Reduced Resistance of SWATH Models in Waves

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Abstract

EXPERIMENTAL studies into the resistance increase in regular head waves with two tandem strut Small Water Plane Area Twin Hull (SWATH) models have revealed that there is little increase in the added resistance as speed increases, and, as the wave height increases, the resistance decreases (by as much as 24% of the calm water resistance) over the speed range of Froude numbers, $F_n = V\sqrt{gL_b}$ where V is the SWATH speed, g is the acceleration due to gravity, and L_b is the body length, between 0.31 and 0.39.

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One of the main merits of Small Water Plane Area Twin Hull (SWATH) ships is their ability to sustain speed with only little loss in rough weather. However, an exact prediction of the power increase is not possible at present. Yeh and Neal[1] showed that both mean added resistance and mean added power in rough water are functions of the speed and wave height. Using the results of Yeh and Neal,[1] Smith et al.[2] estimated the power increase in rough weather of a 2400-ton SWATH ship and found that the power increase is more than 10% in the sea state of 4, whereas the corresponding sea trial result for the SWATH MESA 80 is less than 2% speed loss.[3] To resolve this contradiction and because added power is of prime importance in estimating the design power margin of SWATHs, studies into the added resistance in regular waves were conducted with two tandem strut SWATH models, SWATH1 and SWATH2.

The lower portion of the demihulls of SWATH1 have circular cross sections with ellipsoidal and tapered ends. The upper portion of the demihull has the same waterplane at all drafts and is of airfoil section. The forward and aft struts are identical to each other. The circular hulls of the SWATH1 are replaced with hulls of rectangular cross sections with rounded corners, and this model is designated as SWATH2. Model experiments were carried out both in regular waves and calm water at the Hydrodynamics Laboratory of Glasgow University (77 m in length, 4.6 m in width, and with 2.4 m water depth) using the constant speed technique. The added resistance was then derived by subtracting the calm water resistance from the resistance in waves. The models were free to heave, trim, and surge, but restricted in yaw and sway. A full description of the models and details of the experiments can be found in Chun and McGregor.[4]

In tests on SWATH1 over a wide range of frequencies (0.3 to 1.6 Hz), the resistance increases are very small, even near heave and pitch resonance frequencies, and become negative over some speed range. At the frequency of wavelength to body length ratio, $L_w/L_b = 1$, shown in Fig. 1 as a typical example, it is remarkable to see that the resistance of SWATH1 decreases between $F_n = 0.31$ and 0.39, as the wave height increases, by as much as 24% of the calm water resistance at $F_n = 0.326$ for $L_w/H_w = 15$ where H_w is the wave height. This decrease was also found in the same speed range at other frequencies. The large resistance increase at the last speed is due to the excessive bow trim and green water washing over the deck.

It can be seen that as the wave height increases, the resistance decreases systematically with the tendency that the resistance peak shifts to the slower speeds and that the hollow and hump are flattened. This resistance decrease and tendency can be seen also with the SWATH2 rectangular hulled model over the same speed range. The corresponding behavior of the added resistance coefficients, $R_{AW}/\rho g H_w^2 \nabla^{1/3}$, in Figs. 2 and 3, shows reductions over the same speed range for a range of wave steepness (R_{AW} = added resistance, ρ = density of water, and ∇ = displaced volume).

These decreases are caused by very complicated hydrodynamic interactions between the many components of the model and the oncoming waves, and a full explanation will require a considerable theoretical investigation of first and second order wave effects and a steady suction force generated be the entrance of the submerged body in oscillation. (This is underway.)

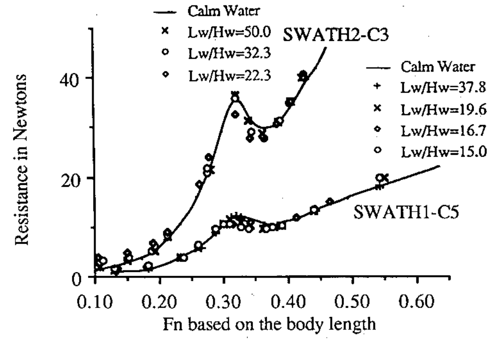

Fig. 1 Total resistance for SWATH1 and SWATH2 vs $F_n(L_w/L_b = 1)$.

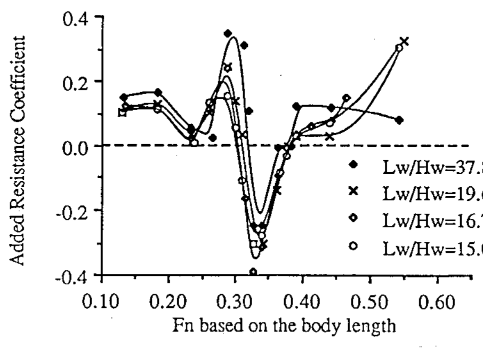

Fig. 2 SWATH1-C5 added resistance coefficient vs $F_n(f = 1.02$ Hz, $L_w/L_b = 1)$.

