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FEM Analysis on the Frame of Cross Roll Straightener for Steel Pipes

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Abstract. The intensity and rigidity of cross-roll pipe straightener frame are analyzed with the Finite Element Method (FEM) and the stress of the frame is tested. The FEM results are compared with experimental results and the accuracy and rationality of FEA results are verified. The analysis results have significant guidance to design and transformation the structural type of cross roll straightener and its frame.

Introduction

The frame is one of important part of cross roll straightener. The frame bears all of the straightening loads. The intensity and rigidity of cross roll straightener frame has the direct influence on the quality of steel pipe.

Integrated Bow Frame is widely used in Cross roll straightener for easily roller changing and maintaining. Two upright columns are added in the operation side in order to enhance the rigid of strength and reduce the weight of machine as demonstrated by Cui Fu (1983). Some research is done in strengthening theory and technology at home and abroad. Cui Fu (2005) has cleared out the correct method of calculating strengthening power on the base of differentiating elastic deformation and plastic deformation in order to get the more correct calculation of strengthening power.

The methods for getting high accuracy strengthening quality was put forward by Zhang Peiqing(2002)by using twice strengthening in general strengthener.The strengthening force calculation method for six roll strengthener was raised by Wangxiujun(2002).It is proved the calculation accuracy of this method satisfies the requests of engineering after comparing with measured results.Liqiang(1994) measured the parameters of strengtheningφ426mm.the results provided the help for theoretic analyzing pipe strengthening force of six roll strengthener.There is no research on the frame of cross-roll steel pipe straightener by FEM yet by now world wide.

The frame of φ168 cross roll straightener is made up of upper carriage, lower carriage, upright column and bow frame. The three dimensional stereo model of frame is shown on Fig.1.There are some kinds of load on the frame such as straightening force, pre-tightening force of drag bolt, forces from drive system and so on. More simplifications would be made to found the mechanical model if the intensity and rigidity of cross roll straightener frame are calculated with traditional material mechanics method. Therefore, the results will be very inaccuracy. The calculation of intensity and rigidity of cross roll straightener frame can be solved by FEM and the precision of results will be gradually improved with the function of business FEM software strengthened.

Model simplification

The three dimensional solid model of frame is found with computer aided design software Pro/E and then introduced into ANSYS. The material, elastic modulus and poisson ratio of each frame part are shown on Table1.

Table 1 Material of each part of frame

Part	upper carriage	lower carriage	bow frame	upright column Ⅰ	upright column Ⅱ
Material	ZG270~350	ZG270~350	Q235	45＃	45＃
Elastic modulus [Pa[	2.02×1011	2.02×1011	2.06×1011	2.10×1011	2.10×1011
Poisson ratio	0.3	0.3	0.25	0.3	0.3

The elements types are defined before dividing network. 20 nodes SOLID186 tetrahedron units are adopted in the upper carriage and 8 nodes SOLID45 tetrahedron units are used in the lower carriage, bow frame and two upright columns. The total unit number of frames is 302682, nodes 190856. The unit division of frames is shown on Fig.1.

