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OPERATIONAL LOADS OF DREDGE PUMPS IN THEIR BASIC SERVICE STATES ON SELECTED TYPES OF DREDGERS

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Abstract

This paper presents results of operational investigations dealing with dredge pumps, one of the most important mechanical energy consumers installed on dredgers. The investigations covered measurements of parameters which characterize the loads of dredge pumps in their two basic service states, namely during loading the spoil into a soil hold – hopper (of a dredger or hopper barge) and during transferring the spoil 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) [1]. 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 [1,2].

Irrespective of a type of dredger the dredge pumps can operate in two basic service states [1,3,4]:

- 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.

To know service loads of dredge pumps (and also other large power consumers) is crucial in the designing of dredger power systems as it makes it possible to predict loads to be applied to pumps on a designed dredger.

This paper presents results of operational investigations which concern the driving loads of dredge pumps on 10 dredgers of various types. The investigations have been a part of a more comprehensive research on power consumption of technological processes on three main types of dredgers, carried out in the years 2000÷2003 and 2005÷2006 [5]. The results have been supplemented with those from other investigations carried out by other measuring teams, and dealing with four successive dredgers [5, 6, 7, and 8].

2. Measurement methods

The measurement methods implemented during the investigations depended on design solution of dredge pump driving system, as well as on stationary measuring instruments installed on a given dredger and their possible use for determination of instantaneous power demanded by a dredge pump. By making use of the measurement results and knowing efficiency characteristics of power transmission systems, instantaneous power values on drive coupling of a given dredge pump, were determined [9]. To this end the following methods were applied [9]:

– the method to which the measuring of the parameters of electric current absorbed from the network by electric motor driving the pump, was applied; the method was used on the dredgers of diesel-electric drive of the pumps (the dredgers : the *Inż. M. Bukowski, Inż. S. Łęgowski, Geopotes 15*),
– the method to which the measuring of the parameters characterizing operation of the pumps , i.e. their capacity (measured by means of stationary instruments) and lifting height (measured by means of manometers installed on suction and pressure side of pumps) was applied; the knowledge of values of pump lifting height as well as efficiency characteristics of a given pump (corrected with regard to the case of water-soil mixture pumping [4]) and its mechanical transmission gear (if applied), made it possible to determine the power on the pump drive coupling ; the method was applied to determination of the service loads of dredge pumps on the following dredgers and barge unloading dredgers: the *Kostera, Kronos, Trojan, Toruń, Małż II, Rozkolec* and *Raja*.

On the basis of the performed analysis of changes in loads of dredge pumps it was assumed that measurements of operational loads of the pumps will be carried out every 5th minute [9].

To determine operational load characteristics of dredge pumps, knowledge of changes of the loads for a long period is necessary. A large number of instantaneous values of the loads make it possible to perform their statistical assessment properly. The average duration time of dredging work carried out by dredgers amounts to about 2500 h/year [9]. As to carry out such investigations on every tested dredgers for so long time was not possible the service investigations were planned to cover at least 5% of the duration time of dredging work on each of the tested dredger, i.e. about 125 h [9]. Most of the service investigations were carried out in 24 h cycles.

The performed investigations made it possible to determine the load distribution characteristics of dredge pumps during loading the winning to the soil hold and during transferring the soil ashore; the characteristics contained the following:

$(N_{DP}^{av})^{ls} (N_{DP}^{av})^{sp}$ - average loads on dredge pumps during loading and transferring -away the spoil, respectively;

$(\sigma_{DP})^{ls}$ $(\sigma_{DP})^{sp}$ - standard deviations of load distribution of dredge pumps;

$\nu_{DP} = \frac{\sigma_{DP}}{N_{DP}^{av}}$ - variation coefficient of load distribution of dredge pump;

λ_{DP}^{ls} (λ_{DP}^{sp}) - a coefficient which determines participation of duration time of dredge pump operation during loading and transferring the spoil ashore, respectively.

