The Effect of Ribblet Structure on Resistance in Fast Speed Ship Model

Gunawan M. Baqi, M.A. Talahatu and Yanuar

Department of Mechanical Engineering,
University of Indonesia, Jakarta 16424, Indonesia

Abstract: Energy efficiency is the major interesting topic to be studied for many years. In sea transportation, reduction of fuel consumption become important to increase profit. Reduction resistance of ship is closed related to fuel consumption demand. Reducing resistance to fluid flow can be obtained by providing special roughness (ribblet), polymer additives, coating, surfactants and fiber on the surface of the ship's hull. Fish skin surface like shark fish is generated by special roughness. This phenomena is one method to reduction in frictional resistance of ship. The purpose of this research is to identify the effect of coating ribblet form to estimation on drag reduction in the resistance of high speed ship model. This research carried out experimentally using towing tank test. The ship model is Indonesian fast patrol boat (FPB-57) with main-hull L = 2.45 m, B = 0.40 m and T = 0.19 m is pulled by an electric motor which speed can be varied and adjusted. The ship model resistance was precisely measured by a load cell transducer. The ribblet form is varried by three form: blade form, scalloped form and sawtooth. Comparison of ship model resistance with 3 different ribblet form is shown on the graph as a function of the total resistance coefficient and Froude number. It was found out that the ship model with coating ribblet could have less resistance compared to mono-hull of similar displacement. The results shows the drag reduction about 10 % at Fr 0.55 for blade ribblet form.

Key words: Special roughness (ribblet) · Total resistance coefficient · Fast patrol boat FPB 57 · Energy efficiency · Froudes number

INTRODUCTION

Research about drag reduction in many aspects is continue done for increase of human purposes in the present. Dragreduction of civil transport ship not only directly concerns performance, but also indirectly, of course, cost and environment. Fuel consumption represents about 20% of the direct operating cost which is of utmost importance for the shipping line, for a typical long range transport of ship. Drag reduction directly impacts on the direct operating cost. Ship resistance reduction due to fuel consumption tobe concerned study.

The water animals like fish is naturally secret mucus that is generated thick layer layer. The mucus secreted by fish causes a reduction in drag as they move through water and also protects the fish from abrasion, by making the fish slide across objects rather than scrape and disease, by making the surface of the fish difficult for microscopic organisms to adhere [1]. Additive solution eg

biopolymer to be one method to reduce drag phenomena in ship. Biopolymers, for example: high molecular weight polysaccharides produced by living organisms can provide effective drag reduction. Polysaccharides of several fresh water and marine algae, fish slimes, seawater slime and other fresh water biological growths have been found to be good drag reducers [2]. Hoyt and W. White [2] have tested the effect of adding hagfish slime and reduced drag reduction until 14.5%. Ripken and Pilch [3] reported that slime dogfish was able to reduce the flow resistance. Rosen and Neri [4] also have examined a variety of slime produced by several species of river and sea fish. From the study concluded that a reduction in the flow resistance. Tests were conducted with a rheometer.

Yanuar *et al.* [5], experimentally the drag reduction effects due to the introduction of slime solution into a catamaran ship model at the basin. The test results show that an effective drag reduction of up to 7% at Fr = 0.45 can be achieved. Yanuar *et al.* [6] also investigated drag
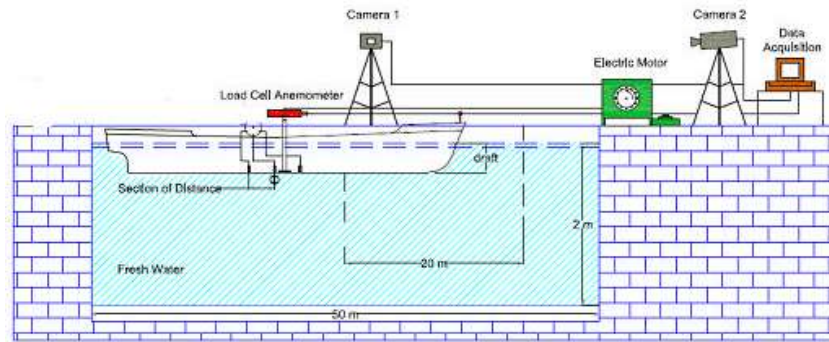
Corresponding Author: Gunawan, M. Baqi, Department of Mechanical Engineering,
University of Indonesia, Jakarta 16424, Indonesia.

