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Effect of Tool Angle on New Shearing Method of 1100 Aluminium Sheet

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Sheet metal cutting is a general metal forming. A new flexible shearing method has been invented for sheet metal by authors. It has been named as MM-shearing method. There are several advantages in the method, for example small cutting force, beautiful cut surface, no shear droop and small burr on the cut surface. Moreover, the cutting speed is high, and the equipment based on the method is inexpensive. The structure of MM-shearing method is very simple as it uses only a tool, blankholder and die except the moving equipment. There are some important parameters in the MM-shearing method, such as tool angle, clearance between the tool and die, sheet thickness and cutting speed. In this paper, a series of experiment was carried out to examine suitable tool angle. The experimental material of sheet metal is 1100 aluminium sheet (Japanese Industrial Standard), which is widely used in sheet metal forming. The cutting force, ratio of sheared surface and fractured surface, burr height, surface roughness are examined experimentally. The principle and characteristic of MM-shearing method are made clear in terms of the tool angle in this paper.

Keywords: *aluminium sheet, shearing, tool angle, cutting force*

1. Introduction

Shearing with shear edge or with punch and die, slitting, lasers and high pressure jet water are used in the manufacture industrial field, for cutting of sheet metal [1-4]. When shearing with shear edge is adopted to cut sheet metal, the edge must be satisfactorily long to sheet metal length. When shearing with punch and die are used to cut sheet metal, the edge length is not enough for the sheet length. Therefore, the punch shears sheet metal several times corresponding to the sheet length, and several lines of discontinuity are observed on the cut surface. Slitting is suitable not for short production runs, but for the long ones. When lasers are used to cut sheet metal, the expensive equipment to generate lasers and assist gas are needed, and there are small regular jagged lines on the cut surface. When high pressure jet water is used to cut sheet metal, the equipment which generates high pressure water becomes expensive, and the cutting speed becomes low.

The authors have invented a new flexible shearing method for sheet metal. This new method has been named as MM-shearing method. In the case of sheet metal cutting by tool, the sheet metal is cut by drop of the tool in the thickness direction with shearing machine or press machine. On the other hand, the sheet metal is cut by moving of the tool to the length direction using MM-shearing method. There is different mechanism between conventional shearing and MM-shearing method in the tool moving direction.

There are several advantages in the MM-shearing method. For example, MM-shearing method can cut sheet metal in small cutting force, high cutting speed and low cost for cutting production. Moreover, in an ideal condition, sheet metal has beautiful cut surface which no shear droop and small burr by the method. The principle and characteristic of the MM-shearing method are described in this paper. A series of experiments was carried out to examine suitable tool angle which is inclination of tool edge. The effect of tool angle on cutting force, cut surface, burr height, surface roughness and so on are discussed, and the mechanism of the MM-shearing is made clear in this paper.

2. Experimental Procedure

2.1 Principle of MM-shearing method

The schematic illustration of MM-shearing method is shown in Fig. 1.The shaded part of tool and die is the cutting edge. Firstly, sheet metal which will be cut is held firmly by blank holder and die. When fixed sheet metal is moved toward the arrow direction in Fig. 1, it is pushed toward lower direction by the tool. The sheet metal which is remained between blank holder and die is cut by cutting edge of tool toward length direction. On the other hand, the chip is cut by cutting edge of die. The structure of MM-shearing method is very simple which using only a tool, blank holder and die except the moving apparatus.

2.2 Experimental equipment and conditions

The photograph of the experimental equipment is shown in Fig. 2. A milling machine is used for feeding the sheet metal in horizontal direction. The moving speed is constantly the same at cutting speed v_s of 170mm/min. When the sheet metal is cut, the tool receives horizontal and vertical forces. The horizontal force F_h and horizontal force F_v are measured by two load cells as shown in Fig. 2.

