Journal of the Korean Society of Marine Engineering, Vol.32, No.3, pp.421~429, 2008(ISSN 1226-9549)

A Study on the Correlation Analysis of the Present Status of Positive Displacement Pumps Installed in Ships

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(Manuscript : Received March 25, 2008 ; Revised May 19, 2008)

Abstract : Various kinds of ship are operated to transport cargo or passengers at sea in the world. Most of the important auxiliary machineries installed in those ships are fluid machineries such as pumps, compressors, and fans. A large percentage of fluid machinery is pumps which are classified turbo and positive displacement pumps. This paper analyzes only positive displacement pumps. This thesis has two aims: (a) to analyze the present status of pumps installed in merchant and training ships and (b) to find the correlation among sea going pump kW, port pump kW, total pump kW, GE kW, ME MCR, number of pumps, ME kgf, pump kgf. Based on ship's type, this paper seeks to find special characteristics as a result of analyzing head, flow rate, and kW. Moreover this paper analyzes and compares number of pumps, pump kW/ME MCR, pump kW/GE kW under the conditions of seagoing and berthing according to ship's type.

Key words : Merchant ships, Training ships, Positive displacement pump, Correlation analysis.

1. Introduction

Currently, there are numerous types of ships[1] that are operated at sea around the world. Most of the auxiliary machineries that are installed in a ship are fluid machinery[2] such as pumps, compressors and fans. A large percentage of the fluid machineries in the ship are pumps. However, the only research that has taken place on pumps is on the types of pumps, pump's specifications, internal fluid flow and pump performance[3]. Practically, no systematic study has taken place on the relation between ship type and the using status and characteristics of ship's pumps. Pumps are important machineries for main engine and loading /unloading in the ships, most of which are classified into turbo and positive dis- placement types except a few special pumps.

This paper is based on the present state of installation of positive displacement pumps in the way of ① - ④ below.

① Analyze ship's characteristics through comparing and analyzing pressure head, flow rate, kW and number of pumps classified by ships' type.

② Characterize according to the distribution of positive displacement pumps by

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ship's type.

③ Compare and analyze the power of dividing pump kW by ME (Main Engine) MCR (Maximum Continuous Rating) under the conditions of seagoing and berthing.

④ Analyze the characteristics by means of dividing weight of pump by weight of ME.

Based on the results, the correlation between the variables in ①②③ and ④ stated above is analyzed.

First of all, by simultaneously testing all the ships types and compare all ships separately according to ship's type to identify the correlation between pump and the above parameters.

The varieties of ships are broad and have special characters. We would like to verify whether the ship that was chosen for this study can represent the diversity of ships.

2. The status of pump installation classified by ship's type

The object ships of this study were the ship operated by a shipping company, whereas all LNGC (Liquified Natural Gas Carrier) operated by Korean flag shipping companies were the object of this study. The biggest ships classified by ship's type as illustrated in Fig. 1 were selected for the study, and Table 1 shows the specifications of the selected ships.

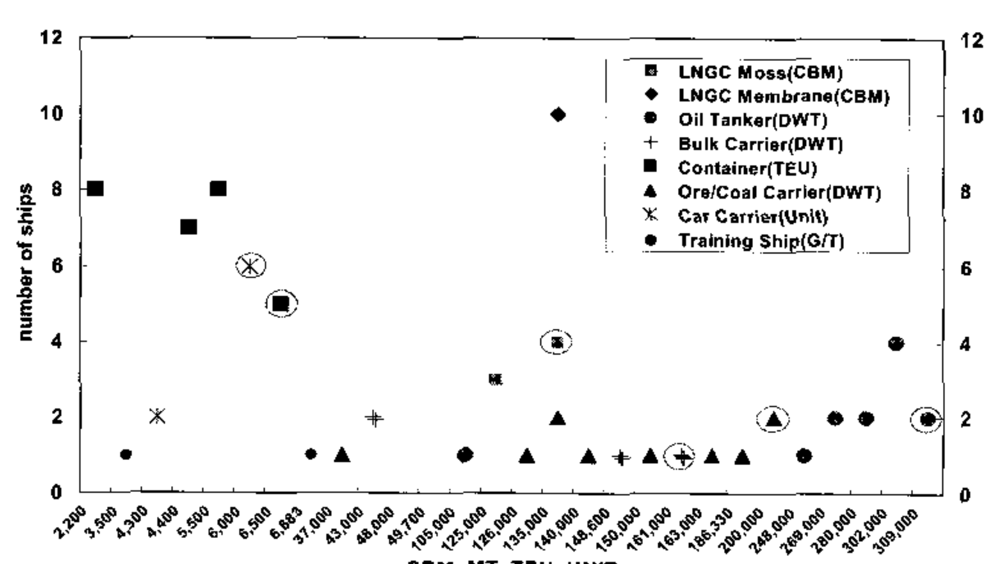

Fig. 1 The subjects of ships for research

Table 1 Specifications of ships for research

	Built (year)	Length(LOA) (m)	Deadweight Grosston(MT)	M/E M.C.R. (kW)	M/E N.C.R. (kW)	G/E output (kW)
LNGC(MOSS)	2000	289	77,584	29,082	26,174	3250 x 3
oil tanker	2005	333	309,000	29,127	25,287	1000 x 3
bulk	1997	280	161,121	17,091	15,928	600 x 3
container	2001	304	80,500	66,844	60,613	3000 x 4
ore/coal	1990	298	200,100	15,123	13,609	560 x 3
car carrier	1997	200	21,505	14,511	13,057	1180 x 3
T/S Hannara	1993	93	3,640	2,982	2,535	480 x 3
T/S Hanbada	2005	117	6,686	6,062	5,153	960 x 3

The kW, head, flow rate of positive displacement pumps of all types of ship were analyzed and Figs. 2~6 show the characteristics of the ships analyzed, with the graph for Bulk Carrier, Car Carrier and Training Ship (Hannara) omitted. The vertical axis on the left of the graph indicates pump kW which is the kW in case of one pump and sums up the kW in case of several pumps of same type, while the vertical axis on the right of the graph shows pump flow rate and head and the vertical axis on the left side shows pump kW. All data used in the paper is based on the data booklet and electric load analysis as the finished plan issued by shipyard.

