A Performance Improvement Programme

Massimo Stori – Cantiere Navale Vittoria - Italy
(massimostori@vittoria.biz)

Abstract

An experimental systematic approach to FPB's performance improvement is presented. Current performances of an existing FPB have been investigated and cost effective solutions have been identified and applied in a systematic way in order to improve the boat's performance. Propulsive and vibration data have been collected and analyzed in order to have informations about the effectiveness of each measure taken. The results have been successful.

The boat

The boat under investigation (see picture) is one of a class of three FPB's with the following main characteristics :

Length over all	m	13,67
Beam	m	4,20
Mean draft	m	0,86
Displacement	t	15,310
Propulsion engines (2)		Cummins
WOT power	Kw	492
WOT revolutions	r.p.m.	2.300
Reduction gear ratio		1:1,581
Propellers (2)		Eliche Radice
Number of blades	n.	4
Diameter	m	0,630
Pitch	m	0,930
P/D		1,48
Design speed	knots	32

Table 1 – Main characteristics

The boats have been delivered by the Shipyard to the Owner in Summer 2003. The FPB was back at the Shipyard eighteeen months after delivery, at the end of 2004.

Speed performances at acceptance trials

The shipbuilding contract of the FPB under examination specified the top speed of the boat to be measured during the acceptance trials, with engine(s) running at nominal r.p.m., delivering nominal power. Trials were, as usually, performed with clean hull in calm sea conditions. The trail displacement was defined as the half load displacement (50 % of consumables on board).

Speed performances in operations

Fouling has a great impact on hull resistance. Shipowners in Mediterranean countries know by experience that the high seawater temperatures experienced in summertime help the growing of weeds and barnacles on the hull.

Moreover, ships, like men, tend to put on weight with age, and it is very difficult to bring them back to the original "shape". Increase in weight means more difficulty in planing and lower top speed.

The combined effects of these two factors makes thing even worse. The expectation that a FPB maintains in times the same performances measured at sea trials is often frustrated, and performances in operations are inevitably lower than expected.

The investigation

The Shipyard made a proposal, which was accepted by the Shipowner, to apply measures both to reduce the hull resistance and increase the propeller efficiency, quantifying their effects. During the period spent at the Shipyard the hull was scheduled to be painted. The list of the jobs is summarized in the flow chart of Figure 2 :

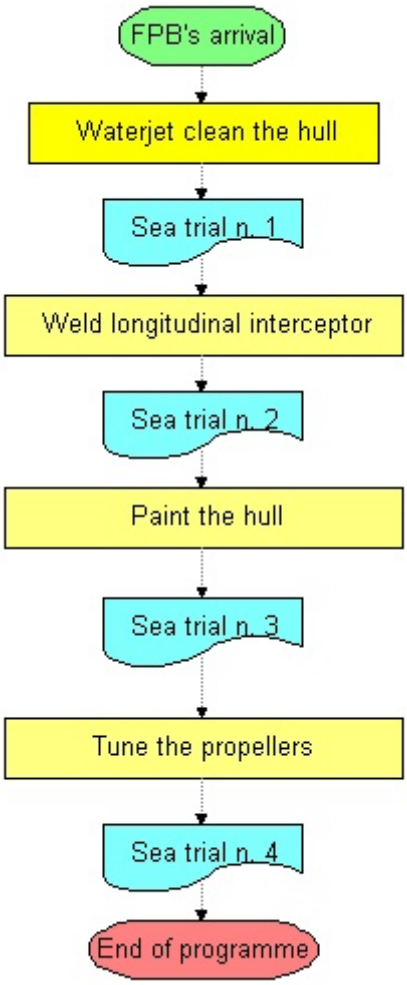

Figure 2 – Programme flow chart

The trial base

All trials have been carried out in the Channel downstream the Shipyard. The trial base is straight, has a length of about 1 mile, with calm water all the times. For each speed two tracks have been recorded, one downstream and and one upstream to average out the effect of current and wind. No attempt has been made to calculate a shallow water effect or a blockage effect since all measures were comparative in nature.

The trial instrumentation

The shaft power was measured by 2 torquemeters, one for each shaft, positioned after the reduction gear on the propeller shaft and 2 rpm pick-ups.

