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ANALYSIS OF CHANGEABILITY OF OPERATIONAL LOADS OF MAIN ENGINES ON DREDGERS

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Abstract

This paper presents an analysis of changeability of operational loads of main engines and power consumers on dredgers of three basic types. The principles of processing measurement results, which should be used for statistical analysis of operational loads of dredger main engines and power consumers, have been formulated.

Key words*: Trailing suction hopper dredgers, cutter suction dredgers, bucket ladder dredgers, main engines, main consumers*

1. Introduction

Operational loads of main engines on ships are time-changeable depending on current power demand from the side of consumers driven by the engines. In the case of the main engine driving ship propeller only (e.g. on transport ships) load change depends on changes of : sailing speed and draught , sea and wind state , course angle , icing state of operation area, currents etc , and also on decisions as to conducting maneuvers. If main engine propells also a shaft generator then engine load changes affect also load changes of the generator. [1].

As far as technological ships are concerned the situation is more complex as their main engines drive a greater number of main consumers which are more different as to their operational characteristics. Dredgers are those of the most sophisticated type of technological ships. The number of kinds of main consumers reaches 4 and the total number of them ranges even 10.

This paper presents results of the author's own operational investigations dealing with operational loads of main engines on dredgers. Changeability of operational loads of main engines has been characterized, influence of particular kinds of main consumers on operational loads of main engines have been presented. The principles of processing measurement results, which should be used in statistical analyzing operational loads of main engines on dredgers, have been formulated.

The results have been presented for the three basic types of dredgers: trailing suction hopper dredgers, cutter suction dredgers and bucket ladder dredgers.

2. Main consumers on dredgers

In line with the principles given in [2] **main consumers** constitute different, separately driven devices intended for realization of given technological processes in accordance with a type and tasks of a dredger. The main consumers on dredgers should cover the following categories [3]:

— consumers associated with dredger's self propelling, positioning and maneuvering (main propellers, bow thrusters and swing winches);
— consumers associated with loosening, dredging and transporting the soil (e.g. dredge pumps, jet pumps, cutter heads or bucket chains).

Number of main consumers on a given dredger depends on the two factors:

– firstly, if the dredger is fitted with its own propelling system,
– secondly, how many working operations the dredger realizes.

If a dredger is self-propelled and adjusted to realizing three working operations (i.e. loosening the spoil, lifting the output onto the dredger and transporting it to dump site) then number of kinds of main consumers equals always 4 regardless dredger type. In the case of lack of self propulsion or realizing only the two first working operations the number of kinds of main consumers is lower – equal to 2÷3. Tab. 1 shows how many and which kinds of main consumers are installed on particular types of dredgers.

Tab. 1

Kinds of main consumers which are installed on particular types of dredgers

Types of dredgers	Kinds of main consumers							Number of kinds of main consumers
	Propellers	Dredge pumps	Jet pumps	Bow and stern thrusters	Cutter head	Bucket chain	Swing winches	
Trailing suction hopper dredger	X	X	X	X	-	-	-	4
Cutter suction dredger	-	X	-	-	X	-	X	3
Seagoing cutter suction dreger	X	X	-	-	X	-	X	4
Bucket ladder dredger	-	-	-	-	-	X	X	2
Seagoing bucket ladder dredger	X	-	-	-	-	X	X	3
Bucket ladder dredger with shore discharging installation	-	X	-	-	-	X	X	3

3. Changeability of loads of main engines and power consumers during operations conducted within scope of dredging work

The analysis of changeability of loads of main engines and consumers was made with the use of measurement data contained in the DRAGA data base [4] and acquired a.o. in the frame of KBN research project [3]. The measuring instruments used for the measurements made it possible to perform them with 3 Hz sampling frequency. For the analysis three dredgers were selected, one of each type. They were: the trailing suction hopper dredger *Inż. St. Łęgowski*, the cutter suction dredger *Trojan* and the bucket ladder dredger *Inż. T. Wenda*. The selected dredgers are characterized by diesel electric drive systems of main consumers. The only exception was the dredge pump installed on the dredger *Trojan*, driven by a diesel mechanical system (driven by a diesel engine through a toothed gear).

