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RIGIDITY TEST AND ANALYSIS OF BLADE CARRIER FOR NC GUILLOTINE PLATE SHEARING MACHINE

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Abstract. The guillotine plate shearing machine is a widely used plate processing equipment with shear blades installed in the upper and lower tool holder. The rigidity of the tool holder directly affects the rigidity of the blade, which affects the precision of the plate shearing. The NC guillotine plate shearing machine has been taken as the research object. The method of strain electrical measurement was used to test the machine tool holder. The results of the finite element simulation and experimental testing appeared to coincide, which proved the efficiency of the finite element method in solving this type of problems.

Keywords: shearing machine; tool holder; finite element; test.

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Problem statement. Shearing machines are being increasingly widely used in auto-industry, engineering machinery, shipbuilding, aviation and aerospace. With the users' growing demand for high-quality products, shearing machines are urgently needed, since they offer better performance. They are usually categorized by the shape of shear blades, their relative position, and the type of the rolled piece. Accordingly, the machines may have parallel blade shears (also named parallel cutting edge shears), oblique edge shears, slitting shears, or flying shears in their composition. This paper studies oblique edge shears, i.e. those with the upper and lower shear blades arranged at a certain angle [1]. The rigidity of the blade carrier has a direct impact on the rigidity of the blade, thereby influencing the accuracy of plate shearing. Thus, it is rather necessary to study the rigidity of blade carrier [2].

BASIC MATERIAL

1. Blade carrier rigidity test

1.1. Test principle and content

In the test system, sensors are adopted as the primary instrument, and data collectors connected to a computer are used as the secondary instrument. The system is of superior performance, high reliability, excellent shock and vibration resistance, and high measurement precision. It is capable of recording, processing, and storing experimental data automatically.

Instruments and devices applied during the on-site test include:

– 8 displacement sensors with dial indicators, having a measurement range of 0-10 mm,

– 8 magnet stands;

– 2 bridge boxes with 8 channels in total;

– strain amplifier KD6005;

– data acquisition system AZ308;

– vibration and dynamic signal collecting and analyzing system CRAS V7.0.

Signals detected by the displacement sensors are transformed into voltage signals through a related circuit. The displacement sensors need to be calibrated to convert the voltage signals to the displacement of the measuring point, that is, every 1 mV of the voltage signal corresponds to the displacement of the sensor. The deformation data can be calculated with the help of the measured value and associated formulas [3].

In this paper, the deformation data of measuring points on the upper and lower blades of the shearing machine are tested when shearing a Q235 plate that is 4000 long and 6 mm thick.

1.2. Test method

When shearing, the upper blade carrier moves up and down reciprocally, while the lower blade carrier stays still. Accordingly, the meter of the displacement sensor is fixed onto a smooth steel plate connected to the bolts on the upper blade carrier (Fig. 2), where 19 measuring points are equally distributed to measure the relative displacement. When measuring the displacement of the lower blade carrier, the meter is fixed directly onto the measuring point, and the magnet stand adheres to the base bedded in the ground. As the lower blade carrier is stationary, the acquired data indicate the absolute displacement to the ground. The meter should be located on the latter half stroke of the lower blade in order to accommodate the influence of the upper blade during shearing. The maximum shearing length of the upper blade shall be limited within 2 m. The machine should be shut immediately after shearing for the upper blade to not hit the displacement indicator and further damage the meter. There are 7 measuring points chosen on the lower blade.

1.3. Results analysis

For convenient data processing, a coordinate system of the shearing machine is established as shown in Fig. 3, which is applicable to this test.

On each measuring point, the value of voltage signal is taken three times to obtain an average value. Through calculation, the displacement of each measuring point in the shearing process was obtained, shown in the table 1:

By analyzing the data, it can be established that the measuring points on the upper blade deform towards the minus X direction, i.e. the upper blade recedes towards the rear of the machine. The deformation of the measuring points in the middle of the blade is larger than that of the ends, with the biggest displacement found at the 10th point, valued -0.46 mm.

Similar experiment results for the lower blade are given in Table 2.

It can be inferred from the data that the measuring points on the lower blade deform towards the positive X direction, i.e. the lower blade recedes towards the front of the machine.

