ISSN: 1231-4005
e-ISSN: 23540133
DOI: 10.5604/01.3001.0010.3061

RESEARCH INJECTION PRESSURE WITH THE KISTLER 4067E PRESSURE TRANSMITTER ON SULZER ENGINE 3AL25/30

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Abstract

Commonly used in the shipbuilding are combustion piston diesel engines that serve as power generators and main propulsion engines. More stringent of environmental regulations, however, require a more detailed understanding of the processes involved in piston engine combustion to reduce emissions to the environment. Also, the main reason for interest in research in the injection system is also the desire to obtain the highest piston engine power at the lowest fuel consumption. The article presents a study of changes in fuel injection pressure, which allows the operator to analyse the thermodynamic processes taking place in the cylinder. The injection pressure measurement allows you to make proper operating, maintenance and even repair decisions on the object under test. The purpose of this article is to investigate the operation of the injection pressure sensor and to compare the pressure curves measured by the Kistler 4067E sensor in various piston engine-operating states and the simulated failures of the SULZER 3AL25/30 diesel engine. The study was conducted on the SULZER 3AL25/30 engine at the Marine Engine Laboratory at the Gdynia Maritime University. Tests carried out with a measuring instrument for sampling are equipped with a Kistler 4067E pressure transducer, a Kistler 4624A amplifier and a Unitest 2008 computer system serviced with a recorder, processing and signal recording. For a thorough analysis, research conducted at different loads and different simulated engine failure.

Keywords: *diesel, engine, marine engine, injection pressure*

1. Introduction

Currently used marine engines are the most common internal combustion piston engines. Among them are mainly two-stroke or four-stroke diesel engines. For many years, attention has been paid to the very accurate measurement of cylinder pressure. Pressure measurements are performed not only to know the value of the parameter at a given time or in a given process, but also to know the course of pressure changes. Knowledge of these changes allows the operator to analyse the thermodynamic processes taking place in a given cylinder, and consequently make proper operational decisions, including maintenance and even repairs. Measurement and analysis of pressure

In the cylinder is a difficult process. This is due to the fact that during the measurement the engine should work under steady conditions, that is, at constant rotational speeds and under constant load, which in the sea conditions may be difficult. Changing the load by, for example, waving the water surrounding the ship's hull or changing the course of the ship may cause differences in measurements.

The current economic and ecological requirements regulated by international regulations determine the ship operators (ship owners, inspectors, crew) to introduce measures to maximize the power of piston engines with the lowest fuel consumption. This applies to main propulsion engines and generators engines. For the piston engine to work in areas of highest efficiency, it is essential to maintain the injection system in the best possible technical condition. This means that the fuel dose supplied to the combustion chamber should be given in a suitable form. The injected fuel stream should be adequately sprayed, crushed (the shape of the stream and the quality of the crushing of the individual drops is important). Also important are the time at which fuel is delivered to the cylinder, start and end of the injection with respect to the angle of rotation of the crankshaft. The above-mentioned parameters are significantly influenced by the technical condition of pairs of precision injection pumps and injectors. Therefore, the fuel injection pressure measurements are performed.

2. The purpose of the research

The purpose of this study is to investigate the operation of the injection pressure sensor and to compare the pressure curves measured with this sensor made in different operating states of the piston engine. The tests were carried out for the following internal combustion engine loads: 0 kW, 50 kW, 100 kW, 150 kW, 220 kW.

Research position

The research facility was a generator set (Fig. 1). The team consists of three-cylinder, mid-speed SULZER 3AL25/30 direct injection engine and generator GD8-500-50 located at the Marine Engine Laboratory at the Gdynia Maritime Academy. The generator produces electricity to the knife resistor. The engine is supercharged and features a VTR 160 Brown-Boveri turbocharger with air cooler. Characteristic data of the generator are presented in the table below (Tab. 1).

Fig. 1. Photo of the piston engine SULZER 3AL25/30

Kistler 4067E piezoresistive pressure sensor

Piezoresistors are built of a series of compressed silicon wafers through which the current flows with the given electrical parameters. The resistance of this circuit is investigated, which varies due to changes in deformation of the plates. Plates like piezoelectric transducers are compressed by pressure force indirectly through the diaphragm.

