Simulation of Micro Blanking Process of Square Hole with Fillet Based on DEFORM-3D

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Keywords: Micro blanking DEFORM-3D Burr Blanking clearance.

Abstract. Simulation of Micro Blanking Process of Square Hole with Fillet was carried out based on DEFORM-3D. The ratio of burnish depth, shear depth and fracture depth to sheet thickness under different relative blanking clearance (c/t) was analyzed. The results show that the burnish depth at the fillet increases generally with the increasing blanking clearance, while the burnish depth at the straight-line segment firstly increases and then decreases with the increasing blanking clearance. The relationship between burr height and relative blanking clearances (c/t) was discussed. Results show that the average burr height increases with the increasing blanking clearance.

Introduction

With the technology developing, demands for micro products are growing. Miniature components are finding more and more applications in aerospace, military, medical and other fields. Micro blanking technology got a continuous development in recent years as a kind of high efficient, precision micro processing technology. Deformation process of micro blanking is different from that of traditional blanking process. Traditional theories of plastic deformation can no more explain phenomenon in micro blanking process [1]. A new theory system of micro blanking therefore gradually develops.

It is difficult to observe the process of the blanking process in micro scale, due to the narrow deformation zone and instantaneous effect. As a result, recording and analyzing the blanking process usually require very expensive and special equipment, consume huge amount of labor power as well as material and financial resources, and will extend the cycle of the technological design. Hence, a new research method was proposed to replace the traditional research methods.

With the continuous development of computer hardware and software, computer simulation technology has been widely used in various engineering fields [2]. The DEFORM-3D software is particularly prominent for simulating the metal plastic forming.

This paper simulated the micro blanking process of square hole with fillet using DEFORM-3D. The ratios of burnish depth, shear depth, and fracture depth to sheet thickness were investigated under different blanking clearances. Further, burr distribution at rounded corners and line segment was also discussed.

Finite element modeling (FEM)

Geometric modeling. AutoCAD software and CREO software were used to model the geometry of punch, bottom die, sheet and blank holder. Because the model is central symmetrical, the 1/4 model was adopted for reducing the amount of computations. Horizontal section size of punch, die and other components were designed with AutoCAD software firstly. The punch model was designed with a length of 0.5 mm and with a fillet radius of 0.1 mm, while die geometry was chosen as variables for producing different clearance ranging from 5% to 15% with the increment of 1% showed in Fig. 1. A 3D model was then built utilizing the CAD drawing and imported into DEFORM-3D, assembled exactly. The assembled model is displayed in Fig. 1.

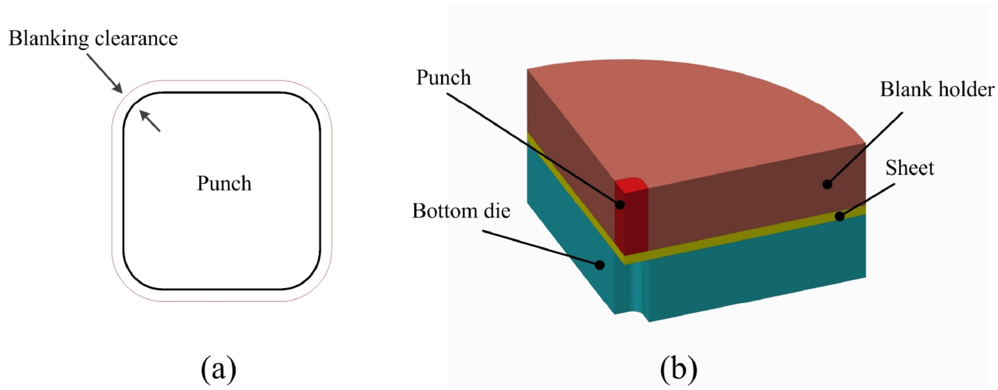

Fig. 1. Geometric model (a) the sketch map of punch and blanking clearance (b) the assembled model

FEM pre-process. Simulation of the micro blanking process of AISI1010 was carried out. A series of relative blanking clearances ranging from 5% to 15% with an increment of 1% were chosen for analyzing the relationship between the ratio of each depth to sheet thickness and the relationship between blanking clearance and distribution of edge burr. The sheet material was set as AISI1010, also named 10# steel. In this simulation, the equivalent plastic strain, equivalent plastic strain rate and temperature are a function of flow stress as shown in Eq.1.

$$\bar{s} = \bar{s}(\bar{e}, \dot{\bar{e}}, T). \tag{1}$$

where $\bar{s}$ is flow stress, $\bar{e}$ is equivalent plastic strain, $\dot{\bar{e}}$ is equivalent plastic strain rate and T is temperature.

The specific components of AISI1010 are shown in Table 1.

