe and their influence on the AE signal changes. On the basis of results of the research, the analysis of the AE signal presenting the coarse of fuel pressure changes in the injection pipe and pump was done, and there were distinguished friction processes occurring in the precise pair of injection pump and field characterizing the flow out of fuel from injector.

Introduction

The importance of an acoustic emission (AE) signal in the estimation of machinery's technical condition has steadily increased in recent years. Research

on the tribological processes occurring in diesel engines, particularly in the piston – connecting rod set are described below (Fig. 1) [1, 2].

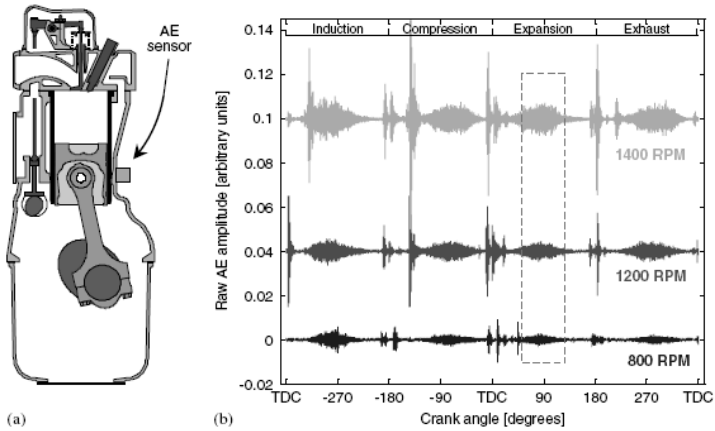

Fig. 1. Running engine: (a) cross-section showing sensor location, (b) AE against crank angle at three speeds [2]

Additionally, the influence of lubricating oil on the AE signal has been examined under different engine loads (Fig. 2).

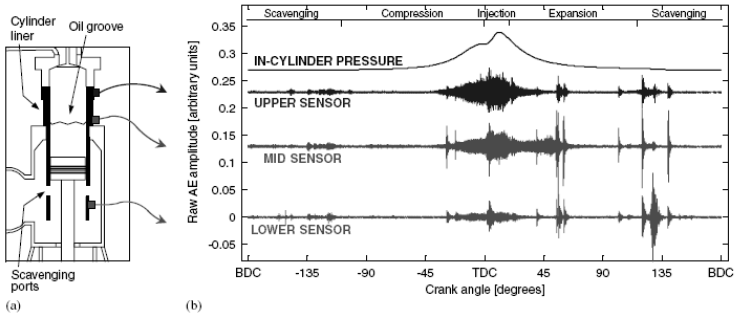

Fig. 2. Large, 2-stroke marine diesel: (a) cross-section showing sensor locations, and (b) one cycle of Raw AE at 100% MCR [2]

Acoustic emission, which is understood as spreading under the influence of the external stimulus of the elastic wave, provides the possibility to accurately evaluate the technical condition of the piston – connecting rod set.

The authors of this publication got busy studying, among other things, the problem of AE signal application in the examination of the injection apparatus condition in the range of a quick but simple evaluation method of the repeatability of fuel injection pressure changes. Changes in the maximum value of fuel pressure in the high-pressure fuel oil pipe cause the repeatability rate of fuel injection pressure increase, which results in an increase in the non-uniformity of the engine's performance.

The stimulus causing sudden energy freeing in the form of AE, in the case of injection system, are among the others, the tribological processes in the injection pump, fuel flow, the movement of the injector nozzle and others.

1. Phenomenon occurring in the high pressure fuel oil pipe of a diesel engine

The "Q" factor of the injection system, to a large extent, depends on the parameters of the pump element, the coefficient of fuel oil elasticity and the movement principles of the nozzle's needles during injector's spring operation. Shifting with a constant speed pumping element causes the trapezoidal shape of the fuel oil pressing coarse [4].