It is suitable for measuring static and dynamic pressure. The piezoresistive element on the measuring medium side is covered with a robust membrane. Fig. 2 shows the general view of the Kistler 4067E.

The transmitter is connected to the Kistler 4624A signal amplifier (Fig. 3), which supplies the sensor and transmits the processed signal to the computer.

Tab. 1. Parameters of the test stand

ENGINE		
diameter of the piston	250	[mm]
stroke of the piston	300	[mm]
nominal power	408	[kW]
average effective pressure	1.5	[MPa]
injector opening pressure	25	[MPa]
nominal rotational speed	750	[RPM]
number of cylinders	3	[–]
SYNCHRONOUS GENERATOR		
power	50	[kVA]
rotation speed	750	[RPM]
tension	400	[V]
electricity	723	[A]
frequency	50	[Hz]

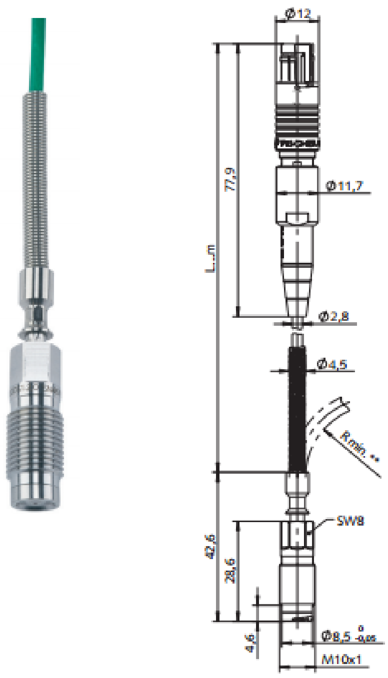

Fig. 2. General view of the KISTLER 4067E pressure transmitter

Fig. 3. Signal amplifier Kistler 4624A

Installation of pressure transducer

The sensor can be mounted directly in the mounting hole (Fig. 4) or by means of clamping adapters (Fig. 5) when the wall thickness of the cable is too small. Adapters are available for different diameters of injection wires. To ensure sealing, the sealing surface must be clean and free of metal particles.

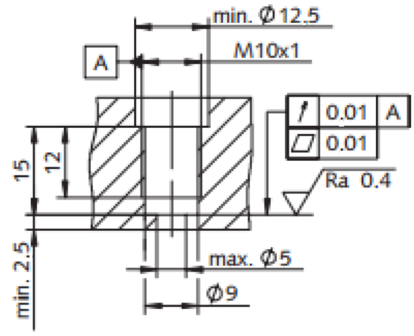

Fig. 4. How to make a hole fixing the transducer directly on the high-pressure conduit

