

# POSSIBILITY OF USING VISUALIZATION TO PRESENT RUNNING POINT OF MARINE DIESEL ENGINE IN SHIPS OPERATION

**Jacek Krzyżanowski, Kazimierz Witkowski**

*Gdynia Maritime University, Mechanical Faculty  
Morska Street 83, 81-225 Gdynia  
tel.: +48 81 6901332  
e-mail: wika@am.gdynia.pl*

## **Abstract**

*The following paper introduces us to possibility of using visualization to present running point of main marine diesel engine during ship operation. Construction development of ship marine diesel engine going towards more and more power results in large mechanical and thermal load. So ship marine diesel engines of new generation are more susceptible to damage caused by overloading than the ones of older generation. For this reason more and more attention is paid to proper operation of these main marine engines understood as the way of choosing the right parameters resulting in adequate point of engine operation. This kind of exploitation is being reflected in more and more rigorous requirements imposed by ship engine producers concerning the conditions of their exploitation. This paper presents measured parameters during engine operation and of the sometime confirming its current performance. Special attention has been paid to the measurement of torque. Measurement of torque and revolution speed of the main marine diesel engine have been linked with the possibility of visual presentation of running point of the engine. By means of research carried out of HCP Engine Test Bed it was possible to prove effectiveness of succession of measurement instruments and torque meter action. Visualization algorithm which can be used to present field of work and running point of the engine has also been tested.*

**Keywords:** *monitoring, marine diesel engine, torque, field of work engine*

## **1. Introduction**

Vessel piston engines, owing to their complex construction, high level of thermal and mechanical loads, specific conditions of operation, impact of aggressive products of combustion of residual fuels, and many other factors, are exposed to various kinds of damages and breakdowns.

Thus, their contemporary operation requires introduction of more and more extensive computer-supported control-measurement systems that will allow relevant operation of the monitoring and diagnostic process. This can bring important measurable and immeasurable benefits. The monitoring systems of piston marine engines are currently more broadly used. Unfortunately, the torque measurement aspect of these systems is used relatively rarely. The continuous control of the cooperation of an engine with its propeller by using torque action measurement will allow you to avoid the hazardous conditions of an engine overload, which can lead to breakdown.

Removal of emergency damages normally requires shipyard repairs, and removes the vessel from operation for longer periods, which results in substantial financial losses for the shipowner.

## **2. Piston marine engine as an operation watercraft**

A marine engine is certainly a technically complex object. The statistical data concerning occurrence of certain damages and their potential negative impact on the course of the working processes indicates the usefulness of implementation of modern systems of monitoring and diagnosis of marine engines.

Currently, monitoring and diagnosis of marine engines is mainly based on measurements and analysis of a number of selected operating parameters, whose available set of data is often insufficient.

During an engine operation, two kinds of output processes are generated that should be used as diagnostic signals:

- useful data directly associated with the execution of the working processes. The parameters, among other things, are: torque ( $M_o$ ), crankshaft speed ( $n$ ), power ( $N$ ), combustion process parameters, compression pressure, fuel consumption etc.,
- residual data which are generated as secondary effects of the working processes, for example: vibrations and noise, or the quantity and composition of the waste gas.

The parameters that simultaneously meet the following criteria should be used for monitoring and diagnosis:

- information values, namely quantity of information on the technical condition of an engine that is contained in a given parameter,
- degree of damage location that is possibly strictly connected with one specific structural parameter,
- availability and ease of measurement.

Very often, in the selection of a given parameter, what is most decisive is the criterion of availability and ease of measurement, and less are the two previously listed. There are, however, examples of parameters with high importance in monitoring and diagnostics that are relatively easy to measure, but nevertheless are not commonly used. For example, still in the operation conditions of power plant, one uses torque measurement only incidentally. Its measurement would allow specification of the engine load condition on the current basis. This is very important, because each vessel engine is designed for strictly defined operation parameters, including:

- rotational speed of crankshaft ( $n$ ),
- torque ( $M_o$ ),
- power ( $N$ ).

The scope of these parameters determines the engine's power possibilities, and the values of the aforementioned parameters stated by the manufacturer are called fixed, which means that an engine may work safely without any time constraints. While exceeding these parameters may lead to engine overload and may result in occurrence of hazardous, so-called sudden (overload) damage [1]. This is also counted among the damages arising for operational reasons, as its occurrence resulted from the deviation from the principles of operation, by triggering excessive loads [1].

Operating an engine at insufficient use of any of these parameters, any pair of them or all three at once is also possible. It's called engine operation at partial loads. Engine overload does not occur now, but often this mode of operation is not favourable, as it proceeds at low engine effective efficiency. The operating parameters are thus far from optimum. Reduction in the values of  $n$ ,  $M_o$  and  $N$  below threshold – below  $n_{min}$ ,  $M_{min}$  and  $N_{min}$ , may lead to unstable operation and automatic engine stoppage.

The fixed torque measurement is based on the obtained values, visualization of the running point of the engine. In the field, engine operation should allow the operator to make proper decisions in time, concerning engine operational settings and preventing overload.