3. Load distribution of dredge pumps during loading the spoil to hopper

The analysis covered results obtained from 8 trailing suction hopper dredgers. Tab. 1 shows the data which characterize load distributions of dredge pumps of the analyzed dredgers during carrying–out operations associated with loading the spoil to soil hold , i.e. $((N_{DP}^{av})^{ls}, (\sigma_{DP})^{ls}, (\nu_{DP})^{ls}, \lambda_{DP}^{ls}$. There are also given values of the nominal power on couplings of dredge pumps N_{DP}^{nom} as well as calculated values of the relative average loads of dredge pumps $\overline{N}_{DP}^{av}$. In Fig. 1 are showed the load histograms of dredge pumps on selected dredgers during loading the spoil to hopper (soil hold). Particular numerical values of instantaneous loads on dredge pumps were grouped into left-side open quantification intervals of identical width. The quantification interval width resulted from division of the range determined by the minimum and maximum service power of dredge pumps. With a view of accuracy of calculations 10 quantification intervals were assumed [10]. The histograms are presented together with relevant curves of normal distribution density, i.e. one of the theoretical distributions most often used for approximation of load distribution of main power consumers on dredgers [3, 9, and 10].

Tab.1. Characteristics of load distributions of dredge pumps on dredgers during loading the spoil to hopper

Dredger	N_{DP}^{nom}	N_{DP}^{av}	$\overline{N}_{DP}^{av}$	σ_{DP}	ν_{DP}	λ_{DP}^{ls}	m	References
	kW	kW	-	kW	-	-		
Kostera	125	82,1	0,657	6,9	0,084	0,98	846	[∗]
Kronos	150	95,1	0,634	7,8	0,082	0,97	498	[∗]
Łęgowski	2×550	774,9	0,704	62,3	0,08	0,98	1542	[∗]
Bukowski	2×550	786,4 488,4*)	0,715 0,444	54,5 61,1	0,069 0,125	0,97 0,95	486 497	[∗]
Nautilus	870	706,8	0,812	26,2	0,037			[6]
Gogland	2×1180	1787,1	0,757	61,2	0,034			[7]
Geopotes 15	2×1550	1987,7	0,641	71,9	0,036	0,98	592	[∗]
Lange Wapper	3200	2482,6	0,776					[8]
average			0,712		0,06	0,972		

*) – pump operation connected with very soft soil (silts)
m - sample number
[∗] – self investigations

All the investigated dredgers operated in spoil the medium sandy soil. Only in one case (the dredger „*Bukowski”)* the dredger operated in spoil the very soft soil (the so called silts) during removing the silt from water path. For dredging the soil of the kind other values of operational parameters of the pumps are recommended [2, 4], therefore in the case of the dredger „*Bukowski*” the respective results are given for two kinds of dredged soil.

The performed calculations of load distributions of dredge pumps during loading the spoil showed that for particular dredgers the relative average loads were contained within the range of 0,634÷0,776 at the mean value of 0,712 and distribution variation coefficient value contained in the range of 0,034 ÷0,082 at the mean value of 0,06. The presented data concern operation in medium sandy soils. The rather small values of distribution variation coefficients of pumps result from operational conditions of the pumps during loading the spoil. Power values demanded by the pumps are influenced first of all by water-soil mixture density and depth of water in a dredged area. The rather small changes of the parameters at the practically constant length of the piping (it concerns external trailing suction pipes) result just from the small values of the above mentioned coefficients.

The pump operation in light soils is associated with lower average values of pump loads. On the dredger „*Bukowski*” the average load value of the pumps dredging the light soil (silt) reached less than 65% of the loads of the same pumps during operation in medium soils.

Values of the coefficient λ_{DP}^{ls} were contained in the range of 0,95÷0,98 at the mean value of 0,972.