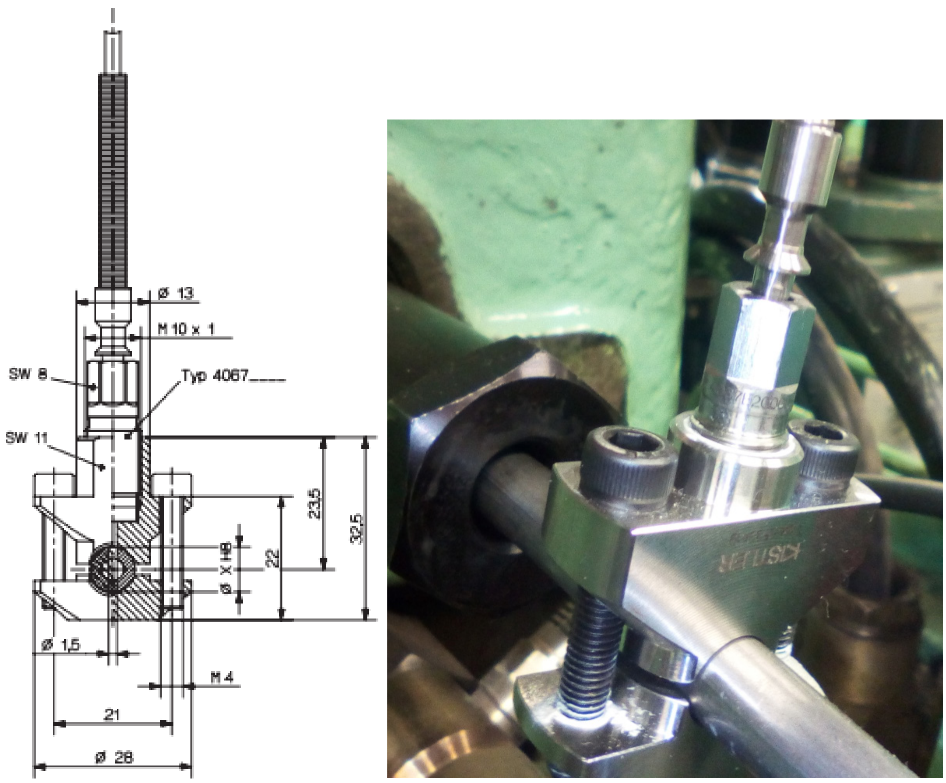

Fig. 5. Mounting the pressure sensor with the adapter

Monitoring system

Data transmission from the injection pressure transducers to the computer consisted of starting the measurement process in the operating window of the computer program. After starting the measurement, the system took data from 16 cycles (one cycle = 720º crankshaft rotation) at 0.5º WOK (Crankshaft rotation). Unitest 2008 then averaged the data and presented it in the form of graphs (Fig. 6), while simultaneously marking the upper dead centre of the piston position of the individual cylinders. The entire process of performing one measurement and processing the results in graphical form did not last more than a dozen seconds.

Figure 6 illustrates the test results for cylinders 1, 2 and 3 as developed graphs and pressure change graphs for the injection system as a function of the crankshaft rotation stage for leakage simulation on cylinder injection pump 2 at 220 kW load.