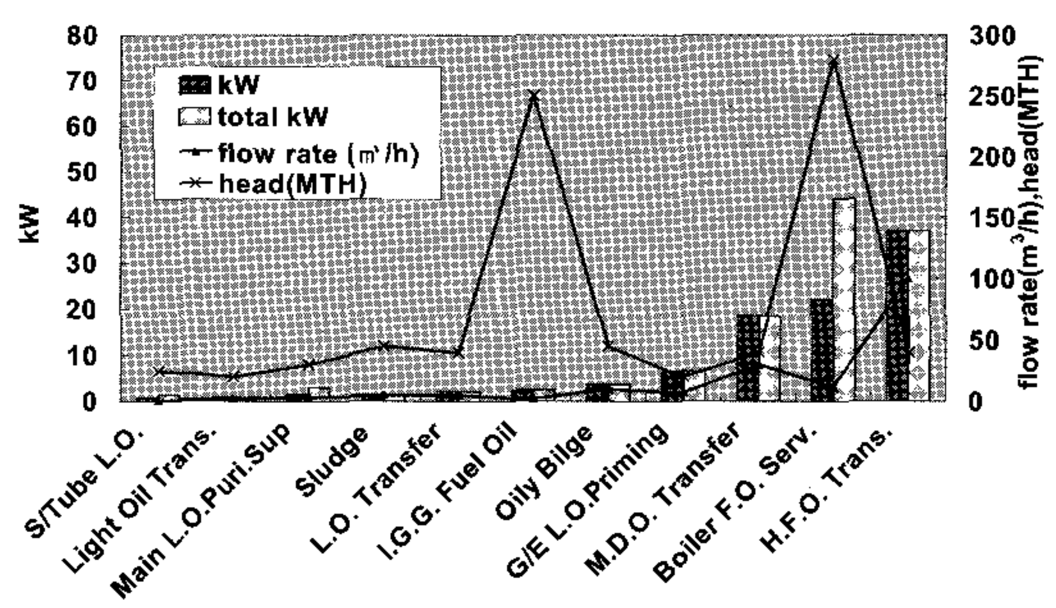

Fig. 2 LNGC positive displacement pump

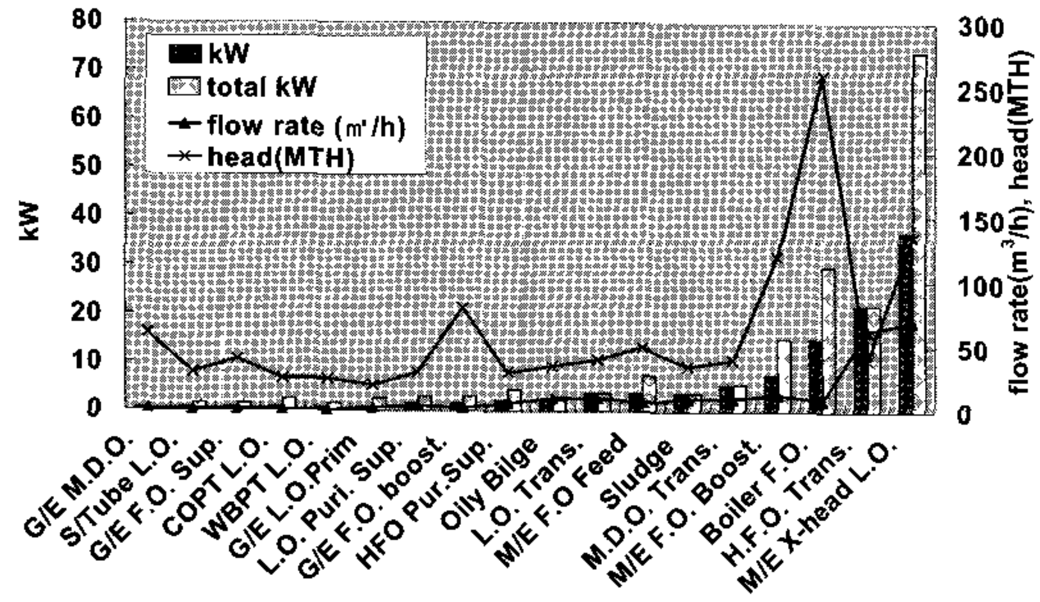

Fig. 3 oil tanker Positive displacement pump

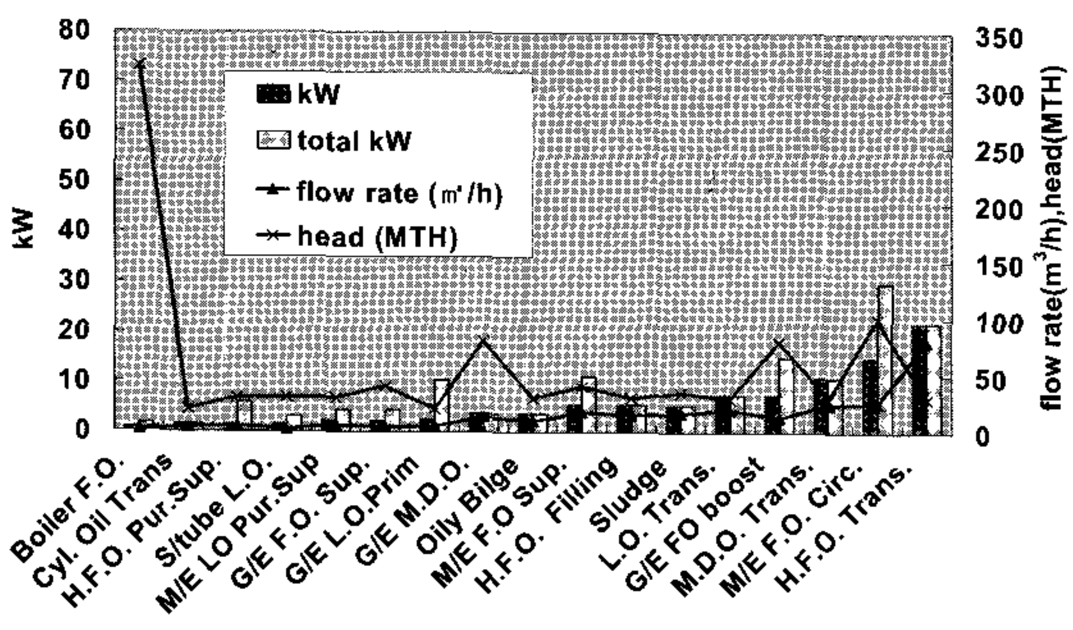

Fig. 4 Container Positive displacement pump

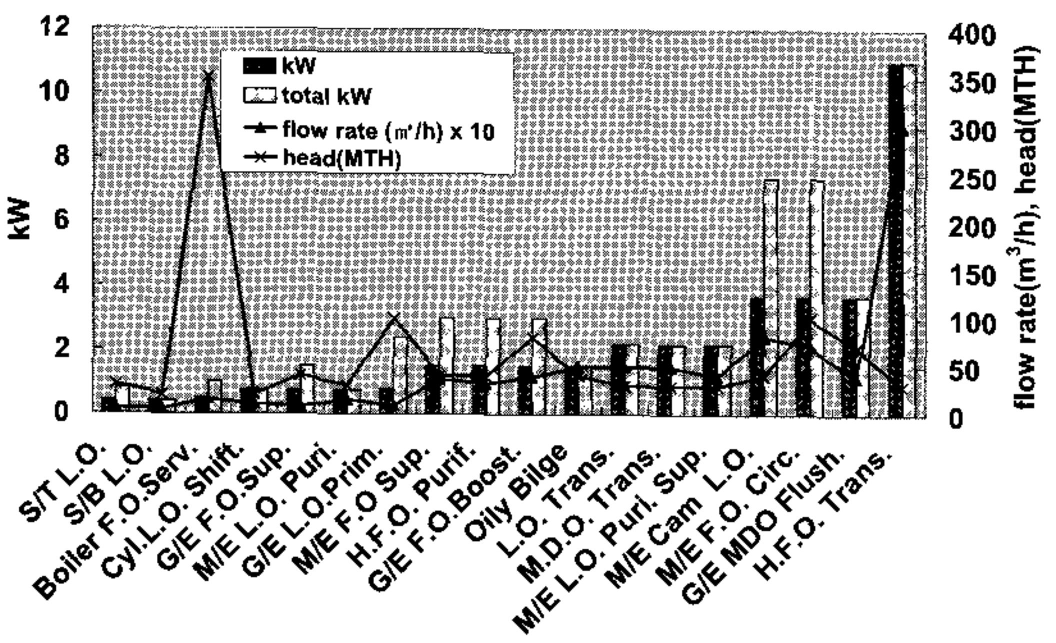

Fig. 5 Ore/coal carrier Positive displacement pump

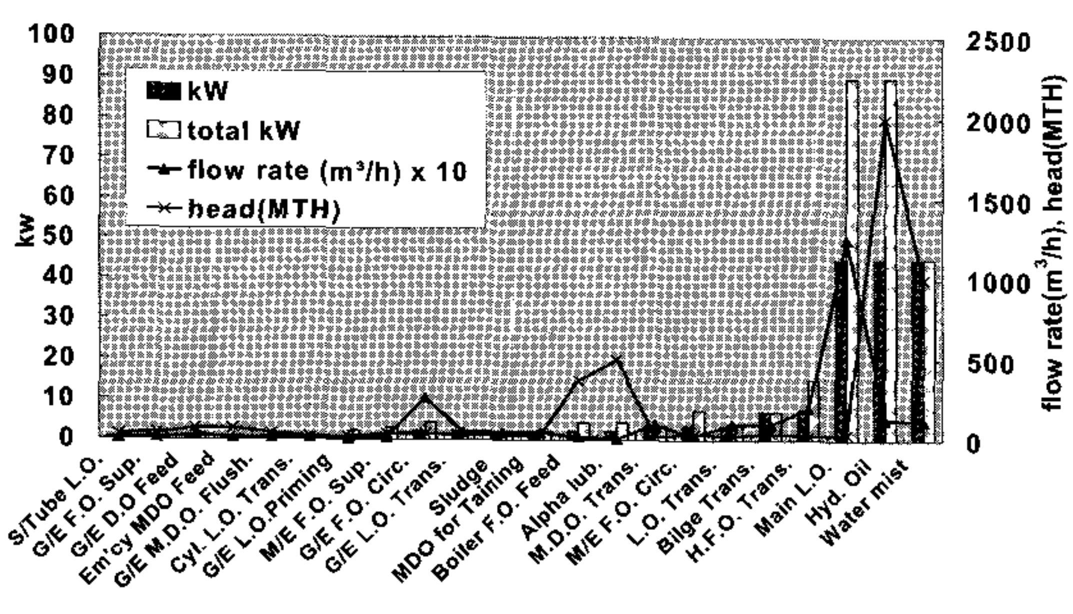

Fig. 6 Hanbada Positive displacement pump

2.1 The usage characteristic of positive displacement pumps classified by ship's type

In case of positive displacement pump the maximum value of kW and flow rate per pump are based on commonly used pumps of all types of ship. Heavy fuel oil transfer pump shows the maximum value of kW and flow rate in case of LNGC, Container Ship and Ore/Coal Carrier. ME crosshead L.O. (Lubricating oil) pump was the maximum value of kW and flow rate for Oil Tanker. Even though there are two major diesel ME makers for ship, the object ship has the diesel ME made by Sulzer and ME crosshead L.O. pump shows maximum value. In addition, the ME L.O. pump of T/S Hanbada is different from Merchant ships, i.e., the former is a positive displacement pump, while Merchant ships have turbo pumps. The maximum kW of pumps on T/S Hanbada was hydraulic oil pump. T/S Hanbada installed the pumps to use for MC and ME. The maximum kW was L.O. pump.

The maximum head is observed from the boiler F.O. service pump that is a pump supplying fuel to boiler in all ships except T/S Hanbada. The head of boiler F.O. (Fuel oil) service pump of T/S Hanbada is also high but the head of the hydraulic oil pump supplying high pressure of hydraulic oil into ME is higher than the head of boiler F.O. service pump.