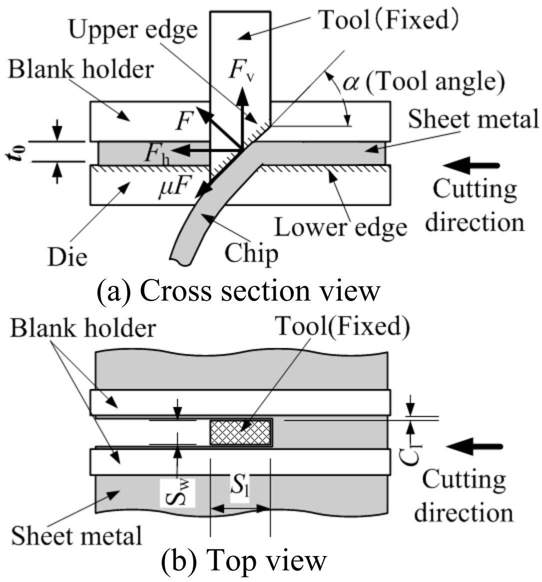


Fig. 1 Schematic illustration of MM-shearing

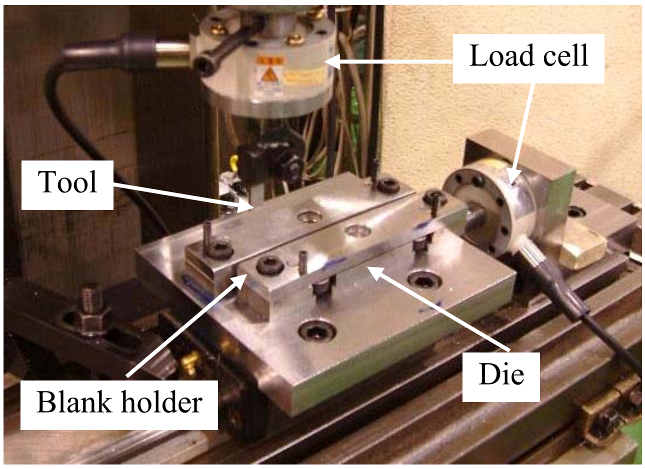


Fig. 2 Photograph of experiment equipment

The materials of the tool, blank holder and die are SKD11 (JIS, Japanese Industrial Standard) which is quenched. The length of tool S_l is 16.0 mm, the width of tool S_w is 3.2 mm. The tool angle α is from 10 to 60 degrees at every 5 degrees. The experimental material of sheet metal is A1100 (JIS). The length of test piece of sheet metal l is 100 mm. The width of test piece of sheet metal w is 80 mm. The thickness of test piece of sheet metal t_0 is 1.5 mm. The clearance C_l is constantly 0.1mm between the tool and die. The experiment conditions are summarized in Table 1.

Table 1 Experiment conditions

Tool	Length S_l / mm	16
	Width S_w / mm	3.2
	Tool angle α / degrees	10,15,20,25,30, 35,40,45,50,60
	Material	SKD11(JIS)
Sheet metal	Length l / mm	100
	Width w / mm	80
	Thickness t_0 / mm	1.5
	Material	A1100(JIS)
Clearance C_l / mm		0.1
Cutting speed v_s / mm/min		170

3. Experimental Result and Discussion

3.1 Relationship between shearing distance and cutting force

Fig. 3 shows variation of horizontal cutting force F_h during shearing. Fig. 4 shows variation of vertical cutting force F_v during shearing. The cutting forces F_h and F_v rise rapidly when cutting begins. Afterwards, the cutting forces F_h and F_v become an almost constant value in the cutting progresses. When cutting ends at stroke s=100 mm, the cutting forces F_h and F_v descend rapidly, and become 0kN. The same situation is observed between shearing distance and the cutting force regardless of variation of tool angle. The cutting force is a constant value regardless of the shearing distance, except when cutting begins and cutting ends. So the MM-shearing method is a stable cutting method of sheet metal.

3.2 Effect of tool angle on cutting forces

The effect of tool angle on cutting forces F_h, F_v, F is shown in Fig. 5. The cutting forces F_h, F_v are average value measured by load cells while shearing distance s increased from 20 to 80 mm. The horizontal cutting force F_h becomes small within the range from 15 to 45 degrees in tool angle. The vertical cutting force F_v becomes small within the range from 20 to 60 degrees in tool angle.

