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Service investigations of a ship propulsion system co-operating with suspended electric generator

SUMMARY

Design assumptions for a ship propulsion system with suspended electric generator can be verified just during sea trials. In the paper results of investigations performed onboard a new ship with such propulsion system are presented. The correctness of propeller choice and range of possible co-operation of the propulsion system with the suspended generator is also assessed.

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INTRODUCTION

The ship main engines, apart from their basic function of the power delivery to the propeller, are more and more often used also to drive the suspended electric generators.

Since such engine delivers power to two consumers: the propeller and generator, it is important to ensure the loading on the engine applied by the consumers to be in compliance with the engine producer's guidelines.

A curve of the power demanded by the propeller in service conditions of a clean-hull ship immersed to the design waterline, should pass through a point of the characteristics determined by the engine's producer.

The propeller power and torque vary subject to service conditions, therefore a position of the propeller curve on the engine load area is changeable. It is assumed that the service condition changes are not only those due to weather conditions, speed or draught changes in consequence of a changed ship loading condition or going in shallow waters, but also those caused by hull surface roughness, shell plating deformations due to production and exploitation processes, hull fouling, ageing processes of ship's hull and her propulsion system. It causes changing the propeller curve position over the engine load area.

In the case, if switching-on an additional power consumer (generator) is not accounted for and the propeller is supplied with the power in accordance with the propeller characteristics for actual sailing conditions, the curve expressing an increased engine power demand can be shifted onto the prohibited area of engine operation. This is specially important for the propulsion systems with the fixed pitch propellers.

In the case of a controllable pitch propeller it is possible,by changing the propeller pitch, to influence the propeller curve position on the engine operating area, at the same service conditions, i.e. to control the power distribution between the propeller and generator.

Design assumptions about the cooperation of the engine-propeller-hull-generator system can be verified only when the ship is completed, during sea trials.

Results are presented of the investigations carried out onboard the ship whose propulsion system consisted of the main, medium-speed diesel engine, reduction gear and controllable pitch propeller. The system co-operated with a suspended, reduction gear-driven, electric generator.

PROPULSION SYSTEM OF THE INVESTIGATED SHIP

The investigations were carried out onboard the container ship of 9200 dwt, the length L_{oa} = 133.0 m, breadth B = 22.9 m and draught T = 7.6 m. A scheme of her propulsion system is shown in Fig.1.

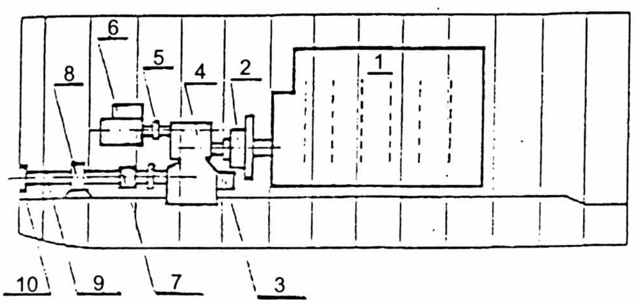


Fig.1. Scheme of the ship's propulsion system
1 - main engine, 2 - elastic coupling, 3 - propeller pitch control mechanism, 4 - main propulsion and generator reduction gear, 5 - generator coupling, 6 - electric generator, 7 - sleeve-flange coupling, 8 - shaft bearing, 9 - propeller shaft, 10 - propeller-shaft seal

The propulsion system consisted of :

- MAN-B&W 6L58/64 main engine of: the service power N_e = 7800 kW at the service speed n_e = 400 rpm
- ABB Zamech, 4-blade CP propeller of PH 1350/4-RK 250 type, of: the diameter D = 4.9 m and pitch ratio H/D = 0.9255
- ABB Zamech MAV 100-10 reduction gear for main propulsion and generator, of:

		for co-operating with the generator
input speed :	400 rpm	390 rpm
output speed		
for propeller :	150 rpm	147 rpm
for generator :		1800 rpm

- the suspended electric generator of SIEMENS 1 FC 8632--4 EF 82 - Z type, of 1000 kW service power and 1800 rpm speed.

DESCRIPTION OF THE PROBLEM

Application of the CP propeller to the investigated propulsion system makes obtaining an abitrary power value at the generator terminals possible.

Any change of propeller pitch setting causes a change of engine power distribution between the propeller and suspended generator. However application of such generator should be accounted for already in the ship power plant design phase. At the time the propeller should be so selected as to obtain that the power consumed by it and the power delivered to the suspended generator jointly would give the loading on the main engine in compliance with engine producer's guidelines.

This principle concerns both fixed pitch and CP propellers. In the design phase a CP propeller is considered as the fixed pitch propeller selected for such optimum pitch value which ensures the maximum propeller efficiency.

Every pitch change of CP propeller worsens its efficiency which, at the extreme blade pivot angle, can drop even by 5 to 6 % relative to the maximum efficiency value.

