A Study on Development of a New Concept Cargo River Ship with Reduced Resistance Acting on Hull in Calm Water

Nghiên cứu phát triển tàu hàng sông mới, giảm lực cản tác động lên thân tàu trong nước tĩnh

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Abstract

In this paper, a new hull form is developed for the cargo river ship with a drastically reduced viscous resistance by using Air Circular Tank (ACT) and small air resistance hull form by using CFD (Computation Fluid Dynamic). At first, viscous resistance acting on the new hull is calculated and compared with those of the experimental results to validate the CFD results. Then, ACT is attached on the ship, resistance acting on the new hull is computed by the CFD. Simulated results as pressures distribution around hull, viscous resistance acting on the hull with and without ACT are compared at others. Secondly, air resistance is computed by the CFD. From results of pressure, velocity distribution around hull and air resistance, a new hull shape is developed. The CFD results as pressure distribution and resistances are useful to understand what happened at the ACT. And so on, the problems as the interaction effects between accommodation and hull, effects of hull shape on resistances are found in this paper.

Keywords: New concept ship, ACT, CFD, Viscous Resistance; Air resistance.

Tóm tắt

Trong bài báo này, thân tàu mới được phát triển cho tàu chở hàng sông. Hình dáng thân tàu mới này có thể giảm được lượng đáng kể lực cản tác động lên tàu thông qua ứng dụng khoang khí tuần hoàn (ACT) bố trí tại đáy tàu và có lực cản khí động tác động lên tàu khá nhỏ, thông qua sử dụng CFD. Thứ nhất, lực cản nhớt tác động lên tàu được tính, so sánh với kết quả thực nghiệm để kiểm nghiệm kết quả CFD. Từ đó, thân tàu được bố trí ACT tại đáy và được tính toán lực cản nhớt tác động lên tàu. Kết quả mô phỏng như phân bố áp suất, lực cản tác động lên tàu sẽ được so sánh khi tàu có và không sử dụng ACT. Thứ hai, lực cản khí động sẽ được tính toán khảo sát, thông qua kết quả mô phỏng về phân bố áp suất, vận tốc dòng và lực cản khí động, hình dáng tàu mới sẽ được phát triển. Kết quả tính CFD như phân bố áp suất, lực cản sẽ hữu ích để hiểu rõ hiện tượng sẩy ra tại ACT. Bên cạnh đó, ảnh hưởng tương tác thân và thượng tầng, ảnh hưởng hình dáng đến lực cản cũng được giải quyết trong bài báo này.

Từ khóa: Kiểu dáng tàu mới, ACT, CFD, lực cản nhớt, lực cản khí động.

1. Introduction

In the field of marine and ocean engineering, research and development of a new concept ship with a high performance and minimum resistance hull form are important and popular on the world now day. Some researchers were reported on reduced viscous resistance acting on the hull of the ship, others one presented the results of study on reduced air resistance acting on the ship. Following as summary reports are the most popular research in this field.

Mizokami. S et al., (2010) [1] presented a full scale air lubrication system and verification by the full scale model experiment using a large cement carrier. The research was found that around 10-15% reduction of total resistance can be achieved for the ship. Other research had done with the same method that using air lubrication system at the bottom of a ship to reduce resistance acting on the ship. Ceccio. SL et al., (2012) [2] presented an air lubrication drag reduction on great lakes ships. The paper concluded that the economic and environmental impacts of successfully implemented air lubrication could be significant, as a ship's fuel consumption may be reduced by 5 to 20%. Zverkhoskyi. O et al., (2014) [3] presented a research on using air cavitation tank to reduce resistance acting on a ship. The author proposed an ACT at the bottom of ship to reduce resistance. In other papers, [4, 5, 6, 7] the authors reported the drag reduction by a proposed air circulating tank. By using ACT, a larger amount of wetted surface area at bottom of the ship can reduce. The conclusions of the researches that resistance

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acting on the ship with a ACT can reduce up to 25-35% of total resistances. Other research had done with the same method can be seen, [8, 9] the authors reported on results of a study on reducing resistance acting on a ship by using ACT. In the research, a commercial CFD code was used to compute the ship with and without ATC at the bottom hull of the non ballast water ship.

