Effect of Shear Clearance on Shear Section Quality and Microscopic State of Deformation Zone of Non-oriented Electrical Steel Sheet

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Abstract. In this paper, the non-oriented electrical steel with thickness of 0.50mm is subjected to oblique cutting test under the clearance of 2% -12% of the thickness of the plate. The shear fracture surface is examined by SEM and other approach. The experimental results show that the area of plastic deformation zone increases and the microstructure flow becomes violent sourced by the shear clearance increases, which also can lead the height of the rollover, the fracture zone, the fracture angle and the burr become larger. In addition, the shear clearance increases, the depth of the hardened layer increases, the maximum hardness increases first and then decreases, and the maximum hardness value appears near the starting point of the fracture. When the lateral clearance is 3%-5%, the shear section is smooth , shear plastic deformation zone and degree of work hardening is small.

Introduction

Soft magnetic electrical silicon steel is an important soft magnetic alloy for power electronics and military industry, where are use as the core of various motors, generators and transformers[1].In the process of electrical steel shearing, the burr, warping, microstructure deformation and work hardening will cause the cutting edge damage of the electrical steel, which will affect the performance of the motor and transformer. So it is very important to explore a new technology to reduce the edge damage and burr.

Clearance is the main influencing factor on the shear zone, burr and punching force [2].At present, many scholars have studied the shearing craftwork and forming mechanism. Li is found that the tool clearance and edge angle radius increases will cause the increase of section burr in shear test on aluminum plate. [3].S.K.Maiti et al. are through the shear processing under different clearance found the influence of lateral clearance on shear plastic deformation, work hardening, section morphology and shear force[4-5].Chen study found that the sub-grains of the plastic deformation zone were elongated and rotated along the shear direction, and strain localization is very intense, especially in the vicinity of the upper and lower edge[6].

However, the effect of shear clearance on the quality of electrical steel sheet is lack of in-depth research. In this paper, the effect of shear clearance on the shearing surface morphology, microstructure deformation, and work hardening are studied by experiments.

Test Materials and Methods

Test materials The electrical steel with thickness of 0.50mm is use for the test, the microstructure showning in Figure 1. The grain structure is equiaxed ferrite, and the phase structure belongs to α-Fe. The lattice structure is body-centered cubic (BCC) which the average grain size is 36.7μm, where have 15-20 grains in the thickness direction.

Test methods. Slanting blade transverse shear cutting principle shown in Figure 2. Two cutting tools were installed in the upper and lower two turret, the lower edge of the knife blade placed on the blade relative to the lower edge of the blade angle α=1°, oblique cutting edge shear in the shear process, each moment the blade only cut a small part of width of plate.

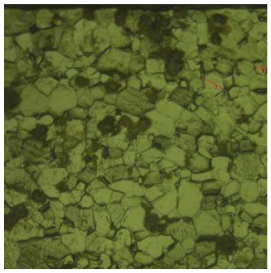

Fig.1 Microstructure of electrical steel

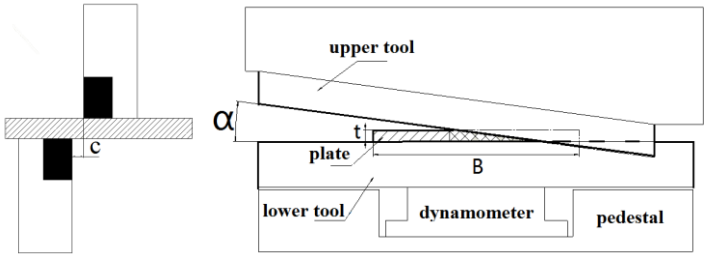

Fig.2 Oblique shear principle:(A) Sectional view ;(b) Front view

In the KFJG-400 precision oblique cutting shear bed for shear processing, tool lateral clearance of 0.01-0.065mm, the processing parameters shown in Table 1.

Table1 The exprimental parameters of shearing

Lateral clearance （μm）	10	15	20	25	30	35	40	45	50	55	60
Relative lateral clearance c/t （%）	2	3	4	5	6	7	8	9	10	11	12

The Shear surface was obtained by SEM and Taylor Hobson white light interferometer. The cross-section was obtained by cold mosaic and the cross-section was observed under the super-depth microscope. The cross-section sample after polishing was carried out to observe the microstructure of the plastic deformation zone at the shear edge.

In order to study the work hardening behavior of the processing, the cross section was obtained by line cutting. After the cold mosaic polishing, the hardness of the section was measured by HXD-1000TM micro-Vickers hardness tester, the test force was 0.025gf, holding time 10s. In the shear section along the shear direction evenly measured hardness, measuring point spacing 0.05mm, hardness measurement bitmap is Fig. 3.