The ship's speed was measured by a DGPS (Differential Position System). During the trials, an average of 6 to 8 satellites were constantly engaged by DGPS receiver. The precision of speed measurements ranges between 0,1 - 0,2 knots.

The vibrations were measured using one piezoelectric accelerometer, positioned amidships on the main deck of the FPB, just above the propellers. Data were recorded by a Bruel and Kjaer 2260 system.

The trial programme

1. Arrival of the boat

Upon arrival at the Shipyard, the boat was lifted by the shipyard's crane and waterjet cleaned. The painting of the hull was found to be in good conditions, considering that the boat had been in operation for 18 months, without any application of new paint above the initial coating.
The first trial session was held immediately after the cleaning. The measured values for speed, power and engine r.p.m. are given in Appendix 1, Table 1-1 ÷ 1-3.

2. Longitudinal interceptors

The first improvement action which was taken was to weld on the boat one set of light alloy longitudinal strips along the chine of the boat. These strips decrease the crossflow and increase the pressure under the hull and the lift. The lenght and the section of the longitudinal interceptors has been computed by Humphree® Sweden AB. After welding, the area was brushed, and the second set of trials was performed. The measured values for speed, power and engine r.p.m. are given in Appendix 1, Table 2-1 ÷ 2-3.

3. Hull painting

The hull of the boat has been painted according to the technical specifications given by Jotun International, using the new product SeaLion I system, a silicone based fouling release coating. The SeaLion I system provides a smooth, low-energy surface to which fouling organisms either do not attack or only attack poorly and therefore can easily be removed by the speed of the boat. The system consists of SeaLion I Tiecoat, with a typical dry film thickness of 75 µm and SeaLion I Topcoat, with a typical dry film thickness of 105 µm.

The third set of trials was performed immediately after painting. The measured values for speed, power and engine r.p.m. are given in Appendix 1, Table 3-1 ÷ 3-3.

4. Propeller tuning

As a last attempt to improve performances a check was carried out at Tech-Helice shop to measure the propeller geometry and the corresponding ISO Class. ISO 484/2 defines the class of propellers in terms of pitch variation within one blade, from blade to blade of the same propeller and from two propellers powering the same boat. The results of such measurements are summarized in the following Figures 3 and 4:

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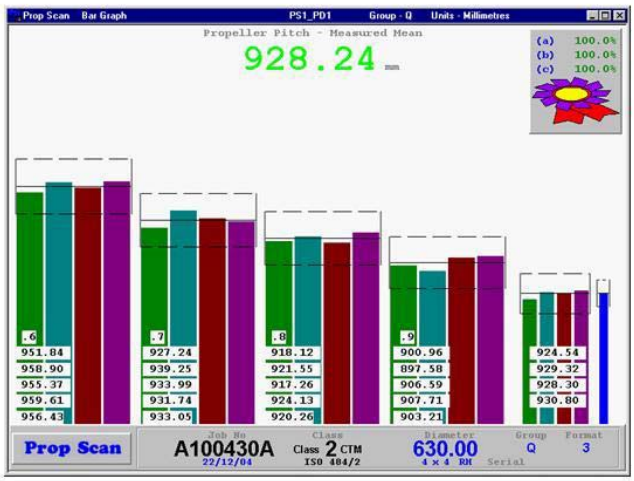

Diametre	630
Pas	928
Rotation	RH
Class ISO	2

Figure 3 – Right handed propeller pitch measurements

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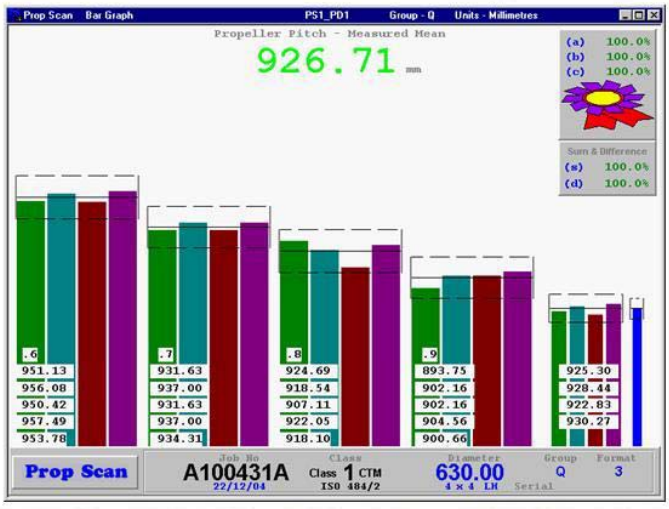

