Fuel- and Cost-Savings by Hydrodynamic Measures

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Introduction

In times of high fuel prices and low freight rates the overall cost efficiency of vessels becomes of great importance to ship owners and operators. One of the simplest and most effective measures to improve the situation is through improvements to hydrodynamic efficiency.
Even if the ship lines, propeller and rudder are well optimised, significant improvements are possible by relative simple hydrodynamic measures. This paper presents a comparison of possible power savings by three such methods for six very different ships. This work results from collaboration between Grieg Shipping Group and Mewis Ship Hydrodynamics.

The concept of the Grieg Shipping Group

The Grieg Group was established in 1884, being family owned through 4 generations. An important part of the Grieg Group is the Grieg Shipping Group as the ship management and ship owner part of the group. Grieg Star Shipping is the chartering company under the umbrella of the Grieg Group.

Figure 1. STAR JUVENTAS, J-class vessel, 46,000 DWT

The vessels in service with the company are specialised open hatch self-loading type with a transport capacity of between 30,000 and 50,000 DWT. The vessels are typically equipped with two Gantry cranes and tween decks in some holds. The ships are very adaptable, being able to transport cargoes as e.g. wood products (paper and pulp), bulk cargoes, project cargoes and other types of unitized dry cargos. Figure 1 shows the STAR JUVENTAS loaded with wind turbines blades. The two Gantry cranes are located directly forward the bridge and can travel throughout the length of the payload area.

The new K-class vessel

In 2006 Grieg Shipping Group ordered 4 new vessels at a Korean shipyard. Within 2015 the target is to reduce the energy consumption by 20% considering the baseline of the J-class design from end of 1990. The new K-class is a part of this process, with a design target of about 15-20 % lower fuel consumption in comparison with their predecessors, the J-class.
The improvement of the hydrodynamic aspects was performed in cooperation with Friedrich Mewis, MSH, consultant and former director at HSVA. The collaboration resulted in a constructive discussion with the shipyard and an improvement was made mainly for the bulb and forward lines. Also the aft body lines were slightly modified from the yards initial proposal. The main contributors to hydrodynamic measures and improvement may be summarized as followed:

1. Improvement of bow lines, checked by CFD calculations
   2 % power reduction possible, corresponding to 0.9 % operating cost reduction
2. Trim optimisation, model tests at HMRI
   Average 3 % power reduction possible
   1.5 % realizable, corresponding to 0.7 % operating cost reduction
3. Speed reduction, calculations by MSH
   30 % power reduction possible, corresponding to 3 % operating cost reduction
   15 % power reduction realizable, corresponding to 1.5 % operating cost reduction
4. Power saving device, installation of a PBCF, no model tests
   3 % expected power reduction, corresponding to 1.4 % operating cost reduction

K-class, sum of power reductions: 21.5 %, corresponding to 4.5 % operating cost reduction

J-class vessel, ships in service

Since the results of hydrodynamic improvement of the new K-class vessel were encouraging, the Grieg Shipping Group immediately embarked on the hydrodynamic optimisation of the J-class vessels, which have been in service since 2004 - 2006.
The results were:

1. Improvement of ship lines, not possible (ships already in service)

2. Trim optimisation, model tests at HSVA
   Average 1 % power reduction possible
   0.5 % realizable, corresponding to 0.2 % operating cost reduction

3. Speed reduction, calculations by MSH
   32 % power reduction possible, corresponding to 3 % operating cost reduction
   16 % power reduction realizable, corresponding to 1.5 % operating cost reduction

4. Power saving device, retrofitting of a Mewis Duct®, model tests at HSVA
   6 % power reduction, corresponding to 2.7 % operating cost reduction

J-class, sum of power reductions: 22.5 %, corresponding to 4.4 % operating cost reduction

It must be mentioned that the realizable savings related to item 3 is very much dependent on the market situation when it comes to fulfilment of cargo contracts and delivery times in the port. The focus is to take an active role when it comes to required lean time in port and reduce the speed accordingly. Savings are estimated based on reduction of speed when possible, given a constant fleet and constant long term contracts. Contracts in the spot marked are taken case-by-case.

Investigations of four further ships

The results for J- and K-class vessels show the large potential of fuel- and cost-savings by simple hydrodynamic measures. This prompted the investigation of applying similar measures for some very different ship types:

1. Small Bulk Carrier 12,700 DWT, 16.2 kts
2. Very Large Tanker, VLCC, 300,000 DWT, 15.5 kts
3. Container Feeder Ship, 1,700 TEU, 20.0 kts
4. Very Large Container Vessel, 13,500 TEU, 24.6 kts