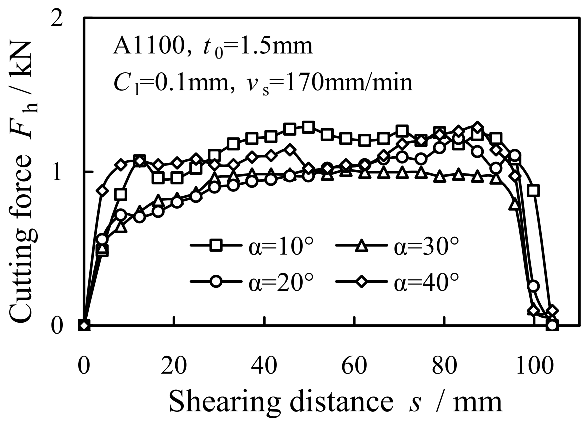


Fig. 3 Relation between shearing distance and horizontal force

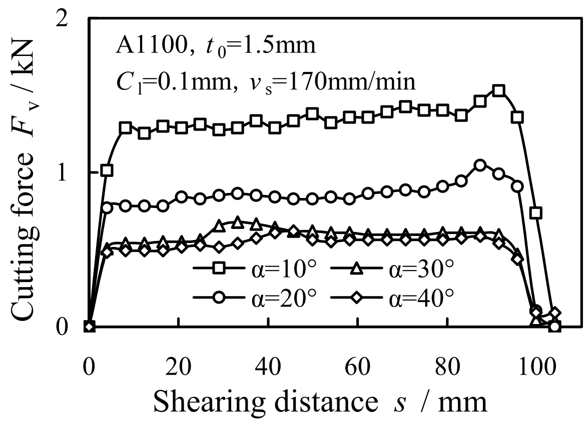


Fig. 4 Relation between shearing distance and vertical force

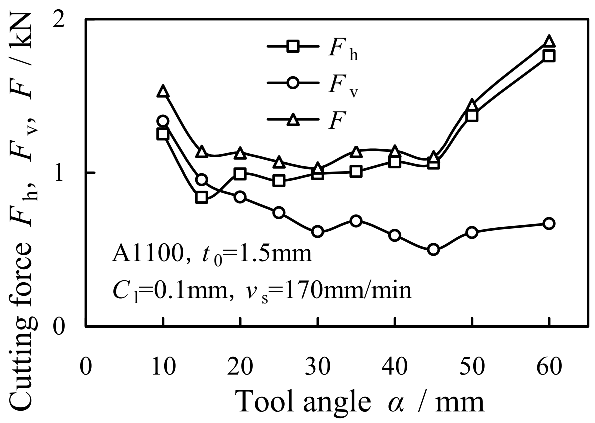


Fig. 5 Effect of tool angle on cutting force

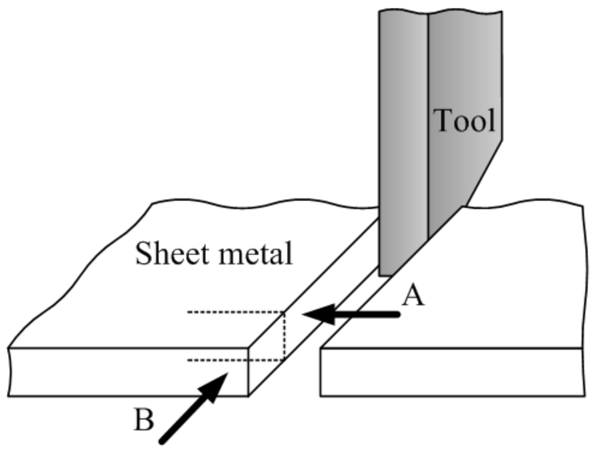


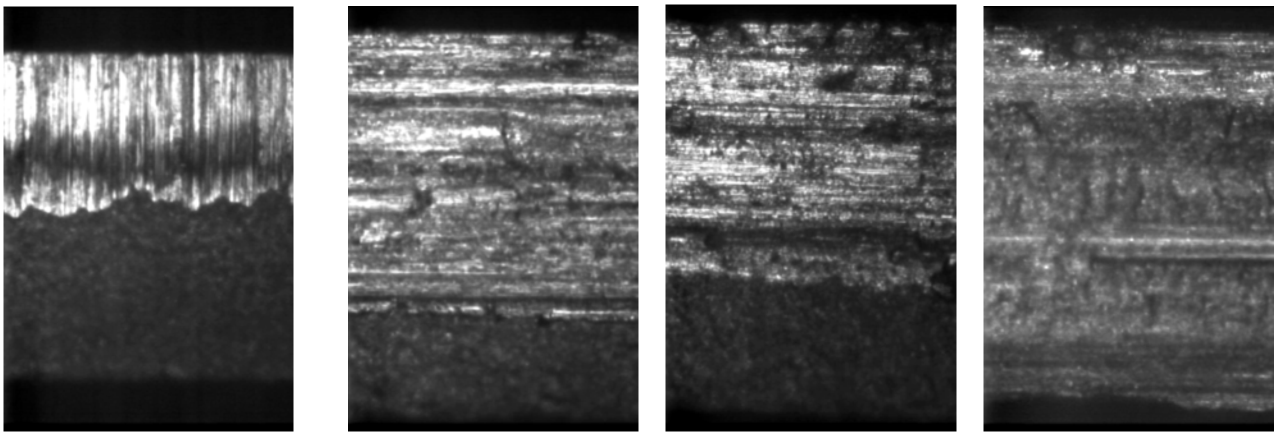
Fig. 6 Directions of observation

3.3 Observation of cut surface

In order to discuss the effect of tool angle on cut surfaces by MM-shearing method, appearances of cut surfaces are examined from two directions as shown in Fig. 6.

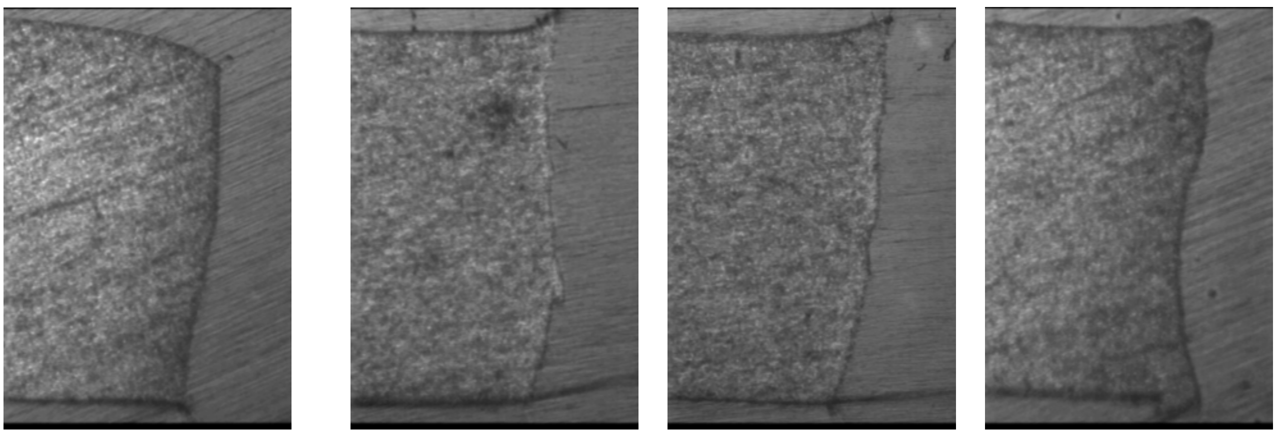
Fig. 7 shows the appearance photograph of cut surface from A direction in Fig. 6. The cut surface which is cut by conventional shearing method consists of small area fraction of sheared surface and large area fraction of fractured surface as shown in Fig. 7 (a), and grazing stripe pattern is observed in the vertical direction. In contrast, the cut surface at tool angle α=30 degrees or α=40 degrees consists of large area fraction of sheared surface and small area fraction of fractured surface as shown in Fig. 7 (b) or Fig. 7 (c). The ratio of sheared surface is significantly larger than that in conventional shearing method. Scratching pattern is observed at tool angle α=50 degrees as shown in Fig. 7 (d). The grazing stripe pattern is observed in the horizontal direction corresponding to tool edge motion regardless of variation of tool angle.

Fig. 8 shows the appearance photograph of cross sections from B direction in Fig. 6. The shear droop occurs on the cross section which is cut by conventional shearing method as shown in Fig. 8 (a), and the inclination of fractured surface is large. In contrast, there is no shear droop occurs on the cross section which is cut by MM-shearing method regardless of variation of tool angle as shown in Fig. 8(b)-(d). The inclination of fractured surface is small. But the burr height becomes larger at tool angle α=50 degrees as shown in Fig. 8 (d).



(a) Conventional shearing (b) Tool angle α=30° (c) Tool angle α=40° (d) Tool angle α=50°

Fig. 7 Photograph of cut surface by MM-shearing and conventional shearing



(a) Conventional shearing (b) Tool angle α=30° (c) Tool angle α=40° (d) Tool angle α=50°

Fig. 8 Photograph of cross section by MM-shearing and conventional shearing

3.4 Effect of tool angle on cut surface properties

The effect of tool angle on ratio of sheared and fractured surfaces is shown in Fig. 9. The ratio of sheared surface is about 75% when tool angle α is from 15 to 45 degrees. When the tool angle exceeds 45 degrees, the ratio of sheared surface decreases suddenly and reached about 20%.