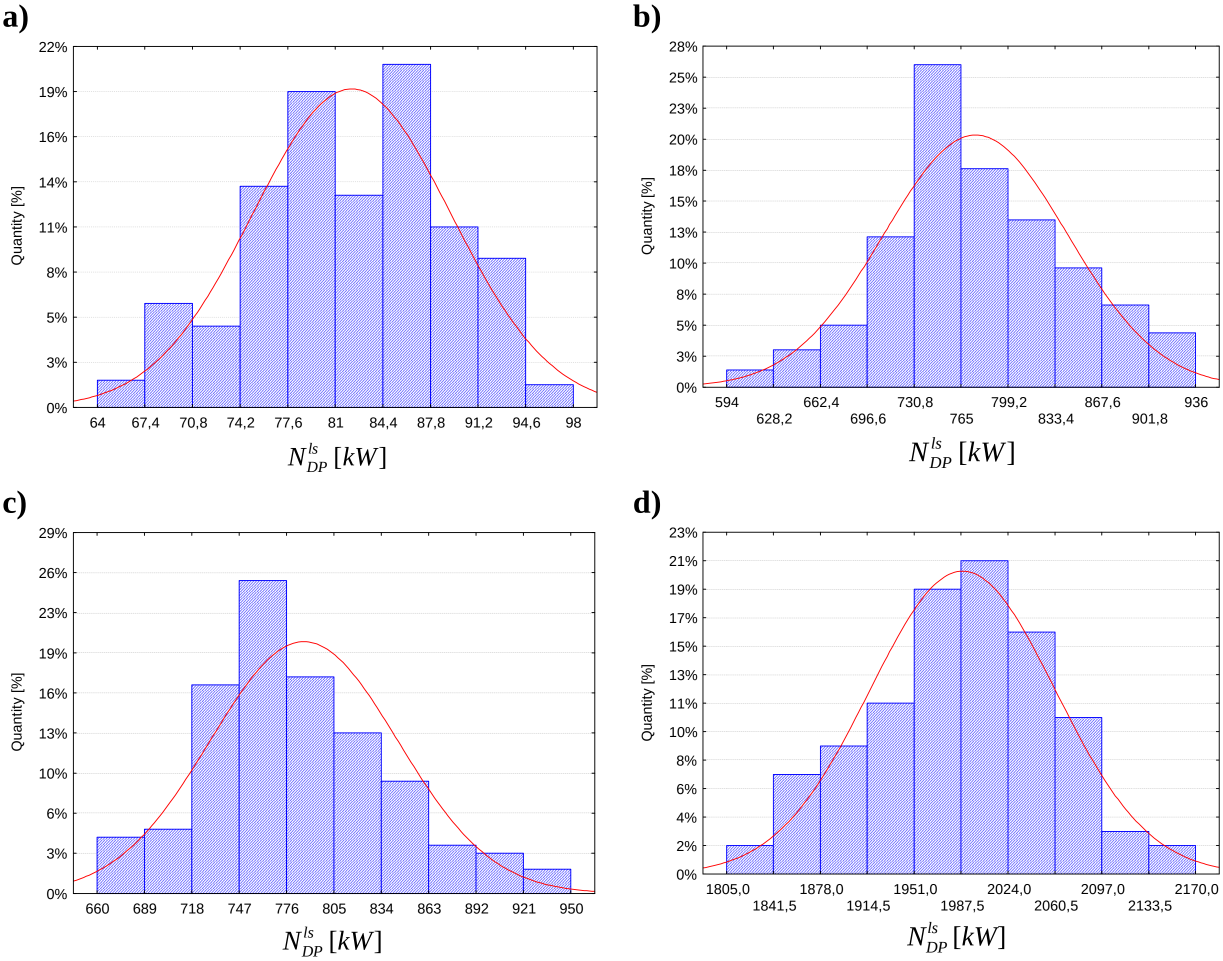

Fig.1. Load histograms of dredge pumps on trailing suction hopper dredgers during loading the spoil; a) the dredger „Kostera”, b) the dredger „Łęgowski”, c) the dredger „Bukowski”, d) the dredger „Geopotes 15”.

4. Load distribution of dredge pumps during transferring the spoil ashore

The analysis covered results obtained from 13 dredgers (including 7 trailing suction hopper dredgers, 3 cutter suction dredgers, 2 barge unloading dredgers and 1 bucket ladder dredger) The below presented Tab. 2 shows the data which characterize load distributions of dredge pumps of the 13 dredgers during carrying –out operations associated with transferring the spoil ashore. Like in the case of the loading, in Tab. 2 are given the nominal power values of the dredge pumps intended for transferring the winning ashore. The principles for elaboration of histograms are the same as in the case of the pump service state of loading the winning.

