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IMPROVING THE PERFORMANCE OF STREAMLINED BOATS BY ENAMEL COATING

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ABSTRACT

A study was conducted to evaluate the effect of enamel coating on boat hull drag. The results were compared with drag required for varnished uncoated boats. Models of rice barge and fishing boat were used in this study. The speed range of 0.6 to 1.5 m/s at different loads varying from 6 to 9 kg for rice barge and 4.6 to 6.4 kg for fishing boats were used during testing. The total weight of the coated and uncoated boats were kept the same. It was observed that the drag force required by the coated boats was less than the identical uncoated ones at all speeds and loads. For both uncoated and coated boats the drag required increased with speed. The maximum recorded reductions in drag were 26% for the rice barge and 28% for the fishing boat model.

Key words : Boat, enamel, drag, coating

INTRODUCTION

Boats have been around for a long time. Although various new materials are used for boat construction, wood is still widely used for boats. Boats are widely used in agriculture for food distribution, transportation of agricultural goods and fisheries. Since boats consume a large amount of fuel, like other vehicles, they also need attention in the direction of saving energy, especially on draft aspects in order to cut down the fuel consumption. The reduction in fuel consumption would directly yield profit to the farmer.

Various studies have been carried out demonstrating the cause of drag force of the boats. If wave drag is neglected, then the hydraulic drag, in general, consists of two components, namely form or pressure drag and drag due to friction forces. Form or pressure drag is due to normal stresses and hence is a function of the shape of the body in flow and can be controlled by the pressure field on the body's surface. Pressure drag can be reduced by employing a streamlined boat hull shape. On the other hand frictional drag on a boat is primarily a function of surface roughness and wetted area and is due to the tangential stresses. The reduction in frictional drag can be achieved by reducing the surface roughness of the boat hull.

Salokhe and Gee-Clough (1988) found that enamel coating on cage wheel lugs reduced the soil adhesion considerably. Studies on model boats by Salokhe et al. (1992) showed that enamel coating reduced the drag of the boats considerably compared to similar uncoated boats. However their study related that the shape of the boats proved to be an important factor. The non-streamlined boats reduced the benefits of coating. Considering these findings, it was expected that the enamel coating would have considerable effect on drag force reductions due to reduced friction of the boat surface and by employing a streamlined boat hull. Thus the present study was aimed at investigating the effect of coating on the streamlined boat performance.

LITERATURE REVIEW

Salokhe and Gee-Clough (1988) investigated the effect of lug surface coating by nine different materials and found that enamel coating was the most promising material in reducing soil adhesion on cage wheel lugs. Mufti (1988) found that friction characteristics of enamel improved the scouring and the draft requirement of enamel coated floats and moldboard plough. Wang and Zhu (1980) recommended that boat-tractor should have the bow lifted up while working in the field to reduce the motion resistance. Thai (1985) tested optimized hull designs with different weights and speeds. Computations indicated that the most efficient hull shape was semi-elliptical in cross-section. The hull with the shape factor K=(length x submerged cross-sectional area at rear)/(displaced volume) = 1.5, gave the lowest drag because it had the smallest wedge angle (21.24°). Povkh (1984) discovered the various types of coatings to reduce drag. It was proved that the principle improvement was due to reduction of skin friction. Salokhe et al. (1990) found that a drag reduction up to 15% could be achieved by enamel coating. Tzou and Landweber (1967) conducted studies to determine the viscous drag of model ships and observed that the viscous drag of a ship model varies with the Froude number. It has been reported that skin friction resistance for a normal merchant ship accounts for more than 66% of the total resistance. Todd (1966) has pointed out that the viscous resistance accounts for as much as 85-90% of the total resistance in an average cargo ship and some 50% or more even for high speed surface ship. Klinzing et al. (1969) worked with water flow through damped flexible tubes and found a friction reduction of 20% and higher.