The effect of tool angle on burr height is shown in Fig. 10. The burr height is less than 0.1mm when tool angle α is from 10 to 45 degrees. But the burr height rapidly increases when tool angle α exceeds 45 degrees.

The effect of tool angle on arithmetic average roughness of cut surface in cutting direction is shown in Fig. 11. The arithmetic average roughness of cut surface is about 1μm when tool angle α is from 20 to 45 degrees. When the tool angle exceeds 45 degrees, the arithmetic average roughness of cut surface increases significantly and reached about 3μm.

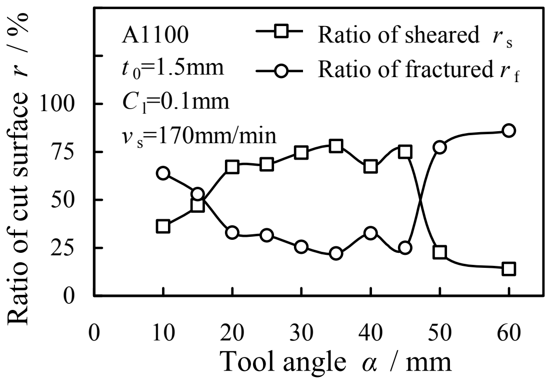


Fig. 9 Effect of tool angle on ratio of sheared surface and fractured surface

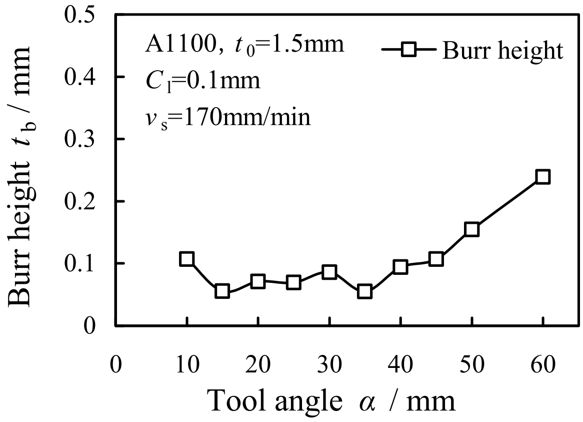


Fig. 10 Effect of tool angle on burr height

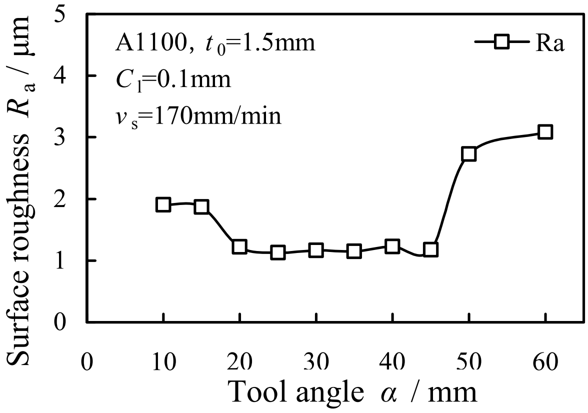


Fig. 11 Effect of tool angle on surface roughness

Table 2 Summaries of experimental result

	Tool angle									
	10	15	20	25	30	34	40	45	50	60
Cutting force	NG	OK	OK	OK	OK	OK	OK	OK	NG	NG
Ratio of sheared	NG	NG	OK	OK	OK	OK	OK	OK	NG	NG
Burr height	NG	OK	OK	OK	OK	OK	OK	OK	NG	NG
Surface roughness	NG	NG	OK	OK	OK	OK	OK	OK	NG	NG

OK is good condition
NG is not good condition

The summaries of experimental result is shown in Table 2. When tool angle α changes within the range from 20 to 45 degrees, the cutting force is small, the ratio of sheared surface is large, the burr height and the surface roughness is very small, and the quality of cut surface is excellent.

4. Conclusion

A new flexible shearing method for sheet metal was nemed MM-shearing method invented by the authors. The effect of tool angle on cutting force, ratio of sheared surface and fractured surface, burr height and surface roughness was examined by experimental method. In order to obtain high quality cut surface of sheet metal, the optimum range of tool angle α for MM-shearing method is from 20 to 45 degrees.

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