The service state of „ dredging work" is that characterized by the largest number of main consumers under operation, therefore during the state their influence on loads of main engines is the greatest. In Fig. 1, 2, 3 are exemplified the characteristic runs of changeable loads of main engines and consumers on the three analyzed types of dredgers working during „dredging work". They cover about 3 hours of dredger operation.

Trailing suction hopper dredgers conduct dredging work performing in cycles the following operations: loading soil into its own hold (trailing), moving under load to a dump site, unloading (gravitational or hydraulically) as well as going back to a loading site. During dredging work all main consumers are under operation, however character of their operation is strictly dependent on operations contained in the scope of working cycle. In the basic type of power system of trailing suction hopper dredger its main engine (engines) ensures driving for all main consumers. When analyzing the load runs of main engines and main consumers driven by them attention is drawn to characteristic loads of bow thruster used during loading the soil.

The bow thrusters during loading the soil are used to positioning the dredger moving with 2÷3 kn speed. During loading the soil bow thrusters are under intermittent running. Number of their starts during the loading was in the range of 2÷20. And, duration times of single operation of bow thruster were in the range of 20÷400 sec. During hydraulically unloading character of bow thruster operation is different. Then the positioned dredger does not move. Its operation is as a rule almost continuous with 2÷6 load changes only. It should be simultaneously stressed that in favourable external conditions the bow thruster are not used at all during the hydraulically unloading. The remaining main consumers are characterized by a lower load changeability. In the case of main propellers the number of load changes during loading the output was 2÷6 , and during moving with and without output - from 6 to 12 load changes. An even smaller number of load changes concerns pumps both dredge and jet ones. In this case only 0÷3 load changes of a given pump were recorded both during loading the output and its hydraulically unloading.

If the bow thruster operation is neglected the number of load changes of main engines will be contained in the range of 11÷26 per dredging work cycle (during loading the output - 3÷10 load changes, during moving with and without output - 6÷12 load changes, and during hydraulically unloading - 1÷4 load changes of main engines). The mean value of frequency of load changes of main engines, without taking into account bow thruster operation, reached 4,86 changes per hour and was close to the mean value of load changes of main engines on fishing trawlers [1].

Suction cutter dredgers and bucket dredgers conduct dredging work with the use of swing winches, making the so called „ butterfly" bands over digging site. The loosened spoil is lifted onto a dredger and discharged to hopper barges or hydraulically transported directly to land by means of dredge pumps. During dredging work screw propellers are standing by (they are only used during free floating between works or loading sites or when going to port). Cutter heads (or bucket chains in the case of bucket dredgers), swing winches and dredge pump (pumps) on suction cutter dredgers, are always under operation. In the basic type of power system of the dredgers the dredge pump is driven by a separate main (diesel) engine and another main engine drives the unit composed of cutter head and swing winches or bucket chain and swing winches.

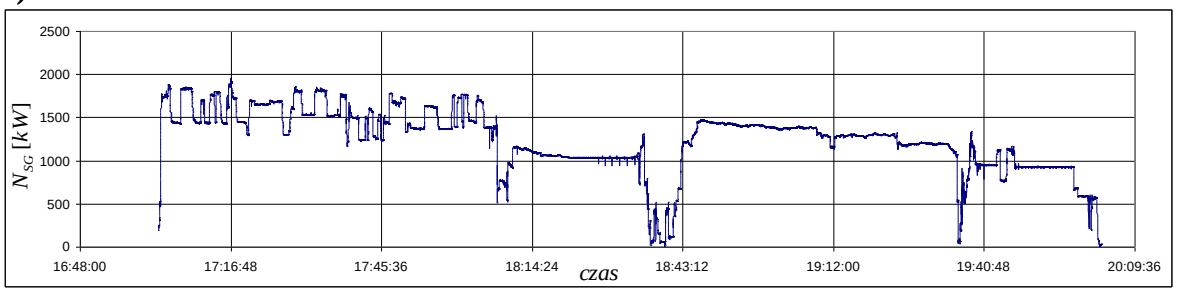
Number of load changes of dredge pumps on the dredgers is very similar to that for suction hopper dredgers. On the investigated dredger *Trojan* it was contained within the range of 1÷3 changes per hour.