MATERIALS AND METHODS

The boats, rice barge and fishing boat, which are widely used in Thailand and India, respectively, were selected for the study (Birewar, 1991). The original dimensions of each of these boats were measured. The scale factors selected were 1:8 for the rice barge and 1:6 for the fishing boat. Thus the length of the rice barge and fishing boat models were 1.05 m and 1.04 m respectively. The operating speed of the rice barge was calculated as 1.0 m/s. The operating range of speed was taken as 0.6 m/s to 1.5 m/s. The maximum speed of operation was constrained by the inflow of water and instability of boats. Figs.1 and 2 show the boats used in this study. Two identical models of each boat type were fabricated. The hull of one boat of each type was covered with enamel coated low carbon steel plates of a boat hull shape. The characteristics of the model boats are given in Table 1. Due to the mounting of enamel coated plates on the boat extra weight was added. However before the experiments the weight of the uncoated boat was made equal to the enamel coated by ballasting.

The experiments were conducted in a water tank of 15 m width, 2.5 m deep and 50 m long. It was equipped with a movable carriage mounted on two steel rails. The carriage could be moved with the help of an AC variable speed motor. To ensure that the boat models were pulled horizontally, a hanging pulley mechanism was employed. The average water temperature was 30° C and specific weight was 9.734 kN/m^3 . The speed of the carriage was measured by a digital tachometer. A strain gage type load cell of 100 N capacity was used to measure the drag. Signals from the load cell were amplified and plotted on an X-Y plotter. The data recorded was digitized to get average drag force.

While testing the models (coated and uncoated) for drag measurements at equal weights, loads of 6 to 9 kg were added to the rice barge models and 4.6 to 6.4 kg were added to the fishing boat. The experiments were conducted at different speeds. The boats were towed with wire rope in smooth water. After ballasting to the selected normal load it was ensured that the towing rope was horizontal. Experiments without ballasting (unequal initial weight) were also conducted to investigate the effects of extra weight of enamel coating on the drag. Different normal loads were added to both models and experiments were conducted at various forward speeds. The experimental data was analyzed statistically.

RESULTS AND DISCUSSION

Drag of enamel coated and uncoated rice barge

Fig. 3 shows a comparison of the drag required for enamel coated and uncoated rice barge models at 6 kg normal load and at different speeds. The drag force required to pull both uncoated and enamel coated model boats increased with speed. The drag required for enamel coated boats was less than the uncoated boat at all speeds. However, the reduction in the drag force required for the enamel coated boat model increased with speed. A minimum reduction of 3.8 % was recorded at 0.6 m/s speed while maximum reduction of 22.4 % was recorded at 1.4 m/s speed. For the same model boats at 7 kg normal load the maximum drag reduction recorded was 25.6% at 1.4 m/s speed. For 8 kg normal load the maximum drag recorded was 19.7 % at 1.1 m/s speed and at 9 kg normal load the maximum drag reduction of 23.2 % was recorded at 1 m/s speed. Thus at 8 and 9 kg normal load maximum reduction in drag force was recorded not at maximum speed but at lower speeds. Perhaps the wave drag was the main constituent of the total drag and the reduction in the drag force due to enamel coating was not significant at higher speeds.

Drag of enamel coated and uncoated fishing boat.

Fig. 4 shows drag requirements for enamel coated and uncoated fishing boats at different speeds and at 4.6 kg normal load. The drag required for both boats increased with speeds. At this particular load as the speed increased, the reduction in the drag due to enamel coating increased. At 0.6 m/s speed the drag reduction due to enamel coating was 4.3 % which increased to 27.7% at 1.5 m/s speed. At 5.2 kg normal load, a similar trend of drag reduction was observed. A maximum of 22 % in drag reduction due to enamel coating was recorded at 1.4 m/s speed. At 5.8 and 6.4 kg normal loads, a reduction in drag of the order of 21.8 % and 20.4 % was recorded at 1.3 and 1.1 m/s speeds, respectively.

Variation of drag force with speed

Fig. 5 shows variation of drag with speed for the coated and uncoated rice barge. It is evident that speed had a very strong effect on the drag force, especially at the higher speed. The difference in drag force at lower speeds is smaller but it increases at higher speeds. Up to about

1 m/s speed the drag force increases linearly but a further increase in speed resulted in drastic increase in drag force. For the fishing boat however, the drag force required at different normal load was the same only at 0.6 m/s speed and further increase in speed caused significant increase in the drag at all normal loads for both uncoated and enamel coated model boats.

