A Study on the Wave Resistance and the Side-hull Location of a 2,500 Ton Class Trimaran

2,500톤급 삼동선의 보조선체위치와 조파저항에 대한 연구

Kuk-Jin Kang[1], Do-Hyun Kim[2]

강 국 진[1], 김 도 현[2]

본 논문은 삼동선의 선형특성에 대한 간략한 소개와 삼동선의 주선체 좌우에 설치되는 보조선체의 위치가 조파저항성능에 미치는 영향과 그 최적위치선정을 위한 연구 결과를 보인다. 조파저항 계산기법을 이용하여 보조선체의 길이방향과 횡방향의 위치 변화에 대한 조파저항을 계산하였으며, 그 유용성을 검증하기 위하여 모형시험결과와 함께 비교하였다. 본 연구를 통하여 보조선체의 횡방향 위치가 삼동선의 조파저항성능에 미치는 영향은 작으나, 길이방향 위치는 그 성능에 커다란 영향을 미치는 것으로 나타났다. 그리고 주선체의 선수부에서 발생된 커다란 파도의 파저에 보조선체의 선수가 놓이는 것이 저항성능에 가장 유리하며, 선속이 빨라짐에 따라서 그 최적위치는 선미쪽으로 옮겨가는 경향을 보였다.

1. Introduction

The demand for high-speed ships has been increased in the car/passenger ferry market during last decade. Many different types of ship concept and hull forms have been considered to meet the demand. Among them, the trimaran, which consists of a slender main hull and two very fine side-hulls, is one of the most interesting hull form. The trimaran has several advantages over other hull forms, such as low resistance at high speeds, easy arrangement on wide deck, superior seakeeping performance in waves, high survivability in damaged condition and reduction of thermal signature and radar cross-section etc.

On the other hand, the trimaran has several disadvantages, such as increase of hull weight, difficult handling in harbor etc.

The feasibility studies and the application examples on the trimaran were introduced in recent FAST symposium and etc.[1,2,3] In particular, many researches on the trimaran and the construction of RV Triton in U.K. is very encouraging the possibility for the future warship.[4,5]

Trimaran should be designed to satisfy the whole hydrodynamic performance at design speed, where the resistance performance is the most important among them. In particular the main hull and side-hull should be optimized at the same time to ensure the excellent resistance performance.

Recently developed panel methods based on the potential theory can calculate the wave resistance very accurately for the high-speed ships and very useful tool to optimize the hull form.

The purpose of the present paper is to show the designed 2,500ton class trimaran and to figure out the wave resistance characteristics according to the variation of the longitudinal and transverse locations of side-hull. For the above purpose, a series of resistance tests and numerical wave calculations were carried out. Furthermore,

1), 2) 한국해양연구원 해양시스템안전연구소
(305-600 대전광역시 유성우체국 사서함 23호 Tel : 042-868-7244)

the relation between the ship speed and the optimum location of side-hull is discussed.

2. Principal Particulars and Hull Form

The key parameters for trimaran design are main hull length to beam ratios, side-hull length and location etc.

The principal particulars of the 2,500ton class trimaran are shown in table 1, which are decided from the concept design[6] referring to the design requirement and the *'RV Triton'*[4].

Table 1 Principal particulars of the 2,500ton class trimaran frigate

Principal particulars	Main-hull	Side-hull	Trimaran
Displacement(ton)	2,324	176	2,500
Length B.P.(L, m)	120.0	45.0	120.0
Breadth(B, m)	9.0	1.8	30.0
Depth(D, m)	12.0		12.0
Draft(T, m)	4.2	2.5	4.2
C_B	0.50	0.423	
C_W	0.7745	0.9	
Cm	0.8468	0.5	
Lcb(%)	-2.48	0.0	
Cruising Speed	18 knots (Fn=0.27)		
Maximum Speed	30 knots (Fn=0.45)		
Propeller	Dia.=3m, Twin		

The wave resistance of the main hull affects dominantly on the resistance performance of the trimaran. Therefore, it is very important to find out the hull form with excellent resistance performance for the design of main hull form at initial design stage. A displacement type hull, which was recently developed as a high-speed hull in KRISO, was selected as a parent ship of the main hull.