The coarse of injection changes is not compatible with the coarse of fuel injection, because flow processes in the injection pump are not continuous and liquefies under high pressure, which are compressible in a certain state of vibration. During the closing of inlet nozzle by passing of the piston, hydraulic impacts are created influencing the whole system that can be observed by means of AE. The AE signal in injection pipes is a result of changes in the fuel oil volume accumulated between the injection pump and the fuel injector, corresponding to pressure changes in the injection pipe. It depends on the mass and elasticity of the accumulated fuel. This process generates a pressure wave itself, proceeding in the fuel injectors' direction with a velocity 4.5 times higher than the acoustic velocity in the air [4]. In classical injection systems, there is a problem that is very difficult to overcome of an uncontrolled hydraulic phenomenon influencing the injection angles, created by mass forces and occurring in a set fuel injection pump – high pressure pipe – injector. They develop various reactions depending on the temporary condition of the fuel injector. When the injector is opened, then the amount of the fuel flowing out will be larger than the amount of fuel flowing in. There is then the creation of a "realizing wave" running in the injection pump direction, which can lead to the creation of bubbles in the injection pipes. When the injector is closed, then the wave is running in the opposite direction from the injector that can cause the returning and piling up of fuel in pipes. This leads to an increase in the average pressure and indirectly influences the changes in the AE signal. As the camshaft revolutions are increasing, the fuel flowing out is increasing as well, and along with it, throttling in the nozzle.

In this connection, increasing pressure can exist in the value of the opening pressure of the pressure valve, which can appear as an overlapping phenomenon of the flow of fuel out of the delivery nozzle with the flow of fuel through the forcing nozzle. The physical-chemical features of the fuel influence the injector's working condition and the combustion process parameters as well. These features, in case of marine engine diagnosis, with "controlled" and changing dependence on the working regularity of the control systems of fuel viscosity, have important meaning. Low fuel viscosity causes weak penetration of this stream in the combustion chamber which is giving, in consequence, a drop in the engine's power and leaks in the injection pump. Too high of fuel density gives larger fuel droplets in the injection process, which can be collected on the combustion chamber walls.

There is lack of relatively cheap and reliable diagnostic systems to control both the combustion and injection processes. Existing systems (for example CoCoS, Doctor, CYLDET, NK-100 etc.) are individually adapted to a particular engine. In a typical application, a pressure sensor mounted in the injection system is used and sold together with specially designed high-pressure pipe. Such a solution significantly increases the cost of the system that creates a financial barrier for the most of ship owners.

2. Results of research

There were series of studies carried out on chosen small and medium powered marine diesel engines. As it turned out, changes in the AE signals are independent of the engine's load and only depend on the type and technical condition of the injection system. The value of the generated voltage in the AE sensor depends on changes in the pressures prevailing in the injection pipe.

In the fuel volume located in the injection pipe between the delivery connector of the injection pump and inlet to the injector, there are disturbances created by:

- fuel pumping by the pump's piston (plunger);
- various piston speeds of the pumping element;
- throttling of fuel flow in passage of the nozzles of the pumping element and the delivery valve (relieving);
- changes of flow sections in the injector; and
- movement of needle in injector nozzle.

The previously mentioned processes are "visible" in the form of the AE signal changes (Fig. 3, location of the AE sensors are presented on Fig. 4).

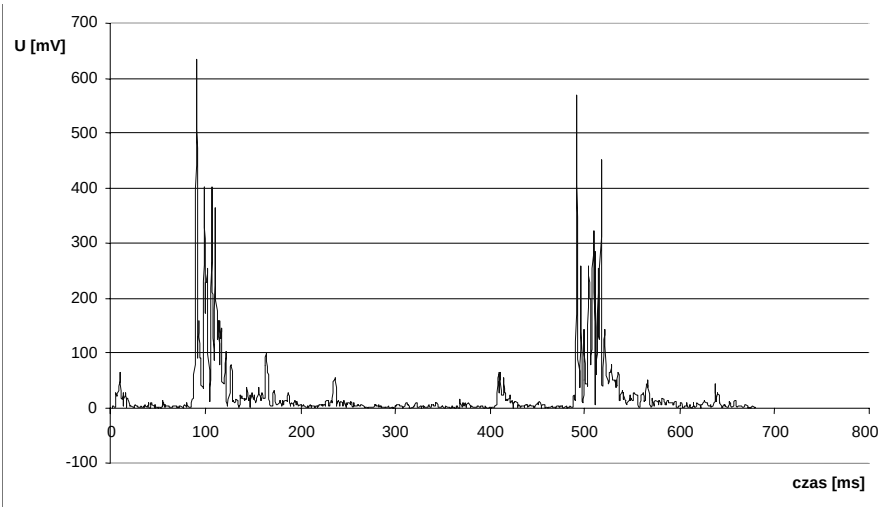

Fig. 3. AE signal in injection pipe (from injection pump side – fig. 4 point A) for two subsequent courses of fuel injection