Effect of load on drag force

It was desirable to know the behavior of the boats when the normal force was increased. Fig. 6 shows the variation of drag with load for uncoated and enamel coated fishing boat models at different speeds. It is clear from the figure that the normal load had a very prominent effect on the drag especially at higher speeds. The drag force increased gradually at the lower speeds but exponentially at the higher speeds.

Experiments were also conducted to study the negative effects of use of enamel coated plates on boat hull drag. For this purpose both models of uncoated and enamel coated boats were ballasted with equal amount of normal load. It was observed that the drag force on coated boats were more than that uncoated boats at equal normal loads throughout the speed range tested (Fig. 7). Thus for models the benefits of enamel coating were nullified by the increase in drag due to extra weight of enamel coating. However, increase in weight due to enamel coating will be very small compared to model boats. Calculations showed that the ratio of weight of enamel coated plates to the total weight of the model boats of rice barge and fishing boats will be 18.5% and 28%, respectively. However, these ratios will be only 2% and 3.2% at maximum loaded condition for rice barge and fishing boat, respectively. Thus the effect of additional weight due to enamel coating will be very small and thus the per cent reduction in drag force due to enamel coating of full scale boats would be more than that of model.

Cost of enamel coating and savings in power

With the present market rates, the cost of enamel coating full sized rice barges and fishing boats was found to be US $ 580 and 280, respectively. The surface area of full size rice barge and fishing boat was 31.4 m^2 and 15.15 m^2, respectively. Calculations of power requirement for full size rice barge and fishing boat and maximum % reduction drag showed that due to enamel coating the rice barge will require 7.9 kW and fishing boat will require 2.8 kW less power than the identical full size but uncoated boats. The enamel coating will also improve the appearance of the hull as well as it will avoid the corrosion of hulls due to its anti-corrosive characteristics in normal waters.

CONCLUSIONS

The studies conducted in this research revealed that enamel coating on a boat hull can reduce the drag of model boats compared to identical uncoated boats. The maximum drag reduction was found to be 25.6% at 1.4 m/s speed and 7 kg load for rice barge and 27.73% at 1.5 m/s speed and 4.6 kg normal load for fishing boat. The operating speed of the boat affects the drag required. Increase in speed caused an increase in drag requirement for all boats. A similar trend was observed at an increase in normal load. Calculations of costing and drag reduction showed that by coating the boat hulls there will be savings in overall power required for both types of boats. The results of this study revealed that enamel coating can be successfully employed for reducing the drag force of boat hulls. Additional weight of enamel coating on full size boats will not affect the benefits of reduction in the drag. Therefore, its use for boat hull coating is recommended.

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Table 1 : Characteristics of the Boat Models

Model	Weight (kg)	V (cm^3)	A^{sw}	L (cm)	B (kg)
Coated rice barge	6.0	14243	3213	107	14.2
Uncoated rice barge	3.8	13826	3112	105	13.8
Uncoated fishing boat	2.5	9356	2510	104	9.3
Coated fishing boat	4.6	9568	2518	106	9.57

V = Maximum displacement volume
A^{sw} = Maximum wetted surface area
L = Uncoated fishing boat
B = Maximum buoyant force