2.2 The distribution feature of positive displacement pump classified by ship's type

Fig. 7 shows the number of positive displacement pumps according to ship's type. LNGC installed a turbine engine as

ME and have a lot of turbo pumps but not many positive displacement pumps, and Oil Tanker and T/S Hanbada have more positive displacement pumps than other types of ship.

Fig. 8 displays the number of pumps according to ship's type, and there is no great deviation classified by ship's type in amount of pumps to be represented as model pumps for the study, and all types of ship have similar number of pumps.

Fig. 9 indicates the standard deviation[4] and mean of number of pumps according to ship's type and the ships selected for this study. The mean is the average value of group. Scatter diagram indicates the scattered extent of the value of variate, and the unit of measuring the variation extent or scattered state of data value is variance. If it scatters widely from the mean, variance is large. On the other hand, if it is close to the mean, variance is small. A square root of variance is standard deviation. Equation (1) is mean, Equation (2) is variance, and Equation (3) is standard deviation.

$$\mu = \frac{(X_1 + X_2 + \cdot\cdot\cdot + X_n)}{N} = \frac{\sum_{i=1}^{n} X_i}{N} \quad (1)$$

$$\sigma^2 = \frac{\sum_{i=1}^{n} (X_i - \mu)^2}{N} \quad (2)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \mu)^2}{N}} \quad (3)$$

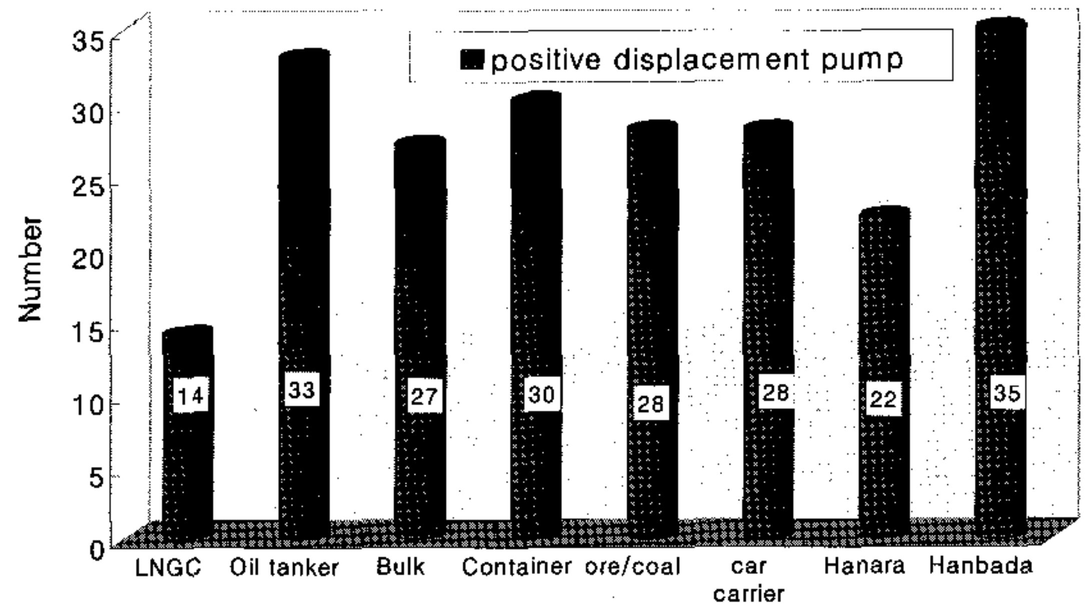

Fig. 7 The number of pumps according to ship's type

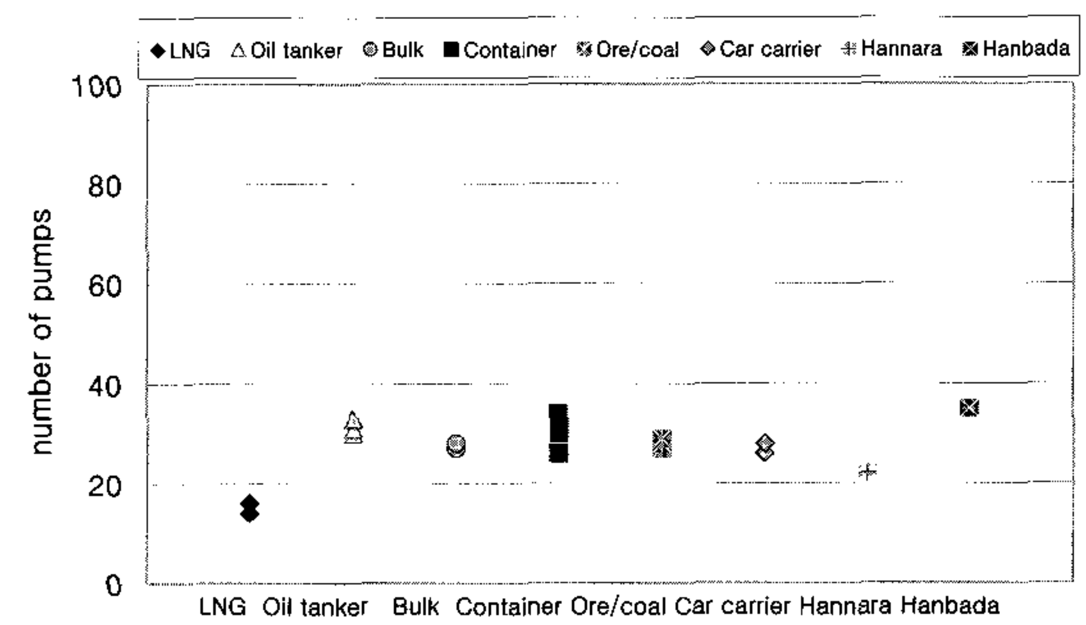

Fig. 8 Comparison between ship for research and ships not for research for the number of pumps according to ship's type