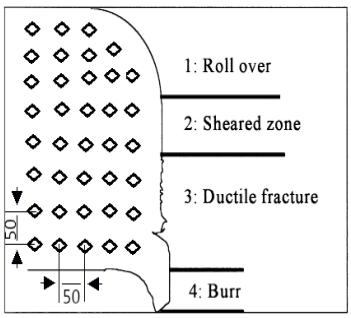

Fig.3 Hardness distribution map

Results

The effect of shear clearance on the shear morphology characteristics Fig. 4 shows the shear surface and cross section topography at different relative clearance c/t. The relative clearance c/t is the percentage of the shear clearance and the thickness of the sheet. It can be seen from Fig. 4 that there are clearly boundary between the shear zone and the fracture zone,

and the height of the shear zone is larger than the fracture zone. In the relative clearance of 3% and 5%, the burr is very small. With the increase of the shear clearance, the oblique angle appears and the burr gradually increases. There is a clear oblique angle and burr in the relative clearance of 10%.

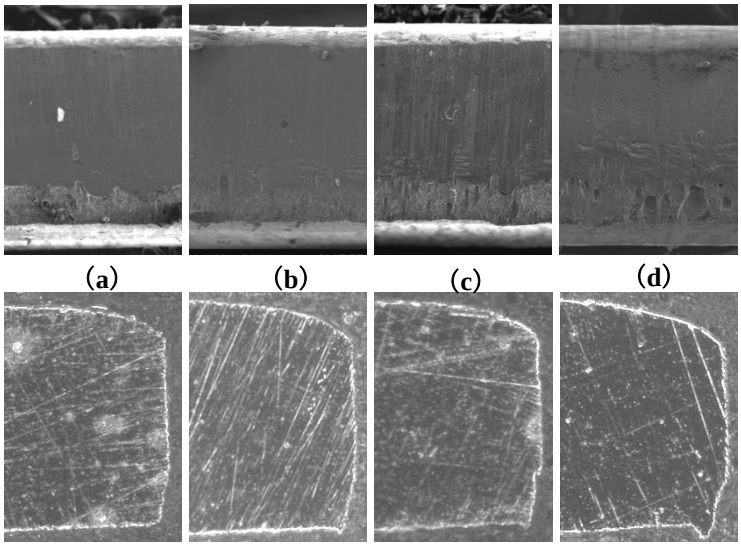

Fig. 4. Shear surface and cross section:(a) c/t= 3%;(b) c/t = 5;(c) c/t= 7%;(d) c/t= 10%

It can be seen from Fig. 5 that the height of the shear zone decreases gradually with the increase of the clearance, but the height of the fracture zone, rollover and burr increase gradually. When the relative clearance is 2%, the height of the shear zone is 290μm, accounting for 58% of the thickness of the sheet; and when the relative clearance is 12%, the height of the shear zone is 185μm only 37% of the sheet. When the relative clearance clearance increase 2% to 12%, the height ratio of sheet thickness of the rollover and fracture zone from 16% and 26% up to 27% and 436%. This shows that the shear clearance ~~changes~~ directly affect the quality and morphology of the shear section.

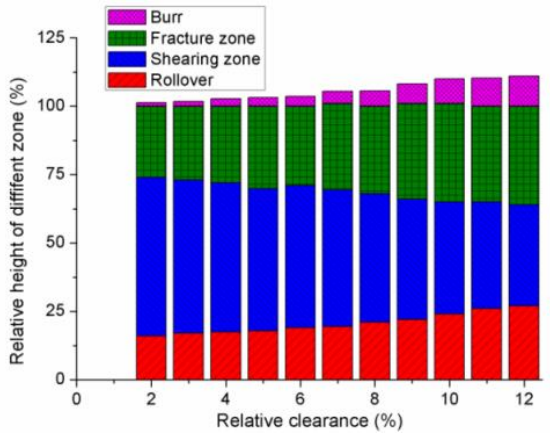

Fig 5. The height of each morphology characteristic under different shear clearances

The effect of shear clearance on hardening of shearing edges During the shearing process, the local hardening of the shear edge of the plate is complicated physical process such as grain torsional deformation, dislocation plug, and subgrain formation[7].In order to study the effect of different shear clearance on shear hardening, the hardness of each section of shear edge is measured by microhardnes tester.

Fig. 6 shows the hardness values generated at different shear clearances. The hardness distributions on the plastic deformation zone are basically same in different shear clearance, and the microhardness values from the rollover to the burr are increased first and then decreased, and from the fracture surface to the matrix are decreased significantly, The work hardening zone was "semi-oval" distribution. The degree of hardening of the shear edge of the plate is also different, the greater the shear clearance, the greater the hardening zone and degree of hardening.

