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Fuel Saving in Fishing by Improving the Propeller Design

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Increase in the number of motorised fishing vessels coupled with ever increasing fuel cost has resulted in a decrease in earning per unit of fishing fleet. Fuel consumption of medium size trawlers operating from Cochin and Mangalore and the outcome of measures adopted to reduce it are analysed. By redesigning the propellers of these vessels an average fuel saving of 20% can be achieved. A general account of the principles for redesigning is given.

Key words: Fuel consumption, medium size trawlers, propeller design

To increase the range of operations a tendency to increase the size of trawlers to 14-15 m has emerged in recent years. It is estimated that 65-70% of the operational cost of these vessels is accounted for by fuel alone. Increasing fuel cost coupled with decreasing catch is fast reducing the medium class craft to an unattractive investment opportunity. It will be helpful to the industry if an improvisation in the existing vessels can be devised which, without major investment and affecting the performance, will reduce the expense on fuel. The possible methods for reduction of fuel consumption without affecting performance are:

- Optimisation of hull design for achieving reduction in resistance thus reducing power requirements at various operating conditions.
- Improvement in propeller design to achieve reduction in hydrodynamic losses thus increasing the thrust available to overcome resistance for a comparable reduction in power requirements and associated fuel saving.

Optimisation of hull design is feasible only on new constructions, and survey among the vessel owners and crew reveals that their caution and conservatism will unduly delay the acceptance of any new hull design. Modification of hulls are practical only in few of the existing vessels and their owners were apprehensive of the expenses and loss of fishing days associated with the modification.

On the contrary, improvement of propellers is very practical, economical and feasible. This requires only replacement of existing propellers with an improved version. The investment involved is affordable and practically no fishing time is lost. If the new propeller is not acceptable the operator can still fix the old one and use the new one for new castings and the loss involved is minimal. Therefore, improvement of propellers was considered ideal in the existing medium class trawlers.

Though nozzle and open propellers are used for propulsion, the former is favoured as a rule due to higher efficiency during trawling. Almost all medium class trawlers operating in Kerala and Karnataka coast are fitted with open propellers. A handful of vessels with nozzle propellers reported reduced performance with respect to fuel consumption and hence changed to open propellers. An investigation into the failure of nozzle propellers revealed that the existing hull would not benefit from nozzle propellers due to:

- Operational characteristics of the vessels with respect to time engaged in free running versus trawling and associated speed-RPM ratios.
- Inability to maintain minimum loading on blades during trawling with respect to thrust requirements of trawling.
- Aft hull shapes influencing the flow over the propellers.

Therefore, the possibility of achieving fuel reduction in medium class trawlers narrowed down to improving, if possible, the existing open propellers.

Standard method for design of open propellers is to use the propeller series charts, the most popular, reliable and satisfactory being the Wageningen-B Series charts developed at Netherlands Ship Model Basin. The lifting line method was not considered due to a number of hull variations with associated flow differences and the different engines propelling them will introduce equal number of variations in propeller parameters. Practical solution is to make available a minimum number of 'stock propellers' taking into account variations in hull design and installed power. However, it was revealed that the 'stock propellers' are designed not based on any standard series charts, but were perfected for performance based on trial and error method. The pitch-diameter ratio of these propellers recommended by different manufactures for similar vessels was same, even though there were variations in their weight and price. The blade element shapes offered by different manufactures varied leading to differences in weight.

The experiments conducted for fuel saving in medium class trawlers operating off Cochin and Mangalore by redesigning the propeller are described in this paper.

Materials and methods

Six trawlers satisfying the following requirements were selected (Table 1).

- The vessels have good fuel consumption characteristics with existing propellers among the medium class trawlers operating in each area
- As far as possible, the vessel parameters and installed engines reflect the existing variations among the medium class trawlers for effective use of 'stock propellers'
- The vessels use the same type of nets and rigging for trawling during the experiment and general monitoring period, which must generally be the same, used by majority of similar class trawlers.

