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Research and Analysis of Shear Performance of Inclined Blade Shears Based on ANSYS

Meili YU*, **Guangchen XU**

Yingkou Institute of Technology, Yingkou, Liaoning, 115014, China

****Corresponding Author:** Meili YU, E-mail: 263042809@qq.com*

Abstract:
Nowadays, enterprise customers have higher and higher requirements for steel plate quality, and the performance research of shearing machine has been widely paid attention to. In this paper, the finite element analysis software ANSYS is used to analyze and verify the key parts of the downcut inclined blade shears. Through continuous analysis and improvement of the model, the weak points are optimized to improve the shear performance and production efficiency of the shears.

Keywords: *ANSYS; Shear quality; Shear property*

1 Introduction

As one of the key equipment in metal sheet and strip production line, the performance of shearing machine directly affects the production cost and product shearing quality. Many scholars have studied the performance of different types of shears through mathematical modeling and simulation, and achieved important results. Among them, Xu Kuan [1] et al. established a three-dimensional disk shear model based on the finite element method. The Gissmo material failure criterion is introduced to calculate and analyze the stress on the upper cutting edge under different lateral clearance, overlap amount and the upper cutting edge Angle. The results show that the upper cutting edge Angle has the most obvious influence on the stress on the upper cutting edge, and the stress on the upper cutting edge decreases with the increase of the upper cutting edge Angle. Chen Baosong [2] from Shanghai Baosteel Construction Engineering Design Co., LTD., analyzed the stamping defects caused by disk shear, and took optimization measures in the aspects of disk shear side clearance, overlap amount, material and daily maintenance, which greatly improved the strip quality and processing efficiency with remarkable results. Wang Zhenhong [3] also optimized the structure of the roller cutting shears, whose optimization object was the upper edge of the shears. In the research process, structural topology was adopted to analyze the mechanical properties of the upper edge knives, and then its optimization performance was realized. Nowadays, enterprise customers have higher and higher requirements for steel plate quality, and the performance research of shearing machine has been widely paid attention to. Based on the current research situation at home and abroad, it is concluded that there are not many researches on the downcut inclined blade shearing machine. Through analyzing different research methods and contents, it is necessary to study the performance of the inclined blade shearing machine, which is also a supplement to the past research. It also plays a certain reference role for the performance improvement and optimization design of the same type of heavy equipment.

2 Theoretical Analysis and Calculation

The object of this study is a hydraulic downcut inclined blade shear machine of an enterprise, and the frame is welding parts, so it has enough stiffness to prevent damage in the operation. When working, the upper cutting edge does not move, and the lower cutting edge moves up and down with the lower tool holder under the thrust of the hydraulic cylinder, and the work advance and fast retreat are constantly carried out, and the stroke is controlled by the hydraulic cylinder. At the same time, the lower cutting edge is installed at a small Angle to reduce the deformation degree of the cut strip. The mechanism diagram of the undercutting inclined blade shears is shown in Figure 1.

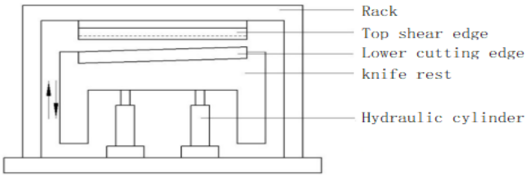

Figure 1 Schematic diagram of the mechanism of the undercutting oblique blade shears

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2.1 Calculation of shear force

Because the cutting edge is installed at an Angle, when cutting, the cutting edge and the plate contact only a part of the section. For shear force, this study uses BB Nosari's calculation formula commonly used at present [1]. The total shear force consists of three parts: P=P1+P2+P3, where P1 is the pure shear force; P2 is the bending force of the part of the upper cutting edge that has been cut during shearing. P3 is the bending force required to bend the metal near the incision.