K. Matumoto et al. (2003) and Y. Nihei et al. (2008) [10, 11] studied on keeping a ship as Pure Care Carrier (PCC) safety in strong wind at ballast condition and reducing resistance acting on the original ship. The authors suggested a new hull design which total resistance reduced by 15% at wind speed 14m/s and 22% at wind speed 10m/s accordingly. A study on the influent of wind is very important in studying the effect of wind on the ship motion to avoid risks of collision and grounding. In other study, presented by T. Fujiwara et al. (2009) [12], wind force acting on container ship has been investigated experimentally. The aerodynamic characteristics on various types of external forms of the container ships were investigated in wind tunnel with a 1.5m block model. A new method for estimating wind force coefficients of container ship had been proposed in this regards. In other study presented by K. Sugata et al. (2010) [13], reduction of wind force acting on a non ballast ship had been focused. A new type model non ballast water ship which helps to reduce 44% of wind force in full loaded condition and by 33% of wind force in non ballast condition have been reported. K. Mizutani et al. (2013) [14], reported on research of reduced air resistance acting on the chip carrier. The total air resistance can reduce from 2% to 15%. Others paper, [15, 16, 17] the authors studied on effects of hull shape, cargo handling equipment on air resistance acting on a ship. The study concluded that total air resistance of ship can be reduced by 10% by experiment at towing tank and the interaction effect between hull and accommodation on deck duce to accommodation shape and wind direction.

In this paper, by summary results of my research in the field of ship hydro dynamic, a new concept of the cargo river ship is proposed. The new concept ship has presented with a special point of reduced resistance acting on hull as well as reduced viscous resistances by using ACT and reduced air resistances by applied new design hull form of the Non Ballast Water Ship (NBS). A study on reducing resistance acting on hull is as well as a study on saving fuel consumption for the ship.

2. Development of a new hull form for the cargo river ships

In the research of development of a new hull shape for the NBS which has done at Osaka Prefecture University (OPU) since 2010 [18-22]. The non ballast water ship was developed in a joint project of OPU with the eight ship building companies in Japan. The ships can drastically reduce their resistance in calm water by eliminating large amount of ballast water. The slender hull form developed for the ships has the minimum viscous resistance. The NBS has a blunt bow shape to reduce viscous resistance in calm water. From these results on reduced viscous resistance acting on the NBS. A new hull form with a blunt bow shape has proposed for the cargo river ship. Figure 1 show a new hull form developed for the river cargo ship, which has an engine room located at bow, using hybrid diesel – electrical propulsion system.

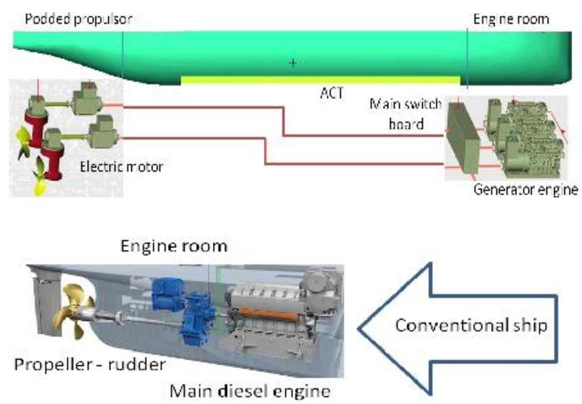

Fig. 1. New concept ship with engine room located at bow and used diesel electric propulsion system

The new hull form has developed with the attacked ACT at the bottom hull surface, and applied slender hull form, without ballast water and has a blunt bow shape. Figure 2 shows the body plan of the under desk surface hull part which is developed for the river cargo ship. This body plan is same as the body plan of the NBS [18-22]. For a river cargo ship 3500 ton, the principal particulars of the ship are designed as follows the table 1.

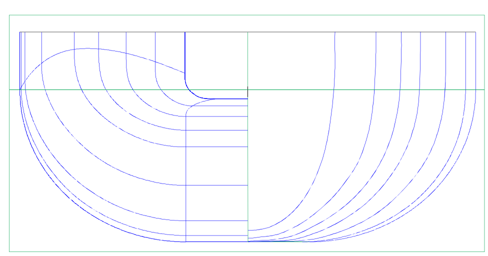

Fig. 2. Body plan of the OPU-NBS has proposed for the new concept cargo river ship

Table 1. Principal particulars of the ship

Name	Valuate	Unit
L_{pp}	85.0	m
Breadth, B	14.5	m
draft	5.60	m
Height	7.20	m
Displacement	5128	ton

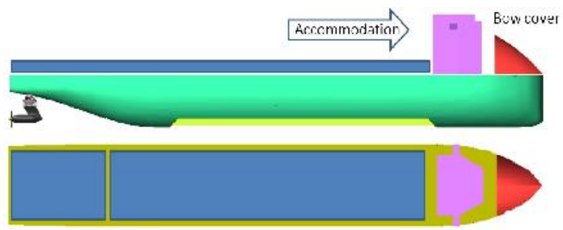

Fig. 3. New concept ship with bow accommodation and bow cover

Follows as the under deck surface of the new hull has developed for the ship, above water surface hull part is developed with an accommodation located at bow of the ship to reduce air resistances acting on hull by using interaction effects between hull and accommodation on its deck. The accommodation has used optimal shape which makes from only plat plate structure for easier in ship building. The new concept has used a bow cover to improving aero dynamic performances of above water surface hull part. Figure 3 shows the developed above water surface hull part for the new concept river cargo ship.