In three-dimensional space described by  $n$ ,  $M_o$ ,  $N$ , there are some areas in which the engine:

- will operate in a stable fashion,
- will not be subjected to overloads,
- the course of working processes will be consistent with the manufacturer's guidelines.

### **3. The vessel engine piston field of operation**

There is a close connection between the rotational speed of a crankshaft, torque, and the power:

$$N = f(M_o, \omega), \quad n = f(\omega) \Rightarrow N = f(M_o, n). \quad (1)$$

As a result of that, the field of the vessel's engine operation is generally presented on a plane, most often in a coordinate system  $N = f(n)$ . This coordinate system is considered by the authors as the most useful in operational practice for a power plant.

A general example of the vessel's engine operation field is presented in Fig. 1 [2]. Shown here is the existing acceptable field of operation, taking into account the restrictions requested by the engine itself, as well as the propeller cooperating with it. From the side of rotational speed, the field is limited by regulator curves – nominal or overload  $r'$  as well as  $n_{min}$ , and from the side of torque, the field is limited by external characteristics –  $h_{e1}$  or  $h_z$ . The left side of the graph is limited, apart from  $n_{min}$ , also by: propeller characteristics of captive operation ( $k_u$ ), and pumping characteristics ( $p$ ).

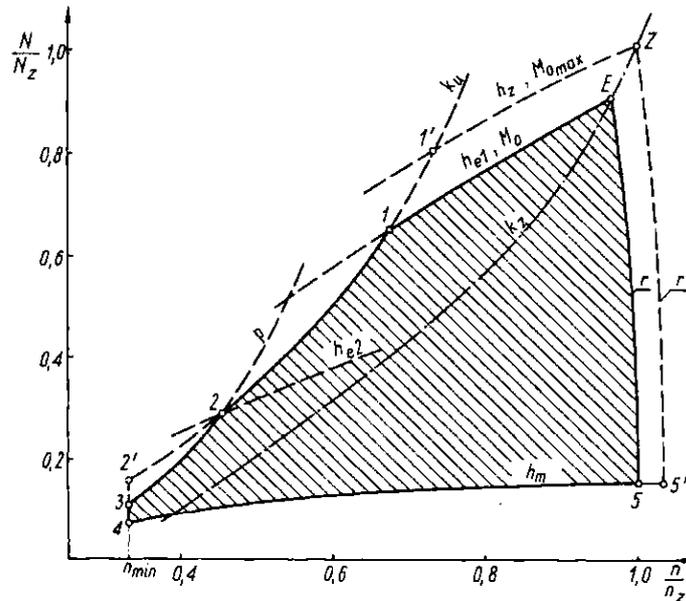


Fig. 1. An example of marine diesel engine field: Z-running point at nominal condition; E- running point at exploitation condition

Figure 2 shows a fragment of the operation field of low-speed, two-stroke vessel engines, type MC/MCE, of MAN [3], in the form typical for this manufacturer. The area presented in this figure shows the possible scope of engine operation regarding "upper" values of power and rotational speeds ( $N = 70$  (110% and  $n = 80$  (105%). The chart has been made in a logarithmic coordinate system, thanks to that, all the characteristics are straight lines. Point A in the chart is a construction point of an engine, marked as MCR (Maximum Continuous Rating), corresponding to the maximum fixed power.

Special attention should be paid to the course of curve 4 that is the line of a border coefficient of air excess, namely the border of smoking. This restricting curve results from deficiency of air as the engine partial loads and is particularly characteristic for highly loaded engines, those presently produced. At air deficiency, heavy non-combusted hydrocarbons are being generated in flue gas, visible as smoke, being therefore solid particles, which are particularly hazardous for human health. As a result of implementation of non-full, incomplete combustion, the engine efficiency worsens. The quantity of the deposits of non-combusted fuel particles increases in the engine combustion chamber, on valves, as well as on combustion ducts. The operation of an engine over this border line is possible, but with the abovementioned effects.

The chart shown in Fig. 2 is not proper for direct use in operational practice. This is determined by, first of all, its limited range (limited to "the right upper corner" of the operation field), but also the adopted logarithmic scale of the coordinate axis. For visualization of operation field, and the current running point of the engine in it, one should assume full scope of parameters and a linear coordinate system.