Operational loads of main consumers used for mechanical loosening the soil (cutter heads, bucket chains) are characterized by frequent changes of loads resulting from character of their work (Fig.2 and 3). The load changeability is mainly associated with the cutting- into

- the soil process performed by successive blades of cutter head (chain buckets). The range of load changeability is determined by value of the coefficient $N^{\max} / N^{\min}$ which is the ratio of maximum and minimum loads of main consumer (where CH stands for cutter head, BC – for bucket chain).

For the cutter head the mean value of the ratio $N_{CH}^{\max} / N_{CH}^{\min} = 2{,}38$ (for medium cohesive soil), and for the bucket chain the ratio $N_{BC}^{\max} / N_{BC}^{\min} = 3{,}56$ (for medium cohesive soil) and $N_{BC}^{\max} / N_{BC}^{\min} = 1{,}62$ (for non-cohesive soil). Similar values of the ratio are characteristic also for swing winches. Influence of changes of dredger hoeing direction on character of loads of a given main consumer is an important regularity. The influence is especially distinctly observed in the case of swing winches.

a)



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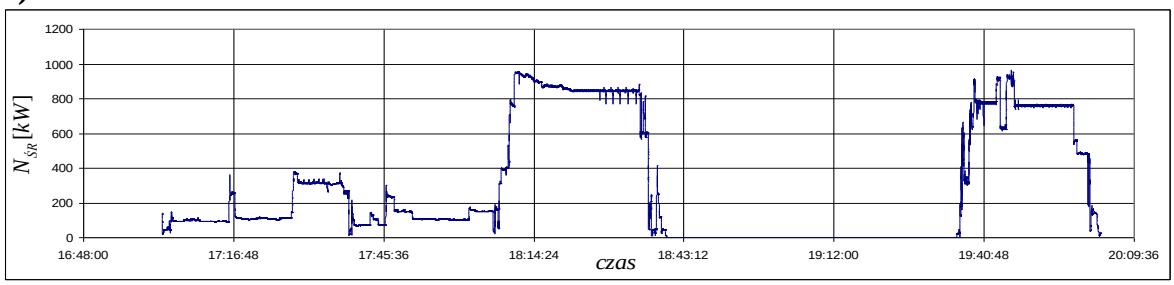

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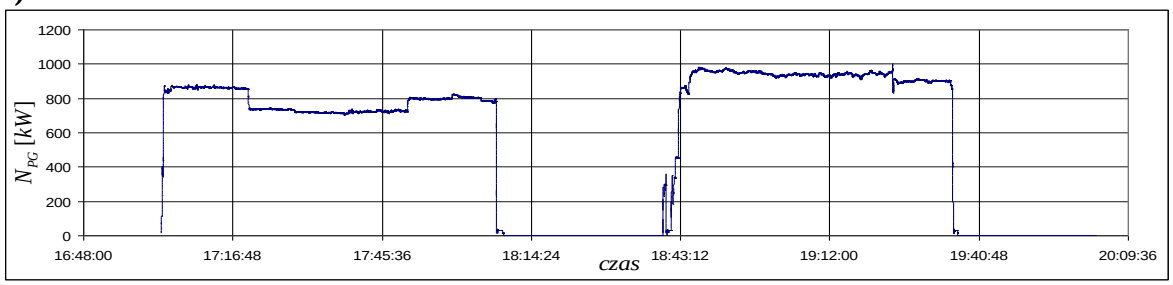

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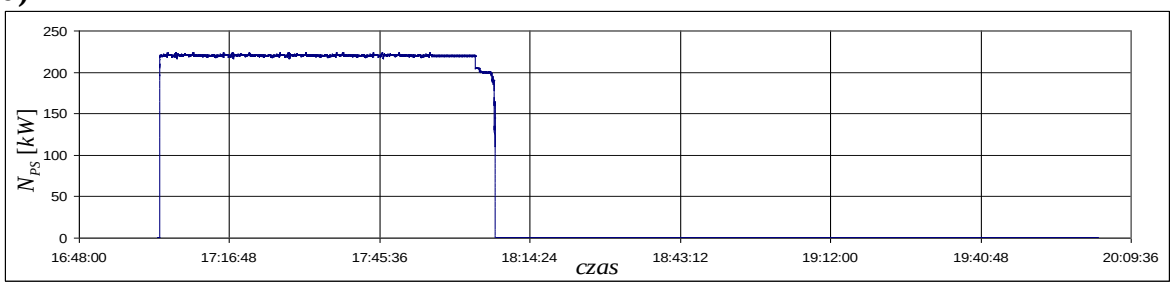