Diametre	630
Pas	926
Rotation	LH
Class ISO	1

Figure 4 – Left handed propeller pitch measurements

Each figure shows four istograms with four vertical bars representing the measured pitch at four different radii of the propeller (0,6 – 0,7 – 0,8 – 0,9) and for each of the four blades. The smaller istogram on the right represents the mean pitch at each of the four radii. The green number on the center top of the figure is the mean propeller pitch. It can be seen that the right handed propeller was in ISO Class 2, while the left handed propeller was found to be ISO Class 1.

The propellers have been tuned to reach both an ISO Class 1 tolerance. The measured pitch after the tuning is given in Figures 5 and 6.

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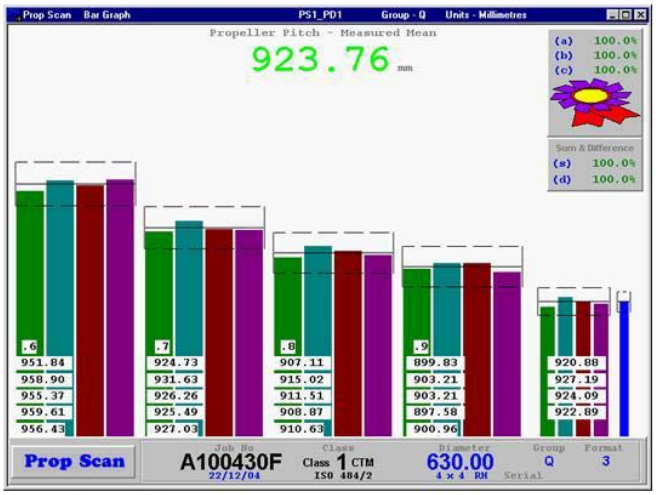

Diametre	630
Pas	923
Rotation	RH
Class ISO	1

Figure 5 – Right handed propeller pitch measurements after tuning

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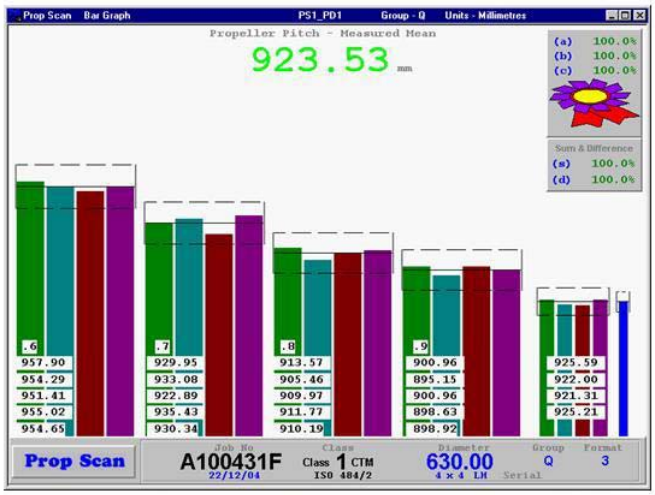

Diametre	630
Pas	923
Rotation	LH
Class ISO	1

Figure 7 – Left handed propeller pitch measurements after tuning

The final set of trials has been performed after the tuning. The measured values for speed, power and engine r.p.m. are given in Appendix 1, Table 4-1 ÷ 4-3.