Fig. 1: Experimental set-up

reduction on Indonesia navy fast patrol boat (FPB) 57 m type model with the following main dimensions: *L*=2450 mm, *B*=400 mm and *T*=190 mm using micro bubble. It was shown that micro bubble injection behind the mid-ship is the best location to achieve the most effective drag reduction and the drag reduction caused by the micro-bubbles can reach 6%-9%.

The compliant skin of the dolphin has also been studied for drag-reducing properties. By responding to the pressure fluctuations across the surface, a compliant material on the surface of an object in a fluid flow has been shown to be beneficial. Though early studies showed dramatic dragreduction benefits, later studies have only been able to confirm 7 per cent drag reduction [7]. Brian Dean and Bharat Bhushan [8] have studied more complex about shark skin drag reduction. They found that shark skin is develope more and more ribblet form. They also investigate some mechanism drag reduction of ribblet form.

The purpose of this research is to identify the effect of coating ribblet form to estimation on drag reduction in the resistance of high speed ship model. This research carried out experimentally using towing tank test. The ship model is Indonesian fast patrol boat (FPB-57) with main-hull L = 2.45 m, B = 0.40 m and T = 0.19 m is pulled by an electric motor which speed can be varied and adjusted. The ship model resistance was precisely measured by a load cell transducer. The ribblet form is varried by three form: blade form, scalloped form and sawtooth. Comparison of ship model resistance with 3 different ribblet form is shown on the graph as a function of the total resistance coefficient and Froude number.

Experimental Set-Up: Figure 1 shows the experimental set-up in the basin. The basin dimension of basin is 50 m of length, 20 m of width of 20 and 2 m of water depth. This experimental set-up consists of load cell transducer, camera, ship models, data interface, computer, electric
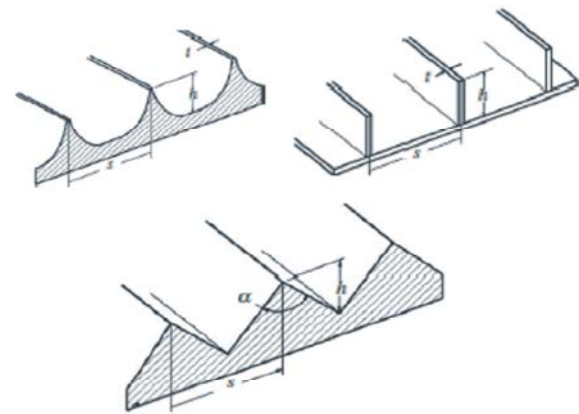

Fig. 2: Positioning of Ribblet

Figure 3. Variation of Ribblet Form

motor and AC voltage regulator. Ship model pulled by an electric motor and the motor rotation can be used to pull the ship model with a constant speed. The comparison of the total resistance between ship models without ribblet and with ribblet placed is analyzed. Total resistance was measured by using a load cell transducer for each run over the test range of Froude numbers. The load cell transducer was connected to the ship model at a point located amidships and vertically above the base line, allowing the model to move freely in the vertical plane. Testing is done by recording the results of the string tension on the load cell through the data acquitision are read on the computer.

Figure 2 shows the positions of ribblet on ships main-hull. Ribblet is placed on the stem of ship hull. There is three variation of ratio area between ribblet with total wetted surface area of ship model. This ratio is 0.07; 0.14 and 0.28 for each ribblet form.

