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10,000 톤의 단동선, 쌍동선, 삼동선 저항 비교

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Comparison of Resistance for Three 10,000 Ton Ships: a Monohull, a Catamaran and a Trimaran

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Abstract

Preliminary conceptual design of hulls is developed and a theoretical evaluation study performed for the comparison of the hull concepts. Systematic variation of the side hull location is carried out to find an optimum position of side hulls for a trimaran by CFD computation. In order to compare computed results, the model test of trimaran was carried out. Shallow water effect is considered due to the route which has critical water depth of 20m for the design speed and investigated on the condition of different speeds and water depth by the numerical computations.

※Keywords: Monohull(단동선), Catamaran(쌍동선), Trimaran(삼동선), North Sea(북해), Shipflow

1. Introduction

The requirements of the project are that the three different ships operate on the typical route (Trondheim - Rotterdam) in North Sea. The demands on North Sea trade are that 350teu will be handled on 48 hours of the timetable between departures and mono cargo deck is required due to the fast loading and unloading time. A ship size of 10,000 displacement tonnes and 27knots in service speed is well suited for the route. According to the limitation of Norwegian harbor, requirement of hull will be maximum LOA, is 220m. And Shallow water effects should be considered around 20m of water depth.

The aim throughout the study was to make a comparison of the concepts from the wave resistance point of view that would find a well

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preformed hull form among the concepts

2. Principal dimensions

The considered hulls are the different typologies as a monohull, a catamaran and a trimaran. Fast loading unloading is required due to the time table so additional requirement of the hull should have one deck.
Monohull, Catamaran and side hull of trimaran hull form is developed by SSPA and main hull of trimaran is developed by KMYT (Kvaerner Masa Yard Technology).

Table 1 Main dimension of the three typologies

	Monohull	Catamaran	Trimaran	
			Main hull	Side hull
LBP(m)	180.0	169.0	201.0	100.0
B(m)	29	7.2	4.0	3.8
Td(m)	5.0	7.0	7.0	3.0
Displ. (m3)	9760	9756	8180	506

3. Wave making resistance

Wave making resistance is computed by XPAN which is a module of SHIPFLOW. XPAN is a free surface potential code for solving linear and nonlinear free surface boundary condition.
Pressure integration and transverse wave cut technique is considered at the initial computation for grid dependence study. However results from the pressure integration method are taken for the comparison of the concepts.
Wave making resistance of trimaran is influence-ed the magnitude of the longitudinal and transverse location of the side hulls according to different speeds. In this study, wave making resistance is investigated where the location of the side hull is varied in transverse and longitud-inal direction as bellow

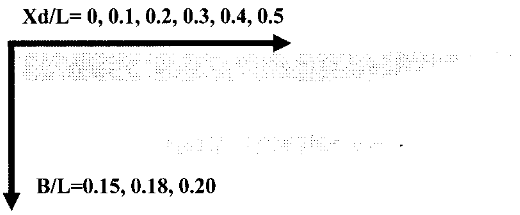

Fig. 1 Variation of side hull location

Monohull

In order to reduce the numerical errors more than hundred cases were computed. To confirm the results from SHIPFLOW the results needs to compare with model test results of similar vessels. It has similar tendency with model test results of similar vessels which from SSPA. So computed wave resistance is assumed well predicted at the speed range.
It can be seen from the Fig. 2 and 3 bellow that the computed the wave pattern

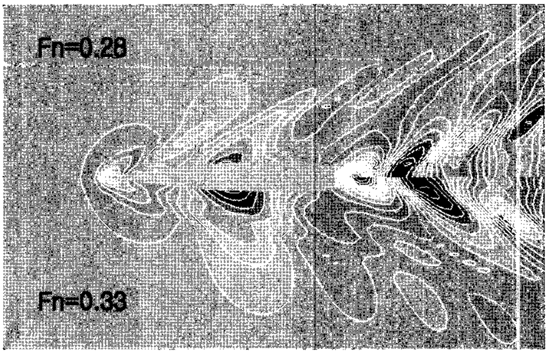

Fig. 2 Wave pattern at Fn 0.28 and 0.33kts

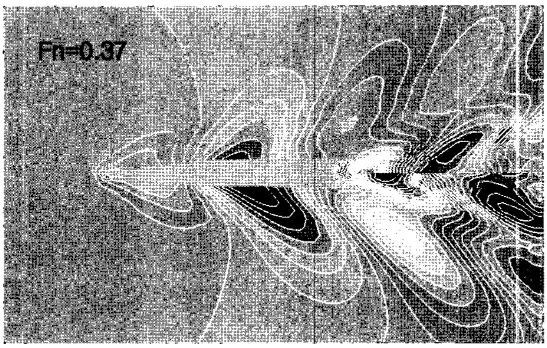

Fig. 3 Wave pattern at 0.37 and 0.43kts

Catamaran

Fig. 4 and 5 presents wave patterns in the different speed range. According to the design requirements which 350 TEU container should be handle the maximum beam of catamaran is required as 40m. Smaller beam than 40m is shown higher wave resistance. So the computations are carrying out with 40m of beam only.