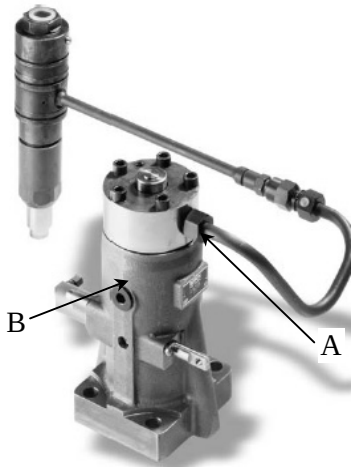

Fig. 4. Location of AE sensors mounting

There is a visible repeating of the courses of fuel injection pressure changes, even without precise analysis. Fig. 5 presents the AE signal directly connected with the work of the injection pump (sensor B Fig. 4) with visible opening pressure of the injector (value of voltage in sensor), maximum injection pressure and the work of the delivery valve (relieving). By means of signal analysis methods, in a very accurate way, there is the possibility to distinguish

friction processes occurring in the precise pair of the injection pump and the characteristic field flow out of fuel from the injector [3].

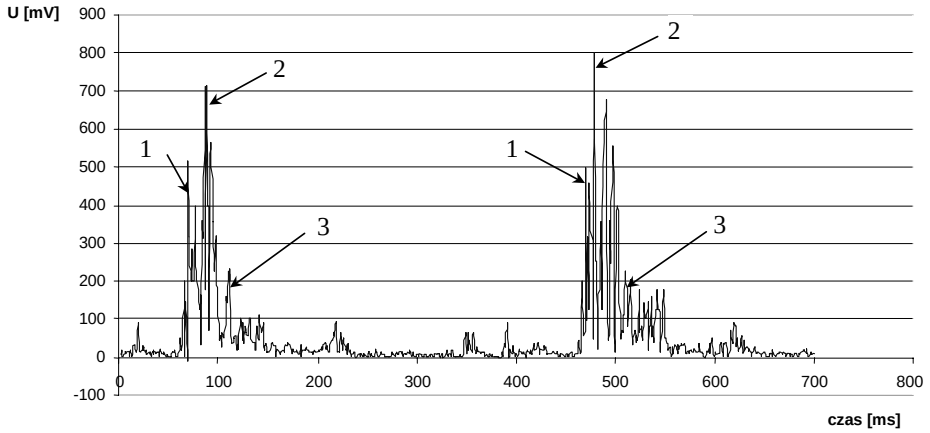

Fig. 5. AE signal presenting the phenomenon in the injection pump of Wartsilla SW 380 engine – sensor located in point B, Fig. 4 (there are visible characteristic magnitudes connected with injector's opening pressure – 1, maximum pressure of injection process – 2 and work/ closing of delivery valve – 3)

Conclusion

The results of the research and their analysis have proved the possibility of the utilization of the AE signal to diagnosis the fuel injection systems in marine diesel engines. Courses of pressure changes in the injection pipe include information about the characteristic phenomenon occurring in the injection pump and proving their usefulness to the evaluation of the repeatability of fuel injection pressure changes. Application of suitable signal analysis tools enables the selection of disturbances occurring during fuel flow from the injection pump to the injector and enables their evaluation from the point of view of the technical condition changes in injection system.

References

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Reviewer:
Zbigniew RANACHOWSKI

Zastosowanie emisji akustycznej w badaniach zjawisk zachodzących w przewodzie wtryskowym paliwa okrętowego silnika spalinowego

Słowa kluczowe

Sygnał emisji akustycznej, diagnoza, silnik okrętowy, system wtryskowy, proces wtrysku.

Streszczenie

W niniejszym artykule przedstawiono możliwości zastosowania sygnałów emisji akustycznej do diagnozowania stanu technicznego okrętowych silników spalinowych, ze szczególnym uwzględnieniem układów wtryskowych w zakresie oceny powtarzalności ciśnienia wtrysku paliwa. Omówione zostały zjawiska i scharakteryzowano zakłócenia zachodzące w przewodzie wtryskowym i ich wpływ na zmiany sygnału EA. W oparciu o wyniki badań dokonano analizy sygnału EA przedstawiającego przebieg zmian ciśnienia paliwa w przewodzie i pompie wtryskowej oraz wyróżniono procesy tarciowe zachodzące w parze precyzyjnej pompy wtryskowej i obszar charakteryzujący wypływ paliwa z wtryskiwacza.