Figure 3 shows the ribblet form. It can be shown that there is 3 variation ribblet form. Scalloped form, blade form and sawtooth form are used in this experiment. For all ribblet form, have ratio heigh per length (h/s) is 0.3.

Analyzes: The resistance offered by a ship to movement through water may be resolved into two principal components: frictional resistance and residual resistance. The most widely used estimation of mono-hull resistance is the method proposed by ITTC.
Total resistance coefficient can be defined as:

$$C_T = (1 + k) C_F + C_w \qquad (1)$$

C_T is total resistance coefficient, C_F is frictional resistance coefficient, C_w is wave resistance coefficient, $(1+k)$ is form factor and can obtained by towing tank test results for the models.

The total resistance coefficient C_T has been calculated as:

$$C_T = \frac{R_T}{0.5\rho \, SV^2} \qquad (3)$$

Where ρ is water density and S is the wetted area of the ship hull.

The Froudes number and Reynolds number are defined as:

$$Fr = \frac{V}{\sqrt{gL}} \qquad (4)$$

$$Re = \frac{VL}{v} \qquad (5)$$

Where V is the speed of the ship, L is the length of the ship, g is acceleration of gravity and i is the kinematic viscosity of water.

Drag reduction is obtained by:

$$DR(\%) = \left| \frac{C_T - C_{TO}}{C_{TO}} \right| \times 100\% \qquad (6)$$

where C_{TO} is the total coefficient resistance of ship without ribblet and C_T is the total coefficient resistance of ship with ribblet form.

RESULTS AND DISCUSSION

Figure 4 shows the Relationship between total resistance coefficient (C_T) and Froude number (Fr) for ship
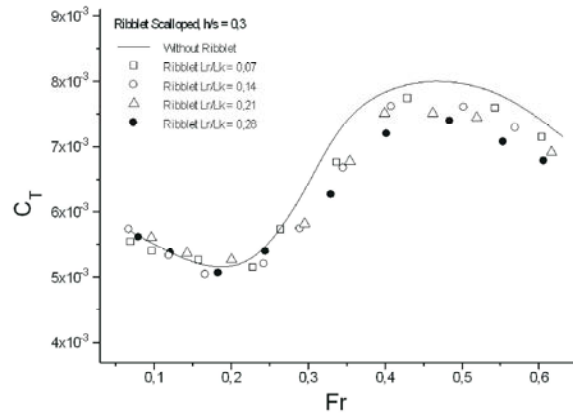

Fig. 4: Total Resistance Coefficient of Ship with Ribblet Scalooped

model with scalloped ribblet compared to the ship model without ribblet. The ship model with scalloped ribblet placed will be varied for 3 variations of ratio area with total wetted hull. Results shows that the total value of the resistance coefficient of the ship model have the same trend. The value of total resistance coefficient (C_T) ship model with ribblet is greater than monohull model with the same displacement at Fr < 0.2. Meanwhile, at Fr > 0.2 for all ship model with ribblet sticking have positive effects, as indicated by the value of total drag coefficient is lower than the ship without ribblet.

In the turbulent-flow regime, fluid resistance typically increases dramatically with an increase in surface area owing to the shear stresses at the surface acting across the new, larger surface area. However, as vortices form above a riblet surface, they remain above the riblets, interacting with the tips only and rarely causing any high-velocity flow in the valleys of the riblets. Since the higher velocity vortices interact only with a small surface area at the riblet tips, only this localized area experiences high-shear stresses. The low-velocity fluid flow in the valleys of the riblets produces very low-shear stresses across the majority of the surface of the riblet. Based on figure 4, it obtained drag reduction ratio for scalloped ribblet is 7% in Lr/Lk = 0.28. The ratio of drag reduction decreases with decrease of ratio area ribblet per wetted surface area hull ship.