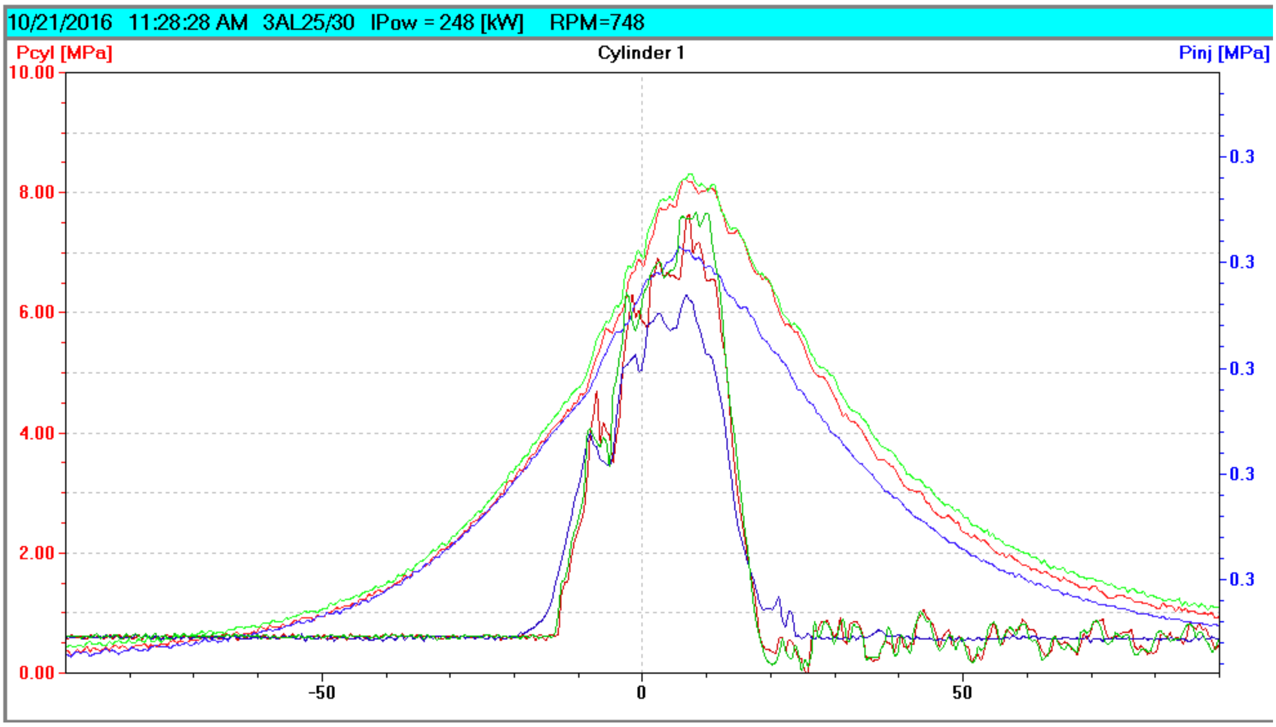

Fig. 6. Graphical representation of fuel injection pressure and combustion chamber pressure for simulated leakage failure on an injection pump at a specified load of 220 kW

3. Measurement results and analysis

The test conditions were identical for all measurements, so the measurements were not influenced by external factors. In the Fig. 7 shows the waveforms combustion pressures of the various fuel nozzles mounted at the ends of the load 220 kW.

The charts are marked:

– P_{imax} [MPa] – maximum fuel injection pressure,
– P_i [MPa] – injection pressure,
– CA [°] – angle of rotation of the crankshaft.

Measurements on individual cylinders for the engine (Fig. 7) without simulated malfunction showed similar values for the maximum fuel injection pressure and the crankshaft angle when the maximum injection pressure for the three cylinders was reached. In the cylinder 2 injection simulation, the lower fuel injection pressure can be seen in the cylinder.

For the engine without simulated malfunction (Fig. 8), it can be seen that the injection pressure curves of individual cylinders do not overlap. This may not be so much of a transducer measurement error as the piston engine's injection system has been unregulated.

Comparing fuel pressure injection graphs of cylinder number two (Fig. 9 and 10) for simulated failures in a calibration graph, it can be seen that the acceleration ramp rate for a motor without simulated malfunction is always the greatest. At the same time, the smallest pressure build-up velocity is in the simulation of leaks on the injection pump. In this case, we also observe the lowest values of the maximum fuel injection pressure.

The most divergent measurement results were obtained during the simulation of leaks on the second cylinder injection pump. The occurrence of this kind of failure causes less fuel to enter the injector and into the cylinder. This results in lower injection pressure (Fig. 11). This situation causes a decrease in the indicated capacity in cylinder number two. Since the rotary speed controller must maintain a constant rotational speed of the generator set, it increases the fuel dose by means of a fuel bar.

