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Research on Multi-physics Field Analysis based on MDO Model of Nuclear Power Valve

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Abstract. In view of the demands in multidisciplinary design optimization (MDO) of nuclear power valve products, the MDO model for valves is established. And for constructing the characteristics evaluation system of nuclear power valves, multi-physics analysis are completed on a typical nuclear power valve based on finite element analysis (FEA). On this basis, a rapid design platform is constructed by combining the MDO model with the multi-characteristic optimization requirement, which integrates parametric design, multi-characteristic simulation, and multidisciplinary design optimization of nuclear power valves together. of nuclear power valves.

Keywords: multi-physics analysis; multidisciplinary design; nuclear power valve.

1 Introduction

In the numerical calculation and analysis of nuclear power valve design, valve body is the main stressed components, which often embody in the irregular and relatively complex geometry, the complex work environment, and the impact damage of valve cavity under the working medium in different flow velocity, temperature, and chemical properties, hence, the analysis work of nuclear power valve is very complex[1-3]. In conventional nuclear power valve design, CAE experts in different fields are indispensable to participate in the multi-physics field analysis. In fact, the analysis contents and evaluation methods for similar nuclear power valve products are basically same, then setting up the analysis system for a certain nuclear power valve also has guiding significance to the similar value products[4]. At the same time, the establishment of the analysis system for nuclear power valve provides the navigation process for the MDO integrated system, and the analysis process can be converted to the analysis templates that can be used in the process of analysis reuse[5].

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2 Establishment of MDO model for nuclear power valves

In order to comprehensively analyze the specific impact of the nuclear power valve under various influence factors, multi-physics field analysis of the whole valve, including structural static analysis, thermal-mechanical coupling analysis, flow field analysis, Seismic analysis, can be completed to predict the valve performance under different work conditions. Fig.1 illustrates the MDO model for nuclear power valves. MDO in valve design in this paper is divided into four parts: mechanical analysis, fluid mechanics analysis, thermal-mechanical coupled analysis and seismic analysis, which are totally based on the boundary and constrain condition of the actual working conditions so as to conform to the engineering practice. And the mixed model of simulation and optimization which contains structural features and boundary conditions is also founded.

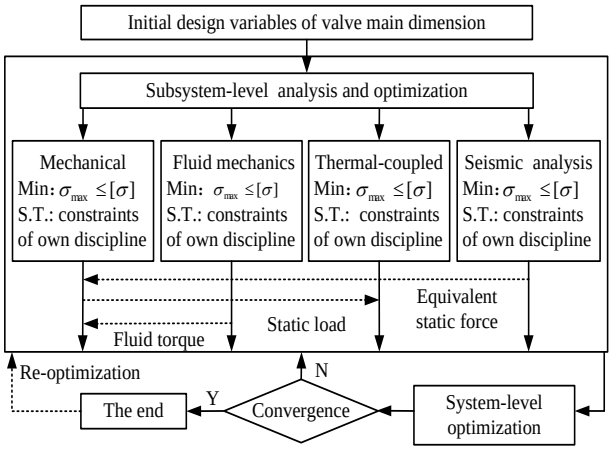

Fig.1. MDO model for valves

3 Multi-physics field analysis of nuclear power valve

Because the valve structure is complicated, conventional analytical method can only calculate the mean stress of the various parts through the empirical formula or a rough formula, so it can not meet the actual needs of engineering. Hence, the finite element analysis has been used for the analysis by ANSYS, in which the coupling analyses under working condition are completed. Due to the structure design of gate valve is the most representative, so the supercritical electric gate valve (DN230-CL2680) is selected as an example to study.

In this paper, the thermal-mechanical coupling analysis is introduced in details, and the structural static analysis, flow field analysis, Seismic analysis and sealing analysis of the valve will not be discussed here. There are kinds of thermal-structure coupling analysis in ANSYS, sequential coupling method and direct coupling method. The sequential coupling method is adopted in this paper, the principle of which is to take

the node temperature obtained by thermal analysis as body force load that is applied in the stress analysis to achieve coupling process, and then the thermal analysis results are loaded directly into the stress analysis through thermal-stress conversion elements, and the thermal analysis can be directly converted to stress analysis in ANSYS.