Results

The results of the trials - ships speed, engine power and engine revolutions are presented in the Figures 8, 9 and 10 respectively. Four trials have been carried out at the following conditions :

Trial condition 1 boat at arrival
Trial condition 2 boat at arrival + interceptors
Trial condition 3 boat at arrival + interceptors + hull painting
Trial condition 4 boat at arrival + interceptors + hull painting + propellers tuning

1 Speed

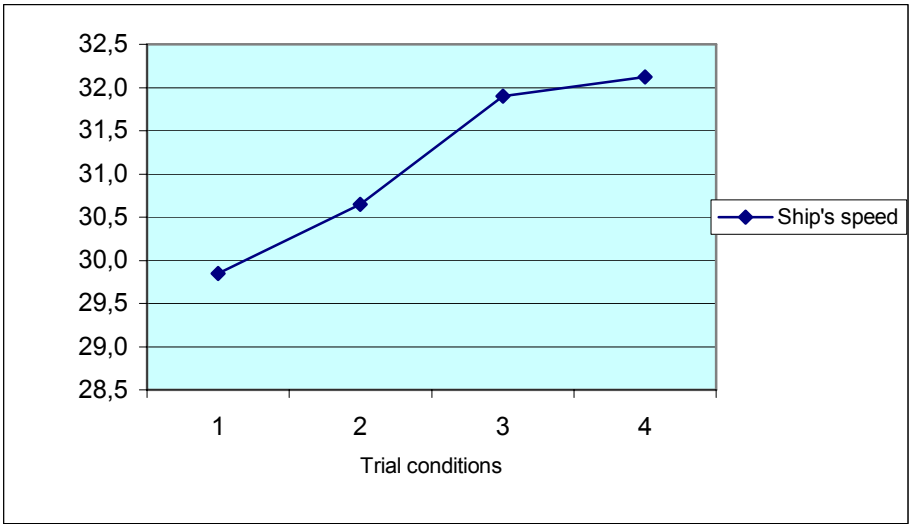

Figure 8 – Boat's speed increase

The speed of the boat was 29,85 knots at arrival and 32,12 knots at departure. The speed improvement was 2,27 knots. The contribution to this increase was by hull painting - + 1,25 knots – followed by longitudinal interceptors - + 0,80 knots – and by propeller tuning - + 0,22 knots.

2. Engine r.p.m.

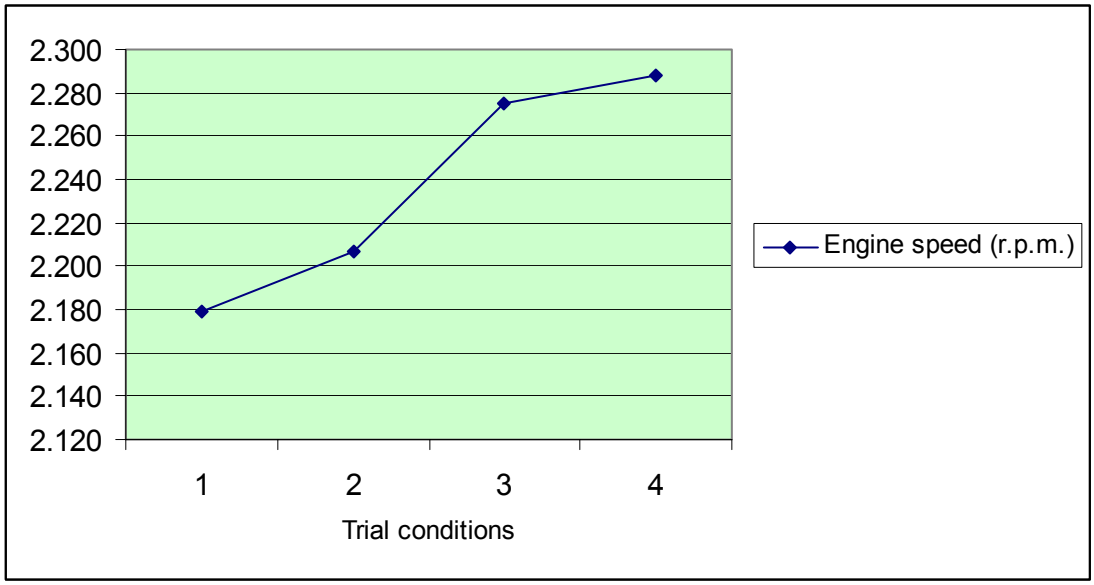

Figure 8 – Engine speed increase

The speed of the engine was 2,178 rpm at arrival, some 120 rpm below nominal speed, and 2.283 rpm at departure, very close to the nominal speed of 2.300 rpm.