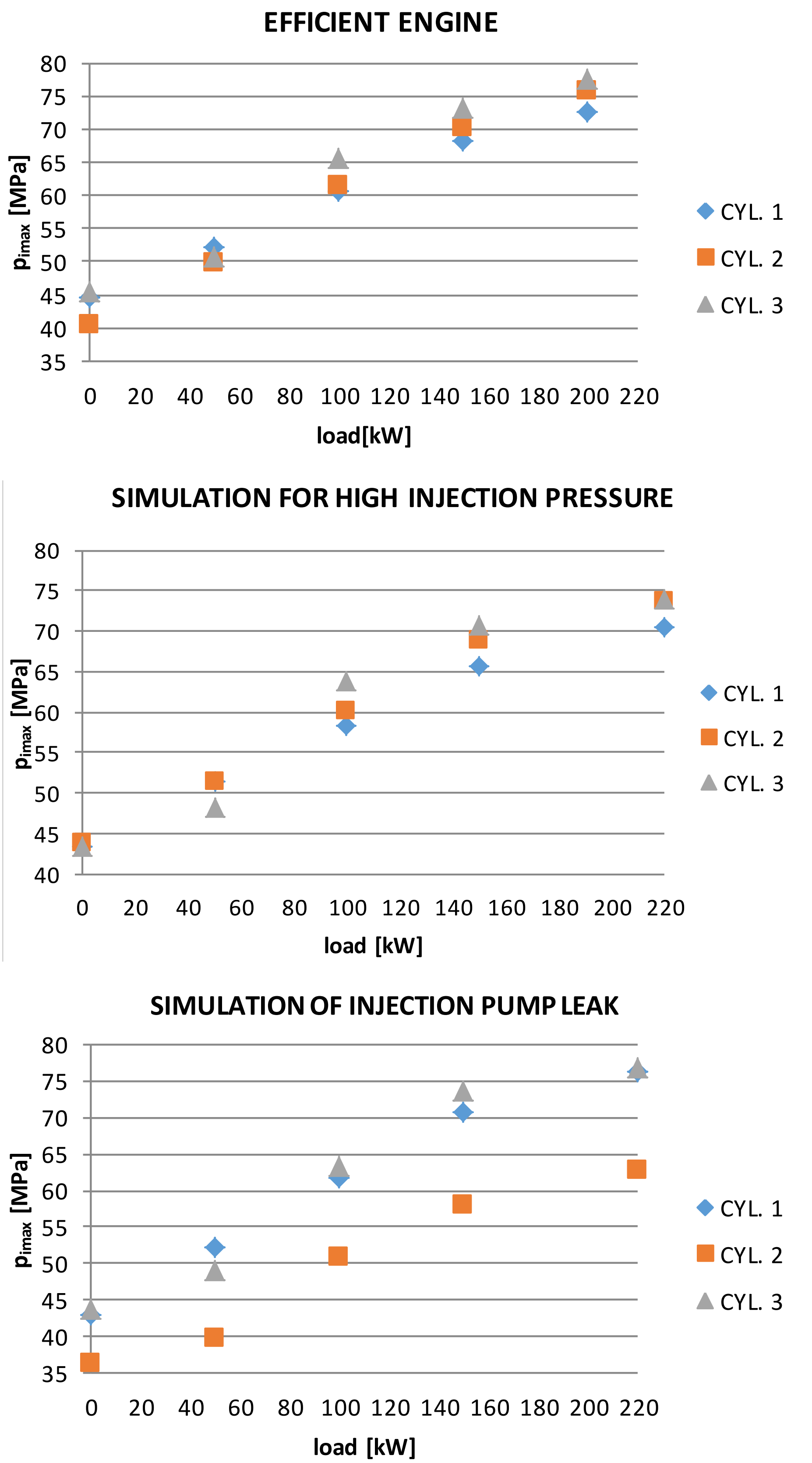

Fig. 7. The injection pressure sequence as a function of the load for the three cylinders

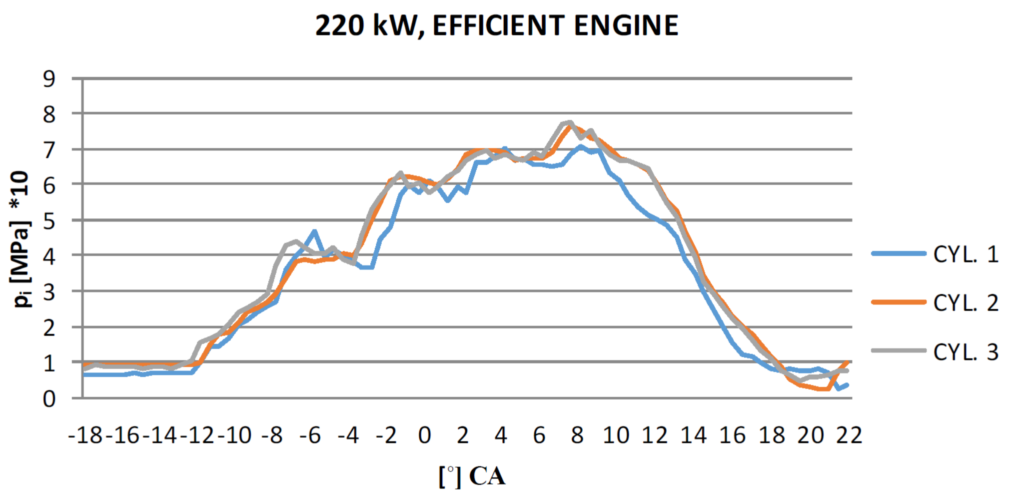

Fig. 8. Course of injection pressure curves at a given 220 kV load and standard engine operation