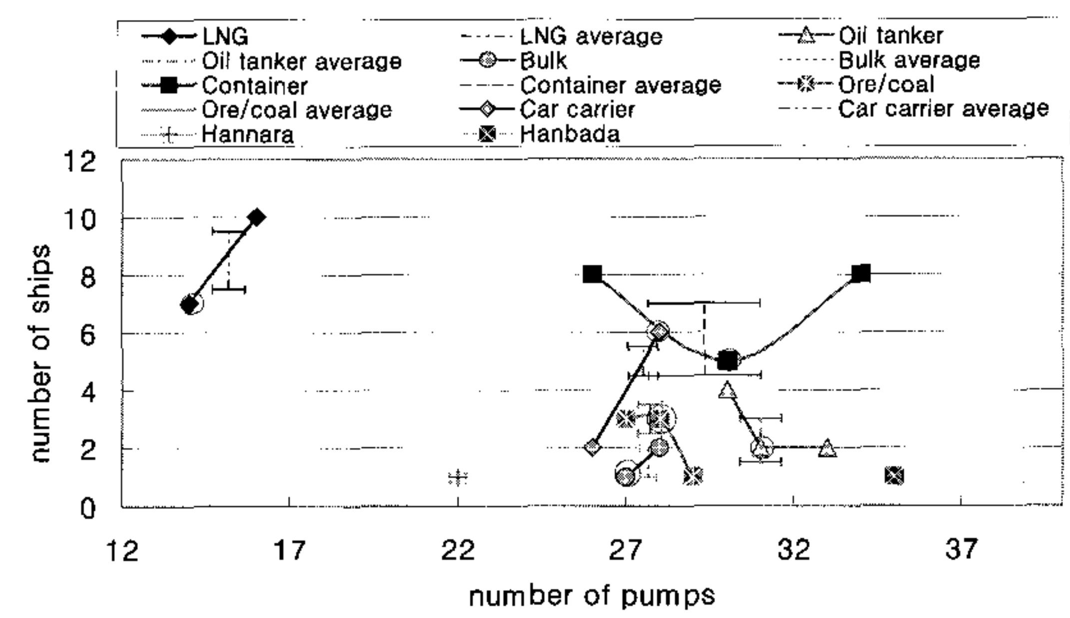

Fig. 9 Standard deviation, mean for the number of pumps according to ship's type

2.3 The feature of total kW vs. ME MCR by ship's type

Fig. 10 shows the value of pump kW divided by ME MCR under the seagoing conditions and berthing according to ship's type. In case of Merchant ships it should be noted that there is no specific features related to the value of pump kW divided by ME MCR and two Training Ships have relatively high values. ME of Training Ships is comparatively small but the graph displayed like as Fig. 10 because positive displacement L.O. pump was installed.

Fig. 11 shows the value of pump kW versus ME MCR and those pumps selected for this study were compared with other pumps which was not selected as an object ship of this study to identify whether the pumps selected for this study can delegate other pumps. It should be noted that the values of the same type of ships are almost same. In addition Fig. 12 details the value in Fig. 11 and shows the standard deviation, mean and selected object ship separately compared with the value of unselected object ship. As the graph can be noted the values are placed mostly on the left of the graph except Training Ships. And it is noted that diesel ship and turbine ship have similar features.

Fig. 13 and 14 indicate the value of pump kW versus ME MCR under the berthing condition, and, except Training Ship, the values are placed mostly on the left of the graph. The values are not much different from the values under the seagoing condition.

