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Hull form design for the fore-body of medium-sized passenger ship with gooseneck bulb

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Abstract

The recent IMO MEPC regulation on EEDI, EEOI and increased fuel cost has worsened the financial condition of the small and medium sized passenger ferry companies, and it is situated to acquire the economic ships with a pretty high resistance performance. The purpose of this research is to develop a design method on the efficient gooseneck bulb for the middle-sized passenger ferry operated in the Far East Asian seas. The hull forms are designed by varying the gooseneck bulb parameters to find the changes on the resistance performance according to the shape of bulb. The numerical series tests are made to derive the regression equation for estimating the resistance through analyzing the data statistically. This equation is set as an objective function, and then using the optimization algorithm searches for the optimal combination of the design variables. After a hull form is designed corresponding to optimized parameters.

Keywords: Medium-sized passenger ship; Gooseneck bulb; Resistance performance; Hull form design; Numerical series test

1. Introduction

Interests in resistance performance of ships have been increased due to the rise in fuel price and enhanced regulations of CO_2 emissions due to global warming. In particular, the continued rise in fuel price results in worsening the financial conditions of the shipping industry a few years ago. To improve the situations, ships are operated at lower sailing speed than designed speed. However, it is required to have the fundamental countermeasure to reduce operating costs of ship. In particular, difficulties of passenger ship companies for operating short-range international routes around domestic harbors and Jeju routes are as follows: decreases in passengers and cargoes by ship due to the emergence of low-cost airlines, increases in operating costs of passenger ship due to continued rise of oil price. It is desperately needed to establish measures to reduce fuel costs of passenger ship and build ship with excellent resistance performance in the domestic shipyard.

Bulbous bow considering actual operating speed and draft has recently been highlighted as a very useful fuel saving method (Choi et al., 2014). In the case of passenger ship with small changes of draft, gooseneck bulb has been applied in Europe in order to maximize the reduction of wave-resistance.

The gooseneck bulb is mainly applied in passenger ship and motor yacht and it is sometimes applied in container ship, LNG carrier and special military watercraft. Even if studies are conducted on designing the bow hull form of passenger ship applying gooseneck bulb mainly in Europe, contents and results of studies are limitedly disclosed. Schneekluth (1987) mentioned the need for designing the bulbous bow in gooseneck bulb shape to improve the resistance performance and schematically described the changes in resistance performance. Heimann and Harries (2003), Heimann (2005), Ossanen et al. (2009) and James (2006) studied gooseneck bulb applied in passenger ship and yachts, respectively. The

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Nomenclature

A_{BT}	cross sectional area of bulb
A_{MS}	cross sectional area at mid-ship
β	regression coefficients
C_{ABT}	cross sectional area ratio
C_B	block coefficient
C_{LPR}	ratio of the length of bulb
C_P	pressure resistance coefficient
C_{RB}	rise of the bulb
C_V	bulb volume ratio
C_{ZB}	central position ratio of bulb
Fn	Froude number
L_B	length of bulb
L_{BP}	length of ship
R_{ap}^2	adjusted coefficients of determination
r_Z	length form FP to bulb top
r_L	height of bulb top.
T_{FP}	draft at FP
X	independent variables that mean bulb parameters
Y	dependent variable that mean pressure resistance coefficient of mode ship
Z_B	central height of bulb
∇_B	volume of bulb
∇_S	volume of ship under waterline

results of their studies were disclosed. Harries et al. (2006) studied container ship. For special military watercraft, some studies examined the changes in resistance performance based on changes in several bulb shapes including gooseneck bulb in particular high-speed ship with the support of US Navy (Cusanelli, 2007). In Korea, 'resistance and propulsion of ship' (Kim, 2009) published by the Society of Naval Architects of Korea described the brief characteristics of gooseneck bulb. There are some papers describing cases applying gooseneck bulb when designing the bow in passenger ship (Jang et al., 2003; Lee et al., 2012; Park and Choi, 2012), but not many papers describe gooseneck bulb. In addition, there are some case studies applying gooseneck bulb in LPG carriers (Park et al., 2005). According to previous studies, cases of gooseneck bulb optimized in particular ship were published. Thus, the effects of reduced resistance were identified in terms of residual resistance or wave resistance, but the causes of improving resistance performance were not analyzed. In addition, since a commercial program such as SHIPFLOW was used as the numerical simulation program in these studies, they did not consider the phenomenon of breaking waves which was one of effects caused by the bulb. Thus, the results of these studies cannot be used as the reference to design a hull form applying gooseneck bulb. To improve it, studies are performed to seek measures to apply gooseneck bulb in medium-sized passenger ship (Yu et al., 2010, 2014; Yu, 2015).

It is required to identify the relationships between parameters of gooseneck bulb (length, width, height, side shape, etc) and resistance performance in order to design a hull form with excellent resistance performance by applying gooseneck bulb. Regression analysis could be used to describe the relationships between parameters and resistance performance. Regression analysis has been used in various areas of the ship for a long time. Hong et al. (1988) selected the hull variables affecting the wave-making resistance and form resistance and then derives the regression equation, and proposed the hull improvement method. Min (1990) compared several regression equations in order to estimate the resistance characteristics of the low-speed full ship.

Along with the resistance estimation of the vessel, the hull optimization technique is being utilized in order to improve the resistance performance. Tahara et al. (1998) performed the optimization of the hull that calculating the flow around the hull as the viscous flow and with the use of SQP(Sequential quadratic programming) as the optimized algorithm. Choi et al. (2006) used SQP as the optimized algorithm, but assuming the flow around the hull as the potential flow and performed the research for the development of the optimized hull. Heimann (2005) designed the bulb hull with the reduced linear wave resistance components, by using FRIENDSHIP module and SHIPFLOW.

The results of a number of studies have been conducted in Europe, and those are shown that applying the gooseneck bulb to the passenger ships, the reduction of fuel costs through improved resistance performance are possible. However, in previous studies, only the results of bulb design have been published that are optimized for a particular ship. Therefore, there is insufficient to function as a reference for developing any vessels applied gooseneck bulb. In order to apply the gooseneck bulb to design the ship with a good resistance performance, it is a need prior to all others that is the understanding of the relationship between the resistance performance and the parameters of gooseneck bulb (for example, bulb length, breath, height and section shape, etc.). The purpose of this study is to establish the measures applying gooseneck bulb more effectively in passenger ship plying around domestic harbors, and to examine the possibility to be applied in passenger ship.

The numerical series tests were carried out to derive regression equations for estimating resistance which could be applied in domestic passenger ship. The hull form data regarding 5 kinds of block coefficients (C_B) and bulb parameters is created and their numerical calculation is performed for 4 kinds of operating speeds. The numerical simulations about fluidity around the hull were carried out with the computing program complied by using a modified marker-density method (Jeong, 2013). The regression equations were derived to estimate the resistance characteristics of gooseneck bulb through statistical analysis. For the hull form with arbitrary block coefficients and operating speeds, the regression equations were derived in each block coefficient to estimate the resistance performance by interpolating the regression coefficients. The gooseneck bulb hull form with excellent resistance performance was designed by optimizing the reference hull on the basis of the regression equations,