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Finite Element Analysis of the End Seal of Hydraulic Testing Machine

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Abstract. The end face sealing hydraulic testing machine is one of the important equipment for testing the pressure resistance of steel pipes. This paper studies a method to verify the sealing conditions and strength conditions by finite element analysis, and find the minimum actual specific pressure under common water pressure. That is to not only meet the sealing conditions, but also maximize the life of the gasket, and meanwhile, change the traditional way of loading by experience.

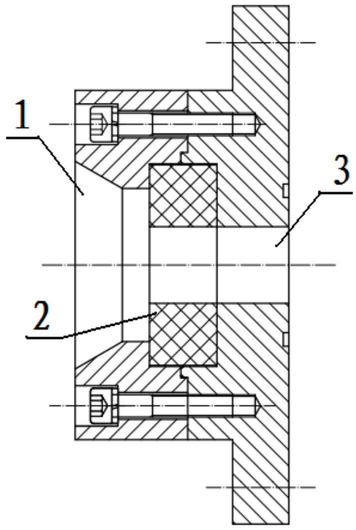
1. Introduction

The fluid steel pipe must be carried out hydrostatic test during the production process, and its pressure resistance is an important quality index of the steel pipe. The sealing device of hydraulic testing machine plays a key role in the pressure resistance test of the steel pipe. Its function is to have certain buffering effect when the steel pipe is in contact with the sealing gasket, and play a role in sealing after the steel pipe is stabilized.

Sealing is very important in testing hydraulic pressure. The main parameters affecting the sealing conditions are the material properties of the gasket, the compression depth, the working pressure, the temperature, the working medium, etc. Among these, the compression depth of the gasket is particularly essential. If the compression depth is too small to meet the sealing requirements, it will cause leakage in the steel pipe and the gasket. While, if there is too much compression, it will affect the life of the gasket. In this way, the gasket will be replaced continuously during the production process, which will influence the production progress. The compression depth of the gasket is directly related to the pressure of the steel pipe to the gasket. The traditional working method relies on experience to pressurize the steel pipe. This method cannot ensure the sealing effect in the actual testing process, nor can it improve the life of the gasket. In this paper, we study a method for satisfying the sealing conditions and maximizing the life of the gasket.

2. Structure of seal head

Fig.1 shows a schematic view of a sealing device of an end face sealing hydraulic testing machine, which is also mentioned as a head. During operation, the steel pipe is first conveyed to the inlet of the 1 steel pipe through the conveying platform to contact the gasket, and the end face is sealed, and the large chamfer of the steel pipe inlet serves as a guiding function. 3 is the water inlet. When the steel pipe is in stable contact with the gasket, the water pressure test can be carried out on the steel pipe through water injection into the water inlet.



1. Entrance of steel pipe 2.The seal 3.The inlet of water

Fig.1 The diagram of Seal-head

3. Analysis of sealing condition

Guarantee liquid sealing conditions: Necessary specific pressure q_1 ,actual specific pressure q_2 , seal allowable specific pressure .Among them:$q_1 \le q_2 \le q$

$$q_1 = \frac{(0.4 + 0.6p)}{\sqrt{b/10}} \times 1.4 \qquad (1)$$

Q1 is the minimum contact stress to ensure the sealing condition, the unit is Mpa, b is the width of the sealing surface, the unit is mm, p is the medium pressure, the unit is Mpa.The allowable specific pressure of the seal refers to the maximum contact stress that the seal can withstand under normal working conditions. The material used in this paper is polyurethane, and the allowable specific pressure is 40Mpa.The actual specific pressure is the contact stress generated in actual production. If the actual specific pressure is equal to the required specific pressure, both the sealing condition and the life of the seal can be greatly improved, that is, we need to work at the minimum actual specific pressure.

4. Finite element analysis of sealing performance

4.1. Determination of material constant of rubber gasket

In order to make the gasket work under the minimum actual specific pressure, the ANSYS workbench finite element method was used to calculate the finite element analysis of the polyurethane gasket with Shore hardness of 80A. The gasket calculated this time is a medium hardness 80A polyurethane with a Young's modulus of 20 MPa and a Poisson's ratio of 0.499.