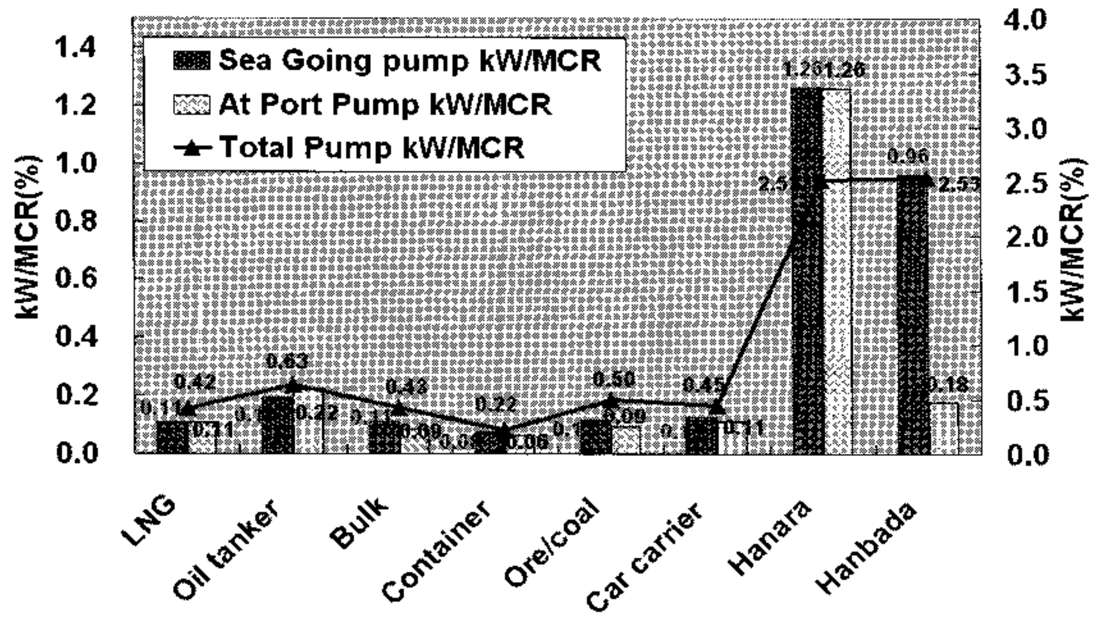

Fig. 10 The power characteristics of pump kW v.s. ME MCR

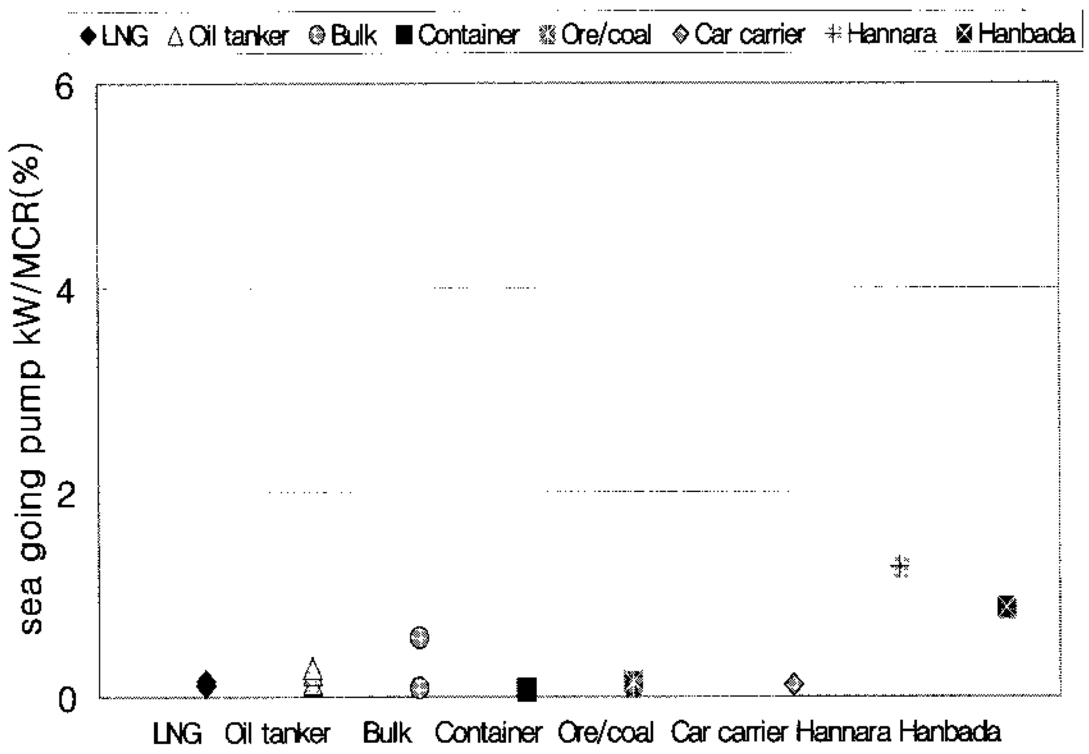

Fig. 11 Comparison between ship for research and ships not for research for the power characteristics of seagoing pump kW v.s. ME MCR

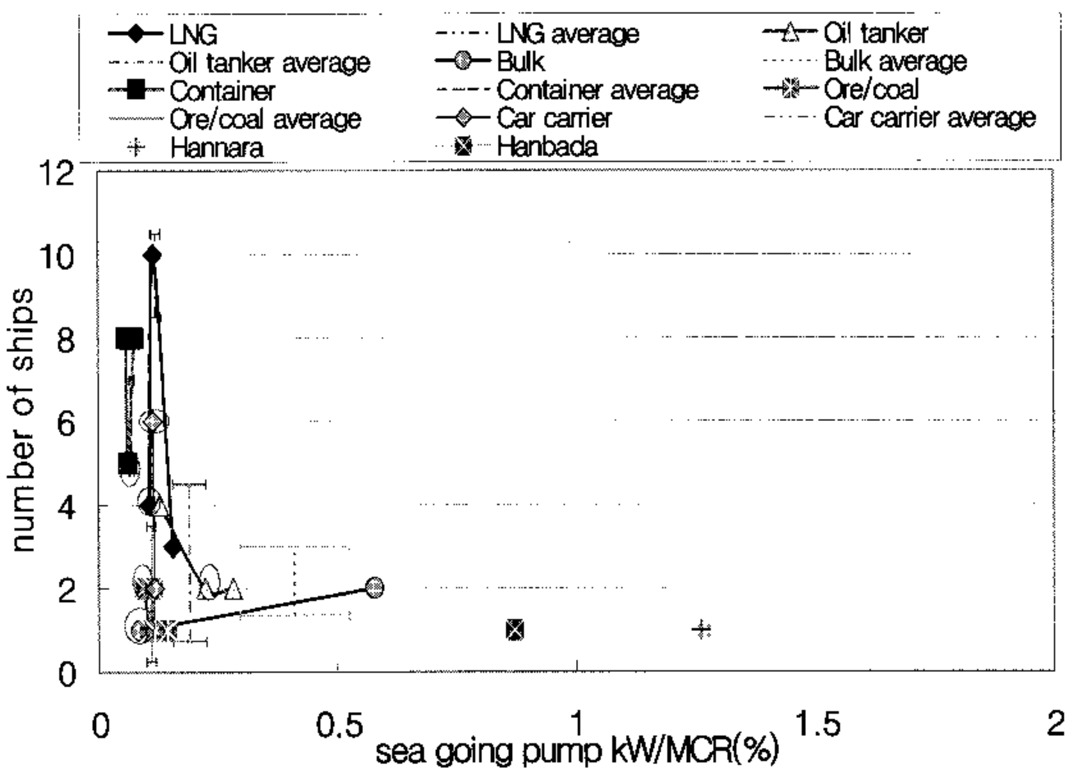

Fig. 12 Standard deviation, mean for the power characteristics of seagoing pump kW v.s. ME MCR

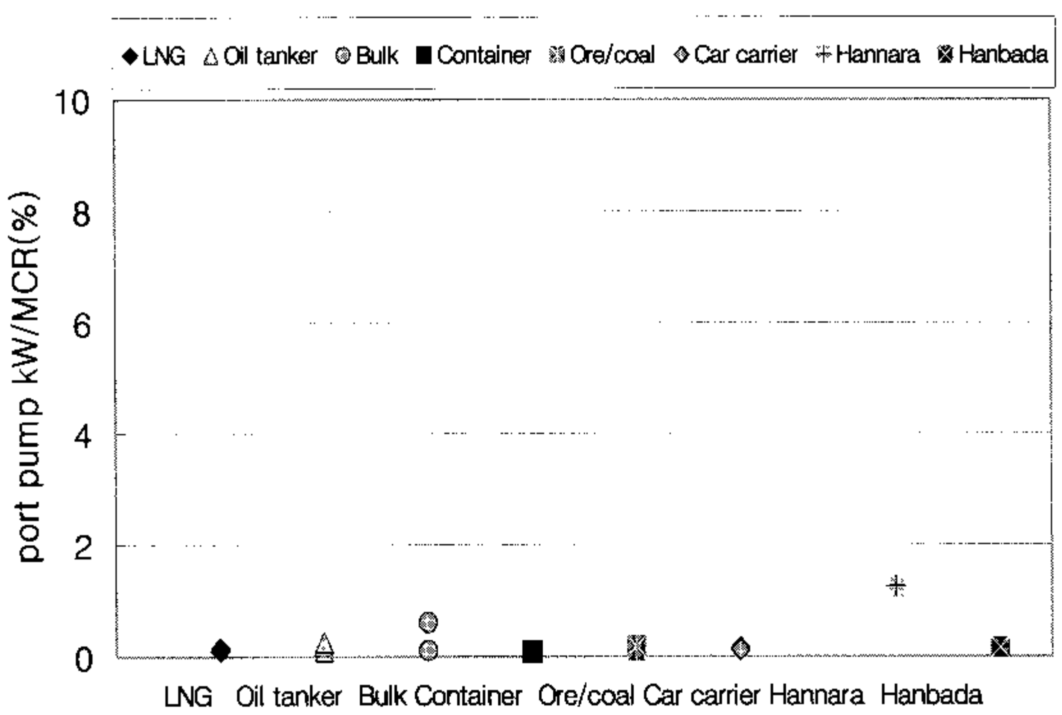

Fig. 13 Comparison between ship for research and ships not for research for the power characteristics of port pump kW v.s. ME MCR

