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Comparative study on the resistance performance of an icebreaking cargo vessel according to the variation of waterline angles in pack ice conditions

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ABSTRACT: *The resistance performance of an icebreaking cargo vessel according to the variation of waterline angles is investigated numerically and experimentally. A recently developed Finite Element (FE) model is used in our analysis. A resistance test with synthetic ice is performed in the towing tank at Pusan National University (PNU) to compare and validate the computed results. We demonstrate good agreement between the experimental and numerical results. Ship-ice interaction loads are numerically calculated based on the Fluid Structure Interaction (FSI) method in the commercial FE package LS-DYNA. Test results from model testing with synthetic ice at the PNU towing tank are used to compare and validate the numerical simulations. For each waterline angle, numerical and experimental comparisons were made for three concentrations (90%, 80%, and 60%) of pack ice. Ice was modeled as a rigid body, but the ice density was the same as that used in the experiments. A comparative study according to the variation of stem angles is expected to be conducted in the near future.*

KEY WORDS: Waterline angle; Fluid structure interaction; Pack ice condition; Synthetic ice.

INTRODUCTION

After the global recession in 2008, oil prices increased even more rapidly as shown in Fig. 1. The price of oil is likely to continue to increase over time. Global climate change, especially due to global warming, will make the Arctic more attractive for oil and gas activities. The shrinking Arctic ice cover will soon make resources more accessible (Kwok et al., 2011). Shipping lanes in Arctic waters are opening up, thereby reducing costs and the risks of access. In the near future, a large quantity of the oil and natural gas produced in the Arctic regions of Russia and North America will be supplied to the Northeast Asian region due to the defletion of oil and gas.

According to the Association for the Study of Peak Oil and Gas, it is expected to be decrease after the peak of production in 2007 if there are no new energy sources.

Many routes in the Arctic are likely to be developed because of not only searching the sources of oil and gas but also the development of the short route for the energy saving.

Regarding the resistance performance of a ship in level ice, Valanto (2001) presented an overview of ship-level ice interaction. They divided the interaction process into several phases: breaking, rotating, sliding, and clearing.

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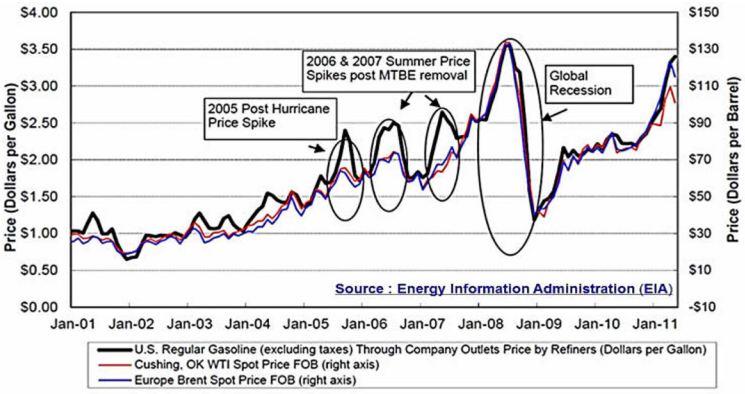

Fig. 1 Comparison of the monthly national average price of gasoline and the price of WTI & Brent crude, 2001-2011.

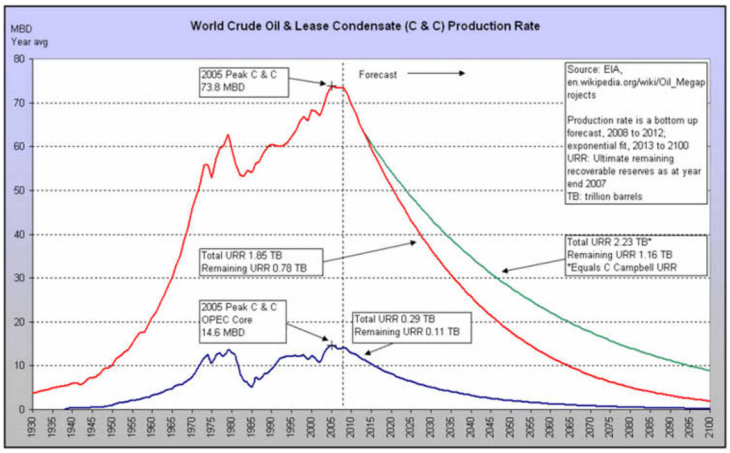

Fig. 2 Prection of oil production for 2100 based on the data from 1930 to 2100 (daniel yergin of the consultancy CERA).

Recently, Wang and Derradji (2010) simulated an icebreaker breaking through level ice using LS-DYNA. They used user-defined ice failure criteria based on the flexural strength. Their results showed reasonable agreement with full-scale measurement. Compared to the level ice case, the analysis of pack ice conditions is not complex in terms of physics if flexural failure is ignored. Combining structural and flow analysis enables us to assess ships and structures in ice interaction more correctly. Using Fluid-Structure Interaction (FSI) methods, most practical ice interaction problems can be solved; examples include a drill ship in pack ice conditions, lifeboat performance in ice-covered water, and ice management strategies. The LS-DYNA software used in our analysis has been successfully applied to this class of structural and flow analysis problems (Wang and Derradji, 2010; 2011; Gagnon and Wang, 2012).

Fig. 3 Typical example of ice-going cargo vessel in broken ice conditions (Bill Robertson).