Sensitivity analysis and optimization of cylindrical pressure hull based on multi-island genetic algorithm

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ABSTRACT
Unmanned underwater vehicles are a kind of important tool in the exploration and exploitation of the ocean today, and pressure hull structures are the most important component of unmanned underwater vehicles. On the premise of meeting the performance requirements, reducing the mass of the pressure hull structure can lessen manufacturing costs and diminish power consumption, which is significant for improving the performance of unmanned underwater vehicles. Therefore, this paper uses numerical simulation to optimize the design of a pressure hull structure with hemispherical ends and a cylindrical middle.

In this paper, the finite element analysis software Ansys is applied to implement the parametric modeling and simulation of the pressure hull structure based on the APDL language, then an optimization process is established to find the optimum parameters by invoking Ansys through ISIGHT; Read the parameters from the input text, write the parameters into the APDL, call ANSYS to calculate them, write a program to call the total weight of the model, the first-order buckling load, and the damage factor in the output file for calculation. The optimization design uses the minimum buoyancy factor as the objective function, the thickness of the hemispherical ends, the thickness of the cylindrical middle, the thickness of the transverse bulkheads, the distance of the spaced frames and the size of the frames as design variables, and the maximum stress failure criterion and the flexural strength factor as constraints. Subsequently, the multi-island genetic algorithm MIGA is used to optimize the structure of the pressure hull structure, reducing the overall mass of the structure while meeting the structural strength, stiffness, and stability requirements. Furthermore, a parametric sensitivity analysis of this typical pressure hull structure is carried out to investigate the influence of design parameters on the yield and buckling strength such as the size of the transverse bulkhead and frame, and the thickness of pressure hull structures. The optimization method proposed in this paper can be used to optimize the parameters of similar pressure hull structures and provide ideas for the lightweight design of other UUV structures.

KEY WORDS: Optimization, the pressure hull,

INTRODUCTION

Unmanned underwater vehicles are a kind of important tool in the exploration and exploitation of the ocean today, and pressure hull structures are the most important component of unmanned underwater vehicles. The cylindrical shell structure is one of the most important forms of deep-sea pressure-resistant structures as one of the most important deep-sea pressure-resistant structural forms (Smith C S, 1991), and it is the basic guarantee of the safety of deep-sea equipment. The low weight-to-displacement ratio is its core technical index (Craven R, Graham D, Dalzel-Job J, 2016). On the premise of meeting the performance requirements, reducing the mass of the pressure hull structure can lessen manufacturing costs and diminish power consumption, which is significant for improving the performance of unmanned underwater vehicles.

There has been a lot of research into the optimization of pressure hull structures. Three different lay-ups were focused to obtain the optimum solution and calculate the relative improvement ratio in the buoyancy factor (Fathallah Elsayed, Qi Hui, Tong Lili, Helal Mahmoud, 2015). Design optimization of the composite submerged cylindrical pressure hull as shown in Figure 1 is carried out using a genetic algorithm and finite element analysis in ANSYS Workbench (Imran Muhammad, Shi Dongyan, Tong Lili, Waqas Hafiz Muhammad, 2019). The number of layers and orientation angles are optimized for five types of layups using three unidirectional composite materials. The grid sandwich structure is applied to the pressure shell of the AUV head as shown in Figure 2 (Li Ning, Zhang Dequan, Liu Haitao, Li Tiejun, 2021). They established an optimal mathematical model and the optimization model is solved. It is concluded that the mass of the optimized pressure shell is 38.26% lower than the traditional solid model. Moreover, Muhammad Imran, Dongyan Shi, Lili Tong, Hafiz Muhammad Waqas, and Muqeeb Uddin describe a design optimization study of the composite egg-shaped submersible pressure hull as shown in Figure 3 employing optimization (2021).

ISIGHT is an integrated platform for multidisciplinary simulations. Script files, which are connected to the software interface, enable the software to operate automatically during optimization. This significantly reduces the handling time and effectively improves work efficiency and accuracy. Therefore, In the design of structural weight reduction, ISIG improved by 0.8%. Yang Fengfu, Tian Haiying, Yan Changxiang, Wu Congjun, and Mu Deqiang (2019) used ISIGHT to optimize the lens structure. The design variable is the lens wall thickness and the constraint

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