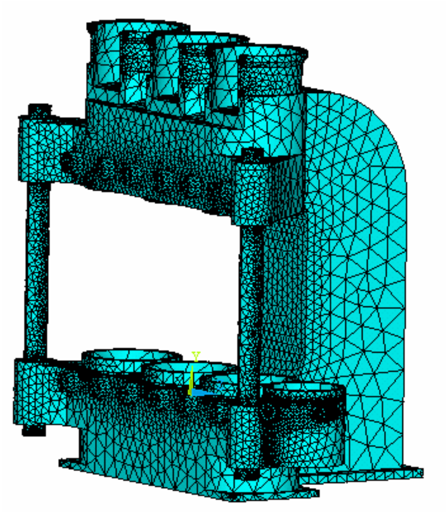


Fig. 1 Unit network division

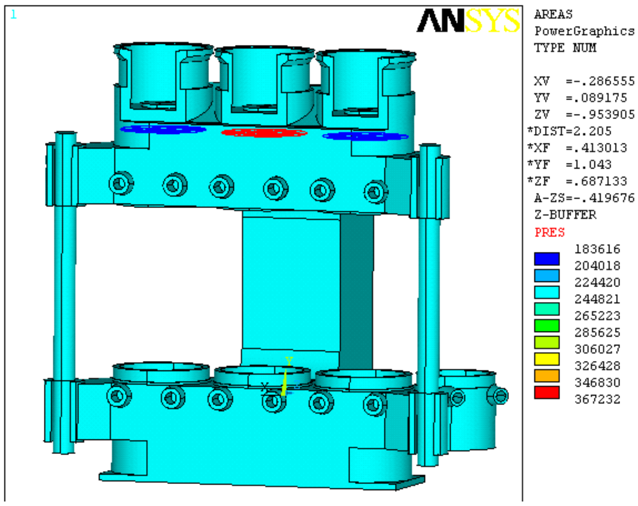


Fig. 2 The frame model after applying forces

The bottom of frames is connected with ground by bolts. This kind of connection is described as rigid constraint. Three constraints of 0 displacements along directions X, Y, Z are applied on the frame bottoms.

The average values of on-site measured loads are adopted to apply on the three upper surfaces of empty cavity mounting first, second and third straightening roller. The straightening load is respectively 74548.11N, 49096.21N, 74548.11N. Considering that the real structure of upper frame is circle surface with mounting hole of press bolts, uniform loads are applied instead of concentrated force. The value of uniform load is 183616.027Pa, 367232.054 Pa, 183616.027Pa in turn. The frame model after applying forces is shown on Fig.2.

Results analysis

The calculations are done by ANSYS10.0. The stress distribution and deformation trend of frame can be defined by stress field and displacement. The stress distribution and deformation of frame are shown on Fig.3 and Fig.4.

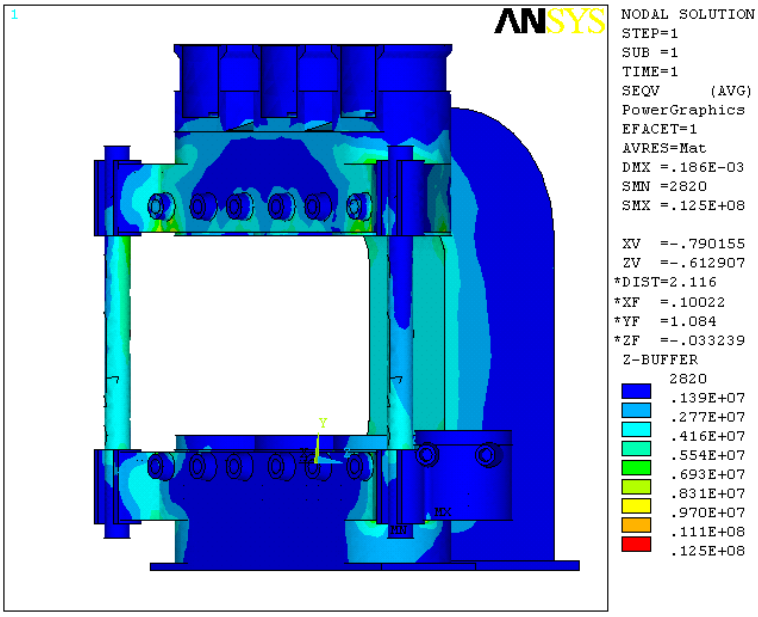
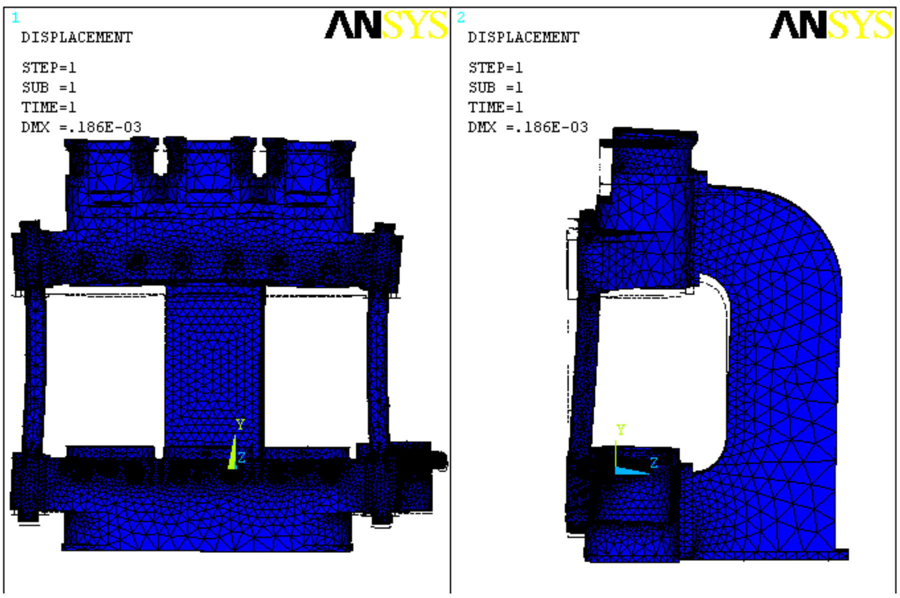