2.2 Determination of working pressure of hydraulic cylinder

Table 1 Commonly used working pressure of various types of hydraulic equipment

Device type	General machine tool	General metallurgical equipment	Agricultural machinery, small construction machinery	Hydraulic press, heavy machinery,Rolling mill push down lifting machinery
Working pressure(MPa)	1～6.3	6.3～16	10～16	20～32

As the power source, the hydraulic cylinder transmits the thrust of the hydraulic cylinder to the cutting edge through the cooperation of various institutions, so as to complete the shear movement. In this topic, the hydraulic downward cutting oblique cutting edge shear machine adopts the hydraulic direct pushing type. Since the upper cutting edge is fixed on the frame and does not move, the hydraulic cylinder pushes the cutting edge to move up and drive the cutting edge to complete the shear. Therefore, the load that the hydraulic cylinder needs to bear in addition to the shear force should also include the gravity of the lower tool holder and the cutting edge, the material of the shear machine has been determined, the theoretical weight of the tool holder is 145kg, and the theoretical weight of the cutting edge is 5kg. The shear force is calculated and the total load required by the two hydraulic cylinders is finally obtained. According to the above table, the working pressure of the hydraulic cylinder can be selected as 14MPa.

3. Cutting Edge Optimization Design of Shearing Machine

3.1 ANSYS finite element analysis of cutting edge

The cutting edge material selected in this paper is 5CrW2Si, which has good hardenability and high temperature mechanical properties [4]. The cutting edge is tightened by 10 bolts and completely fixed on the lower tool holder. The overturning moment in the shearing process mainly acts on the bolts. When cutting the material, the cutting edge and the tool holder can be regarded as one, and the guide rods on both sides are fixed to move up and down continuously, and the plane position does not change, so the nodes on the surface of the 10 bolt holes are completely fixed. The external load on the cutting edge can be directly applied to the maximum shear force of the system pressure, so that the results can be obtained within the safe range. The moving load P (that is, the shear force) acts on the edge of the cutting edge, moving from the left side to the right side, and its magnitude and direction always remain the same.

In this analysis, the whole process is divided into 10 parts, each subject to a downward shear force, one part of the force, the rest of the force is not. The whole step is divided into 10 steps, the load from left to right in turn on the ten small planes, until the last plane, the shear step is completed. The maximum strain and maximum equivalent stress of each loading step can be obtained by calculating and analyzing the moving load acting on each small plane in turn, as shown in Table 2.

Table 2 The maximum deformation and equivalent stress of the cutting edge under each load step

Load steps	1	2	3	4	5	6	7	8	9	10
Max deformation/ 10^{-2}mm	5.16	2.58	2.58	3.24	3.28	3.22	3.24	2.56	2.60	5.12
Max equivalent stress/MPa	182	94	113	143	138	133	114	110	109	175

It can be seen from Table 2 that the distribution of shear edge strain and equivalent stress is not uniform on the whole. Since the deformation in operation belongs to elastic deformation, the distribution of the equivalent stress and equivalent strain of the shear edge can be regarded as the same trend. By comparing the shape and equivalent stress of the cutting edge under different loading steps, it can be found that the equivalent stress of the cutting edge changes most obviously at the first loading step. The maximum equivalent stress and deformation of the cutting edge occur at both ends, and the specific values are 182.2MPa and 0.0516mm respectively. The equivalent stress and deformation within the left and right ends of the cutting edge are the smallest.

Analysis of the calculation results shows that:

(1) The deformation is mainly in the horizontal Y direction, and the deformation in the X direction and the Z direction is relatively small;

(2) The blade is bent to both sides as a whole, and the deformation at the bend is relatively large;

(3) Under moving load, the maximum equivalent stress on the cutting edge is 182.2MPa, located at the bolt holes at both ends of the cutting edge, and the maximum yield limit of the cutting edge is 1920MPa, so the cutting edge is in a safe state.

3.2 Cutting edge optimization design

On the premise of meeting the design conditions, taking the strength limit as the constraint and improving the shear performance of the shear machine as the goal, the method of improving the structure of the shear edge is as follows: by improving the structure of the shear edge, the equivalent stress and deformation of the shear edge are calculated by finite element analysis. The specific methods include: increasing the thickness of the cutting edge, increasing the thickness of the bolt hole, chamfering the corners at both ends of the cutting edge, etc. Therefore, the structural improvement scheme is proposed as shown in Table 3, and the finite element analysis and verification are respectively carried out as shown in Table 4.