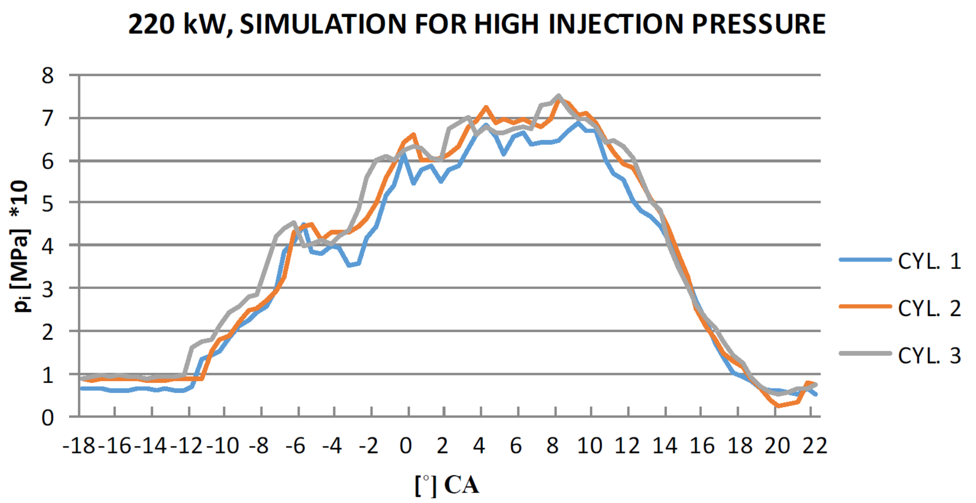

Fig. 9. Course of injection pressure curves at a specified load of 220 kW and simulated injector failure on cylinder number two

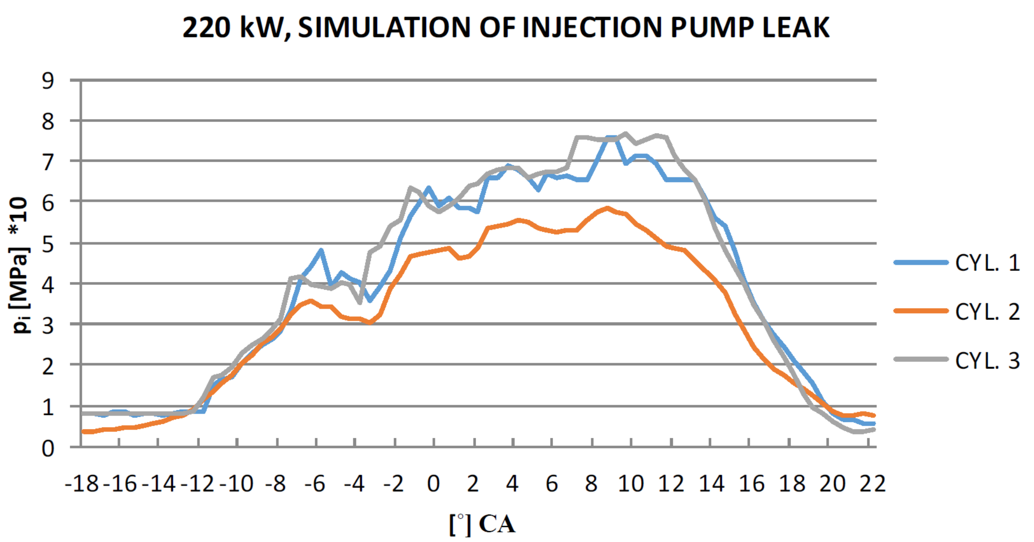

Fig. 10. Course of injection pressure curves at a specified load of 220 kW and simulated leakage failure on injection pump on cylinder number two

