Design of Large-diameter Pipeline Spreader and Finite Element Analysis of its Reliability

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Abstract. In view of the problem that the large-diameter pipeline gets out of the spreader in the hoisting process due to the insufficient spreader strength and rigidity caused by the large hoisting acceleration, a kind of special pipe spreader is designed; 3D software is used to establish the geometric model of spreader, and the finite element analysis theory of the pipeline and spreader is studied; use the finite element analysis software ABAQUS to calculate and analyze the established decomposed model of the spreader and pipeline, and mainly take the influence of wirerope lifting acceleration and swing in the process of spreader hoisting and transportation into account, conduct the simulated calculation for the non-linear contact of composite structure under the gravitational acceleration of 1g, 1.5g and 2g, and get the stress distribution of each part of spreader in the process of pipeline hoisting. The analysis result shows that the maximum stress of each part of spreader is within the tolerance range of the material under the stress of 1g, 1.5g and 2g, meeting the design requirements.

Introduction

The pipeline is the device that connected by the pipe, connector and valve used to convey the gas, liquid or fluid with solid particles. Pipeline is widely used in the water supply, drainage, heat supply, gas supply, long-distance oil and gas transport, agricultural irrigation, hydraulic engineering and various industrial equipments. With the advancement of industrialization in our country, the pipeline has also gradually developed to the large diameter and hi-grade steel, which brings great challenge to the pipeline hoisting and transport[1,2].

Spreader is needed in the process of pipeline hoisting and transportation. Pipeline spreader is the key force-bearing component for the pipeline hoisting and transportation. Now the commonly used spreader in pipeline construction is the sling with different load, but it is easy to slip in the mountainous area with changeable climate and complicated terrain, leading to the safety accidents and affecting production. In view of the flaws of the sling, a kind of special pipeline spreader is designed, and its reliability is analyzed, which solves the slipping and overturning problem of the existing sling, and realizes the quick pipe loading and unloading.

In short, use software to conduct the solid modeling for the spreader, and conduct the finite element analysis for actual working conditions, and the qualitative analysis for the stress distribution and deformation condition of spreader, which can provide theoretical basis for the design improvement of spreader structure[3].

In view of the influence of wirerope hoisting speed and swing on the spreader in the process of pipeline lifting and transportation, in order to analyze the influence of wirerope hoisting speed on spreader safety, exert the gravitational acceleration of 1g and 2g respectively, calculate and analyze; according to the result, determine the strength and reliability of the spreader, and find out the maximum stress part of the spreader, providing certain reference basis for the design and improvement of spreader[4].

Structure design of large-diameter pipeline spreader

In view of the shortcomings of the existing pipeline spreader, a kind of large-diameter pipeline spreader is designed, composed of the pipe clamp body and pipe clamp rocker, and the former one is divided into three parts, mainly the lower-branch welding plate, square spacer and other parts, and the mechanical structure of the spreader is as shown in figure 1. When loading, the pipe clamp body contacts with the pipe, and clamp it and the pipeline by adjusting the rocker; when unloading, adjust the rocker to loosen it and the pipeline. The pipeline for hoisting is the large-diameter steel pipe, the spreader will bear much load, so the spreader is designed to adopt 45# steel, elastic modulus E=200Gpa, Poisson's ratio μ=0.3, density ρ=7.8E-9 T/mm^3, and yield strength 355 Mpa.

The pipeline is the large-diameter steel pipe with the cross-sectional diameter of 1016mm and single quality of 7.6t. In order to facilitate the mechanical analysis on spreader, approximate the pipe to the rigid body, simplify it as the plane strain model, and calculate with 1/3 of its weight, and directly model in ABAQUS as shown in figure 2.

Import the built spreader model to the ABAQUS software, and combine it with the pipeline model, and get the composite structure of the spreader and pipeline as shown in figure 3.

Fig. 1 The Mechanical Structure of Spreader

Fig. 2 The Simplified Model of Pipeline

Fig. 3 The Geometric Model of Composite Structure

Contact Finite Element Analysis of Spreader and Pipeline

Finite Element Model of Spreader and Pipeline. ABAQUS is the powerful finite element analysis software for engineering simulation, which can solve the complicated nonlinear problem. ABAQUS is adopted to solve the nonlinear problem of spreader and pipeline [5]. First, conduct the finite element mesh generation for the composite structure model of the spreader and pipeline, and obtain the finite element model of composite structure and conduct the calculation and analysis on the model. In order to improve the quality of mesh generation and analysis accuracy, divide the spreader into the pipe clamp body, pipe clamp rocker, square spacer, lower-branch welding plate, respectively. The pipe clamp body and pipe clamp rocker adopt the eight-node hexahedron element and four-node tetrahedral element, the square spacer adopts the eight-node hexahedron element and the lower-branch welding plate adopts the four-node tetrahedral element[6]. After the division, the number of element of the pipe clamp body is 84134, that of the pipe clamp rocker is 39284, that of the square spacer is 1880, and that of the lower-branch welding plate is 1568. The finite element model of spreader and pipeline is as shown in figure 4.