3. *Engine power*

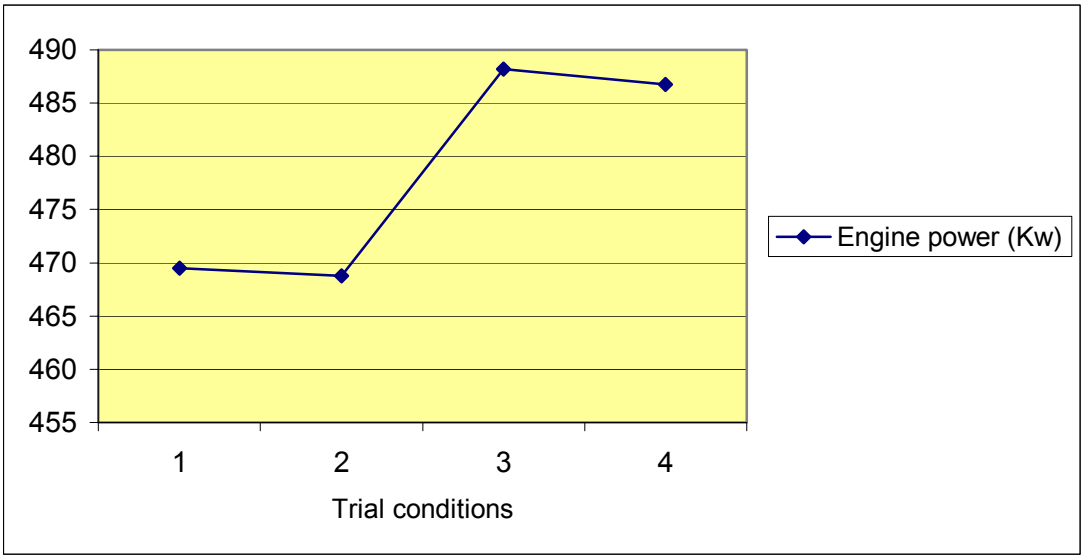

Figure 9 – Engine power

The power delivered by the engines was 488 Kw at departure. Considering the loss in the reduction gear (the torsionmeter was positioned on the propeller shaft) this is slightly more than nominal power. Such optimum condition were reached by a small pitch reduction during propeller tuning.

4. *Vibrations*

Fig. 10 and Fig. 11 show the frequency analisys of vibration data for the propeller before and after tuning. It can be seen that a sharp decrease in vibrations can be observed at the frequency around 190 hz (two times blade frequency). Numerical values are given in Table 5.