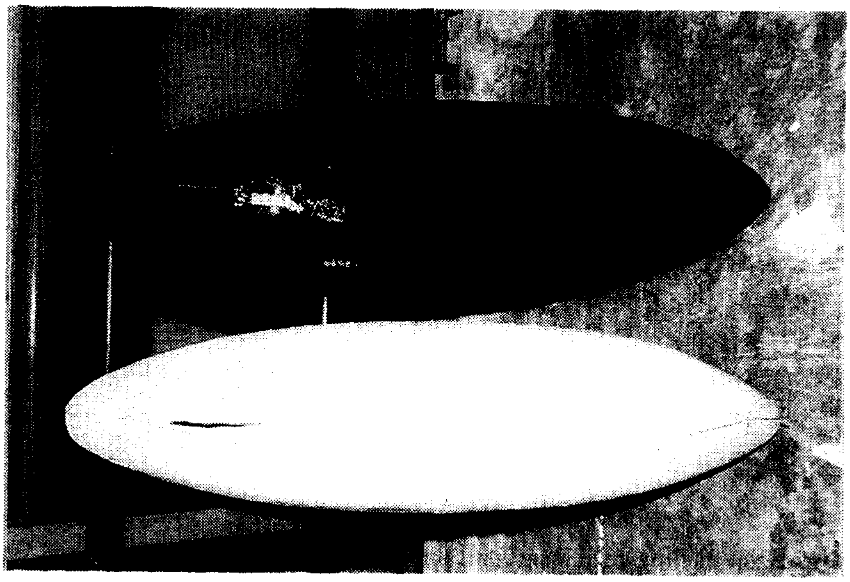


Fig. 1 : Uncoated (top) and coated (bottom) models of rice barge

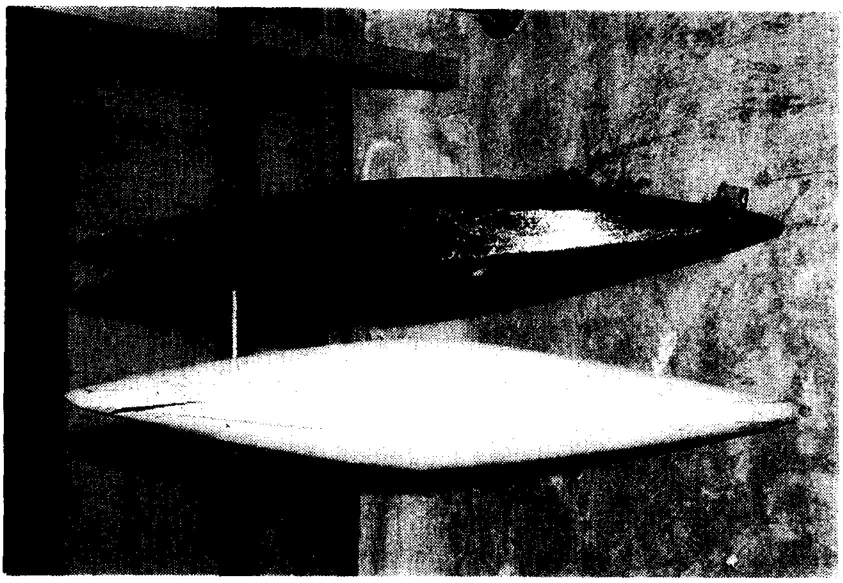


Fig. 2 : Uncoated (top) and coated (bottom) models of fishing boat

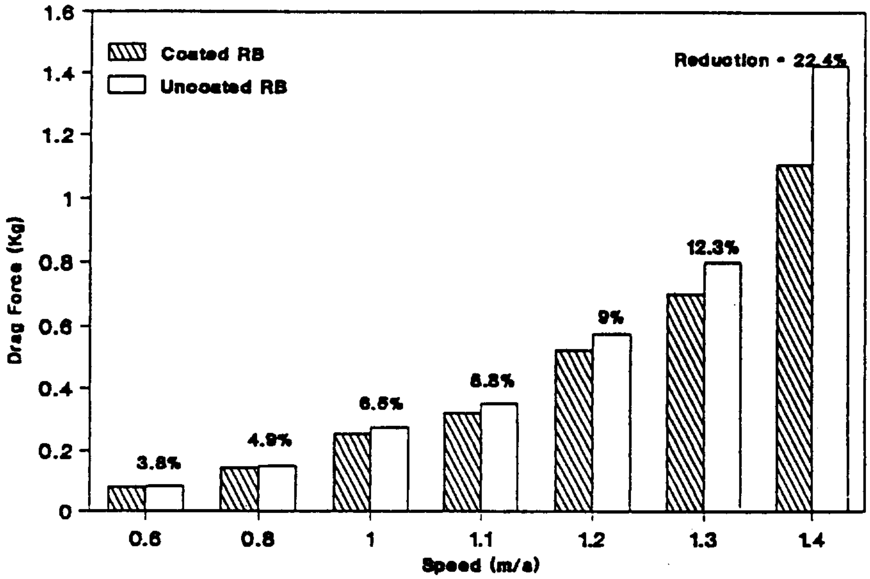


Fig. 3 : Comparison of drag for coated and uncoated rice barge at 6 kg normal load