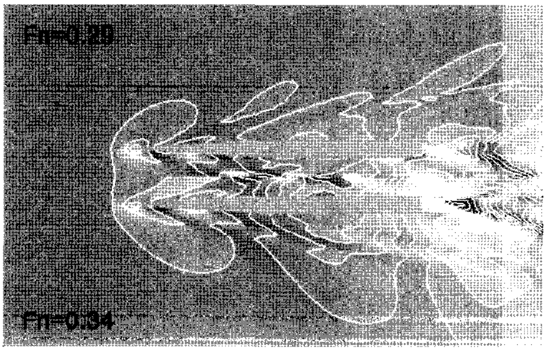

Fig. 4 Wave pattern at Fn 0.29 and 0.34

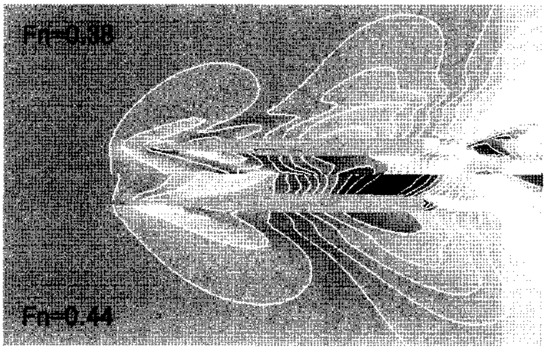

Fig. 5 Wave pattern at Fn 0.38 and 0.44

Trimaran

Initially wave resistance and wave pattern was computed at Fn 0.31 by SHIPFLOW with variation of side hull in transverse and longitudinal direction. The location of the side hulls are varying from Xd/L=0, 0.1, 0.2, 0.3, 0.4, 0.5 also varying B/L 0.15, 0.17 and 0.20. It is clear that the optimum longitudinal position of the side hulls is located around Xd/L=0.3 between hull sterns and side hull location around far aft or far forward of main hull have tendency of higher wave resistance.

Furthermore the computed result shows larger clearance about B/L=0.20 is more favorable where the side hull is located more than Xd/L=0.3 between hull stern. However smaller clearance as about B/L=0.15 gives lower resistance where side hull located Xd/L=0 to 0.20 between hull sterns in longitudinal direction.

The speed influence is investigated to analyze wave interaction. The considered Fn are 0.27, 0.31, 0.35 and 0.41. Also the longitudinal location of side hulls is varied Xd/L=0, 0.2, 0.3, and 0.4 as bellow. The wave resistance and pattern are computed at those Fn.

It is clear that the optimal configuration is not constant through the Fn=0.27 to 0.41 (Fig. 6). The optimal location of side hull is Xd/L=0.3 between hull sterns at Fn=0.31 but Xd/L=0.5 between hull sterns gives lower wave resistance at Fn=0.41. When the Fn is decreased the interference of wave making resistance becomes smaller. The far forward position of side hulls has tendency of less wave resistance at higher Fn.

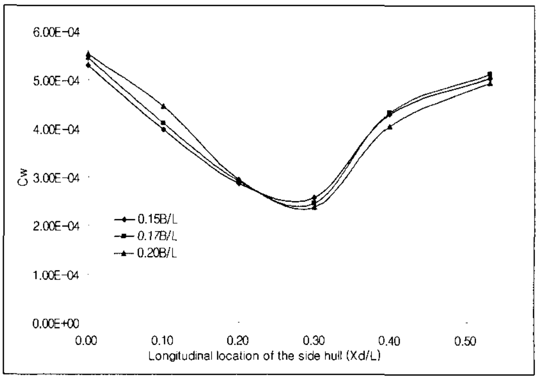

Fig. 6 Computed Cw for various trimaran configurations at Fn 0.31

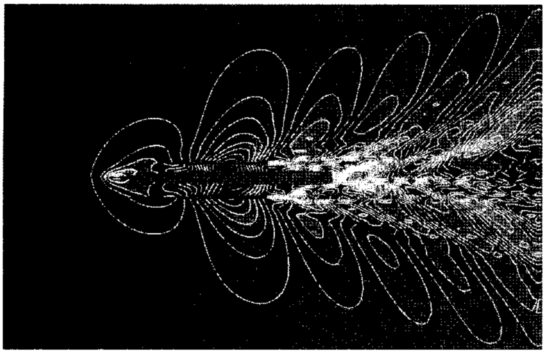

Fig. 7 Wave pattern (B/L 0.15 and 0.17)

4. Frictional resistances

Frictional resistance is computed by XBOUND which is a module of SHIPFLOW. Since the hulls are slender, separation in the stern region of hulls is low and ignorable. So the boundary layer solution is well predicting the resistance.