Figure 5 shows the Relationship between total resistance coefficient (C_T) and Froude number (Fr) for ship model with blade ribblet compared to the ship model without ribblet. The ship model with blade ribblet placed will be varied for 3 variations of ratio area with total wetted hull. The value of total resistance coefficient (C_T) ship model with ribblet is greater than monohull model with the same displacement at Fr < 0.2. Meanwhile,
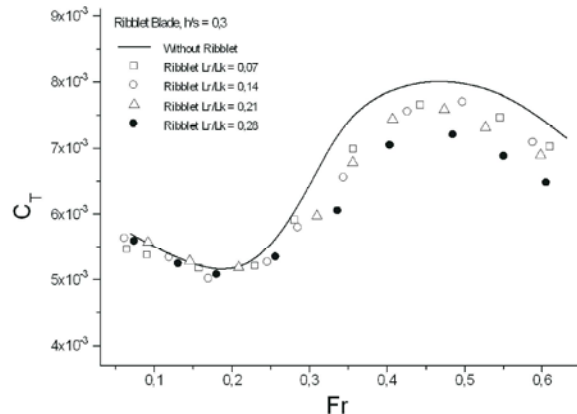
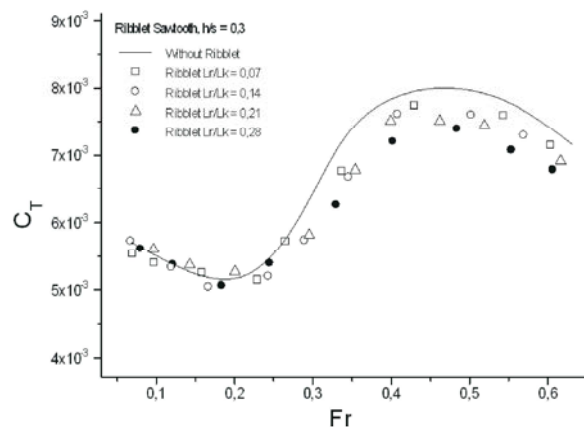Fig. 5: Total Resistance Coefficient of Ship with Ribblet Blade

Fig. 6: Total Resistance Coefficient of Ship with Ribblet Sawtooth

at Fr > 0.2 for all ship model with ribblet sticking have positive effects, as indicated by the value of total drag coefficient is lower than the ship without ribblet.

Blade riblets have been rigorously studied in their characteristic dimension ratios. Due to their inherent weak structure, optimal blade riblet thickness is limited by strength, not fluid dynamics. Blades that are too thin will warp in fluid flow and allow vortices to translate as a result. So for blade ribblet has higher drag reduction. Effect of ribblet is generated regular turbulent to the fluid flow so the resistance will be decreases. The value of drag reduction for blade ribblet up to 10%.

Figure 6 shows the Relationship between total resistance coefficient (C_T) and Froude number (Fr) for ship model with blade ribblet compared to the ship model without ribblet. For the same h/s, blade riblets have the smallest shift in the effective flow origin due to their small cross sectional area and sawtooth have the largest shift

in the effective flow origin. When comparing the optimal drag reduction geometries for sawtooth, scalloped and blade riblets shown in figure 3, it is clear that blade riblets provide the highest level of drag reduction, scalloped riblets provide the second most and sawtooth riblets provide the least benefit. The drag reduction of sawtooth ribblet is nearly similar with scalloped ribblet. There is 4% drag reduction is occured.

CONCLUSION

This paper experimentally investigates the influence of special roughness (ribblet) on the wall of ship model shows that the ship model with ribblet provide smaller total resistance coefficient than ship model without ribblet with equal displacement. Fluid drag in the turbulent boundary layer is, in a large part, owing to the effects of the streamwise vortices formed in the fluid closest to the surface. Turbulence and associated momentum transfer in the outer boundary layers is, in a large part, owing to the translation, ejection and twisting of these vortices. Additionally, the vortices also cause high velocities at the surface that create large shear stresses on the surface. The mechanism of drag reduction with ribblet is generated regular turbulent in the buffer layer. The maximum drag reductuon in this research is 10% for blade ribblet with Lr/Lk = 0.28.

ACKNOWLEDGEMENT

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