Table 3 Structural improvement parts of each plan

option	Improve the parts and contents
Option one	The cutting edge thickness was increased from 30mm to 35mm
Option two	Bolt hole thickened from 8mm to 14mm
Option three	Round the corners of the two ends of the cutting edge by 20mm

Table 4 Comparison of cutting edge structure improvement schemes

option	Max deformation		Max equivalent stress	
	Numerical value/mm	Rate of change/%	Numerical value/MPa	Rate of change/%
Primary structure	0.0516	—	182.17	—
Option one	0.0486	-5.81	184.22	+1.13
Option two	0.0346	-32.9	118.48	-35.0
Option three	0.0458	-11.2	177.25	-2.70

Through analysis, it is concluded that increasing the overall thickness of the cutting edge can only reduce the maximum deformation, but the maximum stress will increase, and the weight of the cutting edge will also increase, resulting in higher requirements for the hydraulic cylinder of the power plant. If scheme 2 is used to increase the thickness near the bolt hole, the maximum deformation and maximum stress will be reduced, and the amplitude is large, while the weight of the cutting edge will increase but not much, and the impact is not large. When scheme 3 is used to chamfered the corners of both ends, the maximum deformation and maximum stress will also be reduced, and the weight will be reduced, but the shear stroke will be increased, affecting the improvement of shear efficiency.

4 Optimization Design of Lower Tool holder of Shearing Machine

4.1 Statics analysis of lower tool holder

The tool holder of the shearing machine is a welding part, and the analysis will be too complicated if the relationship between the welded parts is considered, so the simplification is carried out under the condition of meeting the characteristics of the model. The tool holder material is Q235. Add constraints: The tool holder is connected to the hydraulic cylinder by bolts. Since the hydraulic cylinder works synchronously, there is no plane movement and rotation during the operation, so the nodes on the bottom bolt hole surface are completely fixed. Applied load: The external load on the shearing machine can directly adopt the maximum shear force of the system pressure, which can make the result within the safe range. The moving load (that is, the shear force) acts on the tool holder, moving from the left side to the right side, and the size direction is always unchanged. At the same time, the shear machine is subjected to upward thrust from the hydraulic cylinder. The deformation and equivalent stress distribution of each load step can be obtained through solving, as shown in Table 5.

Table 5 Maximum deformation and equivalent stress of tool rest under each load step

Load steps	1	2	3	4	5	6	7	8	9	10
Max deformation/ 10^{-3}mm	12.0	4.98	2.91	2.69	3.68	3.74	2.77	2.57	5.54	14.4
Max equivalent stress/MPa	9.96	6.28	4.74	7.38	7.51	8.25	8.50	5.27	6.12	12.2

It can be seen from Table 5 that the strain stress distribution of the tool holder is not uniform, and since the deformation during operation belongs to elastic deformation, the distribution trend of the two is the same. At the 10th loading step, the equivalent stress and strain values are the largest, which are 12.2MPa and 0.0144mm, that is, the connection between the beam and the two legs is the weak point of the structure. Figure 2 and Figure. 3 show the maximum deformation and maximum isoeffect diagram at the 10th loading step.

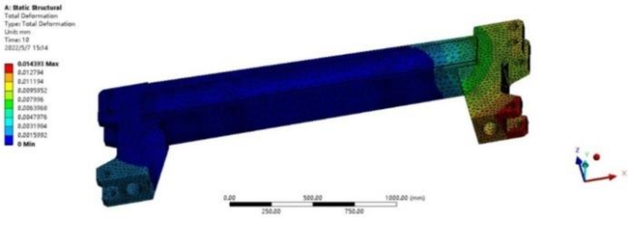

Figure 2 Tool rest deformation diagram (load step 10)

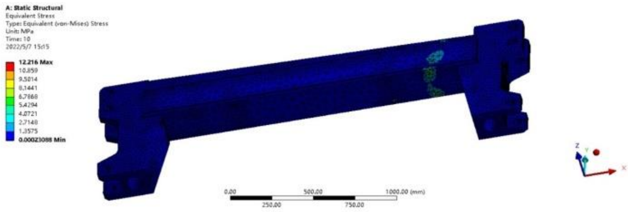

Figure 3 Effect diagram of tool rest (load step 10)

By analyzing the results, it can be found that:

(1) The deformation mainly occurs in the horizontal X direction, and the Y direction and Z direction are relatively small;

(2) The whole tool holder is bent to both ends, and the deformation on both sides is larger;

(3) The maximum equivalent stress of the tool holder is 12.2MPa, which is located at the bottom bolt hole, and the yield limit of the tool holder is 235MPa, so the tool holder is in a safe state.

