

Investigation of Anti-freezing Mechanisms of an Air Bubbling System for Ballast Tanks Using Variable Specific Heat Coefficient

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ABSTRACT

Market demand for vessels operating in cold region has increased recently because of rapid rise in price of oil and gas. These vessels have the water ballast tanks designed to operate under the harsh conditions, particularly in sub-freezing temperatures. An air bubbling system is one of the anti-freezing equipment which is widely used. Numerical simulations are performed to investigate the effectiveness of the variable specific heat coefficient and the validity of air bubbling systems. Even though the ambient air temperature and sea water are -20°C and around 0°C respectively, an air bubbling system effectively protects ballast water from freezing by the circulation of ballast water due to the air bubbles trajectories without any heating system.

KEY WORDS: Cold region; Water ballast tank; Air bubbling system; Latent heat; Sensible heat; Imaginary specific heat; Convection; Ice sheet;

INTRODUCTION

The balance of demand and supply for energy has been threatened by several reasons such as lasting activity of world economy, fast growing of new great consumer country like China and variability surrounding major oil fields in the Middle East. This unbalance resulted in high oil price which could not have ever been seen before. So high oil prices gave rise to the economic feasibility of the development of oil field in cold regions such as the North Sea, Sakhalin and the Arctic Sea. Besides, the marine transportations in arctic route such as the Barents Sea and the Kara Sea have been increased by the economic growth of Russia. Though these arctic routes have required high development and transportation costs, the Arctic Sea route became interesting due to the aforementioned reasons, to the ship owners nowadays, and many orders of the vessels operating in cold region are predicted to meet this need in the future.

Winterization design must be applied for all of the outfitting systems in such vessels. Winterization design aims at avoiding freezing of the equipment or to deice frozen equipment within a certain period (a few hours).

These vessels have the water ballast tanks designed to operate under the harsh conditions, particularly in sub-freezing temperatures. It is realized that freezing of the ballast tank could be discovered generally around the water level along the side hull surface contacted with low temperature of ambient air. Such a freezing area can cause fragmentation of the hull because of restricting internal air flow to outside during ballasting and due to icing on ventilation pipes near the top of the ballast tank. Moreover, the side hull with ice cannot be accepted for design hull strength and hardness on seagoing condition.

Several types of anti-freezing systems including heating coil system, hot air spray system, ballast water circulation system and air bubbling system, have been used in the water ballast tanks to protect against tank freezing. However, there are no rigorous investigations of anti-freezing mechanisms resulting from using air bubbling system among those anti-freezing measures. This study proposes a variable specific heat coefficient in terms of temperature to consider latent heat to simulation of freezing mechanisms. This term is programmed in the commercial CFD (Computational Fluid Dynamics) code, FLUENT, using user defined function.

NUMERICAL METHOD AND MODELING

Governing Equations and Turbulence Modeling

The governing equations employed are in either control volume formulation for finite volume discretization or differential form for finite difference discretization. The equations for conservation of mass or continuity equation, momentum conservation and energy conservation can be written as follows to describe the transport