Table 1 AISI1010 composition

Element	C	Si	Mn	S	P	Gr	Ni	Cu
Min	0.07	0.17	0.35					
Max	0.14	0.37	0.65	0.04	0.35	0.15	0.25	0.25

The young's modulus, yield strength, Poisson's ratio and the ultimate tensile strength for AISI1010 is 210 GPa, 218 MPa, 0.3 and 495 MPa respectively. And the parameters used in FEA of micro blanking are shown in Table 2.

Table 2 Parameters used in FEA of micro blanking

Parameters Used in Simulations	**Value**
Sheet material	AISI1010
Flow stress mode	$\bar{s} = \bar{s}(\bar{e}, \dot{\bar{e}}, T)$
Sheet thickness	0.1[mm]
Material model	Plastic
Fracture model	Normalized Cockcroft & Latham
Punch mode	Elastic
Punch material	WC
Punch movement	10 [mm/s]
interaction	Cold Forming 0.12
Clearance	5%-15%

FEM Post-process. Two terminals at the straight-line segment and the midpoint of the fillet were chosen to measure the ratio of burnish depth, shear depth, and fracture depth to sheet thickness. The three depths were measured from the cross section, divided by the thickness and the ratio could be obtained. The burr height along the blanking edge was measured after the simulation. Five measuring points were assigned along the line segment on both sides while ten measuring points were assigned uniformly along rounded corners of the transitional period. Punch edges were marked in CAD drawing to get the plane coordinates of each point. After that, burr heights of each point were measured using the scale tool.

Results and discussion

The analysis of burnish depth, shear depth and fracture depth. The burnish depth, shear depth and fracture depth could be observed from each cross section under different blanking clearances [3]. The cross section at the straight-line segment under 8% relative blanking clearance was displayed in Fig. 2.

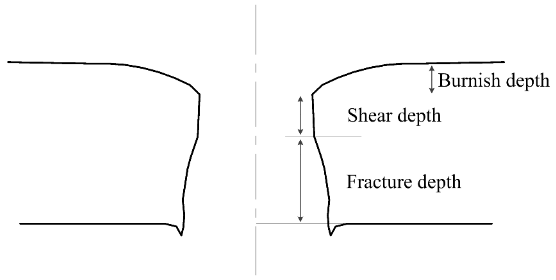

Fig. 2. Cross section at the straight-line segment under 8% relative blanking clearance (c/t)

The burnish depths under different clearances could be obtained through the simulation. Then the ratio of burnish depth to sheet thickness was calculated. The ratio of the burnish depth to sheet thickness at the straight-line segment and at the fillet could be obtained as shown in Fig. 3(a). The ratio of shear depths to sheet thickness under different relative blanking clearance could be obtained in the same way as shown in Fig. 3(b). Also the ratio of fracture depth to sheet thickness with the increasing blanking clearance is presented in Fig. 3(c).

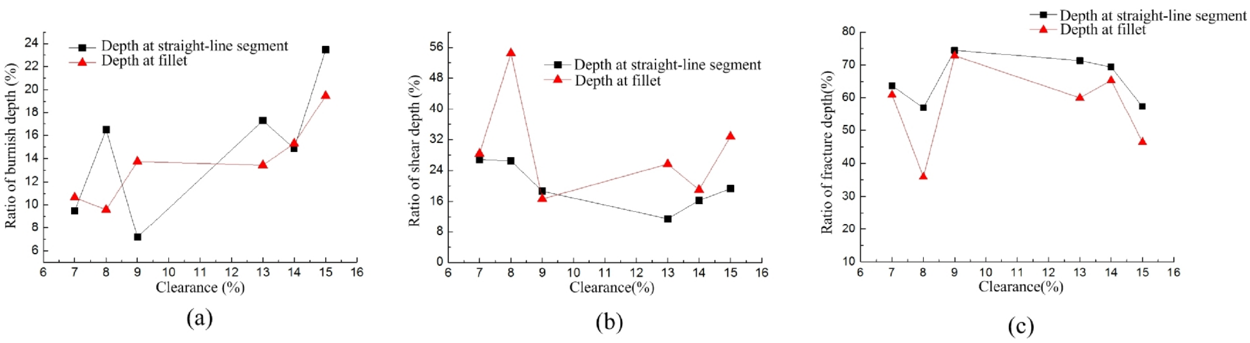

Fig. 3. The ratio of different depth to sheet thickness under various relative blanking clearance (c/t)
(a) the ratio of burnish depth to sheet thickness under various relative blanking clearance
(b) the ratio of shear depths to sheet thickness under various relative blanking clearance
(c) the ratio of fracture depths to sheet thickness under various relative blanking clearance

Fig. 3(a) shows that the burnish depth at the fillet increases generally with the increasing blanking clearance, while the burnish depth at the straight-line segment firstly increases and then decreases with the increasing blanking clearance. From Fig. 3(b), it can be seen that the shear depth firstly decreases and then increases generally with the increasing blanking clearance under both the fillet and the straight-line segment. In Fig. 3(c), the fracture depth firstly decreases, then increases and at last decreases with the increasing blanking clearance at both the fillet and the straight-line segment.

