IJNAOE
©SNAK, 2015

Int. J. Nav. Archit. Ocean Eng. (2015) 7:270~287
http://dx.doi.org/10.1515/ijnaoe-2015-0019
pISSN: 2092-6782, eISSN: 2092-6790

Optimal dimension design of a hatch cover for lightening a bulk carrier

Tae-Sub Um[1] and Myung-Il Roh[2]

[1]*Maritime Research Institute, Hyundai Heavy Industries Co., Ltd., Ulsan, Republic of Korea*
[2]*Department of Naval Architecture and Ocean Engineering, and*
Research Institute of Marine System Engineering, Seoul National University, Seoul, Korea

ABSTRACT: *According to the increase of the operating cost and material cost of a ship due to the change of international oil price, a demand for the lightening of the ship weight is being made from various parties such as shipping companies, ship owners, and shipyards. To satisfy such demand, many studies for a light ship are being made. As one of them, an optimal design method of an existing hull structure, that is, a method for lightening the ship weight based on the optimization technique was proposed in this study. For this, we selected a hatch cover of a bulk carrier as an optimization target and formulated an optimization problem in order to determine optimal principal dimensions of the hatch cover for lightening the bulk carrier. Some dimensions representing the shape of the hatch cover were selected as design variables and some design considerations related to the maximum stress, maximum deflection, and geometry of the hatch cover were selected as constraints. In addition, the minimization of the weight of the hatch cover was selected as an objective function. To solve this optimization problem, we developed an optimization program based on the Sequential Quadratic Programming (SQP) using C++ programming language. To evaluate the applicability of the developed program, it was applied to a problem for finding optimal principal dimensions of the hatch cover of a deadweight 180,000 ton bulk carrier. The result shows that the developed program can decrease the hatch cover's weight by about 8.5%. Thus, this study will be able to contribute to make energy saving and environment-friendly ship in shipyard.*

KEY WORDS: Hatch cover; Hull structure; Lightening; Optimization; Bulk carrier; Environment-friendly ship.

INTRODUTION

Background of this study

Recently, according to the increase of the operating cost and material cost of a ship due to the change of international oil price rise, a demand for lightening the ship weight is being made from various parties such as shipping companies, ship owners, and shipyards. For example, it is known that in case of ship over 40% of total operating cost is caused by fuel cost (Journee and Meijers, 1980). To satisfy such demand, many studies for a light ship are being made like other vehicle industries such as automotive industry (Oujebbour et al., 2014). Some of them include the optimal design of an existing hull structure, the proposal of a hull structure having new concept, the application of composite materials such as Fiber Reinforced Plastic (FRP) to a hull

Corresponding author: *Myung-Il Roh*, e-mail: *miroh@snu.ac.kr*

structure, and so on. Among them, the former studies are producing actual and effective results due to their high possibilities of weight reduction. Thus, an optimal design method of an existing hull structure, that is, a method for lightening the ship weight based on the optimization technique was proposed in this study.

First, a target for optimization, that is, ship type and hull structure to be applied was selected in this study by considering the followings and requirements of shipyards. Even though the Baltic Dry Index (BDI) value had a sudden fallen after America's financial crisis in 2009, but it has been rising recently. It is expected that such a rise of BDI can lead to an increase in demand of a bulk carrier (ship for carrying dry cargo, hereafter referred to as B/C) and an increase in order quantity from the ship owners.

The hatch cover which covers cargo tanks of the B/C is very important part. In the B/C, the cost of hatch cover equipment is accounting for 5~8% of shipbuilding cost (Ha, 2011), and various types of hatch covers are being applied according to the ship type. That is why as well as domestic companies, foreign companies in Europe and Japan also have been competing in the market. To survive the fierce competition in the lightening design of the hatch cover, many efforts have being made in technology development.

The optimization technique is based on iterative design and review to find an optimum with some design considerations (called constraints) by minimizing or maximizing a certain criteria (called objective function). As the objective function and constraints become diverse and subdivided, the optimization technique is getting more and more difficult to be performed by hand; it requires a lot of time. Thus, the importance of automation has increased and a variety of optimization techniques have being studied. With this, an optimization problem which is comprised of design variables, constraints, and objective function(s) should be well formulated to yield a good optimum.

In this study, with two requirements of the structural safety and weight reduction, a hatch cover of a bulk carrier was selected as an optimization target, and the optimization technique was applied to determine optimal principal dimensions of the hatch cover. For this, an optimization problem to determine optimal principal dimensions of the hatch cover was mathematically formulated. Some dimensions representing the shape of the hatch cover were selected as design variables and some design considerations related to the maximum stress, maximum deflection, critical buckling stress, and geometry of the hatch cover were selected as constraints. In addition, the minimization of the weight of the hatch cover was selected as an objective function. To solve this optimization problem, an optimization program based on the SQP was developed with C++ programming language. To evaluate the applicability of the developed program, it was applied to a problem for finding optimal principal dimensions of a deadweight 180,000 *ton* bulk carrier.

Related works

Many studies related to an optimal design method of a hull structure such as longitudinal and transverse strength members have been made since 1960s. Moe and Lund (1968) proposed an optimal design method for longitudinal strength members of a tanker having minimum cost and weight according class rule and Moe (1969) studied an optimal design method for statically indeterminate frames based on nonlinear programming. Na et al. (1985) proposed an optimal design method for transverse strength members having minimum weight based on finite element analysis. Jang and Na (1996a; 1996b; 2000) developed an optimal structural design system for double hull tankers. Their research include an optimal design method for longitudinal strength members of a tanker having minimum weight according the DNV class rule, an optimal design method for transverse strength members having minimum weight based on the generalized slope deflection method, and an optimal design method for whole hull structure having minimum weight by considering tank arrangement. Yum (1990) proposed an optimal design method for a corrugated bulkhead of a B/C having minimum weight based on the generalized slope deflection method. Lee et al. (2002) studied an optimization technique for optimal structural design of midship section of a tanker and a corrugated bulkhead of a B/C based on the hybrid optimization algorithm. Jung (2008) studied on minimum weight design of transverse strength members of a B/C based on finite element analysis (ANSYS). Lim (2009) proposed an optimal design method for panel blocs of a double hull tanker having minimum weight based on the genetic algorithm and finite element analysis (NASTRAN) by considering structural safety and productivity.

Some studies related to design of a hatch cover have been also made. Han et al. (2002) studied on a method for lightening a hatch cover of a large-size container ship based on finite element analysis (PATRAN and NASTRAN). They proposed an improved design for the hatch cover where buckling stiffeners are removed under less stress and the thickness of the top plate of the hatch cover are changed, and however they did not use any optimization technique to do that. Lee et al. (2010) studied the