2.4 The feature of pump weight vs. ME weight by ship's type

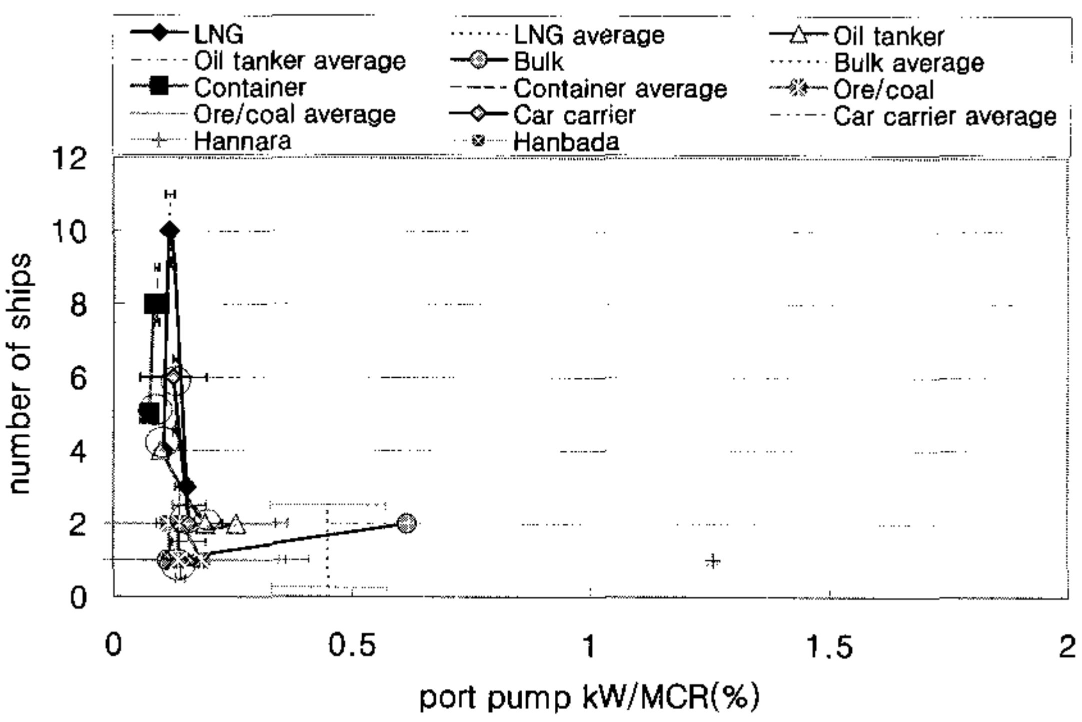

Fig. 14 Standard deviation, mean for the power characteristics of port pump kW v.s. ME MCR

Fig. 15 shows the value of the positive displacement pump weight (in case of more than one pump the values are summed up) versus the ME weight according to ship's type. By comparing the value of the positive displacement pump weight versus ME weight, the percentage of pump can be acquainted. In the graph, the value of Training Ship is bigger and all the rest of it has the almost regular value of 0.22~1.54%. The result shown in Fig.15 is because the size of pump in Training Ship would not be reduced under the particular standard, even though the size of ME in Training Ship has been reduced to keep up with the size of ship. In addition, the the L.O. pump of positive displacement type for ME is the another reason why such result came out in the study.

Fig. 16 shows that various methods were carried out to examine whether the ship selected for this study can delegate the other ships, and the value in the graph is almost positioned in one place.

Fig. 17 indicates that all types of ship except Training Ship, air concentrated at the left of the graph.

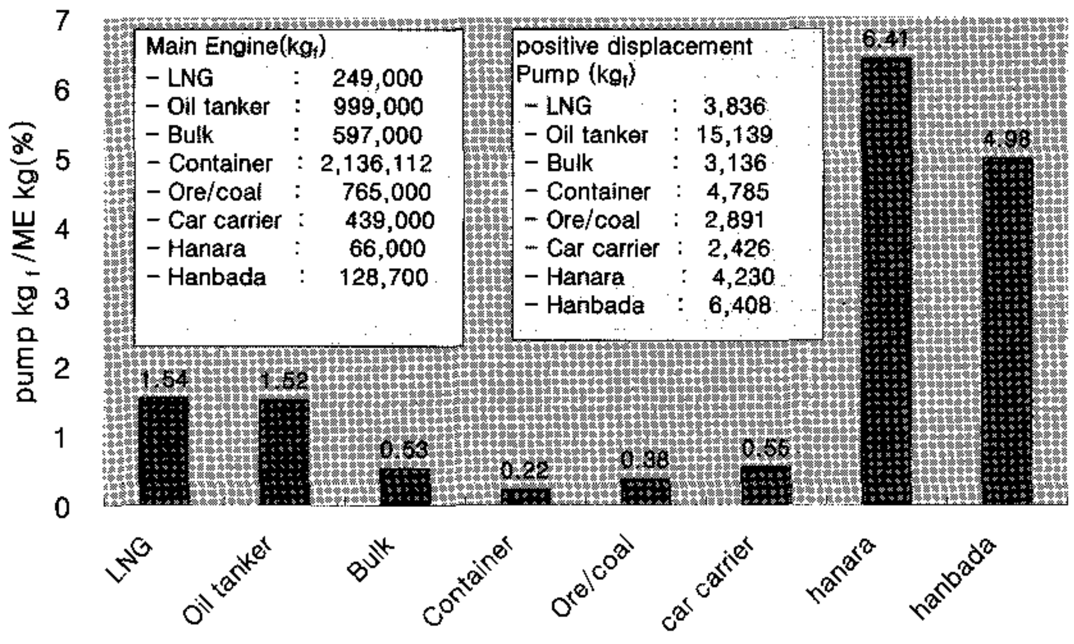

Fig. 15 The weight characteristics of pump v.s. ME

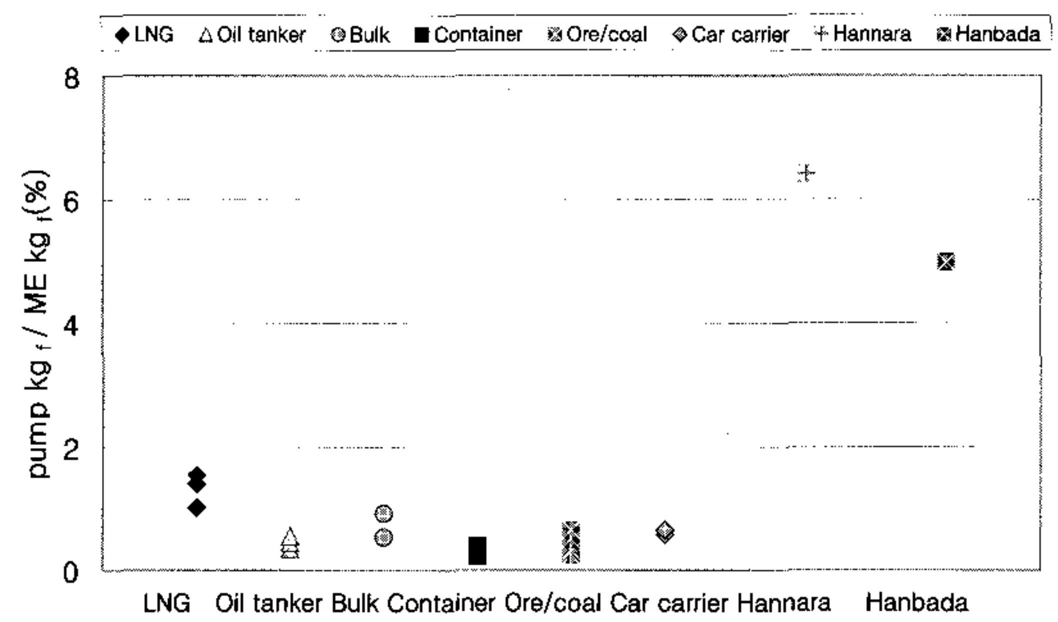

Fig. 16 Comparison between ship for research and ships not for research for the mass characteristics of pump v.s.ME