Freq [Hz]	Amp [mm/s]
23,44	2,08
95,22	3,34
186,77	7,37
190,43	11,32
250,49	2,57

Freq [Hz]	Amp [mm/s]
24,17	2,49
95,95	2,84
187,50	5,61
192,63	5,53
250,49	4,20

Table 5 – Vibration analysis before and after propeller tuning

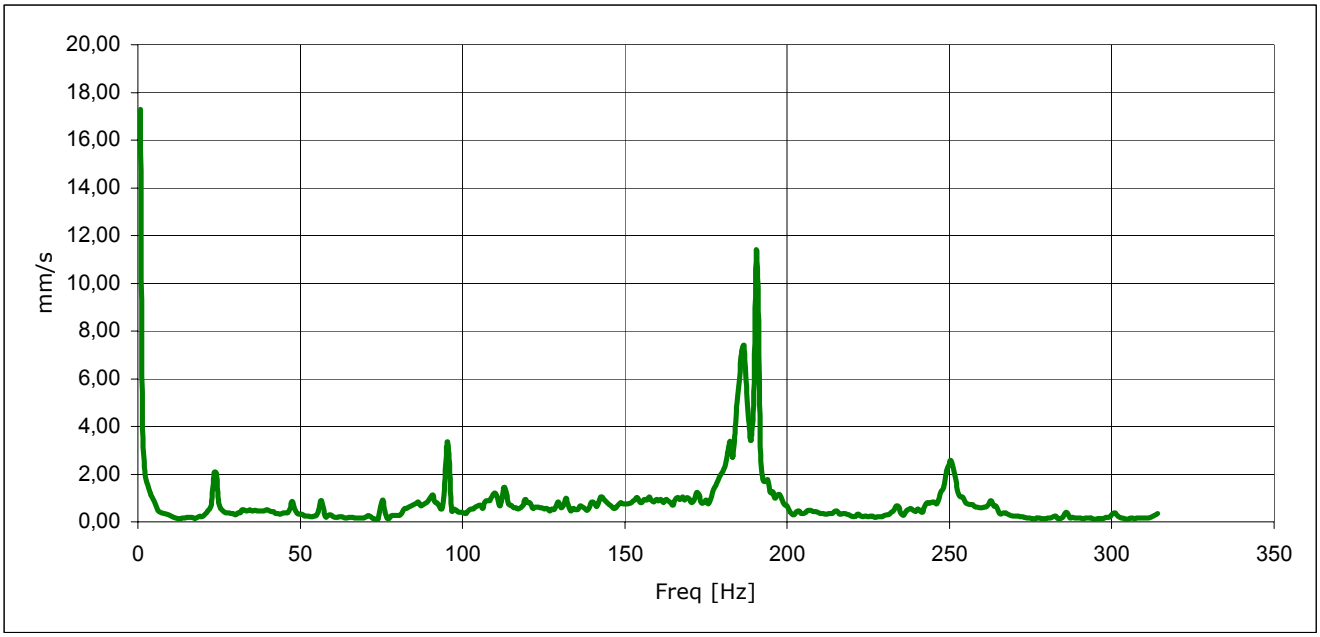

Fig. 10 – Frequency analysis at WOT **before** tuning (shafts' mean rpm = 1.435)

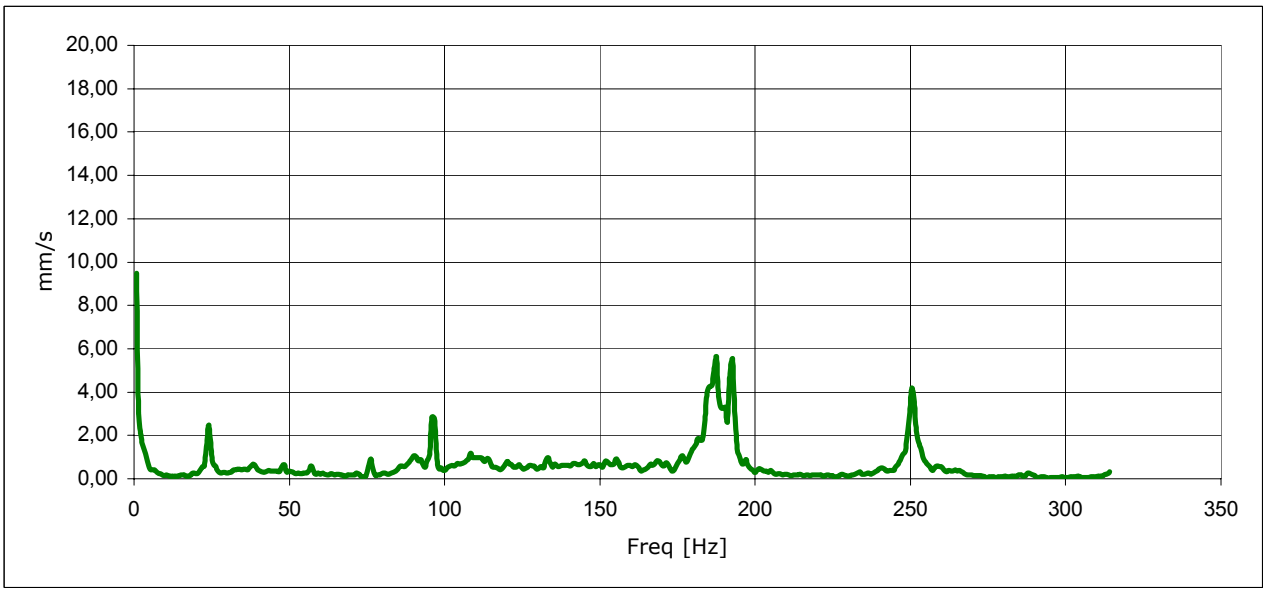

Fig. 11 – Frequency analysis at WOT **after** tuning (shafts' mean rpm = 1.444)

Conclusions

An overview of correcting actions to improve performances of a FPB been presented, to give guidance to Shipowners who are interested in higher speeds, better engine working conditions and/or fuel saving during the operation of boats.
A significant increase in speed was obtained by the addition of longitudinal interceptors.
The application of a new coat of silicone based was beneficial on both speed and power requirements.
Finally a moderate propeller tuning has allowed a speed increase with less power and higher engine speed.
Tuning of the propellers had a good effect on vibration reduction at full speed operations. This can result in longer service of shafts bearings and seal.