Figs 1 & 2 show the graphic model of the designed trimaran and the definition of the side-hull location at each.

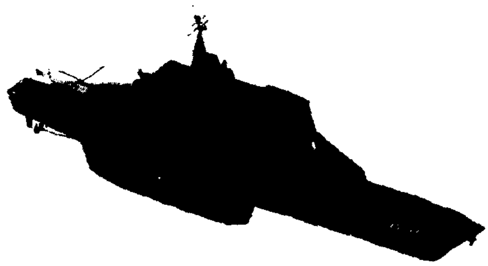

Fig. 1 Graphic design model of the 2,500ton class trimaran

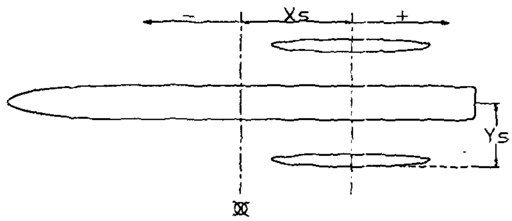

Fig. 2 Definition of side-hull location

3. Model Test and Numerical Method

The numerical and experimental studies were conducted to figure out the influences of side-hull form and location on the resistance characteristics of the trimaran. And the propulsion test was also conducted to investigate the propulsion efficiency of the trimaran.

The 1/16.667 scale trimaran model was manufactured to carry out the resistance tests. Based on the Froude's assumption and 1957 ITTC model-ship correlation line, the full-scale values were predicted from the resistance tests.

Fig. 3 shows the model test scene for the

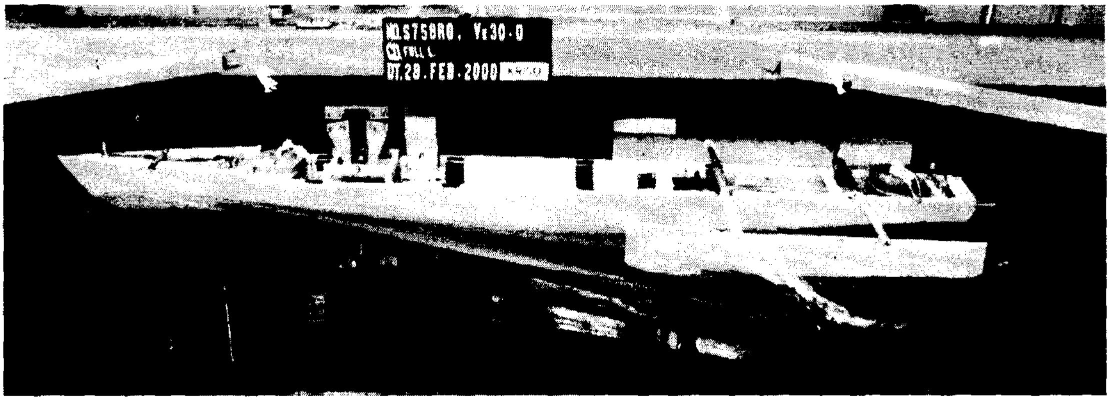

Fig. 3 Running trimaran at 30 knots(Ys/L=0.125, Xs/L=0.3)

resistance test.