The main vessel parameters, pitch dia and general blade element shapes of the vessels were noted. Average weekly fuel consumption was collected from the available data. Speed, engine RPM, and fuel consumption with existing propellers were recorded during free running and trawling. Speed was measured using the boat speed log developed by Central Institute of Fisheries Technology. RPM of the engine was directly read from the RPM meter of the engine. Fuel consumption per h was measured by running the engine connected to a calibrated tank kept at the deck and measuring the consumption and time by running the vessel at the same speed-RPM for not less than 15 minutes at a stretch.

The vessels were then fitted with propellers designed using Wageningen-B series charts. Rake angle was limited to10 degrees. Pattern of one blade of this propeller was initially made in wood taking care to make the blade element shape ensuring correct design thickness at 100 points on the single blade. An aluminium pattern of the propeller was then made using the wooden pattern of one blade and pitch of all blades was perfectly corrected. This aluminium pattern was then used for casting the actual propeller. The propellers were cast in manganese-bronze. The performance data of vessels using this propeller were recorded as detailed earlier.

The blade element shapes of each of the six propellers were then altered differently to achieve shapes between the existing ones and Wageningen-B type. This was done by applying gun metal powder-epoxy resin compound prepared at the casting unit and by grinding the surfaces. Performance data of vessels using the altered propellers were again checked and the propeller, which gave the best result, was selected for final trials on all vessels. The weekly average fuel consumption of these vessels were checked for 3 months during September-December, 1996.

Results and Discussions

The details of the propellers are given in Table 2. The blade element shapes and ordinates of propellers used are shown in Fig. 1. The shape shown is for 0.6R. Performance of the vessels fitted with different propellers is presented in Table 3. Fig. 2 shows the rpm-speed-fuel consumption of the vessels during free running.

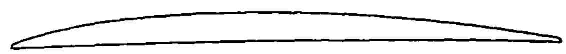
The pitch-diameter relation of the existing propellers in medium class trawlers in the 14-15 m range manufactured by different firms is the same for the same type engine. Engines in almost all the vessels in the range are either Ashok Leyland ALM 400 or Ashok Leyland ALM 402. However, the blade element shapes varied with different manufactures. These blade element shapes do not follow those suggested

Table 1. Details of vessels used in fuel saving experiment

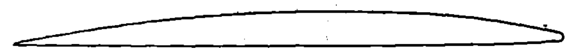
No.	Length, m	Breadth, m	Depth, m	Draft, m	Engine	Fishing method	Area of operation
1	13.9	4.28	2.28	1.23	ALM400	Trawling	Cochin
2	14.0	4.29	2.28	1.22	ALM400	Trawling	Cochin
3	14.0	4.29	2.28	1.25	ALM400	Trawling	Mangalore
4	14.1	4.30	2.41	1.20	ALM402	Trawling	Mangalore
5	14.0	4.32	2.35	1.28	ALM402	Trawling	Mangalore
6	14.3	4.50	2.48	1.40	ALM402	Trawling	Cochin

Ordinates for propeller blades at 0.6 R

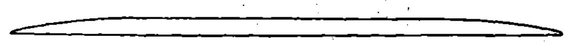
Type	Total blade width		5	10	20	30	40	50	60	70	80	90	95	Maxi mum thick-ness	Distance from leading edge, %
			% distance of blade length from leading edge												
Existing	365	Back	5.5	8.2	11.0	11.0	11.0	11.0	11.0	11.0	11.0	8.2	5.5	11.0	50.0
		Face	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
WAG-B	370	Back	11.0	14.5	18.5	21.0	22.2	21.3	19.6	16.7	12.7	7.4	3.9	22.2	38.9
		Face	2.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		
Improved	370	Back	4.3	7.0	12.0	16.7	20.0	21.6	22.0	20.5	18.3	13.0	8.3	20.3	55.0
		Face	0.5	0.0	0.9	1.5	1.8	1.9	1.9	1.5	1.1	0.0	0.4		



Improved blade element propeller



Wageningen-B type propeller



Existing propeller

Fig. 1. Blade element shapes of propellers and their ordinates

by any of the series charts in use for propeller design. All existing blade elements are flat at the middle and linearly triangular or triangularly curved towards the end. The length of flat portion and edge contours of each element varied between manufacturers. It was found that the existing propellers with maximum flat portion and triangularly curved ends had better fuel efficiency. Therefore, vessels using these propellers were selected for the study. Analysis proved that by adopting better blade element shapes fuel efficiency of these vessels could be improved. It was noted that