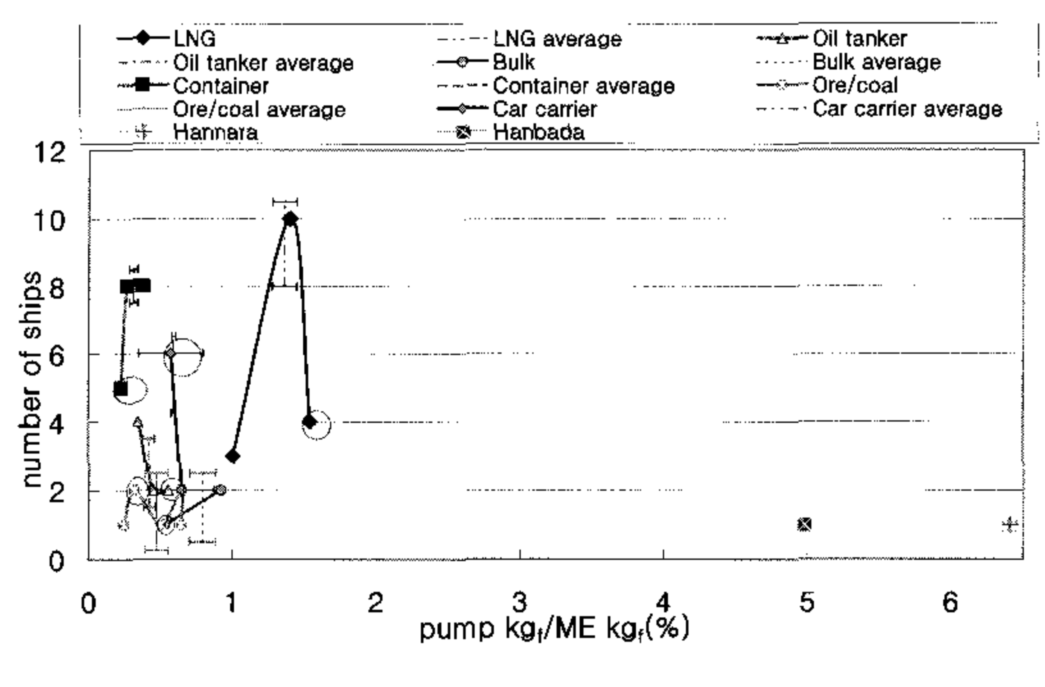

Fig. 17 Standard deviation, mean for the weight characteristics of pump v.s. ME

3. Analyzing correlation of all kinds of parameter classified by ship's type

Table 2 compares the values of each

parameter according to ship's type. Table 3 analyzes correlation of parameters by using the Pearson's correlation coefficient[5] procedures of Statistical Package for the Social Science (SPSS) to analyze the relation of parameters. Pearson's correlation coefficient would be indicated by 'r' and the statistical definition equation used is equation (4).

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{(n-1)S_X S_Y} \quad (4)$$

where, 'n' is size of specimen, Sx is standard deviation of parameter X, and Sy is standard deviation of parameter Y.

Correlation coefficient is an index measuring the extent of the first relation between two parameters. This indicates the relation direction of the first degree and extent of relation between two parameters. The extent of relation that correlation coefficient means is as follows.

- ■ 1.0~0.7(-1.0~-0.7) : Very strong relation
- ■ 0.7~0.4(-0.7~-0.4) : Considerable relation
- ■ 0.4~0.2(-0.4~-0.2) : Slight relation
- ■ 0.2~0.0(-0.2~-0.0) : No relation

Table 3 shows the relation between each parameters. Fig. 18 indicates five top rank items which have strong relation, and Fig. 19 indicates five low rank items which have no relation.

After comparing all types of ship above at the same time LNGC (3 types), Oil Tanker (3 types), Container Ship (3 types) and Coal/Ore Carrier (5 types) have been comparatively analyzed the correlation of each ships according to ship's type. Figure 20 shows that closer correlation was identified than the case of comparing all ships together. Moreover, Fig. 20 is the result which takes an average of each correlation classified by ship's type. In this graph, the most related ship's type in relation to the value of relation is Container ship of 0.90 and LNGC of 0.64, Oil Tanker of 0.61, and Coal/Ore Carrier of 0.61. Thus, the value of each ship's type is higher than the value of all ships' average, because the average value of all ships is 0.34.

Table 2 Various values according to ship's type

	LNG	Oil tanker	Bulk	Container	Ore/coal	Car carrier	Hannara	Hanbada
sea going pump kW	30.9	56.65	19.3	50.3	17.6	18.3	37.6	60.2
port pump kW	30.9	64.85	14.85	41.4	14.35	16.55	37.5	10.9
Total pump kW	121	183.87	73.1	146.2	54.2	65.95	92	292.9
GE kW	9750	3000	1800	12000	1680	3540	1200	2880
ME MCR(kW)	29082	29127	17091	66844	15123	14511	2982	6062
number of pumps	14	33	27	30	28	28	22	35
DWT, G/T(ton)	77584	309000	161210	80500	200100	21505	3460	6686
ME weight(kg)	249000	999000	597000	2136112	765000	439000	66000	128700
pump weight(kg)	3835.5	5489	3163	4785	2413	2506	4230	6408

Table 3 Correlation coefficient of various values

		sea going pump kW	port pump kW	total pump kW	GE kW	ME MCR	number of pumps	DWT, G/T	ME weight	pump weight
sea going pump	Pearson Correlat	1	.528	.892*	.237	.271	.469	.018	.234	.976*
	Sig. (2-tailed)		.178	.003	.572	.516	.241	.966	.577	.000
	N	8	8	8	8	8	8	8	8	8
port pump kW	Pearson Correlat	.528	1	.150	.268	.463	.015	.477	.416	.407
	Sig. (2-tailed)	.178		.723	.521	.248	.972	.232	.306	.317
	N	8	8	8	8	8	8	8	8	8
total pump kW	Pearson Correlat	.892*	.150	1	.125	.041	.502	-.105	-.022	.940*
	Sig. (2-tailed)	.003	.723		.768	.923	.205	.804	.959	.001
	N	8	8	8	8	8	8	8	8	8
GE kW	Pearson Correlat	.237	.268	.125	1	.855*	-.293	-.155	.592	.156
	Sig. (2-tailed)	.572	.521	.768		.007	.482	.713	.122	.711
	N	8	8	8	8	8	8	8	8	8
ME MCR	Pearson Correlat	.271	.463	.041	.855*	1	.041	.218	.913*	.138
	Sig. (2-tailed)	.516	.248	.923	.007		.924	.603	.002	.745
	N	8	8	8	8	8	8	8	8	8
number of pump	Pearson Correlat	.469	.015	.502	-.293	.041	1	.247	.335	.433
	Sig. (2-tailed)	.241	.972	.205	.482	.924		.555	.417	.284
	N	8	8	8	8	8	8	8	8	8
DWT, G/T	Pearson Correlat	.018	.477	-.105	-.155	.218	.247	1	.356	-.043
	Sig. (2-tailed)	.966	.232	.804	.713	.603	.555		.386	.919
	N	8	8	8	8	8	8	8	8	8
ME weight	Pearson Correlat	.234	.416	-.022	.592	.913*	.335	.356	1	.078
	Sig. (2-tailed)	.577	.306	.959	.122	.002	.417	.386		.854
	N	8	8	8	8	8	8	8	8	8
pump weight	Pearson Correlat	.976*	.407	.940*	.156	.138	.433	-.043	.078	1
	Sig. (2-tailed)	.000	.317	.001	.711	.745	.284	.919	.854	
	N	8	8	8	8	8	8	8	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