Tab.2. Characteristics of load distributions of dredge pumps on dredgers during transferring the spoil ashore

Dredger	N_{DP}^{nom}	N_{DP}^{av}	$\overline{N}_{DP}^{av}$	σ_{DP}	ν_{DP}	λ_{DP}^{sp}	m	References
	kW	kW	-	kW	-	-		
Kostera	325	216,5	0,666	29,6	0,137	0,98	918	[∗]
Kronos	420	189,4	0,451	20,6	0,109	0,99	756	[∗]
Łęgowski	1100	832,9	0,757	101,4	0,122	0,99	1156	[∗]
Bukowski	1100	835,7 651,6*)	0,759 0,592	52,8 82,7	0,064 0,127	0,98	465 424	[∗]
Gogland	2360	1815,9	0,769	178,4	0,098			[7]
Geopotes 15	3100	2211,1	0,713	239,9	0,109	0,99	517	[∗]
Lange Wapper	8900	3861,9	0,434					[8]
Trojan	1000	536,7	0,537	122,9	0,229	0,96	1437	[∗]
Toruń	840	431,5	0,514	52,3	0,121	0,96	896	[∗]
Scorpio	2100	1667,5	0,794	278,6	0,167			[5]
Rozkolec	3260	1188,1	0,365	334,8	0,282	0,98	636	[∗]
Raja	540	240,5	0,445	32,3	0,134	0,99	576	[∗]
Małż II	250	158,26	0,633	30,78	0,194	0,96	482	[∗]
average			0,603		0,147	0,978		

[∗] – self investigations

Like in the case of the loading, the investigated dredgers transferred ashore mainly medium soil. And, only the dredger „*Bukowski*" operated also in light soil. For this reason results for two kinds of soil are given for this dredger.

The performed calculations of distribution parameters of loads on dredge pumps during transferring the spoil ashore showed that for particular dredgers the relative average loads were contained in the range of 0,365 ÷0,794 at its mean value of 0,603 and variation coefficient in the range of 0,064 ÷0,282 at its mean value of 0,147. The above given values concern operation in medium soils.

Attention should be paid to the fact of greater absolute average values of loads on pumps during transferring the winning as compared with those in the case of loading (such situation takes place on trailing suction hopper dredgers). It results from that during transferring the spoil power value demanded by the pumps depends mainly on length of piping for transferring the winning. In the case of single dredge pump systems such values are on average 2,2÷2,3 times greater, and for the systems of two dredge pumps such values are about 1,1÷1,2 times greater in the state of transferring the winning ashore.

Values of variation coefficients of load distribution of pumps during transferring the spoil are greater than in the case of loading operations. Varying transfer piping length directly influences changes of pump loads during transferring the winning. As results from the performed investigations the maximum transfer piping length L_{sp}^{max} reached on average $4,46L_{sp}^{min}$ (where L_{sp}^{min} - minimum transfer piping length) [9].

Values of the coefficient λ_{DP}^{sp} are close to those of λ_{DP}^{ls} and are contained in the range of 0,96÷0,99 at its mean value of 0,978.