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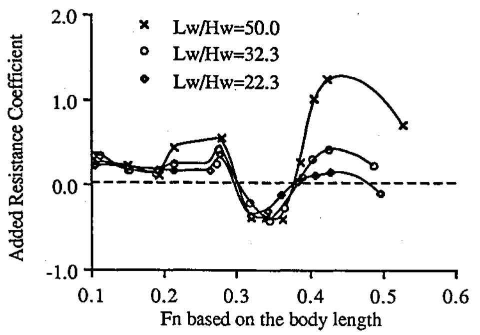

Fig. 3 SWATH2-C3 added resistance coefficient vs $F_n(f = 0.83$ Hz, $L_w/L_b = 1)$.

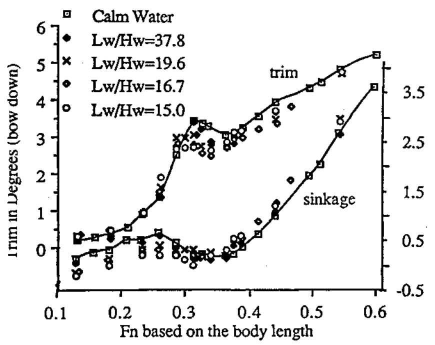

Fig. 4 SWATH1-C5 trims and sinkages vs $F_n(f = 1.02$ Hz, $L_w/L_b = 1)$.

There are various factors which could have an influence. Oscillating foils attached to the hull can create propulsive energy which moves the ship forward.[5] By the same principle, the motions of the struts and hulls of the SWATH could create some propulsive forces. However, the motions are, in general, small, and the effect is likely to be small.

The large calm water resistance peak around $F_n = 0.31$, which is characteristic with the tandem strut SWATH, is caused by the interference wave systems between the fore and aft struts and between the struts and the body.[6] These interferences are a function of not only the relative distance between the components but also of speed. As the model is towed at a constant speed through waves, its apparent speed will be increased owing to the speed of the encountering wave. Hence, this changed speed would affect the wave interference systems and, consequently, shift the peak to the slower speed. In addition, the phase shift toward the slower speeds with increasing wave height may be attributed to the increased speed of water particles near the model due to the increased surge motion.

In addition, the decrease in resistance may possibly be understood from the curves of sinkage and trim shown in Fig. 4. These two curves show the typical results of sinkage and trim variation with speed and wave steepness for the SWATH1 model. Similar results were recorded with the SWATH2 model. The sinkage and trim are nearly independent of the wave length.[4] The trim decreases considerably (depending on the speed) as the wave height increases. The negative added resistance increases over $F_n = 0.31$–0.39 could be partially due to the considerably decreased trims over that speed range. At higher speeds above $F_n = 0.39$, the resistances are not reduced despite the much reduced trims because the mean sinkages are increased at the higher speeds, hence, creating more resistance. It is not clear at this stage whether the changes in sinkage and trim are a cause of the resistance changes or an effect of them.[4,6]

For monohulls, added resistance is usually taken to be proportional to the square of wave height. If the square law is correct, then all of the resistances of a given model at various wave heights but constant wave length can be reduced to a single curve when divided by the square of the wave heights. From Figs. 2 and 3 and other results,[4,6,7] it is difficult to justify the use of the square law between the wave height and added resistance for the SWATHs. It is considered that the square law is less applicable as wave steepness decreases.

In conclusion, the resistance increase of the two tandem strut SWATH models in waves is very small and may be negative. There is little increase in the added resistance as speed increases. This is caused by the combination of several complicated hydrodynamic factors such as variations in trim and sinkages in waves relative to those in calm water, increased apparent speed of the models due to the oncoming waves and the increased surge motion with the increase of wave height, and by the interference effects between the twin struts combined with some motion aspects of the models.

From the propulsion point of view, this negative resistance increase in waves is one of the greatest advantages for the tandem strut SWATH design. As a result, the tandem strut SWATH ship can be seriously considered for naval combatants and ferries where operational speed reduction is of prime importance in spite of other drawbacks.

Added resistance of SWATHs is not proportional to the square of the wave height.

The sinkage and trim are independent of the wave length but dependent on the wave height. The trim in waves is less than in calm water and decreases with increasing wave height. The sinkage in waves decreases up to $F_n = 0.30$ and then increases compared to the calm water results.

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