But the selection of a „too heavy" CP propeller can cause the propulsion system with the suspended generator to operate at a decreased propeller blade pivot angle. Then the power delivered to the propeller would drop and in consequence ship's speed too.

The ship speed v = 17.5 knots was required by contract conditions to be obtainable for the engine service power N_e = 7800 kW and suspended generator power at its terminals N_p = 500 kW.

It was decided, taking into account the above mentioned, to carry out the investigations at the maximum propeller blade pivot angle set for the case of the propulsion system not co-operating with the suspended generator.

RESULTS OF THE INVESTIGATIONS

During the investigations the power N_s delivered to the propeller was measured by means of the Maihak torsiometer. Each of the power N_s value given in the table is the average calculated from 15-min cycles of measurements.

The generator power N_p values were read directly from the main electric switchboard instruments.

The main engine power N_{SG} values were obtained by summing the power N_s values enlarged by reduction gear losses (the assumed reduction gear efficiency η_p = 0.98), and power N_p values enlarged by electrical power production losses (the assumed efficiency of the suspended generator drive and electric efficiency $\eta_{el.}$ = 0.85) in accordance with the following formula;

$$N_{SG} = \frac{N_s}{\eta_p} + \frac{N_p}{\eta_{el}}$$

As the propeller rotational speed n and ship's speed v the average values were assumed calculated from 15-min cycles of measurements.

Measurement results obtained from the ship investigations

N_{SG} engine power	N_s power delivered to propeller	N_p generator power	v ship speed	n engine speed	Investigation cycle
kW	kW	kW	knots	rpm	—
7819	7663	-	18.4	400	I
7848	7691	-	18.5	400	
7673	7520	-	18.4	400	
7064	6485	380	18.1	388	II
7121	6529	390	18.1	390	
7078	6487	390	17.9	391	
7235	6652	380	18.0	388	
7100	6520	380	17.9	391	

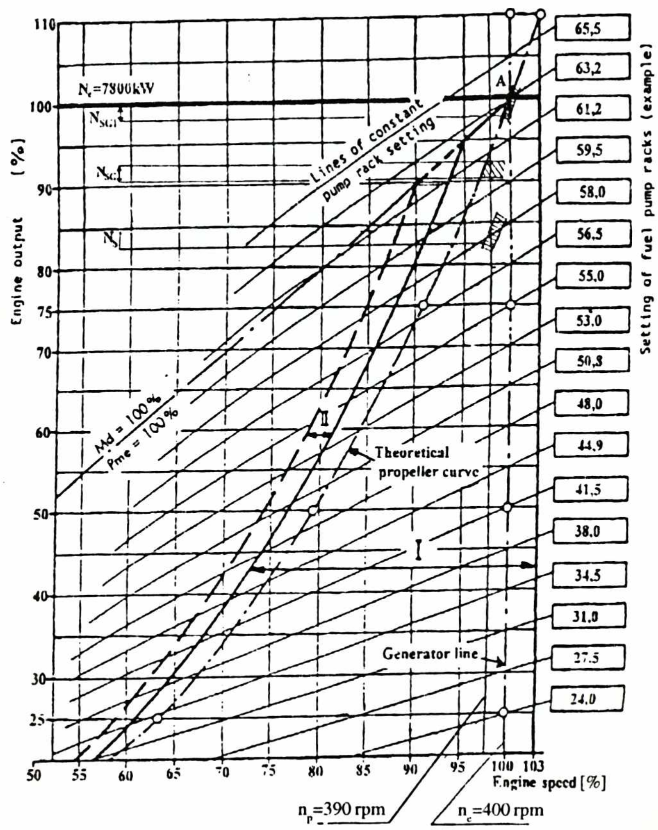
The results of the measurements presented in the table are introduced onto the engine operating area in Fig.2.

A propeller cooperating with MAN engines is assumed correctly selected, if in new-ship sea trial conditions it loads the engine with the service power N_e = 7800 kW equal to 90% its rated power at the service speed n_e = 400 rpm (the point A in Fig.2).

1-st investigation cycle was aimed at determining the engine load during the propulsion system operation at the maximum propeller blade pivot angle and switched-off suspended generator. The ship's speed and engine rotational speed was also measured. An obtained range of loading changes is represented by the N_{SG1} sector in Fig.2.

During 2-nd cycle of the investigations the engine speed was reduced to n_p = 390 rpm , required for the co-operating suspended generator. The ship's speed, engine rotational speed and suspended generator power was also measured.

The N_S sector in Fig.2 illustrates the power range delivered to the propeller, and the N_{SG} sector - the power range developed by the main engine.