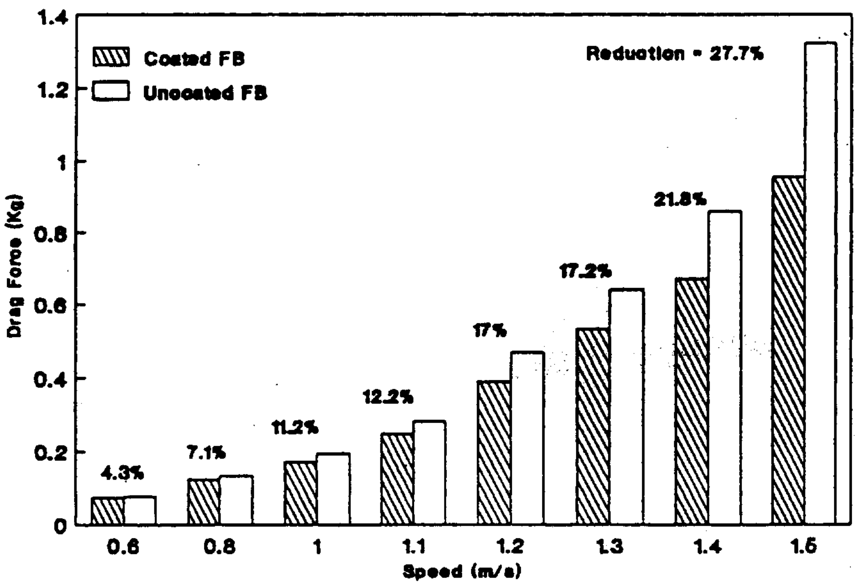
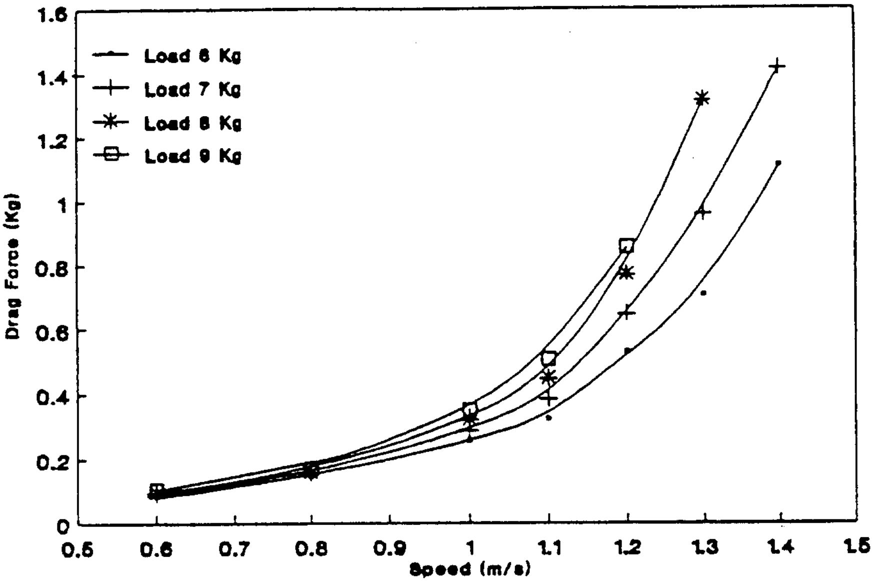
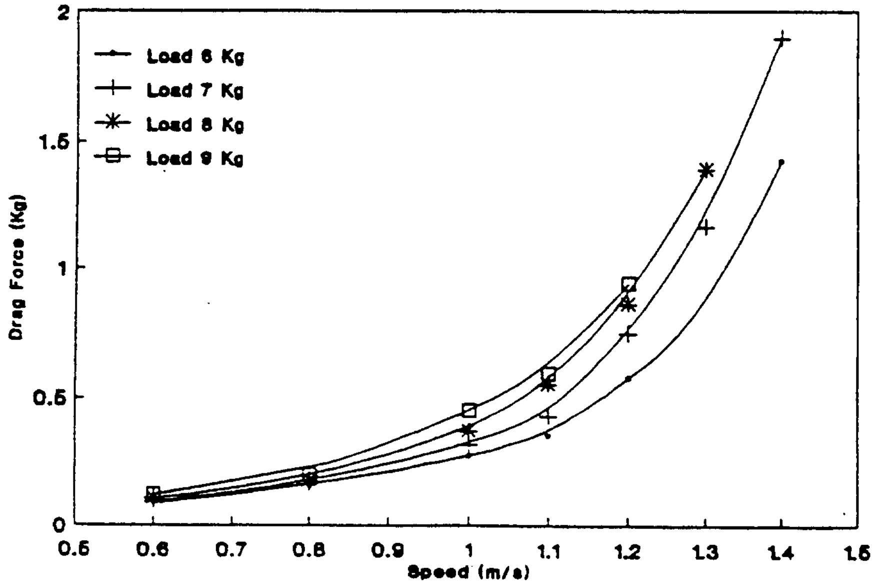


