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Multidisciplinary Design Optimization of Sound Radiation from Underwater Double Cylindrical Shell Structure

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Abstract

Underwater double cylindrical shell structures have been found a wide application in many engineering fields, such as the element of submarines, oil platforms, etc. However, the sound radiation of the underwater double cylindrical shell structures due to interior sound source is difficult to predict precisely, and is always underestimated in the noise control. Underwater acoustic radiation analysis mainly yields to the coupling of structural vibration analysis and acoustic analysis. For example, a weak coupling relay analysis is usually performed by combining ANSYS-based structural vibration analysis and SYSNOISE-based acoustic analysis, and a strong coupling analysis for vibration and acoustic is normally based on VAONE, which is an integrated analysis tool. ABAQUS is another integrated analysis tool for structural vibration/acoustic analysis, which is used in this paper.

In practical engineering, the design of sound radiation from underwater double cylindrical shell structure is a complex issue involved multidisciplinary knowledge (structure vibration, fluid resistance, acoustic radiation and so on), experiences and coupling in multidiscipline. As the inherent complexity, the traditional design methods can't get the optimal solutions and satisfy the performance requirements, and the more finite element analysis lead to time consuming and too long design cycle. In this paper, multidisciplinary design optimization (MDO) is employed into solving the problems of sound radiation of underwater shell structure. Therefore, considering the minimization of the mass of the double cylindrical shell structure as the objective, the structural sound radiation is the only performance constraint related to the design of thicknesses of inner and outer shells.

The sound pressure level (SPL) values at a point of interest of all centred frequency of 1/3 oct frequency band within 300Hz are calculated on ABAQUS, and the average sound pressure level (APL) is used to estimate sound radiation of the structure. In order to construct the relationship between the shell thicknesses and APL, the surrogate modelling approach is employed to approximate the formulation of APL. Sampling points are selected by the Latin Hypercube Sampling method. All variables are normalized to reduce numerical errors. Three types of surrogate models, Polynomial Response Surface (PRS), Kriging, and Radial Basis Neural Network (RBNN), are considered with different parameters. The root mean square error values of the surrogates are compared to get the best approximation for each surrogate type, which are, respectively, the 3rd order polynomial for PRS, the zero order polynomial trend model with Gaussian correlation function for Kriging approximation, the spread constant of 0.2 for RBNN. The Matlab optimization toolbox is then utilized for the solutions of the optimization problems. The results show that the optimal results yield with Kriging and RBNN approximations, whose results are very close to each other. It implies that the MDO of sound radiation from underwater structures is valid and efficient.