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LNG Boil-Off Rate Estimation for LNG Carrier by Unsteady Heat Transfer Analysis

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Introduction

LNG carrier is a special-purpose vessel to transport natural gas (NG) from the place of origin to each consuming country. For the sake of the carrying capacity increase of LNG carrier, the natural gas is conveyed as a state of liquid called LNG (Liquefied Natural Gas) during voyage, because the total volume of NG is surprisingly reduced when it is cooled down to -162^{o}C. In general, a shipping service takes about two weeks so that LNG contained within the insulation containments is subject to the severe heat invasion from external air and sea water. Thus, the interior LNG is always in danger of an unexpected explosion which may trigger the unexpected structural failure of LNG carrier at sea, resulting in tremendous loss of human, environmental and financial resources.

For this reason, the design of insulation containment that sufficiently and effectively protect LNG from the external heat invasion has been a great challenging subject for several decades in the shipbuilding industry. However, this ultimate goal could be accomplished when the boil-off rate (BOR) of LNG during voyage can be accurately estimated. The boil-off rate of LNG is defined as the relative volumetric amount of the evaporated LNG with respect to the initial total LNG volume per unit period of time. According to the world-wide regulation, BOR should not exceed 15% during all the time period of voyage.

Traditionally, BOR has been estimated by the measurement approach during voyage of LNG carriers which were already manufactured. As a result, the BOR prediction for new insulation containment at the design stage has been made usually in the comparative manner (i.e. through the bench making process). The main reason is because both the analytical and experimental methods are extremely limited owing to the complex structural/material composition of insulation containment and the highly nonlinear heat transfer mechanism composed of LNG, insulation containment, and environments. In fact, an insulation containment is manufactured with a number of composite and metallic layers in highly complex lamination pattern.

In this context, the goal of the present study is to propose a numerical method for estimating the BOR of LNG for given insulation containment subject to external temperature conditions during voyage. The heat invasion through the insulation containment is computed by unsteady heat transfer analysis and the BOR is estimated by calculating the evaporated amount of LNG.

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