2. Finite Element Analysis of the Blade Carrier

Taking into account the test results for the shearing machine, numerical simulation of the shearing process is necessarily conducted to determine the feasibility of application of the finite element theory in this field and to provide basis for further research on guillotine plate shearing machines.

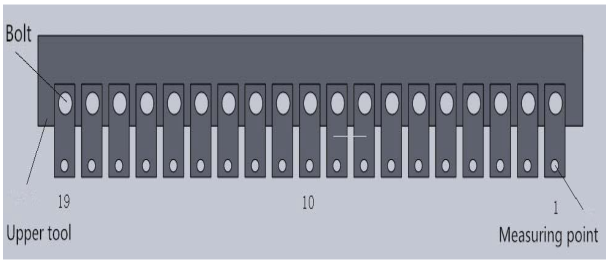

Fig. 1. Measuring points on the upper blade

Fig. 2. Meters installed on the upper blade

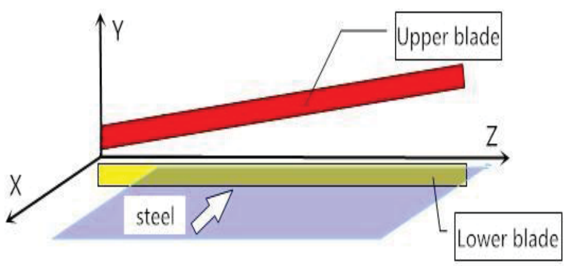

Fig. 3. Coordinate system of the shearing machine

Table 1. Displacement of each measuring point on the upper blade

Measuring point	1	2	3	4	5	6	7
Displacement(mm)	–0.19	–0.22	–0.23	–0.26	–0.29	–0.30	–0.33
Measuring point	8	9	10	11	12	13	14
Displacement(mm)	–0.38	–0.39	–0.46	–0.44	–0.43	–0.38	–0.36
Measuring point	15	16	17	18	19		
Displacement(mm)	–0.33	–0.32	–0.26	–0.24	–0.23		

Table 2. Displacement of each measuring point on the lower blade

Measuring point	1	2	3	4	5	6	7
Displacement (mm)	0.060	0.099	0.123	0.135	0.169	0.195	0.212

2.1. Finite element modeling

A model of the shearing machine is created in Solidworks and imported to ANSYS Workbench to generate a corresponding CAE model. In order to rationalize the grid amount and model generation for easy calculation, the model is adjusted according to the structure and working characteristics of shearing machine in the following way [4; 5].

1. The location and type of the welding seam between weldments are omitted.

2. Components that do not affect the rigidity and strength of the shearing machine are excluded, (such as pin holes and wiring holes).

3. Throat of the machine frame adopts arc transition.

4. The components that have little effect on the rigidity of the machine frame are also excluded (for instance, the rear stop device, stripping device, gap adjustment device and protective cover).

5. Other minor features are removed.

Fig. 4 illustrates the simplified finite element model, containing 272532 nodes and 123326 units.

2.2. Constraints and loading

The machine frame is secured to the ground with four anchor bolts; thus, they are fully constrained. The shearing machine in this paper employs hydraulic oblique blades. The Nozari formula is usually applied for calculating the shearing force of the oblique edge shears in which the blade carrier moves in a straight line [6-8]. The calculated vertical total shearing force is 170.85 kN. Based on the empirical formula $F = 0.3P$, the calculated horizontal total thrust force is 51.3 kN.

The upper blade carrier is connected to the frame through a hydro-cylinder and moves up and down along guide-way plates on the sides. As it is restrained by the cylinder and the guide, the degree of freedom of the upper blade carrier is limited to the Y direction only.

According to an empirical formula, the blank-holder force is associated with the shearing machine type, the thickness and the length of the plate. Through calculation, the average blank-holder force of each cylinder is established to make up 7.2 kN [9; 10].