3. Schema for used CFD and accuracy of results

In this research, the commercial CFD code ANSYS-Fluent v.15.0 is used for computation. The software license has been registered by the authors' School of Transportation and Engineering, Hanoi University of Science and Technology. From the CFD theory and guides, the Finite-Volume Method (FVM) is used for representing and evaluating partial differential equations in the form of algebraic equations, and k-ω turbulence model is the most common model used to simulate flow in turbulent conditions that permit us to calculate basic hydrodynamic performances of a ship [23-27]. In CFD computation, computation of fluid domain, mesh size and mesh number, boundary condition and turbulent viscous model using for the problem affect on CFD results. However, we must be set step by step for the problem follows as experimental references in CFD simulation or user guider for using CFD which published by the International Towing Tank Conference as several experimental in use [9, 14-17, 21, 22]. In this research, the computation fluid domain is designed as 7.5L of length, 8L of depth and 8L of breadth for model length L. Meshing the calculating fluid domain in structured H-grid generated in 1.8 to 3.6 million grids. The velocity inlet is setup for the inlet, the pressure outlet is setup for the outlet of the calculating fluid domain. Figure 4 shows the schema for used CFD to compute dynamic performances of the ship.

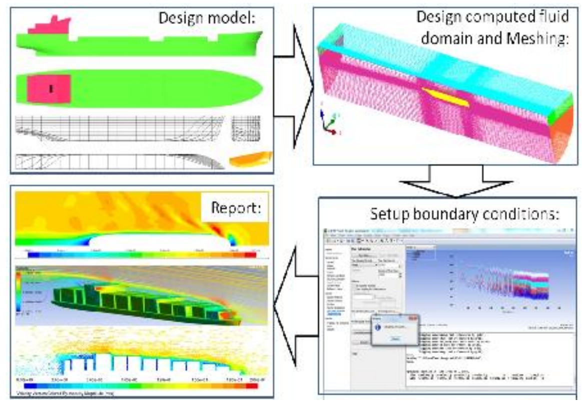

Fig. 4. Schema for using CFD in computation ship hydro dynamics performances

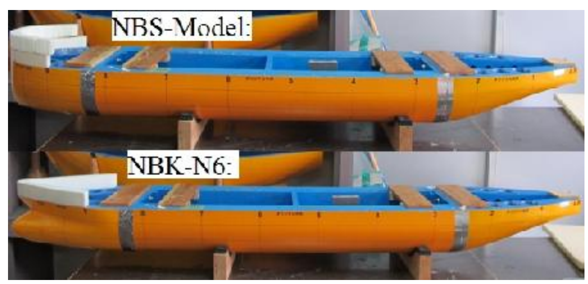

Fig. 5. Models of the OPU-NBS with and without bulbous bow used in experiment at towing tank of Osaka Prefecture University, Japan

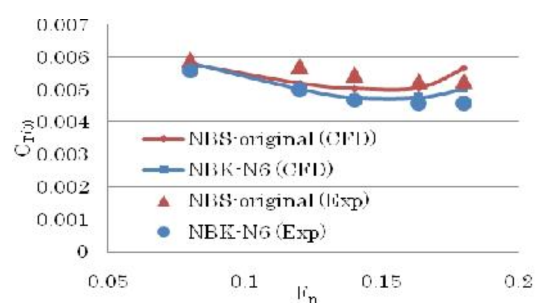

Fig. 6. Total resistances coefficients acting on hulls in calm water obtained by CFD and experiments

Figure 5 shows the two models of NBS ships used to experiment at the towing tank of OPU in Japan to validate the CFD results. The two models ship has same the sterns but different from the bow shapes, NBS-model has a blunt bow shape and NBK-N6 has a bulbous bow shape [9, 21].