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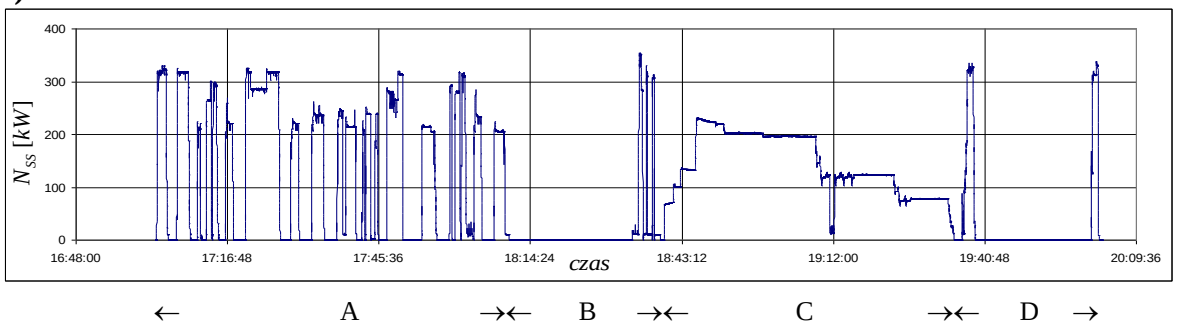
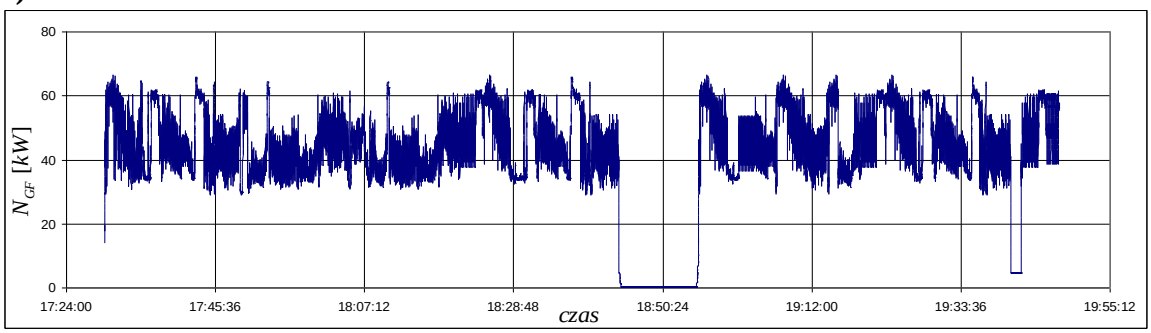


Fig.1. Load changeability of power system elements of the dredger Inż. S. Łęgowski; a) main engines, b) propellers, c) dredge pumps, d) jet pump, e) bow thruster; (A – trailing, B – moving under load to a dump site, C – hydraulically unloading, D – going back to a loading site)

a)