Table 2. Details of propellers

No.	Existing propeller Pitch	Dia	Rake	AE/AO	Wageningen B Type Pitch	Dia	Rake	AE/AO	Improved type Pitch	Dia	Rake	AE/AO
1	1016	660	0°	0.34	1000	644	10°	0.35	1000	644	10°	0.35
2	1016	660	0°	0.34	1000	644	10°	0.35	1000	644	10°	0.35
3	1016	660	0°	0.34	1000	644	10°	0.35	1000	644	10°	0.35
4	1067	660	0°	0.345	1000	644	10°	0.35	1000	644	10°	0.35
5	1067	660	0°	0.345	1000	644	10°	0.35	1000	644	10°	0.35
6	1067	660	0°	0.345	1000	644	10°	0.35	1000	644	10°	0.35

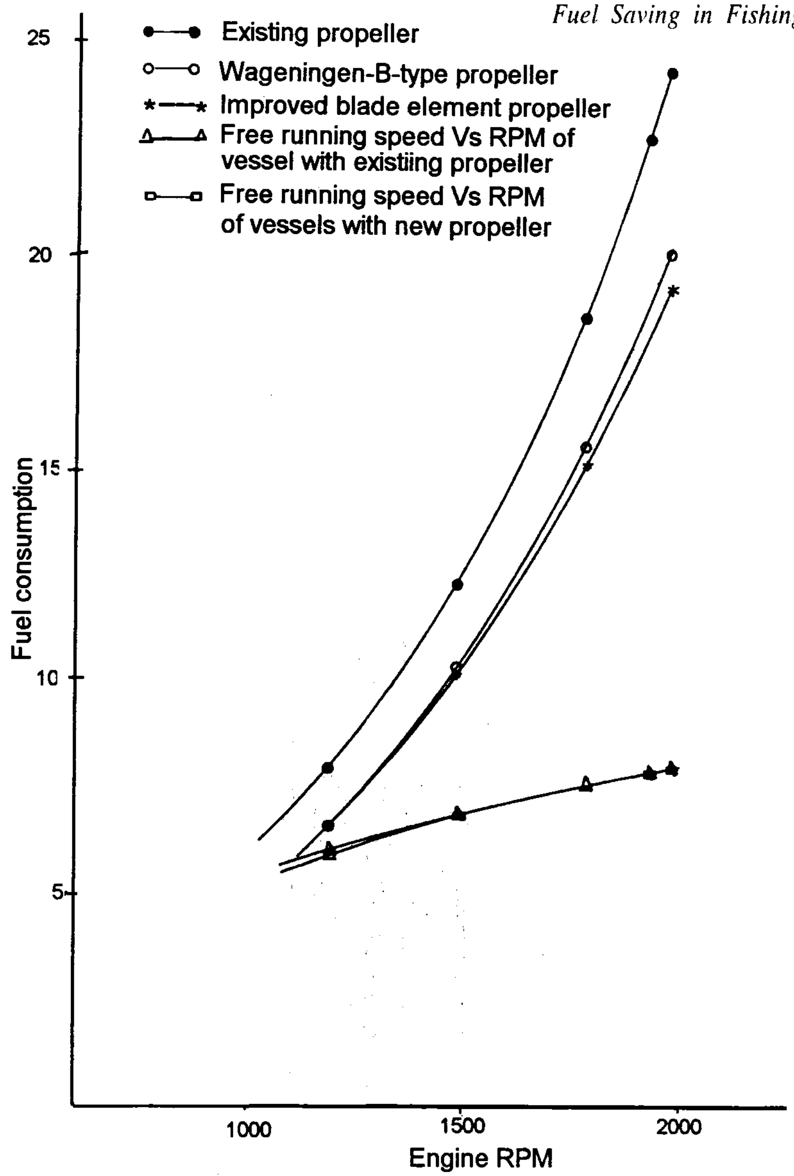


Fig. 2. RPM, speed and fuel consumption of vessels during free running

the variations in vessel parameters, engine and the associated differences in pitch-dia distributions of existing propellers did not significantly vary from the fuel-rpm-speed relations during the runs. The variations were within 1% and, therefore, the mean is recorded.