4.2. Calculate the minimum actual specific pressure

The finite element analysis method is used to calculate the minimum actual specific pressure. The φ76 steel tube is taken as an example.

The first stage gives the seal a necessary specific pressure, i.e., no specific pressure before the steel tube is added to the medium (water). The common pressure of the medium is 3-8Mpa. If it is 3Mpa, the necessary specific pressure is 5.03Mpa according to formula (1). At this time, the deformation of the steel pipe acting on the gasket is 3.4494mm, which is the maximum deformation in the figure, as shown in Figure 2.

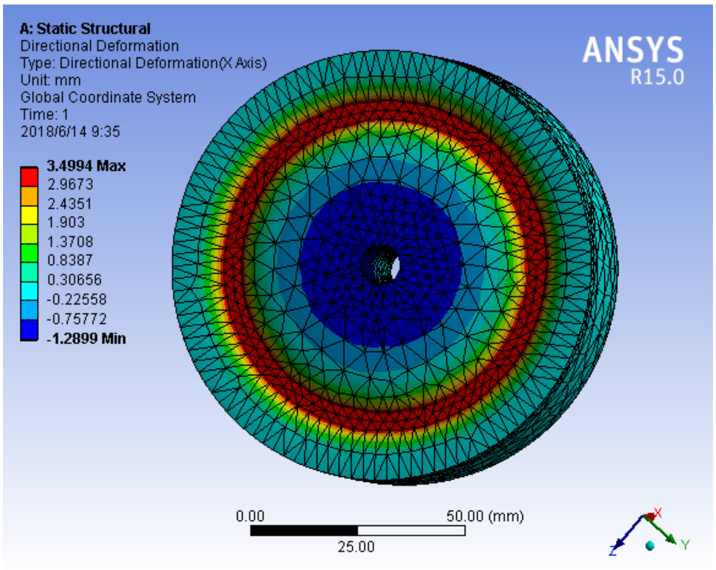


Fig 2. Shows the deformation of the gasket before adding the medium

In the second stage, according to the deformation of the gasket, the finite element analysis is continued. First, in the finite element model, the deformation of the given steel pipe acting on the gasket is 3.4431 mm, that is, the steel pipe works under the minimum actual specific pressure. This results in the minimum force applies to the steel tube. At this point the maximum stress of the gasket is 9.5209 MPa, as shown in Figure 3, this value is used for strength calculation.

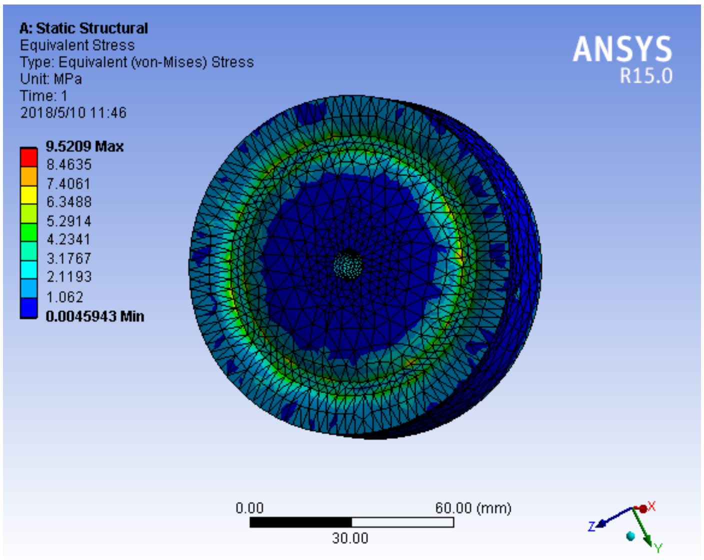


Fig 3. The map of Seal stress distribution

In the third stage, the specific pressure of the medium must be added on the basis of the addition of the steel pipe. The third stage is the process of testing the water pressure of steel pipes. Through the finite element analysis, the actual deformation amount of the water pressure seal is obtained. For example, when the specific pressure of the medium is 3Mpa, the maximum deformation is 3.5217mm, as shown in Fig. 4. The difference is 0.0723 mm in comparison with the amount of deformation before the water pressure is 3.4494 mm. This difference is the gap between the steel pipe and the gasket after the medium is added, and it is used for the calculation of the leakage amount. Table 1 gives the data for the finite element analysis of the above three stages under different water pressures.