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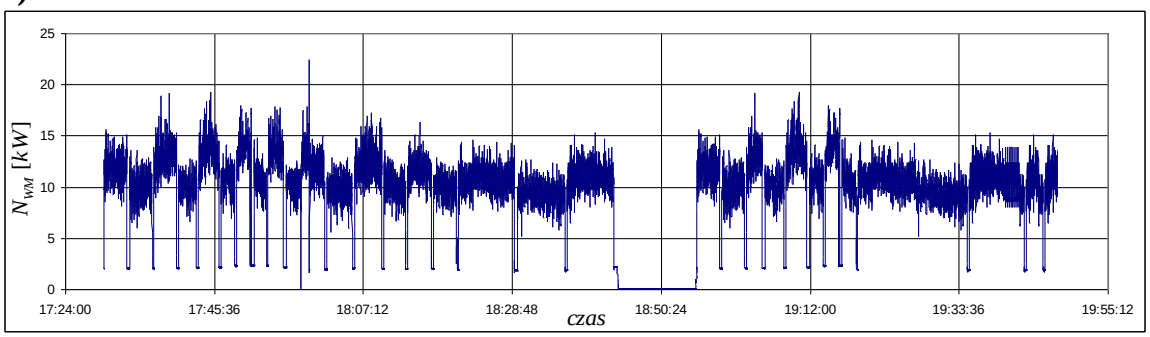
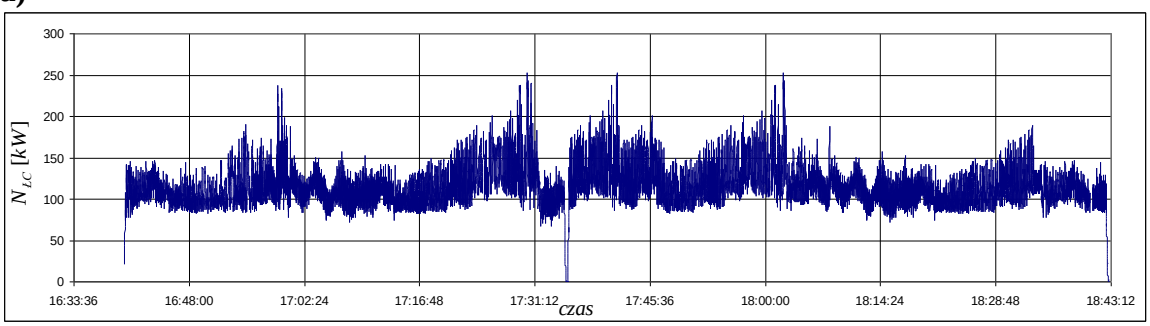


Fig.2. Load changeability of main consumers of the dredger Trojan; a) cutter head, b) swing winches

a)



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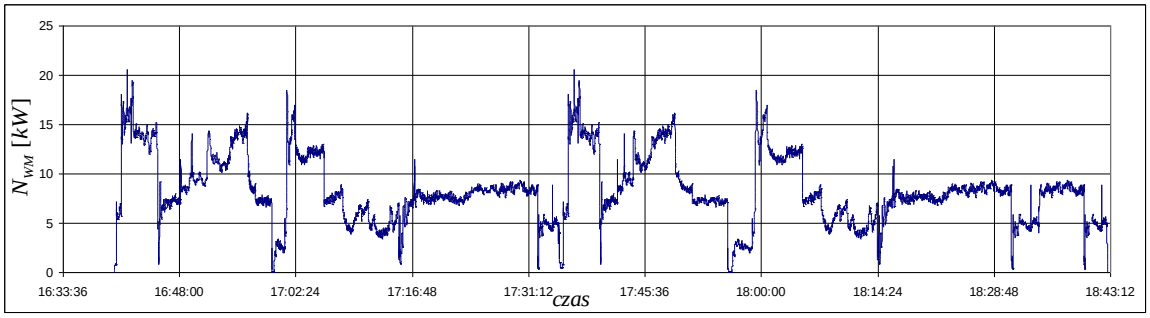

Fig.3. Load changeability of main consumers of the dredger Inż. T. Wenda; a) bucket chain, b) swing winches

4. Processing the results of operational measurements

Measurement instruments and methods to be applied as well as subsequent processing measurement results in order to analyze them statistically, depend on a purpose for which the operational data are collected. This author has conducted multiyear operational investigations of dredgers in order to achieve empirical data necessary for elaborating a set of novel methods of power plant design for dredgers.

From the point of view of design problems of ship power systems, are important such load changes of main engines, which lead to changes of thermal equilibrium state and are associated with distinct fuel consumption change. The thing is in the changes of a value and duration interval which can lead to a change of temperature and rate of exhaust gas as well as temperature of cooling media [1]. Starting from such premises one is able to accept that the changeability frequency of a dozen or so changes per hour at the most , i.e. changes of duration from the range of a few up to a dozen or so minutes would be ultimate, maximum frequency of load changeability in question.

For the above mentioned reasons it is proposed to assume, for statistical analysis of distributions of operational loads of main engines and consumers on dredgers, average values of engine (consumer) loads taken from a given time interval. On the basis of the earlier presented operational data one can state that in the case of suction hopper dredgers the time interval equal to 5 minutes would be sufficient. In the case of suction cutter dredgers and bucket chain dredgers such time interval would be that of making the „butterfly" band. The time interval of making the „butterfly" band by suction cutter dredgers reaches a few up to a dozen or so minutes at the most, and somewhat longer - by bucket dredgers.

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