Each hull of trimaran is operating at different Reynolds numbers so friction resistance is calculated separately. The total friction resistance is calculated as a sum of the frictional resistance from each hull with each frictional coefficient as bellow.

$$Cftot = Cfch(Sch/Stot) + 2Cfsh(Ssh/Stot)$$

where Ssh = Center hull wetted Surface
Sch = Total hulls wetted surface
Stot = Side hull wetted surface

The boundary layer is calculated using 3D momentum integral equations in the small cross flow approximation. Three equations are integrated along the streamlines, namely the longitudinal and transverse momentum integral equations and the entrainment equation. The entrainment rate is computed according to head and the skin fiction coefficient is obtained from a relation based on the Ludwieg-Rillmann formula, but with some adjustments to the constants to make it more applicable to high Reynolds number flows. (Larson, L, Broberg L, Kim K J and Zhang D H (1990)" A Method for Resistance and Flow Prediction in Ship Design " SNAME Transitions, Vol 98, 190,pp495-535)

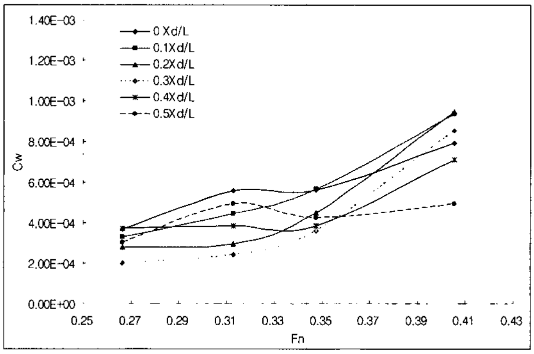

Fig. 8 Computed Cw vs. Fn for B/L 0.17

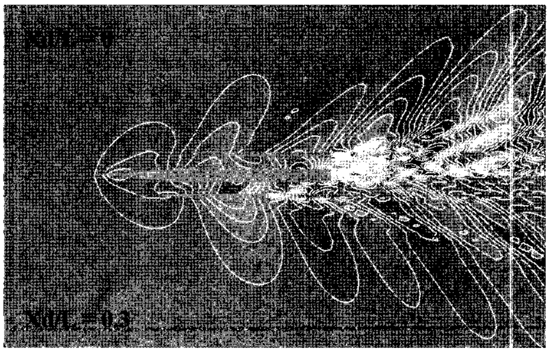

Fig. 9 Wave patterns (Xd/L 0 and 0.3)

5. Trimaran model test

Through the CFD computation of trimaran the optimum position of side hull was found. To continue to invest the hull interaction and to compare with CFD computation results resistance model test is carried out at SSPA towing tank.

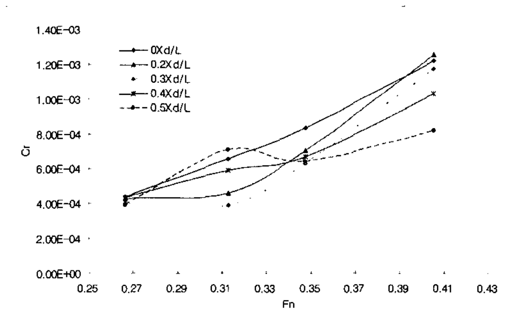

Fig. 10 Measured Cr vs. Fn for B/L 0.17

Table 2 Ranking of computed Cw at Fn range

Ranking	1	2	3	4	5
Fn	Xd/L				
0.27	0.3	0.2	0.6	0	0.4
0.31	0.3	0.2	0.4	0.6	0
0.35	0.3	0.4	0.6	0.2	0
0.41	0.6	0.4	0	0.3	0.2

Table 3 Ranking of measured Cr at speed range

Ranking	1	2	3	4	5
Fn	Xd/L				
0.27	0.6	0.3	0.2	0.4	0
0.31	0.3	0.2	0.4	0	0.6
0.35	0.3	0.6	0.4	0.2	0
0.41	0.6	0.4	0.3	0	0.2

6. Comparison and discuss

According to the measured results (Fig. 6) the re- sidual resistance coefficient shows that side hull position of Xd/L=0.3 between hull sterns gives lower residual resistance at Fn=0.27 and 0.35. The difference in wave resistance between the various longitudinal locations at Fn=0.27 and 0.31 is approximately 12% and 80% respectively.