4.2 Optimization design of lower tool holder

In this paper, the optimal design method of the lower tool holder is the experimental verification method. The optimization design principle is: on the premise of meeting the design requirements, the maximum equivalent stress and deformation are calculated with the strength limit and the original deformation as constraints, so as to improve the shear performance of the shear machine. The specific structural improvement methods include: increasing the overall thickness of the tool rest, increasing the width of the tool rest legs on both sides, increasing the rib plate where the tool rest body is connected to the tool rest legs, increasing the height of the tool rest main part, moving the bolt hole at the bottom of the tool rest used to connect with the base to the interior, chamfering the edge line of the bolt hole, changing the size of the bolt hole, etc. By changing the structure of the tool rest, eight improvement schemes are proposed, as shown in Table 6.

Table 6 Structural improvement areas of each program

Option	Improve the parts and contents
Option one	The overall thickness of the tool holder is increased from 200mm to 250mm
Option two	The width of the legs on both sides is increased from 390mm to 450mm
Option three	Add a 50mm wide rib plate to the place where the main body of the tool holder connects to the leg of the tool holder
Option four	The main part of the tool holder is thickened 50mm from below
Option five	Move the bolt hole at the bottom of the tool holder inward by 15mm
Option six	Invert a 2mm Angle on the edge of the bolt hole
Option seven	Change the bolt hole to M18
Option eight	Change the bolt hole to M22

It can be seen from the analysis results in Table 7 that Option 2, 3, 5, 6 and 7 cannot optimize the tool rest. For the optimization of the structure, only Option 1, 4 and 8 need to be considered, that is, the overall thickness of the tool rest needs to be thickened. Thickening below the main part of the tool rest; Increase the size of the bolt hole. One of them can reduce the amount of deformation, but will increase some of the maximum stress, and will make the weight of the tool holder larger, thereby increasing the requirements for the hydraulic cylinder; Scheme four can greatly reduce the amount of deformation, but it will also increase some maximum stress, and the weight of the tool holder will also increase, but less than scheme one; Plan eight can reduce the amount of deformation, and can reduce the maximum stress, but the amplitude is not very large.

Table 7 Comparison of cutting edge structure improvement schemes

Option	Max deformation		Max equivalent stress	
	Numerical value/mm	Rate of change/%	Numerical value/MPa	Rate of change/%
Primary structure	0.0144	—	12.2	—
Option one	0.0136	-5.56	12.4	1.64
Option two	0.0146	1.39	14.8	21.3
Option three	0.0144	0	13.7	12.3
Option four	0.0114	-20.8	12.3	0.82
Option five	0.0157	9.03	12.9	5.74
Option six	0.0144	0	20.8	70.5
Option seven	0.0148	2.78	18.2	49.2
Option eight	0.0141	-2.08	12.0	-1.64

5 Conclusion

Through the analysis of the key parts of a company's bevel blade shears, it is concluded that in order to achieve the goal of improving the shear performance of the hydraulic bevel blade shears, the structure of the main parts of the hydraulic bevel blade shears can be improved by the following methods:

(1) Increase the thickness near the bolt hole of the cutting edge without affecting the installation of the cutting edge; Appropriately increase the overall thickness of the cutting edge with the thickness near the bolt hole to prevent excessive thickness from increasing the requirements on the hydraulic cylinder; The corners of both ends of the cutting edge are rounded in a small amplitude to prevent excessive chamfering from increasing the shear stroke and reducing the shear efficiency;

(2) The thickness under the main part of the tool holder is mainly increased without affecting the installation of the cutting edge; At the same time, the diameter of bolt hole should be increased appropriately. The overall thickness of the tool holder can also be thickened, but not too much to prevent the requirements of the hydraulic cylinder from being too high;

(3) Increase the thickness of the base where the cutting edge is fixed without affecting the installation of the cutting edge, increase the rib at the connection between the frame beam and the two columns, and appropriately increase the overall thickness of the frame, the width of the frame two columns and the height of the

frame beam to prevent excessive increase in the weight of the frame and increase its manufacturing cost.

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