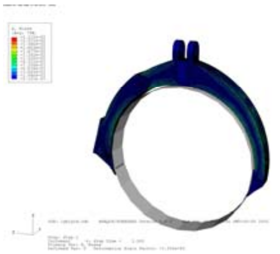
Constraint and Load. Given the friction between the spreader and pipeline contact surface, the friction coefficient is set as 0.3. According to the load condition of spreader, the full constraint should be imposed to the screw hole in the upper part of spreader; the orange part in figure 5 is the displacement boundary condition[7,8]. Mainly analyze the influence of wirerope lifting acceleration and swing in the process of spreader hoisting and transportation on the strength and rigidity of spreader, so conduct the simulated calculation for the spreader model under three different working conditions. Condition 1: impose 1g gravitational acceleration; condition 2: impose 2g gravitational acceleration.

Fig. 4 The Model of Finite Element　　　Fig. 5 Boundary Condition

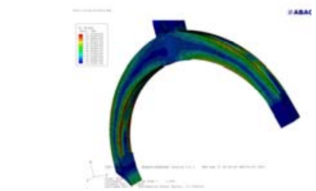
Calculation Result Analysis. Analyze the contact between the spreader and pipeline under the above three working conditions and the results are as follows:

Working Condition 1. It can be seen from figure 6 that only a small part of composite structure bears the stress of 221.5MPa, and most areas bear the stress between 166.2MPa - 129.2MPa. The stressed zone of pipe clamp body is in the upper and lower side of C-type side panel, and the stress ranges from 101.4MPa - 59.1MPa. The stressed zone of pipe clamp rocker is in the lower side of panel, and the stress ranges from 147.8MPa - 55.6MPa. it can be concluded that when the gravitational acceleration is 1g, any part of spreader does not reach yield limit of the material, so the strength meets requirements.

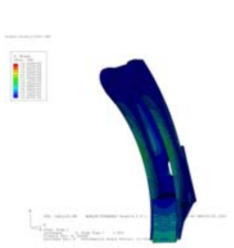
This calculation is ultimately convergent, proving that the pipeline does not get out of the spreader. When the gravitational acceleration is 1g, therefore, the rigidity of spreader also meets the requirements.



（a）Composite Structure

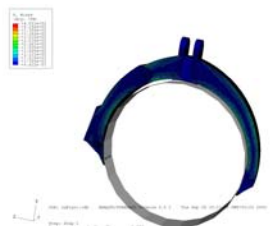


（b）clamp body

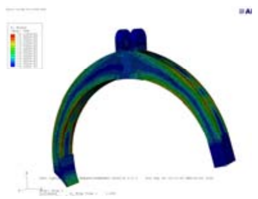


（c）clamp arm

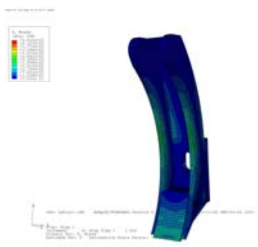
Fig. 6 Working Condition 1



（a）Composite Structure



（b）clamp body



（c）clamp arm

Fig. 7 Working Condition 2

Working Condition 2. It can be found from figure 7 in the overall stress nephogram, the stress in the region of stress concentration has reached 452.3MPa, and most regions with larger stress bear the stress between 339.2MPa and 263.8MPa. It can be concluded that when the gravitational acceleration is 2g, the stress concentration region of spreader has reached the yield strength of material, and most regions with larger stress are still less than the yield limit of material; it is thought that the spreader has reached its working limit at this point. The maximum stress of pipe clamp body and pipe clamp rocker does not reach the ultimate strength of the material. This calculation is still convergent, indicating that the rigidity of the spreader still meets the requirements.

Conclusion

Design the spreader for large-diameter pipeline, and analyze the spreader using finite element analysis software. It can be known from the above analysis that the spreader with the current structure form is safe under the gravitational acceleration of 2g, and the hoisting acceleration of wire rope cannot be exceed 2g. If it swings in transit, the centrifugal acceleration in the lowest point cannot exceed 2g. Otherwise, there will be unpredictable situations. In addition, if the pipe clamp rocker's side panel can be thickened, it will significantly increase the strength of the spreader, which enables it to fully play the performance of each part, and strengthen the overall strength of spreader. Through the one-stage test and application in a construction site, it has been proved that the spreader has reliable structure and convenient operation, satisfying the requirement of engineering safety.

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