From the temperature vector diagram of the valve body after starting 1 min, it can be known that the regional isotherm basic parallel to the valve wall, which indicates that there are mainly radial temperature difference in each region. Here a contrastive analysis is completed at the cutting-edge point A and the point B near inner valve cavity. The curves of temperature change over time at point A and point B are shown diagrammatically in Fig.2. In the process of starting, the equivalent heat transfer between attachment area near point A and high temperature steam, so the temperature rise is faster at point A within the first 100 seconds, the temperature reached 375 ℃at the 124th second; Due to the material properties of heat retardance, temperature rising rate is relatively slower at point B, the temperature change becomes placid after 410 s. As shown in Fig.3, it is the stress changing curve of von Mises σ change over time at point A. It can be seen from the diagram that the total stress (the sum of thermal stress and pressure of the steam) reaches the peak value of 264 MPa around 126s, this process lasts only about 80 seconds.

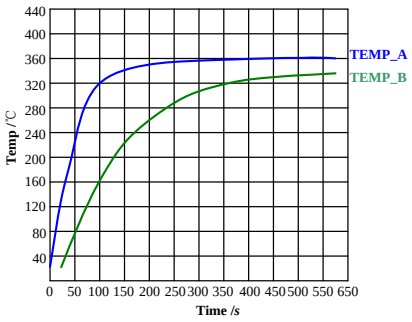

Fig.2. A and B temperature curve

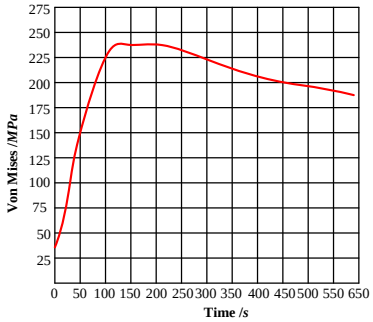

Fig.3. Stress variation curve of point A

4 Implementation of MDO System

Directed by the frame shown in Fig.1 and based on the methods of multi-physics analysis above, the MDO integrated system for valve products is constructed.

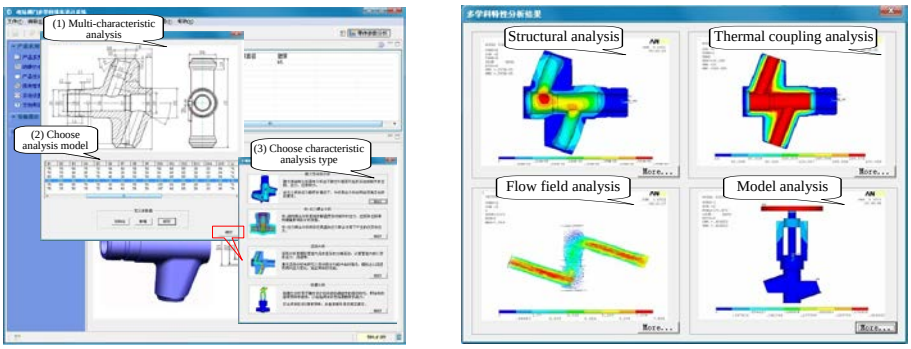

Fig.6. Extract results of multidisciplinary characteristic analysis

Through integration of heterogeneous CAD/CAE software such as UG, ANSYS and iSIGHT, the analytical efficiency is enhanced by coupling respective and unique advantage of various software systems, which is benefit to shorten the development period of nuclear power valve products and realize the rapid response to customer demands.

After modeling valve parts and entering the platform of multidisciplinary finite element analysis, then the multidisciplinary characteristics analysis could be carried out. The results of each characteristic analysis are shown in fig 6. The optimal results are shown in Tab.1 with the optimization constraints above (A: initial design, B: optimal design). From the table, it can be seen that the mass is decreased by 5.52%, and the wall thickness at the passageway of valve body reduced by 3.6%. Meanwhile, the capacity of valve body is expanded so as to improve the flow field performance of the valve,

Table 1. Optimization results

	D_6	D_8	D_{12}	D_{13}	*Pressure (MPa)*	*Mass (Kg)*	*Modal (Hz)*
A	44	48	60	65	102.65	5.81	39.254
B	47.5	51.3	61.6	62.8	119.98	5.56	45.781

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