The numerical method to calculate the wave resistance was developed by Kim, et al.[7]. The method adopted the first order panel method, which was developed by Hess and Smith. For the free surface effects, the pioneering paper by Dawson demonstrated the promising results of the free-surface panel method. Furthermore, Xia, Raven and Kim extended and refined the method. The present method is based on the numerical schemes of the above-cited papers. For the free surface treatment basically the well-known Dawson's approach is adopted in the present method. To enforce the radiation condition the present method employs Dawson's 4-point upwind-difference operator in a longitudinal direction. For a transverse direction 3-point central-difference operator is used. Furthermore, the collocation points are shifted upstream in order to smooth out the source strengths and to prevent the upstream waves at high speeds. The shifted distance is usually about 10%~30% of panel length. To take into account the transom stern effect, the Cheng's method based on dry transom assumption is used in the present approach. Due to the transom stern of the main hull, the static pressure component of a main hull is included by somewhat adhoc fashion when calculating the wave resistance of a trimaran.

4. Results and Discussion

4.1 Effects of Side-hull Location in Longitudinal Direction

Longitudinal location of side-hull was investigated to figure out the influence on the resistance performance of the trimaran. Model tests and numerical calculations were carried out for the side-hull location at Xs/Lpp=-0.15, 0.0, 0.15, 0.30 & 0.45 in length and Ys/Lpp=0.125 in beam. Fig. 4 and 5 show very good agreement between the calculation and the experiment at 18 knots and 30 knots

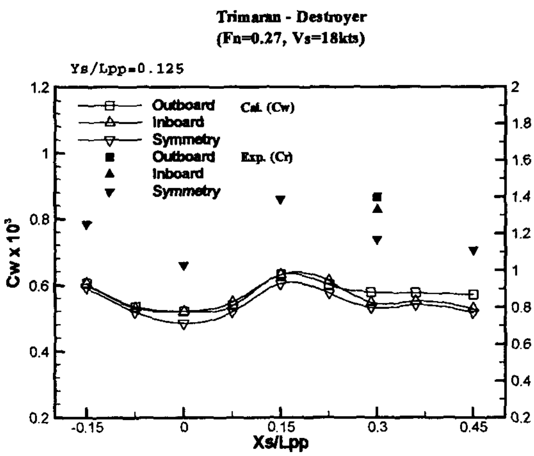

Fig. 4 C_R & C_W at 18 knots (Fn=0.27)

at each.

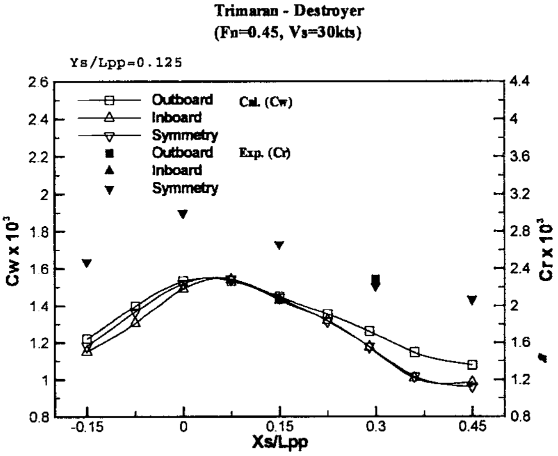

Fig. 5 C_R & C_W at 30 knots (Fn=0.45)

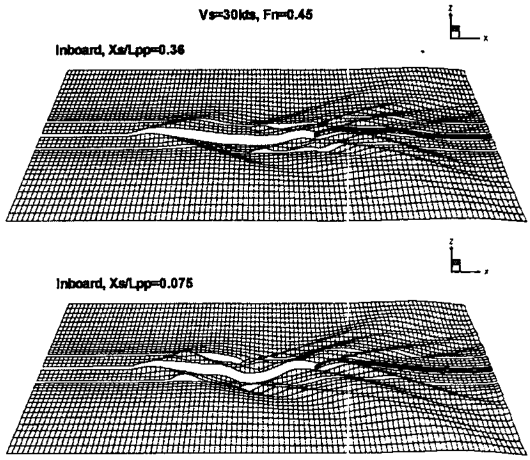

Fig. 7 Comparison of calculated wave patterns (Fn=0.45)

It is almost possible to select the optimum longitudinal location by numerical calculation.

