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DETERMINATION OF OPERATIONAL LOAD PARAMETERS OF DREDGE PUMPS UNDER DREDGING OPERATIONS

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Abstract

This paper presents proposal of a method for determining operational load parameters of dredge pumps, one of the crucial mechanical energy consumers on dredgers. The method based on results of the author's operational investigations, deals with two main service states of dredge pumps on dredgers, namely: the state of loading the solid into soil hold (of dredger or hopper barge) and the state of pumping ashore.

Keywords: *dredgers, dredge pumps, ship power systems.*

1. Introduction

Dredge pumps belong to the most important consumers of mechanical energy on dredgers. Their function is to hydraulically transport loosened soil from the sea bed into soil hold of the dredger or hopper barge (a service state called loading the spoil) as well as from the hold (sometimes directly from the sea bed) through long transfer piping to a dump on shore (a service state called transferring the spoil ashore). The states occur always on suction dredgers (e.g. trailing suction hopper dredgers, cutter suction dredgers, barge unloading dredgers), sometimes also on dredgers with mechanical dredging systems (e.g. bucket ladder dredgers) [8]. Power demand of dredge pumps depends on their use and design assumptions as well as on size of dredger. It is contained in a broad interval ranging from several hundreds kW to even a dozen or so thousands kW [7,8].

Irrespective of a type of dredger the dredge pumps can operate in two basic service states [3,4,6,7,8]:

- the loading of the spoil into the hopper (soil hold) on the dredger or assisting hopper barge; operational conditions of the pump system are characterized by the following features: the static lifting height of the system is as a rule greater than the dynamic one ($H_{st} \geq H_{dyn}$), similar values of flow drag of water-soil mixture on suction and pressure side of pump ($\Delta h_s \approx \Delta h_p$);
- the hydraulic emptying of the soil hold or transferring the spoil directly to a dump on shore (the pumping the spoil ashore); in this case operational conditions of the pump system are characterized by a much greater dynamic lifting height than the static one

($H_{st} << H_{dyn}$) and much greater values of flow drag on the pump pressure side than on its suction side ($\Delta h_s << \Delta h_p$).

The state called loading the spoil into the hold always occurs on trailing suction hopper dredgers (it concerns their own holds) , and may also occur on cutter suction dredgers (in this case it concerns hopper barge holds). The pumping-away the spoil occurs on trailing suction hopper dredgers and cutter suction dredgers, sometimes also on bucket ladder ones. Great differences in the parameters which characterize the pump systems operating in the above mentioned service states must result in great differences in the loads applied upon dredge pumps during loading and pumping-away the spoil. On the trailing suction hopper dredgers the using of the same pumps both for the loading and pumping-away the spoil is common. Then their driving systems are fitted with multi-speed gear transmission devices.

This paper presents a proposal of determining the distribution parameters of operational loads of dredge pumps installed on various types of dredgers, depending on their service states. For the determining of the distribution parameters of pump loads the use of linear form of dependence of mean driving loads of dredge pumps on their rated power outputs, is proposed [1,2]. Standard deviations are proposed to be determined by means of the data concerning the load distribution variability coefficient of dredge pumps, obtained on the basis of operational investigations.

2. Investigations of relations between mean operational loads of dredge pumps and their rated power outputs

Investigations of relations between the mean operational loads of main power consumers N_{MC}^{av} , and their rated power outputs $(N_{MC}^{eff})^{nom}$ are important in view of possible making use of their results further in preliminary design stages of ship power plants.

As far as the main consumers are concerned, it can be considered effective energy flow (i.e. power output or effective power) associated with them, each case expressed by the product of the so called „ generalized potential" and the „ generalized flow" [1].

The investigations of relations between the mean operational loads of main power consumers and their rated power outputs were already performed for fish factory trawlers as well as certain main consumers on dredgers [1,2].

The performed investigations show that for all main power consumers on the investigated ships the following linear relation takes place [1,2]:

$$N_{MC}^{eff} = a + b\,(N_{MC}^{eff})^{nom} \qquad (1)$$

where: a, b - constants

The statement on validity of the linear relation (1) as well as on possibility of determining the constants a, b, is very important as the relation can be used for determining the power demand of main engines for ships of the considered types in the stage of offer or preliminary design [1,2,3].

The dredge pump power output N_{DP}^{eff} is determined by the relation:

$$N_{DP}^{eff} = H_{DP}^{w} \cdot Q_{DP}^{w} \qquad (2)$$

where: H_{DP}^{w} - the dredge pump lifting height determined for water ,

Q_{DP}^{w} - the dredge pump volumetric rate of delivery determined for water.

It is important that producers of dredge pumps usually provide nominal (rated) parameters and characteristics of the pumps valid for the conditions of water pumping but not water-soil mixture pumping. Change of characteristics of dredge pump handling water-soil mixture, as well as change of pipeline characteristics is most influenced by density of the mixture and soil graining (a.o. mean grain diameter, grain-size distribution, grain shape) [7,8]. High variability of the parameters causes that the providing of the parameters of dredge pumps for the conditions of water-soil mixture pumping would be unjustifiable.