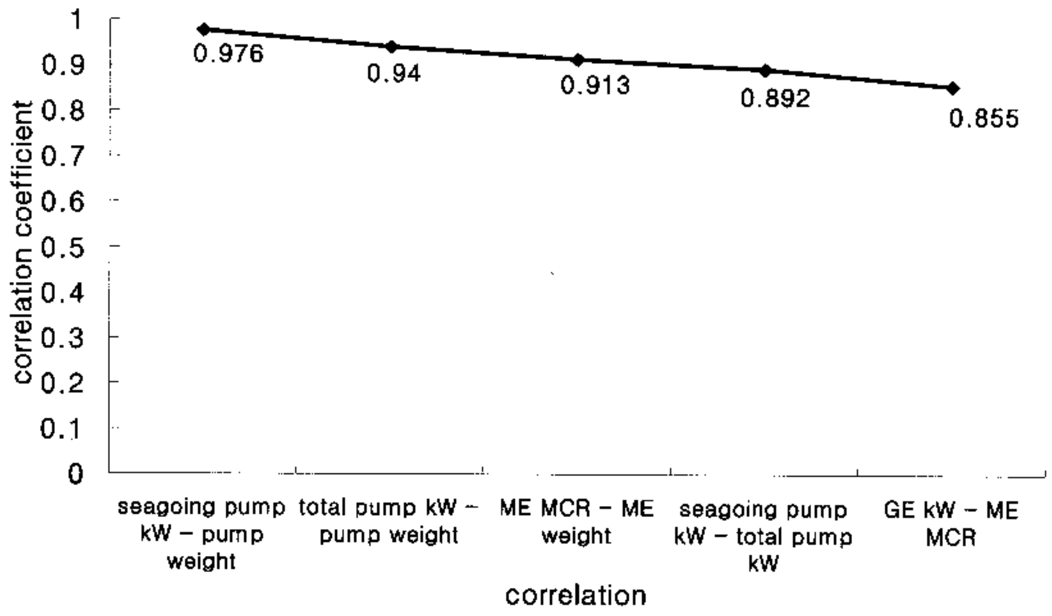

Fig. 18 Correlation coefficient of various values (high rank 5)

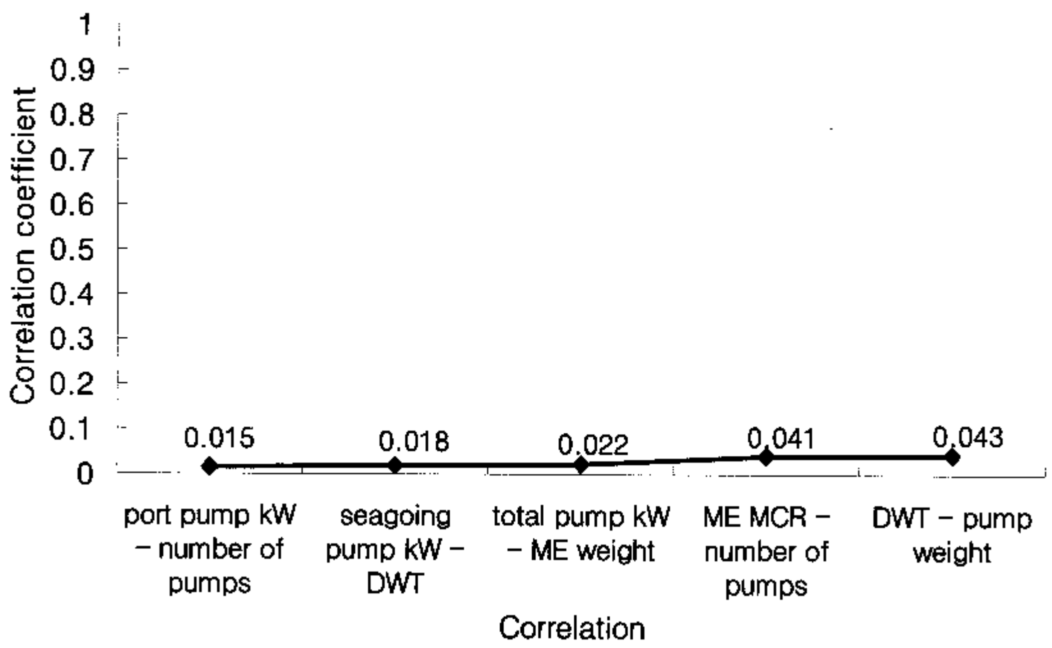

Fig. 19 Correlation coefficient of various values (low rank 5)

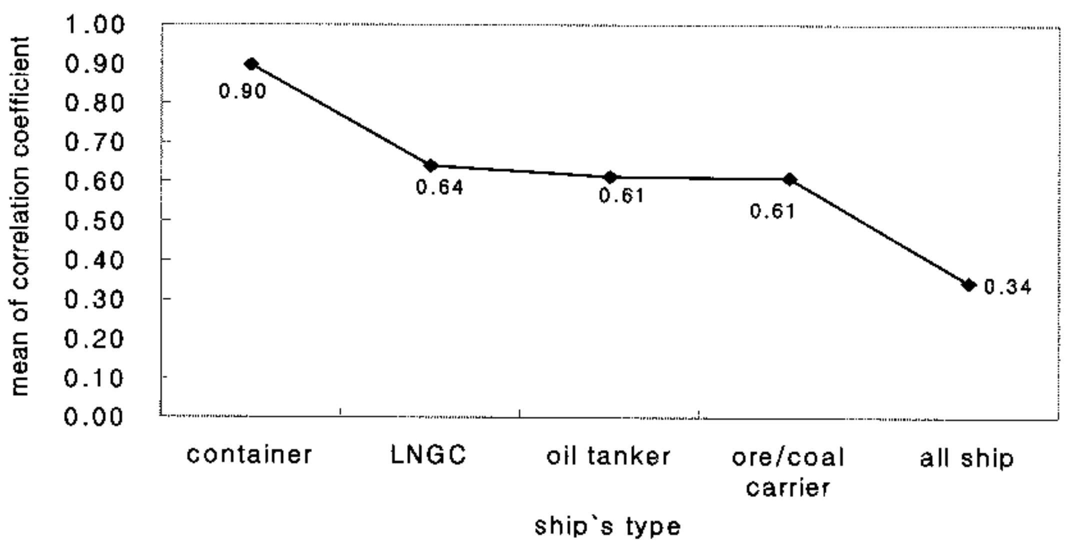

Fig. 20 Mean of correlation coefficient according to ship`s type

4. Conclusion

The following conclusion are drawn from the study that is carried out in relation to the using status and characteristic of positive displacement pumps installed in 6 types of Merchant ship and 2 Training ships classified by ship′s type.

1. Diagrammed the pump installation status of the Merchant ships and Training ships and compared head, kW, flow rate, number of pumps by ship′s type.

2. In order to qualify one ship as the delegate ship, several methods were used. The methods were listed below; ①the distribution of positive displacement pump by ship′s type, ②the feature of total kW vs. ME MCR by ship′s type, ③the feature of weight vs. ME weight vs. ME weight by ship′s type.

The result of the examination indicates that the chosen ships could be justified as a suitable representation of ships their own type.

3. From the values received from 1. and 2 (total pump kW, port pump kW, GE kW, seagoing pump kW, pump weight, ME weight, ME MCR, number of pumps, and ME kW), the following corelation could be obtained.

① The close relation is identified by analyzing separately correlation according to ship′s type.

② The analyzing correlation of all types of ship derives the value of 0.34 meaning slight relation.

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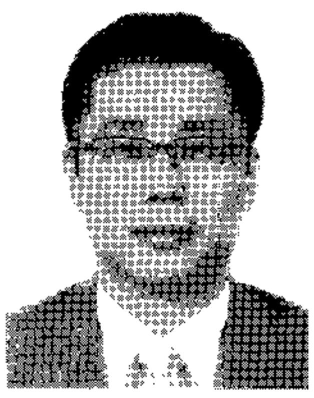

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