Fig. 6 shows the C_R curves obtained from model tests. The differences were caused by the wave interference according to the longitudinal locations of side-hull.

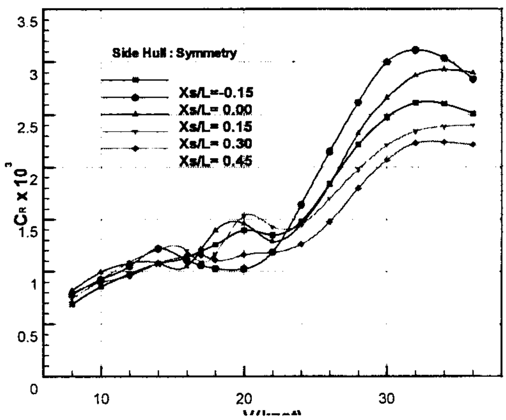

Fig. 6 C_R curves for the longitudinal locations of side-hull

Fig. 7 shows the comparison of calculated wave patterns for the side-hull locations Xs/Lpp=0.36 and 0.075, which shows big difference in wave system. It can be found from the wave system that the former shows favorable wave interference but the latter shows nearly the worst case.

From the above results, it is found that the optimum longitudinal location is related with the ships speed. And the trimaran shows a favorable resistance performance when the side-hull moves toward the stern of main hull at high speeds. However, it is supposed that the optimum longitudinal location is near Xs/Lpp=0.3 if the ships constraint conditions etc. are considered.

4.2 Effects of Side-hull Location in Transverse Direction

Numerical calculations were carried out to investigate the effect of the side-hulls transverse location on the wave resistance characteristics of the trimaran. The trimaran with symmetry type side-hull was used for the calculation. Fig. 8 shows the calculation results for the transverse locations Ys/Lpp=0.125~0.225 while the longitudinal location is fixed at Xs/Lpp=0.15 at 30 knots.

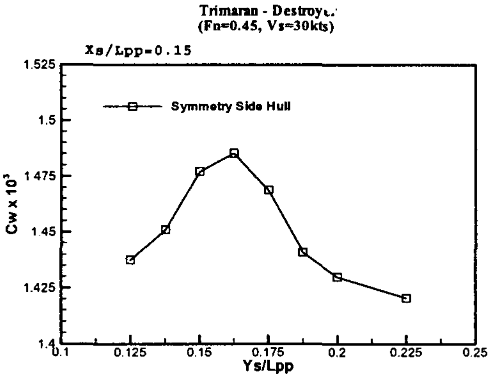

Fig. 8 Calculated Cw curve according to the transverse locations of side-hull

Fig. 9 shows the calculated wave height for the main hull only in transverse direction at main hull center Xs=0.0, which corresponds to the 0.1 Lside-hull aft of side-hull. From these two figures it seems that the wave resistance is related with the wave height a little, which the side-hull stem encounters.

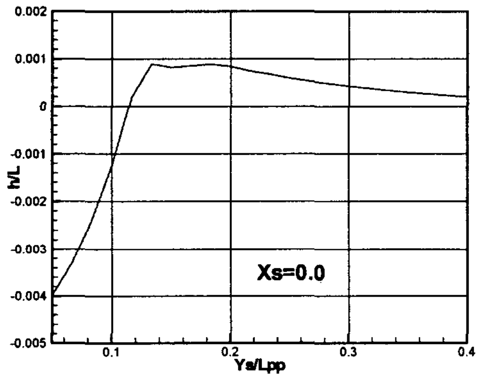

Fig. 9 Wave height generated by main hull in transverse direction (30 knots)

The maximum difference of the wave resistance coefficient Cw due to the transverse locations does not exceed 10% of that due to the longitudinal locations