The 8% relative blanking clearance was found to be the best clearance, under which the shear depth got the maximum value and the fracture depth got the minimum value.

The analysis of burr height under uniform blanking clearance. Distance between the mentioned measuring points was used as the ordinate, while the burr heights were used as abscissa. Fig. 4 displays the burr height-distance diagram of the micro blanking process with a relative blanking clearance (c/t) of 15%.

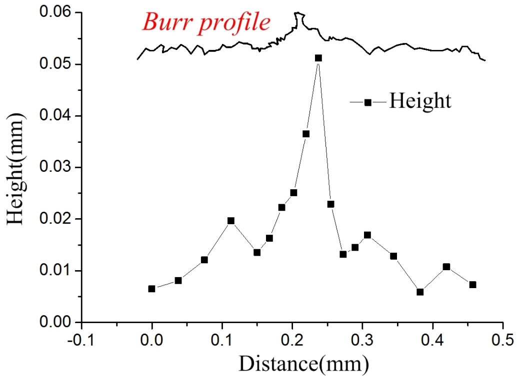

Fig. 4. Burr height-distance curve under 15% blanking clearance

It can be observed that the peak height of the burr appears at the fillet and the average burr height at the fillet is bigger than that at the straight-line segment. The burr distribution under other clearances is similar to this rule.

Under different relative blanking clearances (c/t), average burr height at the straight-line and the fillet was obtained using DEFORM as shown in Fig. 5(a). Fig. 5(b) displays the average burr height along the hole-edge under relative different blanking clearances (c/t).

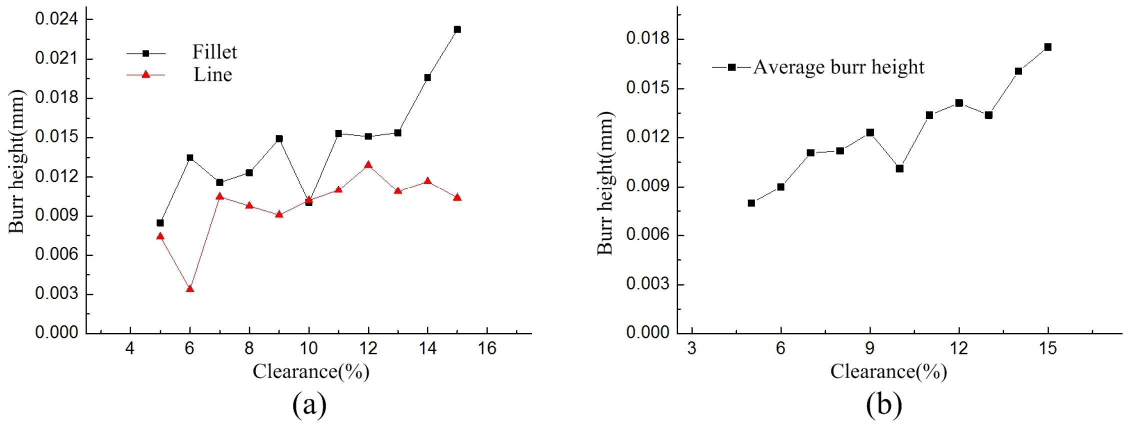

Fig. 5. Burr height-clearance diagram
(a) average burr height-clearance diagram on fillet and straight-line segment
(b) average burr height-clearance diagram

In Fig. 5(a), the average height at the fillet increases significantly with the increasing blanking clearance, while average burr height at the straight-line segment increases a little. Fig. 5(b) shows that the average burr height increases linearly with the increasing blanking clearance. The increase of the overall average height was mainly attributed to the increasing of burr height at the fillet.

Conclusions

The micro blanking process of square hole with fillet was simulated using DEFORM-3D software. Burnish depth, shear depth and fracture depth at the fillet and the straight-line segment under different relative blanking clearance (c/t) was analyzed. Results show that the burnish depths at the fillet increase generally with the increasing blanking clearance, while the burnish depths at the straight-line segment firstly increase and then decrease with the increasing blanking clearance. The shear depths at both the fillet and the straight-line segment firstly decrease and then increase generally with the increasing blanking clearances. The fracture depths firstly decrease, then increase and at last decrease with the increasing blanking clearance at both the fillet and the straight-line segment. The 8% relative blanking clearance was found to be the best clearance, under which the shear depth got the maximum value and the fracture depth got the minimum value.

Burr heights at the fillet and at the straight-line segment under different blanking clearances were obtained. Results show that the average burr heights increase with the increasing blanking clearance. And the average burr heights at the fillet are greater than that at the straight-line segment under the same clearance.

Acknowledgements

This work was financially supported by National Science and Technology Major Projects of China (Grant No. 2013ZX04001-091-1).

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