Fig. 4 : Comparison of drag for coated and uncoated rice barge at 4.6 kg normal load

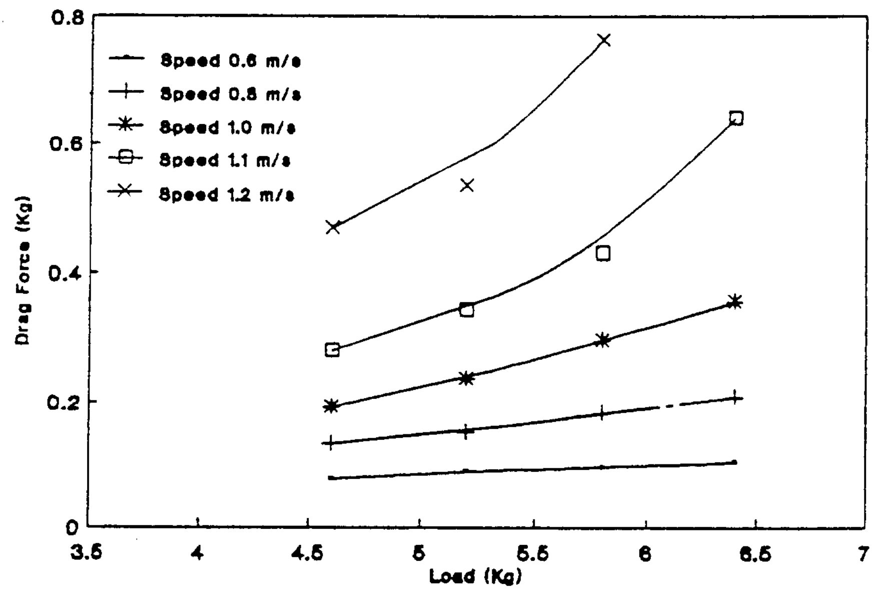


(a)



(b)

Fig. 5 : Variation of drag with speed for coated (a) and uncoated (b) rice barge at different loads