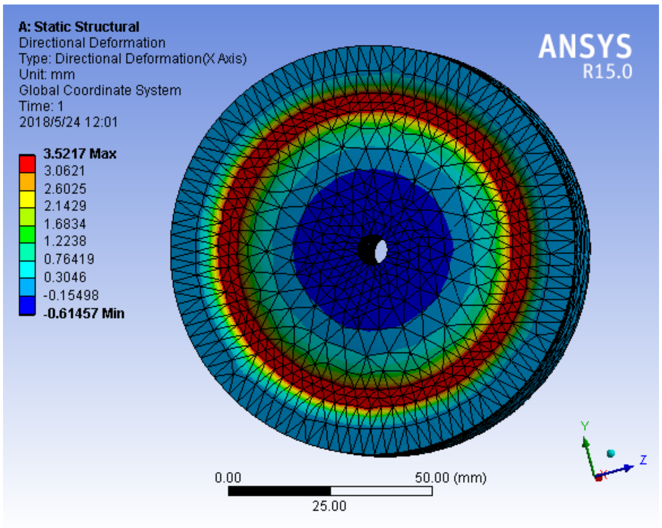


Fig 4. Shows the deformation of the gasket after adding the medium

Table 1. finite element analysis data under different medium pressures

Medium pressure(Mpa)	Must pressure (Mpa)	Minimum force applied to the steel tub(N)	Seal deformation before adding media(mm)	Maximum stress of the gasket(Mpa)	Seal deformation after adding media(mm)
3	5.03	4009.81	3.4494	9.5209	3.5217
4	6.40	5101.952	4.5089	13.218	4.6957
5	7.77	6194.09	5.5723	16.938	5.8142
6	9.14	7286.23	6.6354	20.755	6.9275
7	10.52	8386.33	7.6998	24.443	8.0514
8	11.89	9478.47	8.7613	32.594	9.1516

It can be seen from Table 1 that when the medium pressure (water pressure) is 3-8Mpa, the maximum stress generated by the gasket is within the allowable stress range.

5. Analyze and judge the sealing effect

When the medium leaks, whether the sealing of the sealing device is effective will be judged and analyzed. Its effectiveness means that under the given working conditions, the quality of the medium leaked by the sealing device does not exceed the allowable value of the work. Calculate the leakage velocity calculation formula according to the Bernoulli equation:

$$Q_L = C_d A \rho \sqrt{\frac{2(P-P_0)}{\rho} + 2gh} \tag{2}$$

Q_L: liquid leakage flow, g/s;
C_d: emission factor, usually taking 0.6-0.64;
A: leakage area, m2;
P: medium pressure in the steel pipe, pa;
P_0: standard atmospheric pressure, pa;
g: gravity acceleration, 9.8m/s2;

h: steel pipe and gasket seal, m; ρ: leaking medium density, g/cm3

According to the formula (2), Table 2 shows the calculated values of leakage and leakage rate of φ76 steel pipe under different medium pressures.

Table 2. Leakage rate of leakage under different medium pressures

Medium pressure(Mpa)	Steel pipe and gasket seal(mm)	Leakage(g)	Leak rate %
3	0.0723	0.23	0.01
4	0.1868	0.67	0.03
5	0.137	0.65	0.03
6	0.1681	0.75	0.0326
7	0.2005	0.97	0.042
8	0.3903	2.02	0.088

Through the analysis of the data in Table 2, the leakage rate of the steel pipe under different medium pressures is less than 1% (1% is the industry standard), in line with the sealing conditions.

6. Conclusion

In this paper, a method of verifying the sealing condition and strength condition by finite element analysis is studied by taking φ76 steel pipe as an example, and the minimum force applied to the steel pipe during the minimum actual specific pressure and hydraulic pressure test is obtained. On the one hand, the method satisfies the sealing condition, and the leakage rate is within the allowable range; on the other hand, it maximizes the life of the gasket, which is helpful to reduce the frequency of replacing the gasket in the hydrostatic test and change the the traditional loading method. The result in this paper have been recommended to the manufacturer.

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