Table 1. Main particulars of the ships considered

Case No		1	Grieg J	2	3	4
Ship type		Bulker	J-class	Tanker	Container	Container
Size		12k	46k	300k	1,700TEU	13,500TEU
Lpp	m	130.00	187.00	324.00	165.00	350.00
B	m	21.00	31.00	60.00	27.90	51.20
T	m	7.50	12.00	20.00	8.50	14.00
CB	-	0.79	0.80	0.81	0.65	0.69
DP	m	4.90	7.00	9.70	6.60	8.90
PD	kW	4464	8151	22450	12250	56000
n	rpm	130	91	73	101	100
VD	kts	15.20	16.00	15.50	20.00	24.60
Fn	-	0.21	0.19	0.14	0.26	0.22
CTh	-	1.60	1.31	2.32	1.00	1.25

Trim optimisation

The effect of trim optimisation is investigated by the analysis of model basin self-propulsion data. Full model test results are available for all of the vessels with the exception of the VLCC. However in the case of the VLCC trim optimisation is not possible since the vessel must operate at two fixed draughts. The results of this analysis are shown in Table 2 and reveal relatively low possibilities for power saving at the trim ranges investigated. The reason for this is the well-designed and optimised hull lines at the forward and aft ends of these modern ships. This is contrary to results from some 25 years ago, where vessel trim plays an important role for power requirement.

Table 2. Results of trim optimisation tests, averaged values

Case No		1	Grieg J	2	3	4
Ship type		Bulker	J-class	Tanker	Container	Container
Size		12k	46k	300k	1,700TEU	13,500TEU
Trim optimisation, average possible power savings:						
ΔPD	%	3.0	1.0	0	1.0	0

Note: Positive % are reductions at fuel consumption

Speed reduction

In general the reduction of the ship's speed is a very effective measure for saving fuel costs. However, the results of the calculations within this paper show that this is not true for all ship types.
The calculations take into consideration the following:

- Speed power curve,
- Specific fuel consumption of the engine at low load operation,
- Lower income due to later arrival;

The cost changes through speed reduction are calculated for different cost share values. The cost share value is defined as the relation of fuel costs to total costs. The total costs consist of fuel costs, operation costs, capital repayment, interest repayment, cargo handling costs and maintenance costs. All of these are variable; but the actual fuel price plays the most important role for the actual cost share value.
The calculations were carried out for two cases:

- Case A: The vessel simply operate at slower speeds
- Case B: Adjust the fleet to maintain a constant transport capacity

Both cases resulted in virtually identical cost change curves, but differing fuel reduction curves.

As an example, figure 2 shows the cost change curves for the 13,500 TEU Container vessel. For the 13,500 TEU C/V (actual cost share value of 48 %, dotted line), the optimum speed is found to be 21.5 kts rather than the design speed of 25 kts. The cost reduction at that speed is about 7%, the fuel consumption reduction 43 % at case A, and 35 % at case B. Up to a speed of 16.7 kts the ship could operate without monetary loss. However, it must be considered that the very low loading of the engine would likely cause some additional mechanical problems which are not taken into account here.

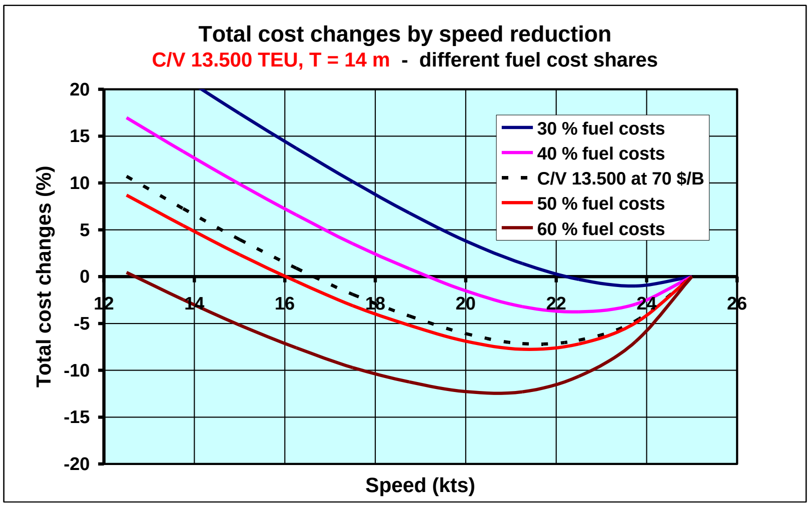

Figure 2. Total cost changes by speed reduction, C/V 13,500 TEU

The figures given in Table 3 are based on a fuel price at the September 1st 2009 of about 70 $/Barrel. These figures represent 100 % of the calculated possible reductions; during practical ship operation are about 50 % of these realizable only.

