Structural Design and Simulation Analysis of 1000kN Large Tonnage Steel Strand Testing Machine

Weilin Gu1, Xiaoyang Li1, Jianhe Feng2, Tingshuai Yang1, Weihua Cui1*

1 School of Mechanical Engineering, University of Jinan, 250022, Jinan, China.
2 Jinan Taisite Instrument Co., Ltd, 250023, Jinan, China.
* Corresponding author. (e-mail: wh_cui2006@163.com).

Abstract. The structure design of 1000kN steel strand testing machine was carried out aiming at the requirement of large-tonnage mechanical performance testing of the steel strand. The structure of the testing machine was simulated to analyze the stress and deformation of key parts in the main structure with the help of finite element analysis software. The results show that the mainframe has good rigidity and the main components meet the strength design requirements.

1. Introduction
Standard steel strand is made of twisted cold drawn round steel wire, which is a new type of building material. It is widely used in road and bridge construction because of its characteristics such as good relaxation performance, good stability, high tensile strength, long warranty time and not easy to break. In addition, the quality of the steel strand that plays a role of "sinew" has become one of the important factors affecting the reliability and safety of the project. According to national standards, the mechanical properties of steel strand must be tested to ensure the safety of engineering use. The performance of the steel strand testing machine has a direct impact on test results and the security of its use, especially for large-tonnage mechanical performance testing of the steel strand.

Data retrieval shows that domestic and foreign scholars have studied the steel strand tensile testing machine. Jialian W[1] et al. solved the slipping and crushing phenomenon during the tensile testing of steel strand by optimizing the fixture mechanism. Hu L[2] et al. took the hydraulic tension testing machine as the research object and optimized its hydraulic system by means of simulation software. Ying-jian W[3] et al. took grid wire tension as the research object and realized the contact detection and pressure measurement between the probe and grid wire with the aid of multi-axis displacement platform to complete the design of high-precision tensile testing machine. ZHOU Chen[4] et al. analyzed the factors affecting the coaxiality of the upper and lower fixtures of the vertical tension testing machine and elaborated the effect of coaxiality error on the tensile test results. Ojo Jeremiah Akinribide[5] optimized the design of the fixture in the universal tensile testing machine and developed a new type of replaceable clamp, which not only guaranteed high reliability but also reduced the use cost.

The stiffness of the main engine of the large-tonnage steel strand testing machine is insufficient, which seriously affects the loading rate of the specimen and the accuracy of the yield point measurement. In view of this, the tensile testing machine for the testing requirements of large-tonnage mechanical performance testing of steel strand is developed. The whole machine is subjected to finite element simulation to analyze its stiffness so as to verify the rationality of the design and provide support for structure improvement based on the structural design of the steel strand tensile testing machine.
2. The main engine structure design of the testing machine

According to the test requirement of the maximum tensile force of 1000kN and the existing phenomenon of slipping and crushing in the steel strand test, the structural design of the steel strand testing machine is accomplished through detailed calculations. The structure of the main machine part is depicted in Fig1 including fixed frame body (composed of upper beam 1, four columns 2, and worktable 4, etc.), movable frame body (composed of lower beam 3, base 6 and two sets of screw nut pairs 9, etc.), clamp block10 and fixture11, etc. Features are as follows:

1) The base is welded with a box frame to increase the mechanical strength and use bolt connection with the foundation to improve the stability of the whole machine.

2) The stretching cylinder is placed underneath using a high-strength thrust cylinder, which is installed in the forward direction. The system applies the pulling force when the piston rod is extended.

3) The clamp block adopts a fully enclosed mosaic groove design and is consist of ultra-high-strength alloy. It has the advantages of high mechanical strength, good toughness and large bearing capacity. The test error caused by the deformation of the fixture can be reduced during the test. And it effectively match with the fixture to prevent the fixture and sample out of groove and play a protective role.

4) The clamp jaw is designed as V-shape. Fig.2 presents that serrated protrusions are set in the V-shaped jaw to increase the biting force between the clamp jaw and the steel strand, in order to prevent slipping phenomenon in the test. Meanwhile, the fixture and the clamp block are inlaid, which can be disassembled and replaced at will.

![Fig.1. Structural diagram of steel strand tensile testing machine](image)

1 upper beam, 2 column, 3 lower beam, 4 worktable, 5 motor, 6 base, 7 thrust cylinder, 8 pressure plate, 9 screw, 10 clamp block, 11 fixture

![Fig.2 Schematic diagram of the fixture and its jaw](image)
3. Finite element analysis of testing machine host
The frame of large tonnage steel strand testing machine is the main carrier of force, in order to ensure the safety of the large tonnage tensile testing, it is necessary to carry out static structure simulation of the testing machine host, and analyze the rigidity of its structure.

3.1. Pre-processing of finite element analysis
In order to reduce the difficulty of simulation, some parts of the model were simplified. The model was saved as x-t format and imported into ANSYS Workbench. The method of automatic meshing is used to refine the stress concentration area. According to the actual working condition of the testing machine, the boundary conditions were set to simulate the performance under the maximum tensile force. Firstly, a fixed constraint was applied to the bottom surface of the base, then an upward thrust of 1000kN was applied to the bottom surface of the worktable and a downward thrust of 1000kN was employed to the top surface of the base. Meanwhile, a downward and upward 1000kN pull force was exerted to the clamping position of the upper and lower beam respectively, as shown in fig. 3.

3.2. Simulation results and discussion
The stress results are shown in Fig. 4. From the results, the stress of the worktable and the fixture of the upper and lower crossbeam is relatively large. Its value is between 150-200MPa, which is less than the yield strength value of the material. It is found from the joint of the parts that the maximum stress with the value of 333.97MPa(Fig.5) is located in the joint area of the screw and the nut, and it is still less than the yield strength of the screw material of 355MPa.It presents that the structure design of the host meets the strength requirements.

As can be seen from Fig.6, the maximum transverse deformation (X axis) of the four columns direction is 0.489mm, only 0.7% of its diameter (75mm). Thus the amount of deformation of the column is small and the rigidity of the mainframe structure is good.

The analysis of the above simulation results indicates that the mainframe structure including the fixed frame body and the movable frame body has good rigidity. Meanwhile the key components—pillars, screws, upper and lower crossbeams, worktables, etc. meet the strength design requirements.
Fig. 4 Simulation results of stress nephogram of host machine

Fig. 5 Local stress nephogram of screw in the host machine
Fig.6 Simulation results of host deformation nephogram

4. Conclusion
The whole structure design of 1000kN large tonnage steel strand tester has been carried out. In particular, zigzag protrusion was set at the jaw of v-clamp to avoid steel strand slipping during the test. At the same time, the finite element simulation tool was used to simulated the main structure including fixed frame and movable frame. The stress state of the key parts, such as screw, column, upper crossbeam, lower crossbeam and worktable, and the deformation of the column are analyzed. The simulation results show that the main parts meet the strength design requirements, the column deformation is small, and the main frame rigidity is good.

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