It is assumed that, since shape of blade element has significant influence on thrust generation, the aerofoil sections used in Wageningen-B type propellers will improve the performance of the vessels. Accordingly, Wageningen-B series charts were used for designing propellers. Since the variations between the vessels with respect to fuel-speed-rpm were insignificant with existing propellers, only one propeller was designed for all the six vessels taking the variations into account.

On design it was found that the pitch-dia relations and AE/AO ratio of the new propeller are near to that of the existing ones. But the blade element shapes do have significant variations as is evident from Fig. 1. The new element is an aerofoil section with lifted leading and trailing edges. The tip of the new propeller was skewed back unlike existing ones. Hammering of existing propellers periodically to correct change of pitch during operation is a common practise and therefore manganese-bronze, which will resist this change, was used to make the new propeller. A rake angle of 10° was used in the propeller whereas the existing ones do not have any rake.

Fuel consumption became considerably reduced when the new propeller was used. Fuel-speed-rpm relations of different vessels were within 2% variation and therefore the mean is given. Mean speed-rpm relation of existing and Wangeningen-B propellers closely followed each other except at rpm less than 1500 where the speed of new propeller at corresponding rpm was lower, but did not affect the operational economy as the vessel usually runs above 1500 rpm during trawling and free running. Fuel saving was about 17% during free running and 14% during trawling (Table 3). This saving could definitely be attributed to improved blade element shape following an aerofoil section which generated better thrust at all rpm above 1500 and also partly to the rake which induced better flow over the propeller face. Propeller induced vibrations present in all vessels under study on varying levels was either nil or reduced very low.

Table 3. Fuel consumption in vessels with different propellers

				Free running			Trawling
Existing propeller	RPM	1200	1500	1800	1950	2000	1825
	Fuel consumption l/h	7.9	12.2	18.5	22.7	24.3	13.7
	Speed Kn	5.98	6.89	7.56	7.86	8.00	3.9
Wageningen B Type	RPM	1200	1500	1800	1950	2000	1840
	Fuel consumption l/h	6.5	10.2	15.5	18.8	20	11.8
	Speed Kn	5.89	6.84	7.6	7.90	7.97	3.85
Improved propeller	RPM	1200	1500	1800	1950	2000	1850
	Fuel consumption l/h	6.50	10.10	15.00	18.00	19.20	11.30
	Speed Kn	5.90	6.85	7.62	7.90	7.95	3.90

The stopping and backing performances of the new propellers were considerably lower. Because of the reduced manoeuvrability the skippers were reluctant to accept the new propellers. Therefore it became necessary to improve the manoeuvrability without significant change in fuel consumption characteristics.

Since the pitch-dia relations of new and existing propellers were near enough to significantly affect the performance, it was evident that change in the blade element shapes and the skew back of new propeller had reduced the backing and stopping performance. Since it is proved that flatter blade sections are superior to aerofoil ones for better backing and stopping qualities, blade element shapes were changed to those between the flatter and aerofoil sections.

On evaluation of performances of the altered propellers with respect to blade element shapes, it was found that only four of them were acceptable with respect to manoeuvring. Among the four which gave acceptable manoeuvrability, the one with better fuel reduction was selected. This features the same maximum thickness as that of Wageningen-B, but at 55% blade length from leading edge instead of 38.9%. From leading edge to the point of maximum thickness, the new shape is narrower, while from point of maximum thickness to trailing edge, thicker, in addition to a slight concavity on the face. This new shape has also improved fuel reduction by another 3% compared to Wageningen-B type. The general blade element shapes and ordinates of the propeller are given in Fig. 1.

The new propeller was fixed to all vessels under study. Fuel consumption of the vessels decreased from an average 1500 l per week with existing propellers to an average 1200 litres per week with improved type leading to saving of 300 l fuel per week. The average saving of fuel is 20%. The cost of conversion calculated per vessel including the cost for recasting during experiment is about Rs 32,000. The existing propeller on sale as scrap could fetch an amount of Rs 6500 making an effective investment of only Rs 25,500 per propeller, which could be recovered within three months of operation of the vessel by way of fuel saving.