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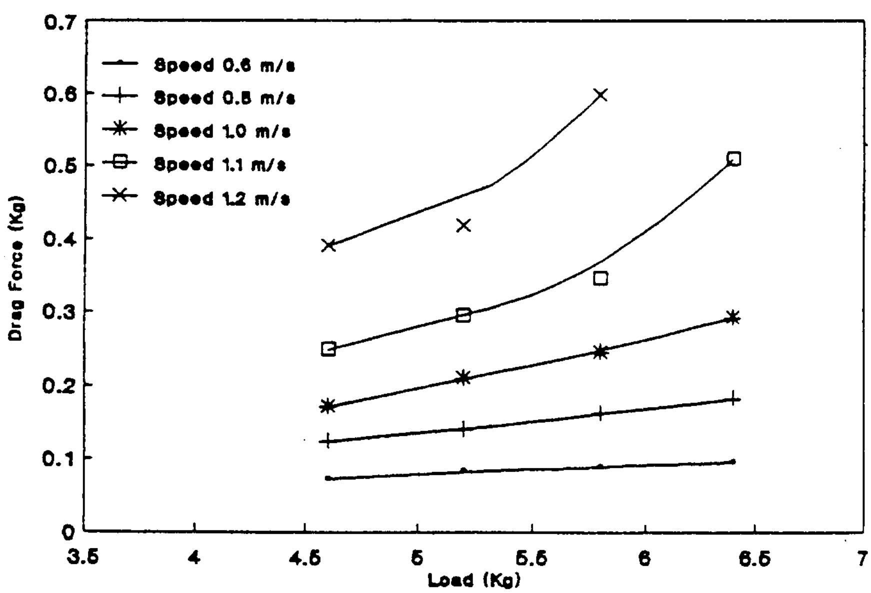
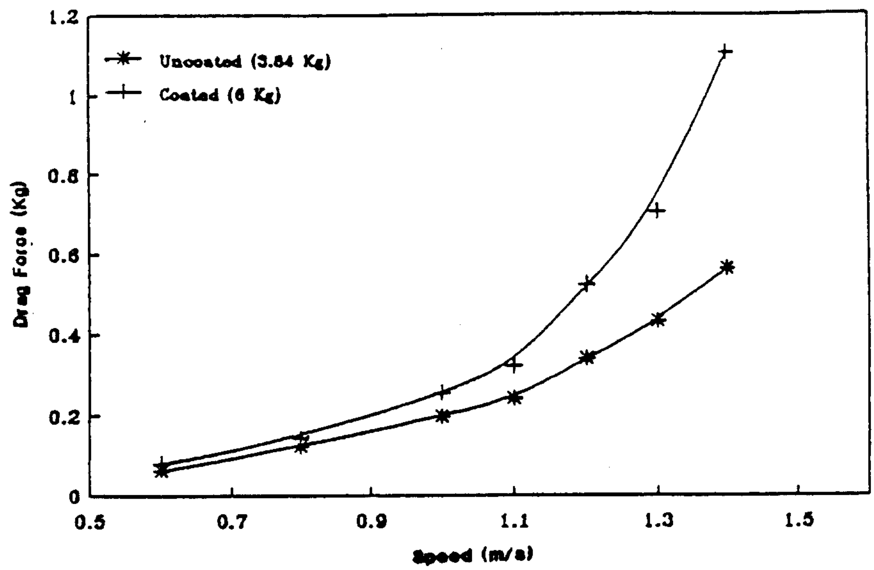


(b)

Fig. 6 : Variation of drag with speed for coated (a) and uncoated (b) fishing boats at different loads



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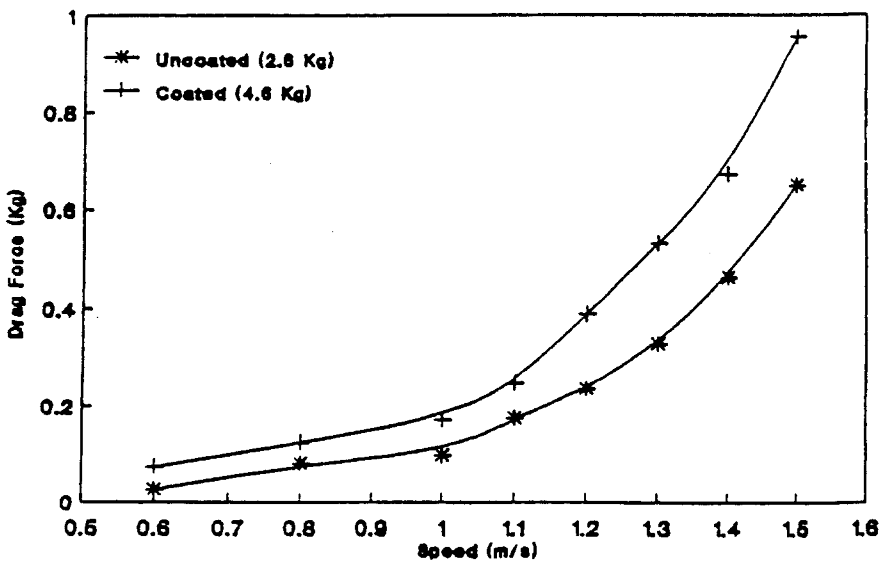

(b)

Fig. 7 : Drag of coated and uncoated (a) rice barge and (b) fishing boat without initial ballasting at different speeds