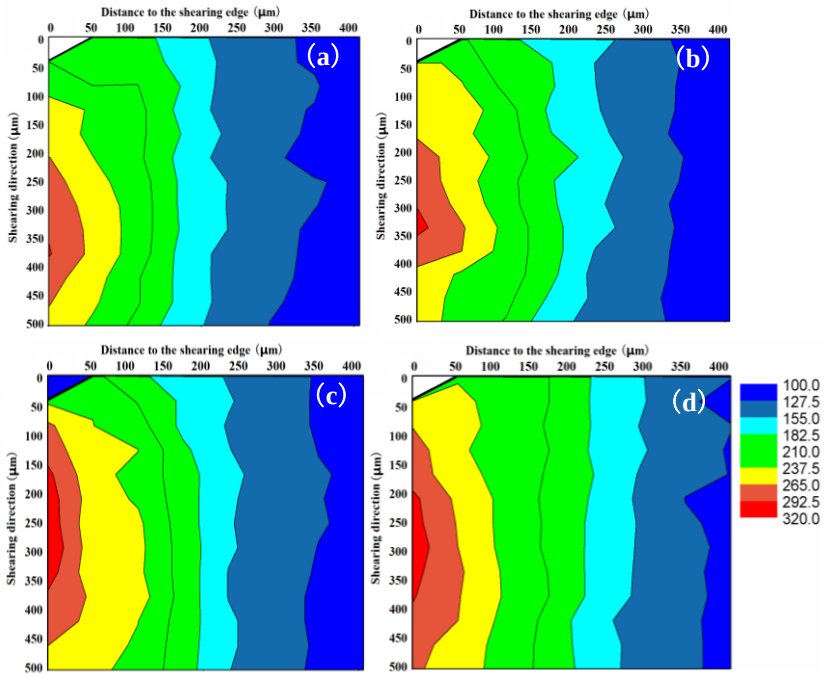

Fig. 6 Micro-hardness of different clearances:(a) c/t= 3%;(b) c/t = 5;(c) c/t= 7%;(d) c/t= 10%

In order to study the work hardening of the characteristic at different shear clearance, the hardness values at 50 μm from the shear edge are selected, the hardness changes from the board surface to the burr of the sheet are shown in Fig.7. That the hardness value gradually increases from the rollover of the sheet, and then gradually reduced to the burr side.

Fig. 8 is the hardness change curve of the distance shear edge. As the distance from the shear edge increases, the hardness gradually decreases to the hardness of the matrix. As a whole, the greater the clearance, the greater the microhardness near the edge of the shear.

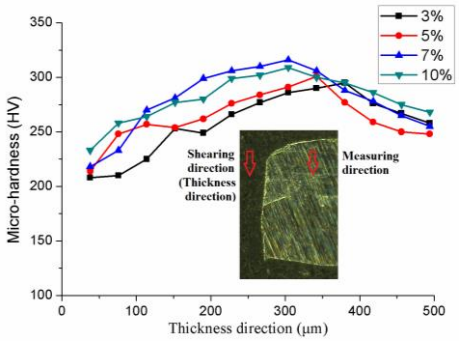

Fig.7 Micro-hardness of shear direction

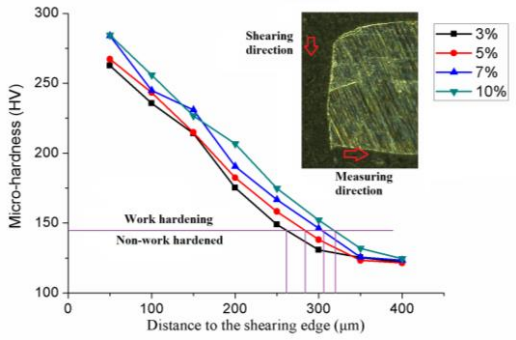

Fig.8 Micro-hardness curve Distance shear edge

Conclusion

(1) The clearance has an important influence on the materal flow, work hardening and shear surface morphology. The area of plastic deformation zone increases and the microstructure flow becomes violent sourced by the shear clearance increases, leading the height of the rollover , fracture zone, burr and fracture angle increases , the shear zone decreases.

(2) With the shear clearance increases, the depth of the hardened layer increases, the maximum hardness increases first and then decreases. And the maximum hardness value appears near the starting point of the fracture.

(3) For non-oriented electrical steel,when the lateral clearance is 3%-5%, the shear section is smooth , shear plastic deformation zone and degree of work hardening is small.

Acknowledgements

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References

[1] Z. Z. He, Y. Zhao, H. W. Luo, Electrical steel , Beijing: 2012,pp.1-14.

[2] Y. Okamoto, N. Kataoka, H. Tahar, Micro Cutting of Thin Copper Plate by Fiber Laser with Laval Nozzle, J Laser Micro Nanoen, 1.3 (2006) 243-246.

[3] M. Li. An experimental investigation on cut surface and burr in trimming aluminum autobody sheet, Int J Mech Sci, 42 (2000) 889-906.

[4] S. K. Maiti, A. A. Ambekar. Assessment of influence of some process parameters on sheet metal blanking, J Mater Process Tech, 102 (2000) 249-256.

[5] Z. Tekiner, et al. An experimental study for the effect of different clearances on burr, smooth-sheared and blanking force on aluminium sheet metal, Mater Design, 27 (2006) 1134-1138.

[6] Z. H. Chen, L. C.Chan, T. C.Lee, An investigation on the formation and propagation of shear band in fine-blanking process, J Mater Process Tech, 138 (2003) 610-614.

[7] M. A. Meyers, Y. B. Xu, Q. Xue, et al. Microstructural evolution in adiabatic shear localization in stainless steel, Acta Mater, 51 (2003) 1307-1325