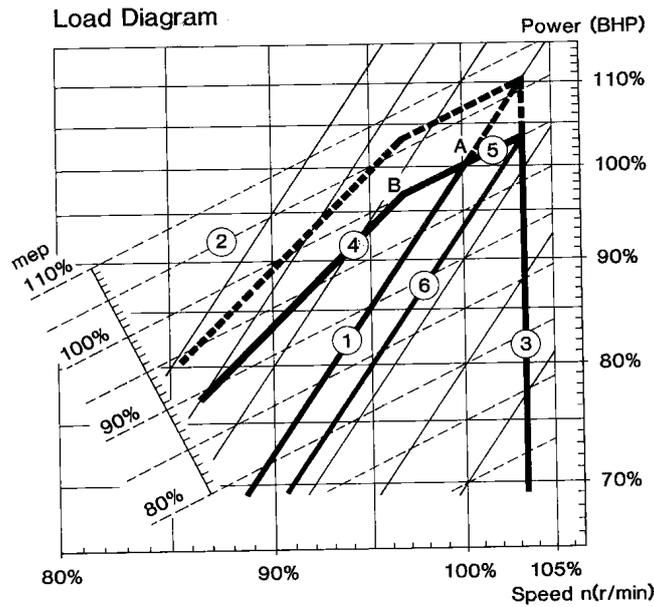


Fig. 2. Marine diesel engine field of MC/MCE type, MANs product: 1-propeller curve at normal condition; 2-line of constant mean effective pressure (torque); 3-line of maximum speed; 4-line of overload limit; 5-line of mean effective pressure limit; 6-propeller curve at light running

#### 4. Visualization application of the operation field of the marine piston engine at HCP Engine Test Bed

On the basis of the general assumptions presented earlier, and the manufacturer’s data, one has made visualization of the field of engine operation 7L70 MC-C made in Fabryka Silników Okrętowych Cegielski Poznan (Fig. 3).



Fig. 3. View of engine 7L70MC/C of HCP Test Bed

This task was implemented under the intentional project 6 ZR6 2005C/06692 [4], the scope of which was concerned the method and devices for optimum control of marine engines. In order to visualize the point of operation in the field of engine operation, a system for remote control of engine operation and monitoring was built and tested at the engine test bed, and coupled with a torque action meter, type ETNP-8, produced by Przedsiębiorstwo Badawczo-Rozwojowe ENAMOR. Thanks to that, constant observation of engine running point in operation field was possible. The example of this is shown in Fig. 4.

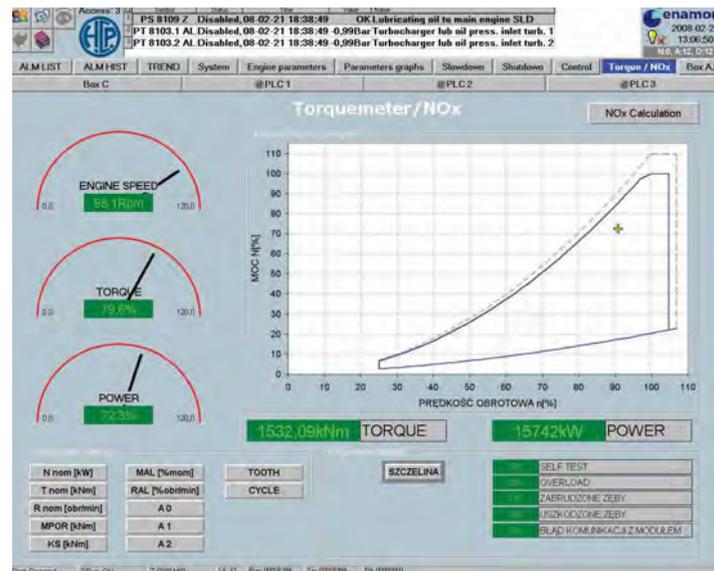


Fig.4. Engine field of 7LMC/C with running point

Testing of a measuring system was conducted as part of the procedure of the manufacturer's engine tests in a wide range of rotational speeds and powers, namely, among others: from 63 (100% n) and 25 (100% N). Both the prepared algorithm of the operation field visualization and the measurement track cooperating with a torque action meter operated correctly.

## 5. Conclusions

Torque is among many values having significance in monitoring and diagnostics of piston marine engines.

Torque does not belong to the parameters whose measurement in operating conditions is formally required. Therefore, still on many commercial ships, the operator does not have direct information about the engine load.

One should aim for torque measurement to become routine. Simultaneously, a very important, practical use of the measurement of this parameter is visualization of the running point of the engine in the field of engine operation. Only then can the operator directly, in a continuous manner, control the condition of an engine operation, preventing its overloading. He may then effectively prevent formation of sudden (overload) damages, which are classified as damages arising for operational reasons.

The measuring system for visualization of the operation field, built and tested at HCP Engine Test Bed, has confirmed its effectiveness in the concerned scope. One should assume that under operating conditions it will also work correctly, being a perfect model for a mechanic to follow. Thus allowing him to avoid operational errors that would cause periodic operation of the engine out of its designated field, and therefore cause overload.

## References

- [1] Michalski, R., *Diagnostyka maszyn roboczych*, Biblioteka problemów eksploatacji, Olsztyn 1994.
- [2] Piotrowski, I., Witkowski, K., *Okrętowe silniki spalinowe*, TRADEMAR, Gdynia 2003.
- [3] Project Guide, *Two-stroke Engines MC Programme*, Vol. 1, Ed. 2, MAN-B&W, 1986.
- [4] *Metoda i urządzenie do optymalnego sterowania silnikami okrętowymi w celu: minimalizacji kosztów, ochrony środowiska i awaryjności silnik*, Projekt celowy nr 6 ZR6 2005C/06692.