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A study on minimum weight design of vertical corrugated bulkheads for chemical tankers

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Abstract

Corrugated bulkhead has been adopted for cargo tank bulkheads of commercial vessels such as bulk carriers, product oil carriers and chemical tankers. It is considered that corrugated bulkhead is a preferred structural solution, compared to the flat stiffened bulkhead, due to several advantages such as lower mass, easier maintenance and smaller corrosion problems. Many researches to find the optimum shape of corrugated bulkhead have been mostly carried out for bulk carriers. Compared to corrugated bulkheads of bulk carriers, ones of chemical tankers are more complicated since they are composed of transverse and longitudinal bulkheads, and they are made of higher priced materials. The purpose of this study is the development of minimum weight design method for corrugated bulkhead of chemical tankers. Evolution strategy is applied as an optimization technique. It has been verified from many researches that evolution strategy searches global optimum point prominently by using multi-individual searching technique. Multi-individual searching methods need excessive time if they connect to 3-D finite element model for repetitive structural analyses. In order to resolve this issue, 2-D beam element connected to deck and lower stool is substituted for a corrugated structure in this study. To verify the reliability of the structural responses by idealized 2-D beam model, they have been compared with ones by 3-D finite element model. In this study, optimum design for corrugated bulkhead of 30 K chemical tanker has been carried out, and the results by developed optimum design program have been compared with design data of existing ship. It is found out that optimum design is about 9% lighter than one of existing ship.

Keywords: Corrugated bulkheads; Chemical tankers; Minimum weight design; Generalized slope deflection method; Evolution strategy

1. Introduction

Corrugated bulkhead is used as the bulkhead of cargo hold compartment of the some kinds of vessels for having easier maintenance, easier loading and unloading and more flexible shape in shrinkage and expansion by thermal load compared to the flat stiffened bulkhead. Corrugated bulkheads can be commonly seen in bulk carriers, product oil carriers and chemical tankers.

A lot of researches on optimal design of corrugated bulkhead have been mostly conducted with bulk carriers. Yim et al. (1987), Yum (1990) and Lee and Roh (2001) performed the researches focusing on optimization method itself and Shin and Nam (2003) performed optimal design of corrugated bulkhead of bulk carrier considering both optimization method and workability to make it applicable to the field work.

As a research except bulk carriers, Shin and Ko (2009) developed the minimum weight design program for product oil carriers including longitudinal corrugated bulkheads.

Chemical tanker is composed of the most complex cargo hold among vessels adopting corrugated bulkheads. And austenitic stainless steel which is corrosion resistant and has high weldability and ductility is appropriate as the material of

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chemical tanker. Lightweight of tank can be reduced by using duplex stainless steel, so cargo loading capacity can be increased (Thomas, 2004). If optimal design could be successfully carried out for chemical tanker made of higher priced materials, a significant economic effect might be expected.

The purpose of this study is the development of minimum weight design method for corrugated bulkheads of the chemical tankers which are composed of vertical and horizontal ones. Andric et al. (2010) show that horizontal corrugated bulkhead is more economic than vertical one through their study. However, when it comes to 30 K class actual ship which has been built by domestic shipbuilder, the portion of vertical bulkhead reaches 540 ton and the portion of horizontal bulkhead 220 ton. In this study, therefore, optimum designs have been carried out for the vertical corrugated bulkhead that accounts for more than 70% of the weight of bulkhead. For reference, both bulk carrier and product oil carrier adopt vertical type corrugated bulkhead 100%.

In this study, evolution strategy is applied as an optimization technique. It has been verified from many researches that evolution strategy searches global optimum point prominently by using multi-individual searching technique. Multi-individual searching methods need excessive time if they connect to 3-D finite element model for repetitive structural analyses. In order to resolve this issue, 2-D beam element connected to deck and lower stool is substituted for a corrugated structure. To verify the reliability of the structural responses by idealized 2-D beam model, they have been compared with ones by 3-D finite element model. As a real application, optimum design for the corrugated bulkhead of 30 K chemical tanker has been carried out, and the results by developed optimum design program have been compared with design data of existing ship.

2. Corrugated bulkhead of chemical tanker

Chemical tanker shall have many cargo hold compartments to contain various chemicals and as the structure to accommodate such needs, corrugated bulkheads are installed as shown in Fig. 1 in consideration of safety, cargo capacity, cleaning efficiency, etc. And because of the importance of cleanliness of cargo hold, the arrangement of strength member inside the cargo hold compartment is often not allowed and thus deck longitudinals and deck transverses are installed on the upper side of deck (Sim et al., 2013).

There are connection structures between corrugated bulkheads and the section of corrugated bulkhead shall be designed

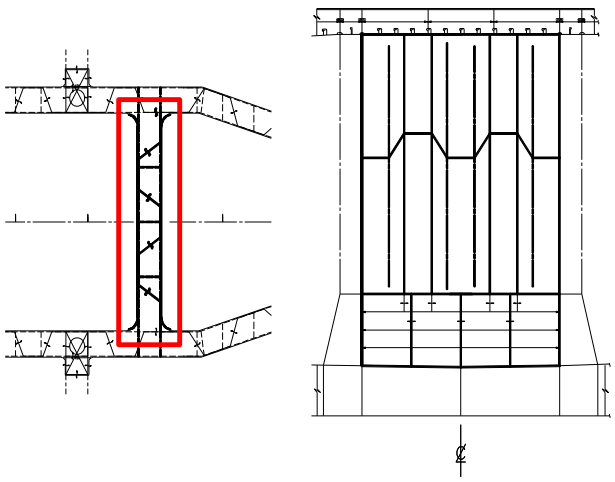

Fig. 2. Definition of I type bulkhead.

in consideration of the characteristics of the cargo in each compartment. The material of the structural member, temperature and density of the cargo are the important design factors as well.

As there are many compartments in a chemical tanker and many types of corrugated bulkhead with different characteristics, in this study, corrugated bulkheads are categorized into several typical types and the constraint conditions were determined for optimization. By analyzing the existing ships, corrugated bulkheads are categorized into vertical corrugated bulkhead and horizontal one and vertical type is again classified into 3 types which include I type installed laterally alone, T type which crosses in longitudinal and lateral direction and general type which have multi zones, which are indicated in Figs. 2–4.

3. Optimization method

Optimization method used in this study is evolution strategy which was first introduced by Rechenberg (1973) and further developed and systemized by Schwefel (1981), which is similar with genetic algorithm that is based on the law of survival of the fittest and natural selection.

Evolution strategy is classified into plus-strategy of $(\mu + \lambda)$ form and comma-strategy of (μ, λ) form. Difference between two strategies is whether the parent individuals participate in selection stage. In plus-strategy, both parent and child individuals participate in selection while child individuals alone participate in comma-strategy.

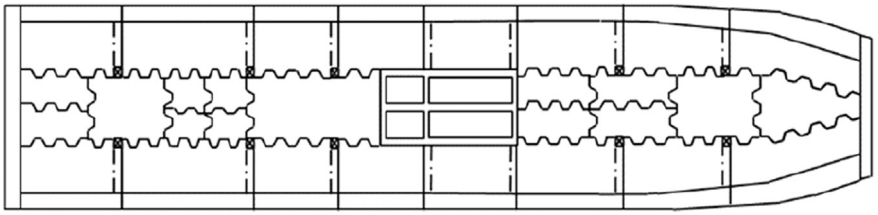

Fig. 1. Compartments of a chemical tanker.

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