Initial Concept Design for a Self-Icebreaking Container Vessel in Ice-Covered Water Region

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ABSTRACT

In this paper, six various types of Self-Icebreaking Container Vessels were designed by CSSRC (China Ship Scientific Research Center) during the initial design stage. This kind of Self-Icebreaking Container Vessels can take on some characteristics of DAV. It can navigate in ice-covered water region with forward icebreaking stern, and also navigate in ice-free water region with conventional bow shape. In the initial design stage, firstly, Computational Fluid Dynamics (CFD) method was utilized to optimize hull form. The Reynolds Averaged Navier-Stokes (RANS) equation has been utilized as optimization method together with the application of Reynolds stress turbulence model and the multi-block structured grid. After completing optimization, in accordance with CFD calculation results, selecting the optimal Self-Icebreaking Container Vessel line based on suitable open water resistance compared to the Original Ship, then, Discrete Element Model (DEM) method was utilized to calculate force of level ice. Objective of this stage mainly observes influencing factors of ice force for the optimal Self-Icebreaking Container Vessel with different thickness of level ice and different ship speed. The computational result indicates that CFD-based method of the optimal Self-Icebreaking Container Vessel can fulfill requirement in open water. At the same time, DEM method also can obtain the corresponding influencing factors of ice force in ice-covered water region.

KEY WORDS: Conceptual design; Self-Icebreaking Container Vessel; CFD; DEM; Optimization.

INTRODUCTION

Technology requirements of polar navigation for Self-Icebreaking transportation hull form are higher than general ice-going vessels, including Container Vessel, Oil Tanker, Bulk Carrier etc. Thus, Chinese Government decided to development this kind of transportation hull form which can voyage polar district at summer or autumn in thin one year ice with old ice inclusions. Respective requirements of the project must be fulfilled navigation in polar district water with ice class rule PC6/PC7 or can be suitable for Finland and Swedish Ice Class Rules (FSICR) IA SUPER and IA in ice-covered water region. Then, China Ship Scientific Research Center (CSSRC) together with China Ship Design & Research Center Co., Ltd (CSDRC) is carrying out research and assessment of icebreaking transportation hull form.

Development goals of the middle long term were made by both CSSRC and CSDRC departments. First of all, initial conceptual design was made for hull lines of Container Vessel, Oil Tanker and Bulk Carrier in accordance with main variation and evolution tendency of icebreaking hull form in the world, especially Double Acting Vessel (DAV) development direction. Secondly, based on financial supporting of Chinese government to develop a series of model ice techniques, incorporating technology of model ice making, powering performance prediction technology, model test technology and corresponding ice loading technology acted on ships and offshore structures at the towing ice tank. Thirdly, the optimization of hull body lines will be verified and validated in ice model test to obtain appropriate hull form, which will be good for still water performance in open water, and also simultaneously satisfy icebreaking performance in polar district and ice-covered water region. At last, venture evaluation and construction were performed simultaneously in detailed design stage for the optimal hull form in order to achieve an appreciable gain in future.

In this paper, initial concept of icebreaking Container Vessel was designed to meet navigation of polar district and ice-covered water region as mentioned above. The design involved many aspects, which contain analysis of calm water performance, ice breaking performance, calculation of stability, evaluation of main engine power and general arrangement. At present, six schemes of hull lines for Self-Icebreaking Container Vessel were designed based on the Original Ship, which has been designed by CSSRC in 2012 in initial design stage, and the Original Ship model test (2050TEU) has already been performed in calm water at the deep water towing tank with main dimensions of 474m × 14m × 7m in CSSRC at April 19th, 2013. According to schedule, the optimal hull body line was respectively carried out model test of calm water and model test of self-propulsion simulation in ice based on calculation results of Computational Fluid Dynamics (CFD) and Discrete Element Model (DEM) from June to September in 2014. The main principal and hull coefficients of original ship and corresponding six hull form schemes designed were listed Tab.1.