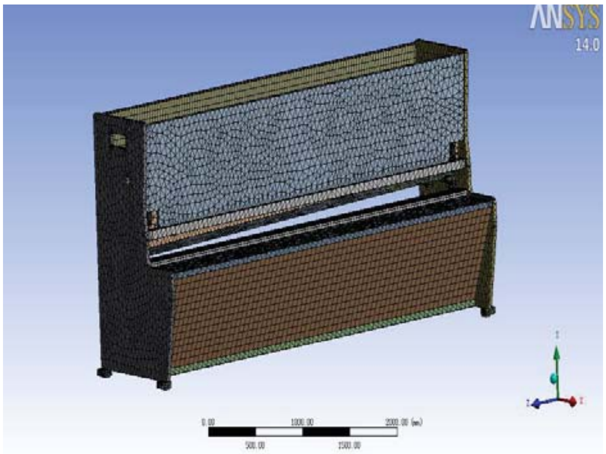

Fig. 4. Finite element model

The position of shearing force changes throughout the shearing process. In response to these changes, loads shall be imposed on each measuring point correspondingly (that is, loads and locations of the measuring points shall be mutually corresponding). There are 19 stress surfaces simulated in this paper, and each measuring point is related to 1 shearing condition, meaning there are 19 shearing conditions in total. Under each of them, the finite element calculation is conducted, with positions of other loads remaining constant. Thereby, the displacements of measuring points on the upper blade and the lower blade along the X direction are determined.

2.3. Calculation results

Finite element calculation results of the measuring points on the upper Blade. As shown in Fig. 5, in the shearing process, under the 10th shearing condition, the maximum displacement of the upper blade is –0.47 mm. It is also found that the maximum displacement of the upper blade changes along with the position of the shearing force. Thus, under each working condition, the maximum displacement occurs within the area where the shearing force is applied.

Finite element calculation results of the measuring points on the lower blade. As shown in Fig. 6, in the shearing process, on the 7th measuring point, the maximum displacement of the lower blade is 0.221 mm. Different from that of the upper blade, the maximum displacement of the lower blade barely changes with the position of the shearing force. It appears on both sides of the central part.

3. Data comparison

Table 5 compares the results of finite element simulation of the horizontal displacement of the upper blade with the experimental data.

As shown in Fig. 7, a measuring point-displacement curve is fitted based on the data provided in Table 5. It is clear that the results of the on-site test and the simulation are virtually identical.

Similarly, Table 6 compares the results of finite element simulation of the horizontal displacement of the lower blade with the experimental data.

As shown in Fig 8, a measuring point-displacement curve is fitted based on the data provided in Table 6. It is proved that the experimental and simulated data are virtually identical, with the deformation increasing from the ends towards the middle of the machine.

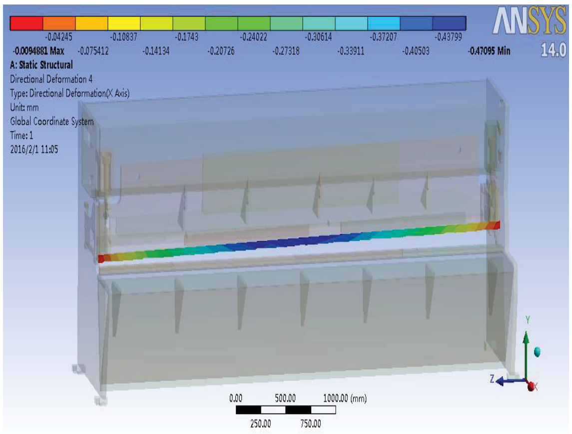

Fig. 5. Deformation of the upper blade (under the 10th working condition)

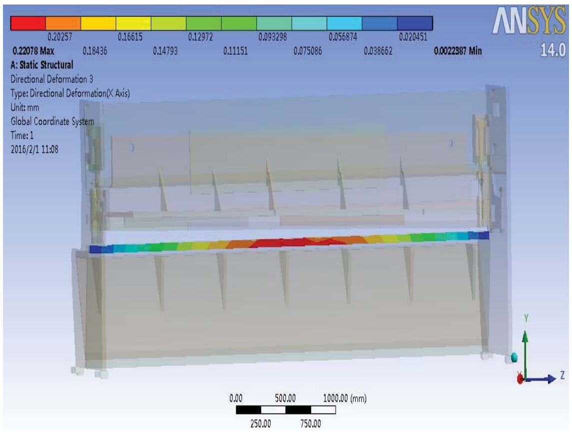

Fig. 6. Deformation of the lower blade (under the 7th working condition)