Table 3. Speed optimisation, results at optimum cost values

Case No		1	Grieg J	2	3	4
Ship type		Bulker	J-class	Tanker	Container	Container
Size		12k	46k	300k	1,700TEU	13,500TEU
Cost share		0.45	0.45	0.28	0.50	0.48
Speed optimisation, Δ costs at optimum speed (Vopt):						
VD	100%	15	16	16	20	25
Vopt.	kts	13.1	14.5	>16	17.4	21.5
Δ Costs	%	9	3	0	9	7
Speed optimisation, Δ fuel at optimum speed (Vopt.):						
Case A	%	45	39	0	46	43
Case B	%	36	32	0	37	35

Note: Positive % are reductions at costs & fuel consumption

Power saving devices

In our case "power saving devices" refers to additional components positioned close to the propeller. For more than 100 years such devices have been in use for the improvement of the propulsion efficiency and there are now many types on the market.
For all vessels the following are compared:

- Pre ducts	1. WED	Schneekluth Duct
	2. SILD	Sumitomo Integrated Lammeren Duct
- Pre swirl fin systems	3. SVA	SVA-fin system
	4. PSS	DSME – Pre Swirl System
- Hub vortex optimiser	5. Costa	Costa Bulb, rudder bulb
	6. PBCF	Mitsui O.S.K Techno – Propeller Boss Cap Fins
- Combined system	7. MD	Becker Marine Systems - Mewis Duct®

Table 4 shows the possible power reductions by all seven devices with the most effective device for each vessel highlighted in pink. The figures are based on a combination of analysis of the losses around the running propeller behind the ship and the author's extensive experience in the area of model testing and development of such devices.

Table 4. Power saving devices, possible power reductions

Case No		1	Grieg J	2	3	4
Ship type		Bulker	J-class	Tanker	Container	Container
Size		12k	46k	300k	1,700TEU	13,500TEU
VD	kts	15.20	16.00	15.50	20.00	24.60
CTh	-	1.60	1.31	2.32	1.00	1.25
Power saving devices, possible power reductions						
WED	%	2.9	2.8	3.4	2.5	2.7
SILD	%	2.8	1.7	4.5	-	-
SVA	%	2.8	2.7	3.3	2.6	2.8
PSS	%	3.8	3.5	4.3	3.2	3.4
Costa	%	3.2	3.1	3.3	2.6	2.8
PBCF	%	3.6	2.9	3.4	2.6	2.6 (?)
MD	%	7.7	6.0	7.3	3.5	-

Note: Positive % are reductions at fuel consumption

The most effective device throughout the range of vessels considered is the MD, and generally provides very significant power savings. The MD power saving figures for the small bulk carrier, the J-class vessel and the VLCC are model test results, the figures for the container vessels are estimated from CFD calculations. The MD is currently not suited for the large container vessel due to the high ship's speed.

Summary

Table 5 shows the possible overall power and money savings by the three measures in study for all 5 ships. For the trim- and speed- reduction figures was assumed that only 50 % of the estimated maximum savings are realizable in practice.

Table 5. Possible total fuel- and cost-savings for 5 different vessels

Case No		1	Grieg J	2	3	4
Ship type		Bulker	J-class	Tanker	Container	Container
Size		12k	46k	300k	1,700TEU	13,500TEU
Cost share		0.45	0.45	0.28	0.50	0.48
Possible power reduction by different measures, % power						
Trim (50%)		1.5	0.5	0	0.5	0
Speed (50%)		18	16	0	18.5	17.5
PSD		7.7	6	7.3	3.5	3.4
Sum	%	27.2	22.5	7.3	22.5	20.9
Possible cost reduction by different measures, % total costs						
Trim (50%)		0.7	0.2	0	0.3	0
Speed (50%)		4.5	1.5	0	4.5	3.5
PSD		3.5	2.7	2.1	1.7	1.7
Sum	%	8.7	4.4	2.1	6.5	5.2

Note: Trim optimisation and Speed reduction: 50 % of estimated gain is realizable

The trim optimisation shows that for all considered ship types there is a small room for improvement. With the exception of large tankers the highest fuel savings are possible by simply reducing the vessel's speed. The monetary comparison shows that the installation of power saving devices leads in 2 of 5 cases to the highest cost reduction. Large bulk carriers and large tankers can only be improved through the use of power saving devices.

Jan Øivind Svardal obtained his master's degree in naval architecture 1998 at the NTNU in Norway. After university he worked with DNV on various tasks, which include: Development of maritime ICT production tools, customer services, condition assessment programmes, newbuilding projects, ship in operation surveyor etc. In 2006 he joined Grieg Shipping Group AS, where he acts as Senior Project Manager dealing with newbuilding programmes and general projects related to business development.

After graduating in Naval Architecture from the University Rostock in 1968, Friedrich Mewis was employed at Schiffbau Versuchsanstalt Potsdam, SVA, in different positions, since 1990 as director of the towing tank. In 1996 he changed to Hamburgische Schiffbau-Versuchsanstalt, HSVA, where he acted as director for Resistance & Propulsion. 2006 he founded his own consultancy company, Mewis Ship Hydrodynamics. One of his main inventions is the Mewis Duct®, which was introduced into the market 2008.