Research on Finite Element Optimal Analysis Method

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Abstract. Finite element technology provides the basis for the complex structural analysis and calculation, which has been widely used in the design and evaluation of large-scale equipment. However, the time and cost of calculations are getting larger and larger due to complexity of the structure. How to improve the economics and rationality of calculations as much as possible under the premise of ensuring accuracy has become the focus of research. In this paper, the simplified high-pressure heater is taken as the research object, and the influence of different grid size on the calculation accuracy is shown. It is shown that the mesh size could be appropriately increased under the premise of the certain calculation accuracy, which could improve the calculation process and shorten the calculation time.

1. Introduction
Finite element analysis provides a prerequisite for the strength check of complex structures, which has been widely used in the design of large equipment. However, with the development of the large-scale equipment, the computational model is more and more complex, leading to the increase of time and cost. How to improve the economics and rationality of calculations as much as possible under the premise of ensuring accuracy has become the focus of the research[1-5].

Finite element calculations generally have a discrete error. When other conditions are constant, the finite element stress solution is closely related to the density of the grid. In general, the refined mesh will cause the finite element stress solution to converge to the real stress, but refining the mesh will greatly increase the amount of computation. In order to balance the calculation amount and the accuracy of the solution, this paper studies the size of the selected mesh, the type of the element and the influence of the integral method in the elastoplastic analysis with the simplified high-addition model (tube plate simplified equivalent solid plate) as the object.

2. Modeling
In this paper, the simplified high-pressure heater is taken as the research object, and the influence of different grid sizes on the calculation accuracy is shown in Table 1.
Table 1. Grid model parameters.

| Grid 1: The grid is divided into Solid186 units, the water chamber is divided into 5 layers, the water supply pipe is divided into 4 layers, the manhole is divided into 5 layers, and the tube plate is divided into 12 layers. The overall grid size is 30mm, totaling 32332 Unit, 150176 nodes. |
| Grid 2: The grid is divided into Solid186 units, the water chamber is divided into 7 layers, the water supply pipe is divided into 5 layers, the manhole is divided into 7 layers, and the tube plate is divided into 24 layers. The overall grid size is 20mm, totaling 121383 Unit, 535,508 nodes. |

Figure 1. Original grid and the refined grid.

3. Results and Discussion

Applying the same boundary conditions to two different mesh models, the friction surface is applied with no frictional constraint, the end of the shell is constrained to axial displacement, the water chamber, the tube sheet, and the inner wall of the water supply pipe are subjected to a pressure load of 40 MPa. The equivalent compressive stress is applied to the part -33.82 MPa, as shown in Figure 2.

Figure 2. Boundary conditions.
After solving, the equivalent stress calculated by two sets of different grids is given. The equivalent stress result of the original grid is shown in Figure 3. The maximum equivalent stress is at the arc foot connecting the tube plate and the water chamber. 585.91 MPa. The equivalent stress results after refining the grid are shown in Figure 4. The maximum equivalent stress is at the arc foot connected to the tube plate and the water chamber, and its value is 579.18 MPa.

| Original mesh | Equivalent Stress | Time: 1 |
|---------------|-------------------|---------|
| 585.91 Max    | 520.83            |         |
| 585.91 Max    | 505.76            |         |
| 505.76 Max    | 500.88            |         |
| 500.88 Max    | 525.52            |         |
| 525.52 Max    | 516.44            |         |
| 516.44 Max    | 500.37            |         |
| 500.37 Max    | 552.95            |         |
| 552.95 Max    | 579.32            |         |
| 579.32 Max    | 0.21175 Min       |         |

**Figure 3.** Equivalent stress of the original mesh.

| Refining the mesh | Equivalent Stress | Time: 1 |
|-------------------|-------------------|---------|
| 579.18 Max        | 579.18            |         |
| 579.18 Max        | 585.91            |         |
| 585.91 Max        | 520.83            |         |
| 520.83 Max        | 505.76            |         |
| 505.76 Max        | 500.88            |         |
| 500.88 Max        | 525.52            |         |
| 525.52 Max        | 516.44            |         |
| 516.44 Max        | 500.37            |         |
| 500.37 Max        | 552.95            |         |
| 552.95 Max        | 579.32            |         |
| 579.32 Max        | 0.21175 Min       |         |

**Figure 4.** After the refinement of the equivalent stress mesh after refining the mesh.

After the refinement of the equivalent stress mesh after refining the mesh, the change ratio of the stress is $|579.18 - 585.91|/585.91 \times 100\% = 1.04\%$, and the error of the two analyses is Within 2.5%. Within the tolerances allowed by the project, it can be considered that the stress calculation results of the model of this size using a 30 mm integral mesh or a 20 mm integral mesh are irrelevant. When the overall size of the grid is 30 mm, the number of nodes is 150176. When the overall size of the mesh is 20 mm, the number of nodes is 535,508. The latter's computing resources are more than three times the cost of the former, and the accuracy improvement is only 1.04%. Therefore, in the subsequent elastoplastic analysis, the overall size of the mesh can be selected to be 30 mm, which can balance the economics and the rationality of the solution.
4. Conclusions
In this paper, the comparison of grid size with calculation accuracy and calculation time is conducted. Under the premise of satisfying the calculation accuracy, the grid size can be appropriately increased to provide economical calculation. The research results provide finite element analysis for subsequent complex structures.

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