In Tab. 1 and 2 are given the rated parameters of the dredge pumps on the investigated dredgers as well as the distribution parameters of operational loads of the pumps during operation in two basic stages of their service (loading the spoil to hopper and pumping the spoil ashore) [6]. The distribution parameters of operational loads of dredge pumps have been obtained as a result of long-lasting operational investigations carried out by this author on a dozen or so dredgers of various types. The problem of operational loads of dredge pumps, which covers measurement methods, measurement system characteristics, distributions of pump loads, has been presented more thoroughly in a few publications of this author [3,4,5,6].

Tab.1. Rated parameters of dredge pumps and characteristics of their operational loads during loading the spoil to hopper, for 8 investigated dredgers

Dredger	Number pumps	Rated parameters of dredge pumps (pumping water)			Characteristics of load distributions of dredge pumps		
		H_{DP}^{w}	Q_{DP}^{w}	N_{DP}^{eff}	N_{DP}^{av}	σ_{DP}	ν_{DP}
		kPa	m^3/s	kW	kW	kW	-
Kostera	1	105	0,65	68,2	82,1	6,9	0,084
Kronos	1	140	0,65	91	95,1	7,8	0,082
Łęgowski	2	175	1,8	2×315	774,9	62,3	0,08
Bukowski	2	175	1,8	2×315	786,4	54,5	0,069
Nautilus	1	210	2,5	525	706,8	26,2	0,037
Gogland	2	220	3,2	2×704	1787,1	61,2	0,034
Geopotes 15	2	265	3,4	2×901	1987,7	71,9	0,036
Lange Wapper	1	395	4,6	1817	2482,6		

Tab.2. Rated parameters of dredge pumps and characteristics of their operational loads during pumping the spoil ashore, for 13 investigated dredgers

Dredger	Number pumps	Rated parameters of dredge pumps (pumping water)			Characteristics of load distributions of dredge pumps		
		H_{DP}^{w}	Q_{DP}^{w}	N_{DP}^{eff}	N_{DP}^{av}	σ_{DP}	ν_{DP}
		kPa	m^3/s	kW	kW	kW	-
Kostera	1	370	0,55	203,5	216,5	29,6	0,137
Kronos	1	490	0,5	245	189,4	20,6	0,109
Łęgowski	2	385	1,6	616	832,9	101,4	0,122
Bukowski	2	385	1,6	616	835,7	52,8	0,064
Gogland	2	430	3,0	1290	1815,9	178,4	0,098
Geopotes 15	2	560	3,0	1680	2211,1	239,9	0,109

Lange Wapper	2	1240	4,1	5084	3861,9		
Trojan	1	600	1,0	600	536,7	122,9	0,229
Toruń	1	530	0,95	503,5	431,5	52,3	0,121
Scorpio	1	610	2,05	1250,5	1667,5	278,6	0,167
Rozkolec	2	1160	1,75	2030	1188,1	334,8	0,282
Raja	1	440	0,7	308	240,5	32,3	0,134
Małż II	1	410	0,4	164	158,26	30,78	0,194

Tab.3. Linear regression equations which determine mean loads of dredge pumps during two basic states of their service

States of dredge pumps	Postać zależności	Statistical evaluation				
		R	σ	F	F_{kr}	m
loading of the spoil to hopper	$(N_{DP}^{av})^{ls} = 1{,}242 \cdot (N_{DP}^{eff})^{ls} + 5{,}745$	0,988	81,4	276,6	5,99	8
pumping the spoil ashore	$(N_{DP}^{av})^{sp} = 0{,}755 \cdot (N_{DP}^{eff})^{sp} + 244{,}43$	0,934	147,4	75,8	4,84	13

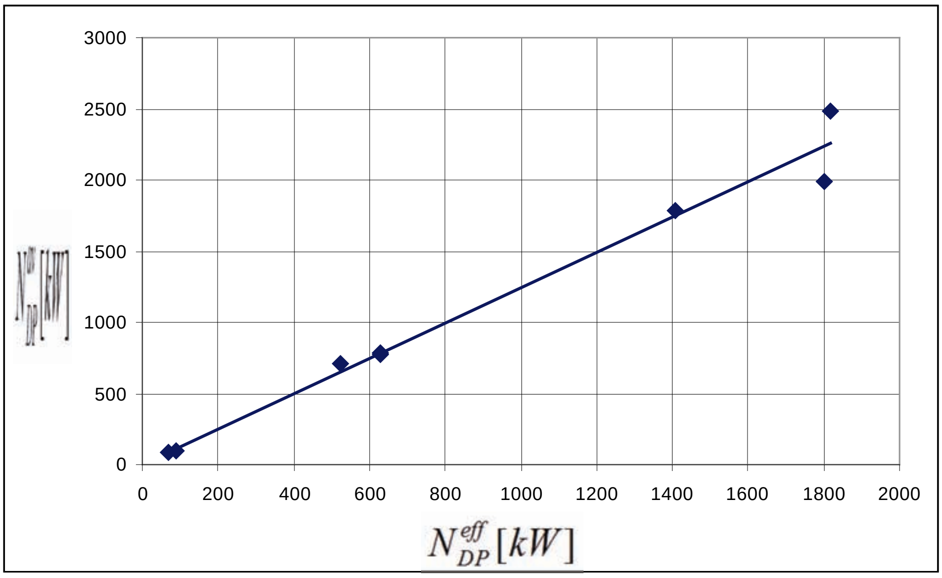

Fig. 1a. The relations $N_{DP}^{av} = f(N_{DP}^{eff})$ *for dredge pumps in state of loading the spoil to hopper*