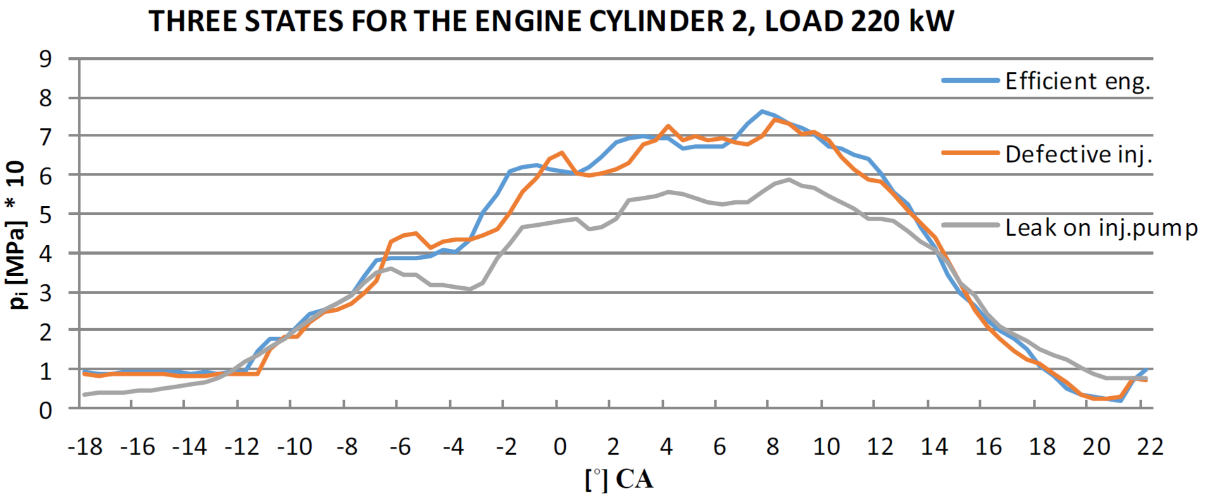

Fig. 11. Fuel injection pressure at 220 kW for cylinder number two. Comparison of effective engine injection pressure waveforms, leakage simulation on injection pump and simulation of faulty injector

4. Conclusion

The study led to the following conclusions:

– measurements on individual cylinders for the engine without simulating malfunctions showed similar values for the maximum fuel injection pressure and the crankshaft angle when the maximum injection pressure for the three cylinders was reached,
– the injection pressure is a unique process. No attempt was made to verify the repeatability of the measuring equipment during laboratory tests,
– the ability to measure fuel injection pressure is a valuable diagnostic indicator for the injection system, especially injection pumps. Under operating conditions, it is still very rare for conventional injection systems,
– if we assume theoretically that, regardless of the mechanical and thermal load of the engine, the injector opening pressure is 25 [MPa], the start and stop angle of the fuel injection can be determined by measuring the fuel injection pressure. The value of the crankshaft rotation angle for the fuel injection start is an important diagnostic parameter, as determined by the engine manufacturer 3AL25/30 at 8° CA before the upper dead position of the piston.

The measuring instrument fulfils its task because it measures the injection pressure. In addition, through its compatibility, it can work with any computer program, so that the measurement results can be presented in any form.

References

[1] Ciesielski, S., *Okrętowe tłokowe silniki spalinowe, Procesy wewnętrzne*, Akademia Marynarki Wojennej, Gdynia 2007.
[2] Jędrzejowski, J., *Obliczanie tłokowego silnika spalinowego*, WNT, Warszawa 1971.
[3] Kasedorf, J., *Zasilanie wtryskowe olejem napędowym*, WKiŁ, Warszawa 1990.
[4] Hendricks, E., *Engine Modelling for Control Applications: A Critical Survey,* Meccanica, 32, Kluwer Academic Publishers, Netherlands 1997.
[5] Wu, H., *Performance simulation and control design for diesel engine NOx emission reduction technologies*, University of Illinois, Urbana, Illinois 2011.
[6] Szpica, D., Czaban, J., *Stanowisko do badań wtryskiwaczy paliwa benzynowego układu zasilania*, Acta Mechanica et Automatica, Vol. 3, No. 1, 2009.
[7] Myszkowski, S., *Diagnostyka i czyszczenie wtryskiwaczy benzyny, Kompendium praktycznej wiedzy*, Dodatek techniczny do Wiadomości Inter Cars SA, Nr 37, Grudzień 2010.