Table 3. Finite element calculation results of the upper blade

Measuring point	1	2	3	4	5	6	7
Displacement (mm)	–0.20	–0.23	–0.25	–0.28	–0.30	–0.32	–0.34
Measuring point	8	9	10	11	12	13	14
Displacement (mm)	–0.38	–0.40	–0.47	–0.46	–0.44	–0.41	–0.40
Measuring point	15	16	17	18	19		
Displacement (mm)	–0.37	–0.36	–0.28	–0.25	–0.23		

Table 4. Finite element calculation results of the lower blade

Measuring point	1	2	3	4	5	6	7
Displacement (mm)	0.073	0.112	0.132	0.150	0.181	0.196	0.221

Table 5. Comparison of the test results and the calculated results

Measuring point	1	2	3	4	5	6	7
Test result	–0.19	–0.22	–0.23	–0.26	–0.29	–0.30	–0.33
Calculation result	–0.20	–0.23	–0.25	–0.28	–0.30	–0.32	–0.34
Measuring point	8	9	10	11	12	13	14
Test result	–0.38	–0.39	–0.46	–0.44	–0.43	–0.38	–0.36
Calculation result	–0.38	–0.40	–0.47	–0.46	–0.44	–0.41	–0.40
Measuring point	15	16	17	18	19		
Test result	–0.33	–0.32	–0.26	–0.24	–0.23		
Calculation result	–0.37	–0.36	–0.28	–0.25	–0.23		

Table 6. Comparison of the test results and the calculated results

Measuring point	1	2	3	4	5	6	7
Test result	0.060	0.099	0.123	0.135	0.169	0.195	0.212
Calculation result	0.073	0.112	0.132	0.150	0.181	0.196	0.221

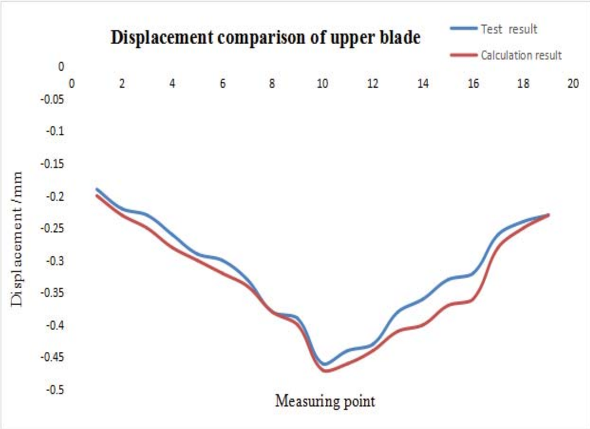

Fig. 7. Displacement comparison of the upper blade

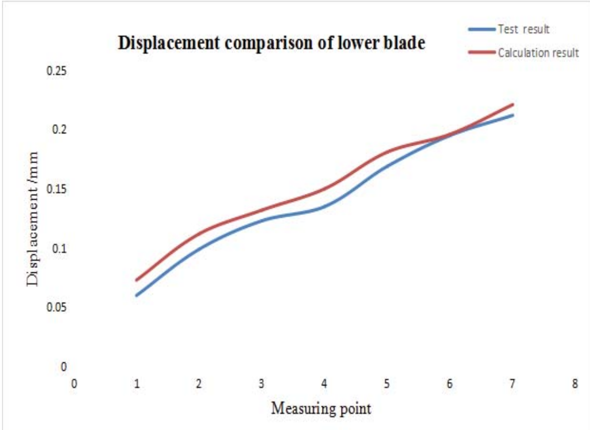

Fig. 8. Displacement comparison of the lower blade

CONCLUSIONS. Combing an experimental test with the finite element method, this paper analyzes the rigidity of the upper and lower blade carriers, concerning the shearing quality of the guillotine plate shearing machine, and compares the theoretical and experimental results. It is established that the blade deformation trend complies with that of the test data. The feasibility of finite element theory in this field is thus substantiated, thereby laying a foundation for further research on guillotine plate shearing machines.

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