After all these corrective actions have been applied to existing hull and propellers, the decision was taken to proceed with a new design propeller which could give better performances.

Acknowledgments

The Shipyard is indebited with the following firms whose contribution made it possible to carry out this programme :

Sea Tech for the data recording and analysis;
Humphree Sweden AB for the design of longitudinal interceptors;
Jotun International for the supply of the paint and the assistance during application;
Tech-Helice for propeller measuring and tuning;
Eliche Radice for the design and construction of the new design propellers.

Appendix 1 – Measured values of speed, power and r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.793	1.793	1.793	1.775	1.775	1.775	1.783
Power	467	474	470,5	456	463	459,5	465
Speed			24,54			24,87	24,70

Table 1-1 – Cleaned hull – initial conditions 1.800 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.994	1.997	1.995	1.998	1.997	1.997	1.996
Power	553	559	556	550	553	551	553.5
Speed			27.80			27.00	27.40

Table 1-2 – Cleaned hull – initial conditions 2.000 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	2.177	2.180	2.178	2.178	2.181	2.180	2.178
Power	636	643	639,5	634	642	638	639
Speed			30,25			29,45	29,85

Table 1-3 – Cleaned hull – initial conditions W.O.T.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.791	1.793	1.792	1.790	1.790	1.790	1.791
Power	455	436	445	459	453	456	450,5
Speed			24,58			24,24	24,41

Table 2-1 – Cleaned hull + longitudinal interceptors - 1.800 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.995	1.968	1.981	2.000	2.000	2.000	1.990
Power	526	540	533	545	537	541	537
Speed			27,80			27,36	27,58

Table 2-2 – Cleaned hull + longitudinal interceptors - 2.000 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	2.215	2.207	2.210	2.196	2.213	2.204	2.207
Power	646	632	639	640	633	636,5	637,75
Speed			30.65			30.65	30.65

Table 2-3 – Cleaned hull + longitudinal interceptors - W.O.T.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.790	1.788	1.789	1.775	1.804	1.791	1.790
Power	447	450	448.5	449	463	456	452,25
Speed			25,52			24,46	24,99

Table 3-1 – Cleaned hull + longitudinal interceptors + Jotun Sealion I - 1.800 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.994	1.998	1.995	2.002	1.995	1.998	1.997
Power	532	533	532.5	536	535	535.5	534
Speed			28,73			27,71	28,22

Table 3-2 – Cleaned hull + longitudinal interceptors + Jotun Sealion I - 2.000 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	2.281	2.280	2.280	2.278	2.264	2.204	2.270
Power	665	664	664.5	665	663	664	664,25
Speed			32.48			31.33	31.90

Table 3-3 – Cleaned hull + longitudinal interceptors + Jotun Sealion I - W.O.T.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.802	1.809	1.805.5	1.796	1.801	1.797.5	1.801.5
Power	430	430	430	440	449	444.5	437,5
Speed			25,28			24,61	24,95

Table 4-1 – Cleaned hull + longitudinal interceptors + Jotun Sealion I + propeller tuning - 1.800 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	1.999	2.000	1.999.5	1.997	2.000	1.998,5	1.999
Power	526	524	525	520	526	523	524
Speed			28,75			27,78	28,26

Table 4-2 – Cleaned hull + longitudinal interceptors + Jotun Sealion I + propeller tuning - 2.000 engine r.p.m.

	Track 1			Track 2			Tracks
	port shaft	starboard shaft	shaft mean	port shaft	starboard shaft	shaft mean	mean
rpm (*)	2.292	2.297	2.280	2.278	2.289	2.204	2.283
Power	660	664	662	660	665	662.5	662,25
Speed			32.61			31.63	32.12

Table 4-3 – Cleaned hull + longitudinal interceptors + Jotun Sealion I + propeller tuning - W.O.T.