Figure 6 shows comparison results between the CFD and the experimental results of resistances acting on the ship in calm water. The experiment had done with the fix models in scale model of the 2m of length model at Froude number of 0.163 in calm water. The experiment was done by the author ar Osaka Prefecture University, Japan. Good agreement between the CFD results and the experimental results are shown in those figures [21, 22]

4. Development of a new hull form with reduced viscous resistances acting on hull by used ACT

The ACT was developed at Osaka Prefecture University by Prof. Y. Ikeda. Several kinds of ACT were developed by many experiments and simulations in 2D [4-6]. For advanced development of the ACT, two ACTs in 3D with different inlet and outlet shapes are developed for the OPU-NBS [9]. In this section, the best ACT is applied for the new concept of the river cargo ship. For the 2m of length model, the designed ACT has limited in 1m of length, 0.18m of breadth and 0.03m of height. For the new concept river cargo ship 3500 ton, the ACT is limited in 42.6m of length, 7.56m of breadth and 1.26m of height. Figure 7 shows the new hull ship with an ACT at the bottom.

Figure 8 shows the computational results of the viscous resistance acting on the ship with and without ACT in calm water. The result has done at Froude number of 0.163 in calm water.

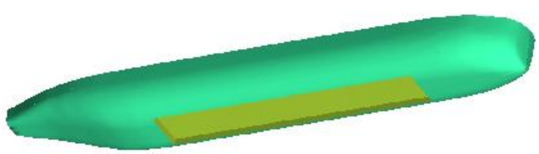

Fig. 7. A new hull form with an ACT at the bottom which proposes for the new concept river cargo ship

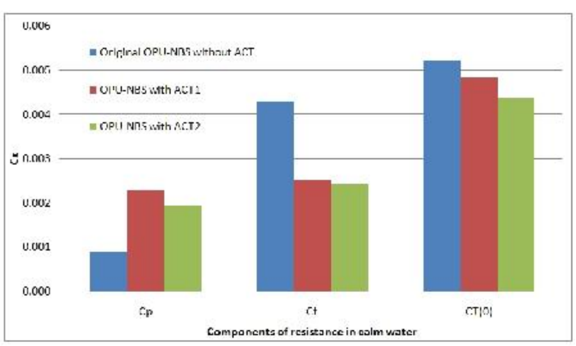

Fig. 8. Viscous resistance coefficient acting on hull of the ships with and without ACT, at F_n=0.163

The results show significant effects of the ACT and kinds of the inlet and outlet shapes on viscous resistance acting on the ships. By using the ACT, the frictional resistance acting on the OPU-NBS in calm water is drastically reduced as shown. The total resistance acting on the ship can drastically reduce by ACT2 attached at the bottom hull, up to 16% by CFD results [9]. Figure 9 shows pressure distribution around hull with and without ACT.

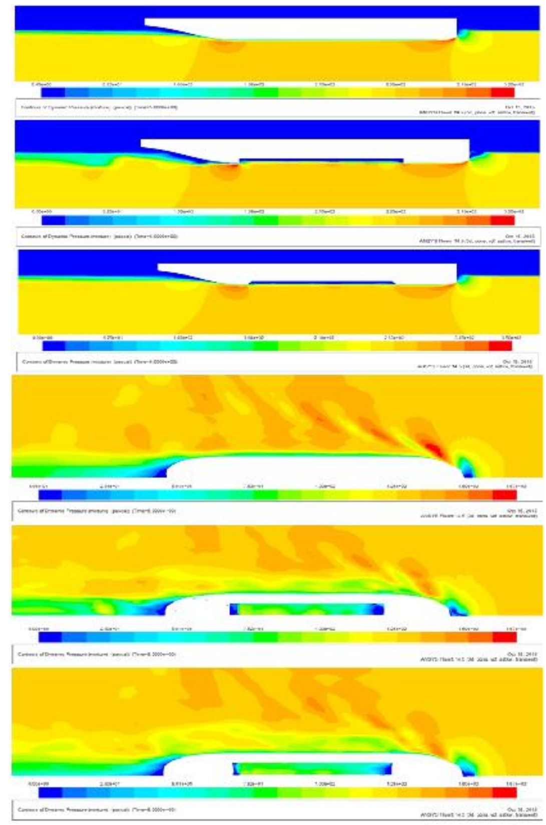

Fig. 9. Dynamic pressure distribution around ships at center plane and at free surface of computed fluid domain, at F_n=0.163

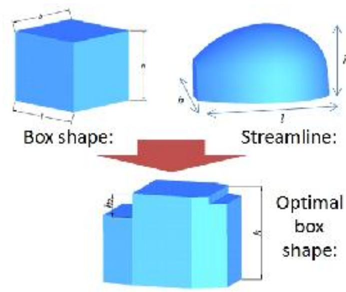

Fig. 10. Proposed an optimal box shape accommodation for a new concept river cargo ship

5. Development of a small air resistances hull form for the new concept ship

In this section the new concept ship has developed by applied some results of the research in reducing air resistances acting on above water surface hull part of the ship which has done by the author [14-17]. At first, the optimal box shape accommodation that made only plat plates is proposed for the new concept river cargo ship.

