Multi-objective Optimization of Submarine Hoses Attached to a CALM Buoy based on Surrogate Mode

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ABSTRACT

Catenary anchor leg mooring (CALM) and marine hoses of offshore petroleum transfer are utilized for an increasing worldwide energy demands and in vast expanse of sea areas. The submarine hose is part and parcel of the connection between the CALM buoy and the subsea template. Floats are frequently attached along the submarine hose to reduce the tension and bending moment into the design, further to extend the service life of hoses. In order to optimize the float parameters, a numerical model of CALM buoy system and Chinese-lantern configuration hoses are established by ANSYS AQWA and OrcaFlex. Meanwhile, combinations of sample points are selected in the design domain by means of the orthogonal experimental design. Then, a surrogate model based on radial basis function is constructed to predict the effective tension and bending moment of the submarine hose with the correlation coefficient 0.9978 and 0.9953 compared to the finite element model. Besides, this study performed sensitivity analysis to acquire the key factor that affects the hydrodynamic performance of the hose. Finally, on the basis of the established data-driven model, the NSGA-II algorithm is applied to optimize various design parameters of the float for minimizing the maximum effective tension and maximum bending moment of the submarine hose, generating Pareto optimal solutions. The hydrodynamic performance is verified by the finite element model to achieve the best in the optimized float designs. This research method provides a float design reference for the Chinese-lantern configuration hoses to upon the fatigue life.

KEY WORDS: Catenary anchor leg mooring (CALM) buoy; Chinese-Lantern configuration hose; float; optimization; sensitivity; surrogate model; NSGA-II algorithm.

INTRODUCTION

With the development of the offshore oil and gas industry, floating production systems are receiving more and more attention by various researchers due to their multiple advantages, which can meet the production conditions not only in deep water conditions, but also in offshore areas where shallow water production is also required, in which the catenary anchor mooring system (CALM) is most widely used. There are many factors affecting the CALM system, and the submarine hoses are subjected to the very complex marine environment and underwater loads, so the configuration design, loads and dynamic response of the hoses are the focus of research in the field of CALM. Therefore, the optimization of the submarine hose is an important problem in CALM engineering. Aiming at the problem of submarine hose and CALM, the experimental research and numerical calculation are carried out (O’Donoghue, 1987; Huang et al., 1989; Richbourg et al., 2006; OCIMF, 2009; Kang et al., 2014; Wang et al., 2014; Gu, 2016; Tonatto et al., 2018; Amaechi et al., 2019; Hasanvand et al., 2020; Amaechi et al., 2021; Amaechi et al., 2021; Edalat et al., 2021). A large number of environment interaction and sensitivity analysis have been obtained through previous studies. The main disadvantage of these hydrodynamic analysis methods is that it is not accurate provide a quantitative solution for hydrodynamic optimization, but can only provide qualitative directions for improvement. Therefore, the surrogate mode is proposed for solving various problems in engineering optimization field. When it is difficult to express the objective function with intuitive function expressions in optimization design, the surrogate model is usually an approximate mathematical model that can replace the more complex and time-consuming numerical analysis in the optimization design. The use of surrogate models can greatly improve the efficiency of optimization design. For example, response surface methodology (RSM), kriging method, radial basis function (RBF), neural network (NN) and support vector machine (SVM) have been used to optimize the marine structures (De Pina et al., 2013; Yang et al., 2011; Da Silva et al., 2013; Deng et al., 2016; Chen et al., 2016; Pillai et al., 2018; Zhang et al., 2018; Wu et al., 2019; Yang et al., 2018; Li et al., 2019; Lin et al., 2019). In this paper, according to the hydrodynamic influence factors of submarine hose, the surrogate mode of radial basis function optimized by genetic algorithm is used to establish the optimization model, which is introducing the NSGA-II algorithm to optimize various design parameters of the float for minimizing the maximum effective tension and maximum bending moment of the submarine hose, generating Pareto optimal solutions. The main purpose of this paper is to optimize the float design for the Chinese-lantern configuration hoses attached to the CALM Buoy.