Fig. 3 The equivalent stress distribution of frame

The maximum equivalent stress of frame is 12.5Mpa. The rules of equivalent stress of frame is the followings：

(1) The equivalent stresses of upper and lower carriage are mainly compressive stress. The equivalent stresses of the area where upper and lower carriage is connected with its projecting supporting arm is tensile stress. And stress concentrations appear.

(2) The equivalent stresses of upright column inner are slightly larger than that of outer. The maximum inner stress locates on the lower of the area where the upper column is connected with lower carriage. The stress of two end of upright column is compressive stress. The outer stress of upright column change from compressive stresses to tensile stress along negative Y direction and increase gradually.



(a) front view (b) right side view

Fig. 4 The deformation of frame

(3) The equivalent stresses of inner bow frame decrease along positive Z direction. The maximum equivalent stresses locate on the area where lower carriage is connected with upright column. The maximum equivalent stress is 12.5Mpa. It is a dangerous point though it is safe. The deformations of frame mainly appear on the Y, Z direction. No deformation appears on the horizontal X direction. The upper carriage bends downward with a maximum deformation in the middle and minimum two ends. The lower carriage bends upward with small deformation. The upright columns bend to the inner side and upright columns inclined to Z direction following upper carriage with a small deformation. The upper half part of bow frame bend to Z direction with Y, Z direction displacement. There is no deformation appears on the lower half part of bow frame. The maximum displacement of frame along Y direction is 0.1556mm and Z direction 0.1502mm.

The comparison of measurement and calculation

The electrometric method is used to measure the stresses of frame refer to reference. The experiments was done with electrical measuring method, that is, strain gages were pasted on the upright column, the signal data were collected by dynamic resistance strain gage and then input to the data acquisition analysis recorder by Integral charge amplifier. The comparison of measurement and calculation are shown on Tab.2. The resulting of measurement is similar to that of calculation.

Summary

The maximum equivalent stresses of frame locate on the area where lower carriage is connected with upright column and the value is 12.5Mpa. It is a dangerous point though it is safe. The deformations of frame mainly appear on the Y,Z direction. No deformation appears on the horizontal X direction. The resulting of measurement is similar to that of FEM calculation. The reasonability and feasibility of FEM are all verified. The analysis results have significant guidance to design and transformation the structural type of cross roll straightener and its frame.

Table 2 The comparison of tests and calculations

Measurement stress [MPa]	Calculation stress [MPa]	Error [%]
2.29	2.51	8.76

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