Figure 10 shows the accommodation shape in compared with a box shape and a streamlined shape. Figure 11 shows compared results of air resistance acting on the three accommodation shapes follows as wind attached angles, drastically reduced air resistance acting on the accommodation, up to 77% by CFD results as shown [17].

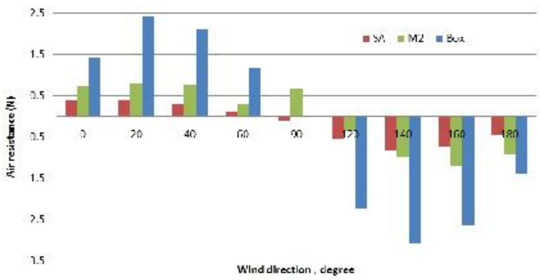

Fig. 11. Air resistance acting on the three accommodation shapes

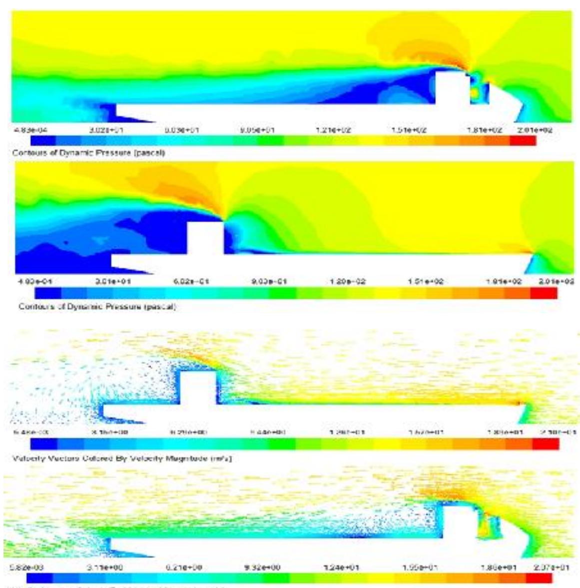

Fig. 12. Pressure distribution and velocity flow distribution around hull of the ships

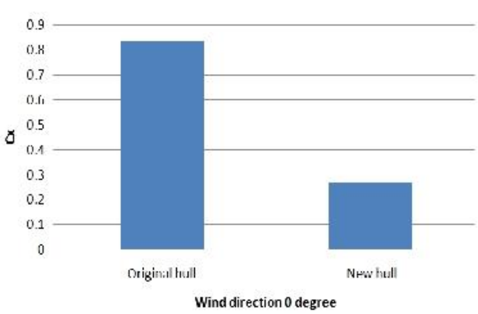

Fig. 12. Air resistance acting on the ship in comparison between the original and new hull

The accommodation has located at bow of the new concept ship to reduce interaction effects between hull and accommodation on its deck. A bow cover is used for the new ship to improve the aero dynamic performances of the new ship (Figure 3). Figure 12 shows the results of pressure distribution and flow velocity distribution around hull. The results as shown in the figure 13, show clearly reduced interaction effects between accommodation and hull on aero dynamic performances of the ship.

The results as shown in the figure 13 shows compared results of air resistance acting on hull of the new concept ship and the original ship which had developed with an accommodation located at stern. Clearly reduced air resistances acting on the ship are shown. The air resistance acting on the new concept ship can reduce up to 68% by CFD results.

6. Conclusions

In this paper, a new concept ship has proposed for the river ship. By using CFD the hydrodynamic performances of the new hulls form are investigated and compared with those of the original ship, flows as are some conclusions of the paper:

- By proposed the hybrid diesel – electric engine system and podded propulsion for the new river cargo ship. At the ballast condition, the new ship needn't use ballast water, that can control it stability and draft for propulsion work well.

- By used the ACT acting at the bottom of hull, the viscous resistance acting on the new ship can be drastically reduced, up to 16% of total viscous resistances.

- By proposed a new bow accommodation and a bow cover for the new concept ship, the new ship can drastically reduced air resistance acting on hull, up to 68% of total air resistances.

- CFD commercial code is also useful tools to compute and analysis the ship hydro dynamic performances. The CFD results are useful to understand clearly the reasons which effect on dynamic performances of ship.

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