Design and Research of 2000T Wide Plate Tensile Testing Machine

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Abstract. Wide plate, wide plate weld, pipeline girth weld and plate welded of panel used to the storage tank were wholly stretched by 2000T wide plate tensile test machine when using the related fixture. Tensile strength, initiation crack position of the joint crack, tolerance of the existing defects of welded joint, possibility of the crack propagation and fracture were studied. Their weak links were found, the formation of defects were avoided by welding technology and technical means. The closed loop control was realized by using advanced servo valve and high performance measure and control system, computer technology was used fully, multifunctional test control of the machine was realized. A number of servo cylinder precise synchronous control loading mechanism was adopted by 2000 T wide plate tensile testing machine, the design of its loading mode, servo cylinder, sensor installation layout and combined structure of super power sensor was the first in China, which created a platform for the development of large structure testing machine in the future.

1. Introduction

With China's reform and opening up, especially the rapid development of industrial production and science and technology in recent years, some products or structures in the energy, environment, construction, shipping and other industries must be large-scale and integrated [1]. For example, long-span Bridges, large passenger planes, large transport pipelines, giant ships and other fields. The safety and performance of these products or structures were so important that their stress-strain and fracture strength under extremely complex external conditions (load, vibration, high and low temperature, corrosion, weathering) must be considered in design and use. It was difficult to obtain reliable test data by using standard sample or small size model test data [2]. In particular, welding structures and composite materials, even using high-end simulation software could not be inferred. To ensure safety, close to the actual structure or full size tests must be carried out. From this point of view, the development and development of large-scale structural testing machine was very important, but also the national economic development needs [3].

At present, the development of large tensile testing machine abroad was far ahead of our country. The countries in the lead were Germany in Europe, America in America and Japan in Asia. Foreign large tensile testing machine developed much earlier than the domestic time, technical strength was also higher than we, load tonnage and a complete range of types. For example, Japan, has tensile testing machine from 1000 tons to 10000 tons, and they have been applied widely and played an important role for the industrial development of Japan. In China, the research and development of large tensile testing machine started late, the technical level and function of the international advanced level was still a big gap. The load capacity of the domestic horizontal tensile testing machine was only 1000 tons, the control method was relatively simple, could not meet the needs of engineering practice.

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Therefore, many enterprises and research institutions have to import from abroad, which is not consistent with the rapid development of the domestic economy.

In recent years, the application of high strength thick plate and wide plate combined welding was more and more extensive, such as oil industry, ship industry and so on. The failure mechanisms of tensile, bending, shearing and fatigue must be studied in order to give full play to the properties of materials. Therefore, comprehensive judgment must be made under complex conditions such as physical property, structural property, size, connection mode, stress state and working environment. If we use the data of small specimen, we will get unreasonable results.

Based on the above objective factors, there was an urgent need to develop a large horizontal pull testing machine with excellent performance and advanced technology, so as to meet the needs of energy, environmental engineering, construction and ship engineering research, save foreign exchange, and prevent the core technology from being subservient to others. For this reason, we developed a 2000T wide plate tensile testing machine. Compared with similar equipment, this testing machine has advantages and innovation in the following aspects:

1. The testing machine could not only carry out tensile test on the wide plate, but also could carry out overall tensile test on the wide plate weld, pipe girth weld and wall plate welding of storage tank under the condition of using relevant fixtures. After the function was extended, the low cycle fatigue test could be carried out on the above test parts;
2. The machine adopts a two-beam, four-column, multi-cylinder synchronous loading structure, which abandoned the previous overall beam and closed frame structure, greatly reduces the weight of the main engine, reduces the production and manufacturing cost, and improves the process of manufacturing, installation and use;
3. Advanced controller and our unique closed-loop feedback multi-channel coordinated load control system were adopt which have been ensured the stability, accuracy and safety of test control. It the instability phenomenon has been avoided by the large change of non-control parameters in the previous equipment and improved the success rate of the test.

2. Technical indicators of 2000T wide plate tensile testing machine

Table 1 was the technical indicators of 2000T wide plate tensile testing machine.

| Measuring force          | 0~20000KN |
|--------------------------|-----------|
| Wide plate thickness     | ≦120mm    |
| Range of testing force   | 2%~100%   |
| Measurement accuracy of test force | ±1.0% indication, resolution 1 KN |
| Displacement measurement range | 0 ~ 1000(displacement of loading cylinder) |
| Displacement resolution  | 0.002mm (displacement of loading cylinder) |
| Displacement measurement accuracy | ≤±0.5% FS (displacement of loading cylinder) |
| Large deformation measurement range | 1000mm, 2% ~ 100% |
| Measurement accuracy of large deformation | ≤±0.5% FS |
|                                |                                                      |
|--------------------------------|------------------------------------------------------|
| Measurement range of small deformation | 50mm, 2% ~ 100%                                       |
| Measurement accuracy of small deformation | ≤±0.5% FS                                             |
| Constant rate control of test force   | 0.1% ~ 100% FS/min                                   |
| Control range of test force          | 2% ~ 100%                                            |
| Control precision of test force      | ±1.0% set value                                      |
| Constant displacement rate control   | 0.1 ~ 20mm/min (load state)                          |
| Displacement control range           | 2% ~ 100%                                            |
| Displacement control precision       | ±1.0% set value                                      |
| Deformation (strain) control range   | 0.1 ~ 100% FS                                        |
| Deformation (strain) control precision | ±1.0% set value                                   |
| Control accuracy of constant test force and displacement | ±1.0% set value                        |
| Stretching space                    | 0 ~ 4000mm                                           |
| Piston stroke of oil cylinder        | ≥1000mm                                              |
| Cylinder drawing speed              | 0 ~ 20mm/min                                         |
| Cylinder no-load return speed        | 100mm/min                                             |