M_d - *torque*
P_{me} - *mean effectiv pressure*
I - *operation range*
II - *operating range permissible for temporary application, e.g. when accelerating manoeuvring*

Fig.2. The operating area of MAN 6L 58/64 engine with the investigation results accounted for

CONCLUSIONS

- During the investigations of the propulsion system non-co-operating with the suspended generator the power delivered to the propeller, measured on the part of the propeller shaft behind the reduction gear, varied between 7673 kW and 7848 kW. Results of two measurement stages revealed that the engine service power $N_e = 7800$ kW was slightly exceeded.

- The observed oscillations of the power delivered to the propeller and of the ship's speed, resulted a.o. from changeable weather conditions and ship's manoeuvring.

- On the basis of the above given observations it can be stated that the propeller was selected appropriate and it loads the engine in accordance with the producer's guidelines, at the maximum blade pivot angle.

- During the investigations of the propulsion system co-operating with the suspended generator the power N_p consumed by the generator resulted from the general ship demands and varied between 380 kW and 390 kW. The power values at the generator terminals were read from the main switchboard instruments, therefore the power absorbed from the main engine to produce the electric energy varied between 447 kW and 459 kW, when accounting for the assumed electric energy production losses.

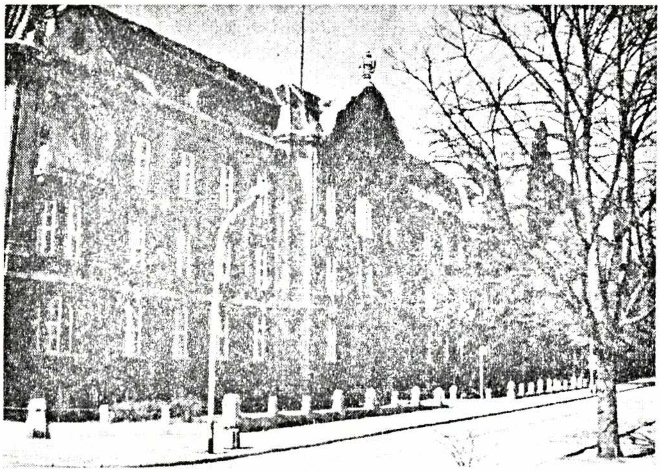
- The main engine power required to drive the generator was obtained by reducing the engine speed. The measurements revealed that the engine power margin of 1013÷1183 kW was only partly utilized by the suspended generator. The power margin will be utilized in full by the suspended generator of 1000 kW service power in the case of shipping the refrigerated containers.

- Switching-on the suspended generator caused dropping the ship speed by 0.4÷0.6 kn.

- The engine speed of 390 rpm (97.5% of its service speed) was assumed for the co-operating with the suspended generator. It can be stated taking into account the classification societies requirements for the permissible frequency variation within ±2.5%, that the operation of the suspended generator is allowable within the engine speed range of 380 to 400 rpm. This range of allowable engine speed variation makes the generator operation possible even in worsened weather conditions.

- Generally it can be concluded that the applied method of investigation of the main engine loading in service and of fulfilling the design assumptions by the ship propulsion system co-operating with the suspended generator is useful and does not cause any substantial troubles in practical application.

Appraised by Stefan Żmudzki, Prof.,D.Sc,M.E.



The old main building of Maritime University in Szczecin

Current reports

TECHNICAL UNIVERSITY OF GDAŃSK
MECHANICAL FACULTY

Computer software system for calculating ship propulsion shaftline flexural vibrations

The system elaborated in the Mechanics and Strength of Materials Chair by Zbigniew Walczyk, Assoc.Prof.,D.Sc. consists of the following programs for:

- static calculations of ship propulsion shaftlines
- forced vibration calculations, embracing the determination of critical speed in resonance states
- natural vibration calculations, including the determination of vibration forms and frequencies.

The system is arranged for carrying out propulsion shaftline dynamic analysis in the flexural vibration range, determining a.o. critical speeds, vibration amplitudes, internal forces and moments, dynamic stresses. It is aimed at dynamic state evaluation of power transmission systems in their design stage as well as during ship operation.

The following system components were distinguished:

- propulsion shafts
- bearing supports
- oil film in the bearings
- ship hull (double bottom structure).

The dynamic characteristics method of mutual influence of the components (e.g. hull and bearing support flexibilities), and wake phenomena which change propeller inertia, damping and elastic structural characteristics, were applied. The static and dynamic calculation algorithm was based on the physical discrete - continuous model with the use of the transfer matrix method.

The software system can be used for multi-variant design calculations of a propulsion transmission system with the possible assessment of its dynamic state sensitivity to changing system's parameters.

For ships in service the software makes it possible to determine the influence of shaftline assembling parameters (e.g. mutual vertical location of bearings), bearing and bearing support stiffnesses, or propeller geometric parameters (possible propeller replacement or its characteristics correction) on dynamic state of the shaftline system.

Input data can be easily prepared by using built-in input data editors. Computation time can be made very short due to the applied special procedures.