4.3 Discussion on the Optimum Location of Side-hull

The present topic is to find out the easy way to predict the optimum location of side-hull at initial design stage. The resistance characteristics of trimaran are highly affected by the wave interference between the main hull and the side-hull. Therefore, the optimum location of side-hull is supposed to be the place where the waves generated by the main hull and the side-hull cancel out each other. Fig. 10 shows the wave profile generated by main hull at 30 knots (Fn=0.45) and five locations of side-hull at the transverse location Ys/Lpp=0.125. This relative location seems to show a close relation with the wave resistance as shown in Fig. 5. Therefore, it can be said carefully that the trimaran has favorable resistance performance when the side-hull stem is located near the primary wave hollow generated by the main hull.

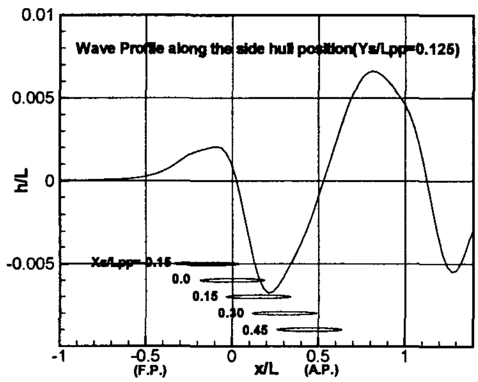

Fig. 10 Relation between wave profile and side-hull location (30 knots)

Fig. 11 show the comparison of C_R curves for the trimaran and the similar mono-hull ships. The trimaran shows good resistance performance in most speed range.

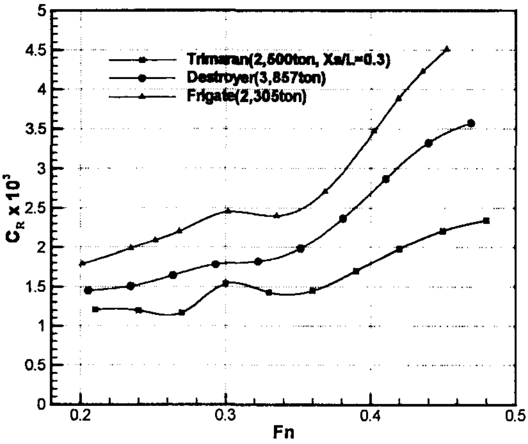

Fig. 11 Comparison of C_R curves

5. Concluding Remarks

The 2,500ton class trimaran was designed and the resistance performance was investigated by the numerical and experimental method. The results obtained from the research can be summarized as follows.

(1) The wave calculation method is very useful tool for the trimaran design.
(2) The longitudinal location of side-hull has a large influence on the wave resistance of the trimaran while the transverse location has a small influence on it.
(3) The optimum location of side-hull is changed according to the ships speed. Then the optimum location moves to the stem or stern part as the trimaran runs fast.
(4) The trimaran shows favorable resistance performance when the side-hull stem is located near the primary wave hollow generated by the main hull.
(5) The trimaran is superior to the similar mono-hull ships in resistance performance.

References

[1] D.J. Andrews and J. W. Zhang, "Trimaran Ships", Naval Engineering Journal (1995), pp. 77-93
[2] Igor Mizine and Eduard Amromin, "Large High Speed Trimaran-Concept Optimization", FAST'99
[3] Jussi Lindstrom et al., "Superslender Monohull with Outriggers", Travemunde, FAST'95
[4] RINA (2000). RV 'TRITON':Trimaran Demonstrator Project. International conference proceeding
[5] http://www. trimaran.dera.gov.uk/
[6] Kang, K. J., et al. "Development of the Core Technologies of Hydrodynamic Performance for Large High Speed Special Ship (4/4)". KRISO report UCE00918-2296 (2000)
[7] Kim, D. H., et al. "Estimation of the Optimum Position for the Side Hulls of a Trimaran by Panel Method. 4th J-K Joint Workshop on Ship & Marine Hydrodynamics", Fukuoka, Japan (1999)