3. **Structure of 2000T wide plate tensile testing machine**

The structure of 2000T wide plate tensile machine was horizontal. The schematic diagram of host was shown in figure 1. The three dimensional figure of host was shown in figure 2.
Figure 1. Schematic diagram of host.

a-front beam b-buffer cylinder c-moving vehicle d-loading cylinder support e-loading cylinder f-sensor g-column support h-column i-column car j-rear beam k-buffer rod assembly l-moving guide rail m-displacement sensor n-pin plug device o-tensile fixture p-specimen q-specimen deformation measurement device

Figure 2. Three dimensional figure of host.
The host was mainly composed of front beam, buffer cylinder, moving vehicle, loading cylinder support, loading cylinder, sensor, column support, column, column car, rear beam, buffer rod assembly, moving guide rail, displacement sensor, pin plug device, tensile fixture and specimen deformation measurement device. Four loading cylinders were fixed on the right end face of the front crossbeam, and four buffer cylinders were fixed by connecting the front and rear sides, the back was connected with the moving car and could move along the moving guide rail with the moving car. The loading cylinder was a force source for loading the specimen. A displacement sensor was built in to measure the position of the piston and feed back to the control system. The loading cylinder was supported by loading cylinder support which was connected and fixed with the following moving vehicle. The force sensor was located between the loading cylinder and the column to measure the load. The left end was connected with the piston rod of the loading cylinder, and the right end was in contact with the upright column through the spherical pressure cap. The column passes through the rear beam at the right end and was connected to the rear beam through the clasp. After the clasp was removed, the relative position of the column and the rear beam could be adjusted. The bottom of the column was connected with the column car and could move along the guide rail with the column car. The left end face of the rear crossbeam was fixed with a clasp seat. The clasp could be adjusted on the clasp seat to connect or separate the column and the rear crossbeam. The rear crossbeam was connected to the front and rear sides to fix the buffer base. The buffer base transmitted the impact of the broken specimen to the buffer cylinder on the front beam through the buffer bar. The buffer cylinder was composed of a buffer spring and a buffer. The four sets of buffer cylinders connected with the connecting rod were used as the buffer device when the sample was broken to realize the sequential buffer, which could well absorb the energy released at the moment of breaking and reduce the impact vibration. The two tensile jigs before and after were connected with the front and rear beams respectively through a pin shaft, and the specimens were welded in the middle of the two tensile jigs. The pin shaft plug and pull action through the pin plug and pull device to achieve hydraulic drive, reduced manual operation. The moving guide rail was fixed on the flat foundation and fixed by the steel rail and elastic strip, which could support and guide the moving car and the column car. A closed frame was formed by the front and rear beams and columns. When the specimen was connected with the front and rear beams through a pin shaft, the tensile test of the specimen could be realized by controlling the loading cylinder.

4. Design of columns of 2000T wide plate tensile testing machine

Fours columns were important parts of 2000T wide plate tensile testing machine.

4.1. Parameters of columns
The material of the four columns were 45, table 2 was the parameters of column.

| Parameters of column. |  |
|----------------------|---|
| Yielding stress $\sigma_s$ | 355Mpa |
| Ultimate strength $\sigma_b$ | 600Mpa |
| Safety factor $n_s$ | 1.5 |
| Modulus of elasticity E | 200Gpa |
| Length l | 523cm |

$$[\sigma] = \frac{\sigma_s}{n_s} = \frac{355\text{Mpa}}{1.5} = 237\text{Mpa} $$ (1)

Where $[\sigma]$ was allowable stress of material.
4.2. Stability check of columns

\[ F = \frac{\pi^2 EI}{l^2} = \frac{\pi^3 Ed^4}{64l^2} \]  

(2)

Where \( F = 5 \times 10^6 N \) was the critical load of columns, \( I = \frac{\pi d^4}{64} \) was the second axial moment of area, \( l \) was the length and \( d \) was the diameter.

Equation (3) was derived from equation (2).

\[ d = \frac{\sqrt[4]{64F I^2}}{\pi E} = 19.38 \text{cm} \]  

(3)

4.3. Strength check

\[ \sigma = \frac{F}{A} = \frac{F}{\pi d^2/4} = 169.5 \text{MPa} < \left[ \sigma \right] \]  

(4)

The value of safety factor was 3 considering the impact of the moment when the plate was actually stretched and broken. Equation (5) was derived from \( \frac{d^4}{d'} = 3 \).

\[ d' = \sqrt[3]{3d^4} = 25.26 \text{cm} \]  

(5)

Where \( d' \) was the actual diameter of columns, the value of \( d' \) was rounded, therefore the value of \( d' \) was 26cm.

5. Conclusion

The current international advanced structure and measurement and control technology with high innovation and advanced was integrated and applied in the development of 2000 tons wide plate tensile testing machine. A lot of experience has been accumulated in the development of this machine, which provides a platform for the development of large-scale structural testing machine in the future.

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