The difference between residual resistance and wave making resistance increases with speed expected. This can be seen from the Fig. 6 & 7.

In the Fig. 6 and 7 the hulls are ranked as bellow (Table 2, Table 3) both computed wave making resistance and measured residual resistance. It can be noticed that SHIPFLOW produces same ranking of the side hull positions than the towing tank results. Therefore SHIPFLOW can be considered as a good toot to compare the various design alternatives.

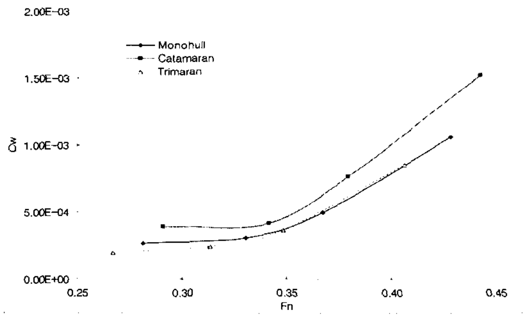

Fig. 11 Measured Cr vs. Fn at B/L 0.17

Deep water condition

Fig. 12 presents a comparison of Cw vs. Fn. It can be seen that the Trimaran has lower resistance at Fn bellow 0.35. at Fn=0.35 the monohull has 9% more wave making resistance than trimaran, the catamaran shows 70% higher.

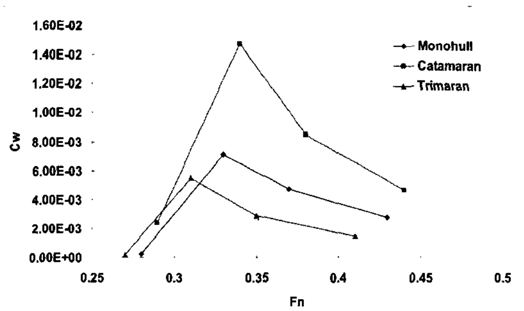

Fig. 12 Comparison of Cw with monohull and trimaran at 20m of water depth

Shallow water condition

The typical route of North Sea trade

(Trondheim – Rotterdam) should be considered the critical water depth of the hulls as 20m due to shallow water effect. Wave resistance due to the shallow water depth is computed by SHIPFLOW (Fig. 12)

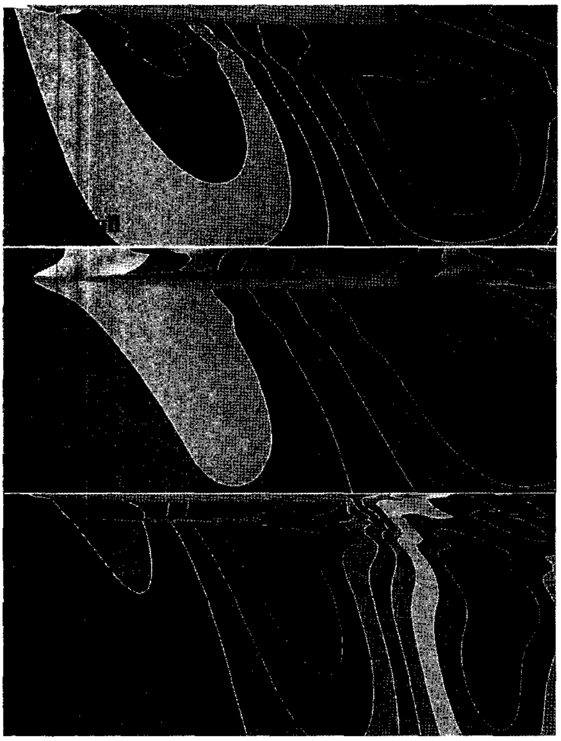

Fig. 13 Comparison of wave at Fn 0.33

7. Conclusions

Model test and CFD computation using SHIPFLOW have been carried out for finding optimized location of side hulls for timaran. The optimum side hull location by SHIPFLOW is found around 60m between hull sterns at service speed. Further more far forward positions are more favorable when the speed is increased. The models test results also shown as same tendency as computed results. SHIPFLOW is useful for finding optimum location of the multi-hull.

The route has shallow water zone approximate 50km continuously. Due to the reason, the study is assuming speed reduction with 50% is take place for a maximum of 7% of the distance for each leg. 20m of water depth influence on an achievement of the high wave making resistance at the service speed. At the critical water depth, Trimaran can be reducing the wave resistance about 30% compared monohull.

The study will show the evaluation of a mono-hull, a catamaran and a trimaran concept in the wave making resistance point of view. Also it gives information of the applicability of multi-hull for the north trade also gives indications for other shipping routes.

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