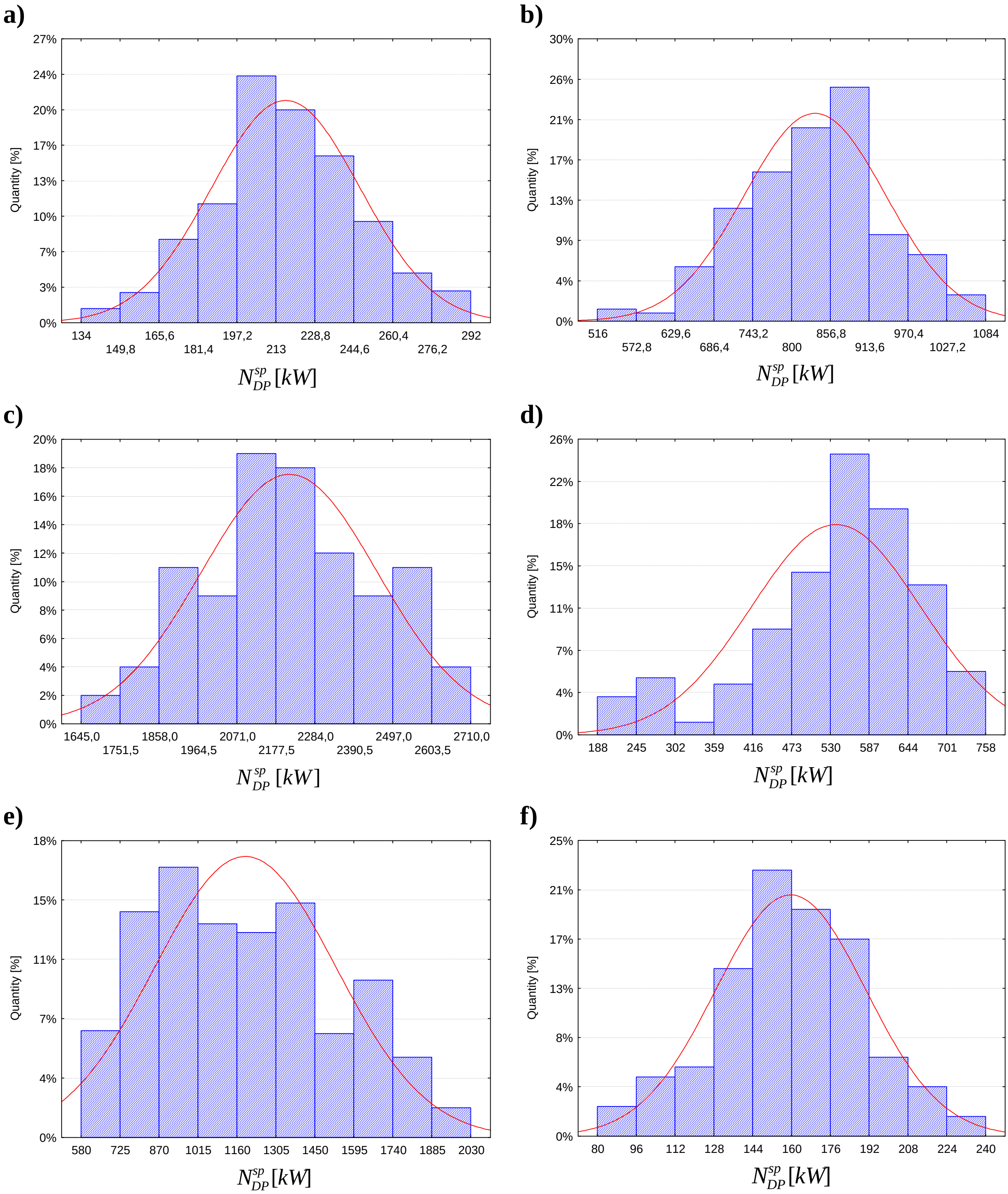

Fig.2. Load histograms of dredge pumps on dredgers during transferring the spoil; a) the tshd „Kostera”, b) the tshd „Łęgowski”, c) the tshd „Geopotes 15”, d) the csd „Trojan”, e) the barge unloading dredger „Rozkolec”, f) the bld „MałżII”

Where: tshd – trailing suction hopper dredger,

csd – cutter suction dredger,
bld – bucket ladder dredger.

5. Summary

All the above presented calculation results concerning characteristics of dredge pumps and histograms of their loads represent real service conditions of such pumps on dredgers. Owing to the large number of investigated dredgers and the wide range of their size the results can be deemed representative of the entire population of dredge pumps operating on dredgers.

The presented results may be useful in predicting operational loads on dredge pumps depending on their service state on dredgers of various kinds. All that , when combined with knowledge of loads on other main power consumers and efficiency characteristics of power transmission systems of particular main power consumers, can make it possible to determine the service load characteristics of main engines installed on dredgers. This is especially important in preliminary design stages of power systems on dredgers.

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