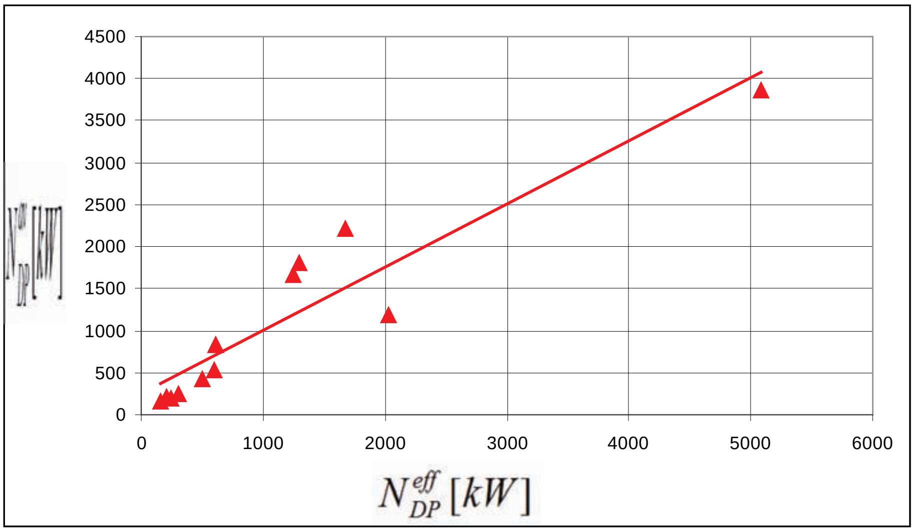

Fig. 1b. The relations $N_{DP}^{av} = f(N_{DP}^{eff})$ *for dredge pump in state of pumping ashore*

If rated parameters of dredge pump (-s) are known it is possible - by making use of the relations given in Tab.3 - to predict its (their) mean load during a considered service state.

3. Standard deviations of operational load distributions of dredge pumps, working time fractions of the pumps in a given service state

Value of the standard deviation σ_{DP} can be determined by using data which deal with the variability coefficient $v_{DP} = \sigma_{DP} / N_{DP}^{av}$ (Tab.1 and 2). Values of the variability coefficients of load distributions of dredge pumps during loading the winning are contained within the interval of $0{,}034 \div 0{,}084$ at the mean value of v_{DP} equal to 0,06 (Tab.1). In the case of the service state of transferring the winning values of the variability coefficients of load distributions of dredge pumps are contained within the interval of $0{,}064 \div 0{,}229$ at the mean value of v_{DP} equal to $0{,}146$ (Tab.2).

The analyzed loads of dredge pumps concern duration time of loading the spoil to the hold (of the dredger or hopper barge) or hydraulic unloading the spoil from the hold (of the dredger or hopper barge), that is determined by values of the usage time coefficients λ_{DP}^{ls}, λ_{DP}^{sp} (Tab.1 and 2 given in [6]).Values of the coefficient λ_{DP}^{ls} are contained in the interval of 0,95÷0,98, at its mean value equal to 0,972. Values of the coefficient λ_{DP}^{sp} are close to the λ_{DP}^{ls} values and are contained in the interval of 0,96÷0,99 , at its mean value of 0,978.

If the relation of the duration time of „dredging operations" has to be determined the coefficient λ_{ls}^{do} or λ_{sp}^{do} is to be additionally taken into account. Values of the coefficients depend on a type of dredger and its design solution.

In addition the case of cutter suction dredger with underwater pump should be highlighted. The so applied pumps operate both during loading the winning into hopper barge (dredging to hopper barges) and during dredging with simultaneous pumping ashore with the use of dredge pump (pumps) installed onboard. For both the situations working conditions of the underwater pump can be assumed the same and corresponding with the conditions of loading the spoil. Of course, the dredge pump installed onboard operates only during pumping the spoil ashore.

4. Summary

All the calculation results which concern load characteristics of dredge pumps, presented in this paper, reflect operational reality of the pumps on dredgers. The results can be deemed representative for the whole population of dredge pumps used on dredgers, in view of the large number of the investigated dredgers and wide range of their size.

The presented results may be useful in predicting operational loads of dredge pumps, depending on their service states typical on various types of dredgers. That will make it possible – in association with knowledge of loads of other main consumers and efficiency characteristics of power transmission systems of particular consumers - to determine characteristics of operational loads of main engines on dredgers. It is especially important in preliminary design stages of power systems for dredgers.

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