

Influence of Clearance and Punch Velocity on the Quality of Pure Thin Copper Sheets Blanked Parts

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Abstract. Research on the influence of clearance and punch velocity to determine the quality of the punched edge were conducted. This study uses pure copper sheet material with the clearance variation of 2.5, 5, 7.5 and 10%. Punch velocity is based on the ability of about Micro Punch CNC machine which is 100 and 2600 mm/min. At highest speed with a clearance of 2.5%, sheared zone is of about 395 μm or 79% of the material thickness. It can be concluded that the punch velocity gives positive influence on the sheared zone in copper. Basically the ideal outcome of the sheared edge of punching result is having rollover and small burr and contain at least 75% of the shear zone. This can be achieved with a clearance of 2.5%.

1. Introduction

The development of science and technology encourages the creation of a new product with good quality. Miniaturization and weight reduction of various industrial products continue to be developed, machines with high accuracy and good quality machining results are needed today [1]. Micromachining is the most efficient technology to produce components with very small size. This technology can accommodate the demand for the products of micro-sized and micro components in various industrial sectors including electronics, medical, optics, biotechnology, and automotive [2].

Shearing process had been observed by some researchers for a variety of material or workpiece and tool conditions to improve the quality of shearing product, especially the quality of material surface. Quality of the punched edge during punching process is evaluated based on part-edge characteristics and dimensional accuracy. Basically, there are a lot of factors that affect the product quality of part-edge characteristic, according to [3-5] and the major factor which affects the product quality of the punched edge are clearance between punch and die and punch velocity.

Based on several experimental studies conducted by FEM [6, 7] clearance has the most significant influence in affecting the accuracy of the punching process. In the simulation also found that the rollover and shear edge increases and fracture edge decreases with decrease in the value of clearance [8]. Mentioned on their research [9-11] when the clearance value is decrease, smooth sheared and punch force will increase. When the clearance value is increasing, rollover depth will also increase, in other hand smooth sheared value will decrease.

In addition, increasing the pace of work in production process is not only closely related to the increase in profitability of the components, improve the working speed can reduce production costs and energy consumption [12]. High-speed blanking will improve the product quality of the punched edge, burr and rollover are in low altitude while the shear zone increases [13]. Thus, further emphasis of this research in addition to optimization of clearance also represents the potential punch velocity as process parameters to influence product quality of tested material feasibility.

2. Experimental conditions



2.1. Micro Punch CNC Machine

One of the products developed is Micro Punch CNC Machine. Micro Punch CNC Machine is a combination of press dies machine with CNC (Computer Numerically Controlled) driving system as shown in figures 1 (a) and (b). Press dies can produce a part with uniform quality with minimum machining time. In addition, the blanking process on press dies system has several advantages, including it can produce a uniform punched edge quality and size products with lower cost in the manufacturing of mass products. The working principle of press dies is using penetration between punch and die.

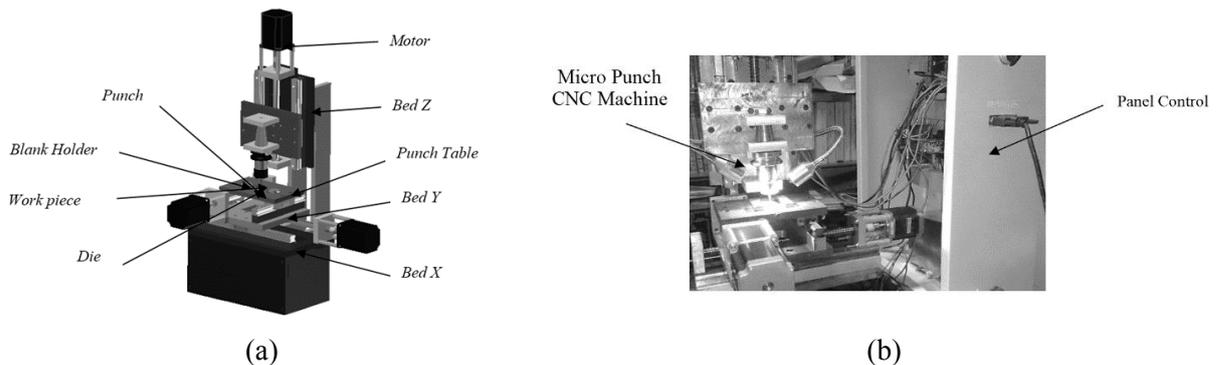


Figure 1. (a) Mechanical Design Micro Punch CNC Machine, (b) Micro Punch CNC Machine

2.2. Initial tool position and condition

The alignment of punch and die reach 10 μm. The accuracy alignment measurement uses "Dino-Lite Edge AM 4515 T5" camera, featured with an LED light source that is located on the side of the punch serves as illumination during alignment process. The alignment between the punch and die is very important before doing the experiment, aimed to minimize the tool wear and to obtain a same cutting edge on the circumference of a circle.

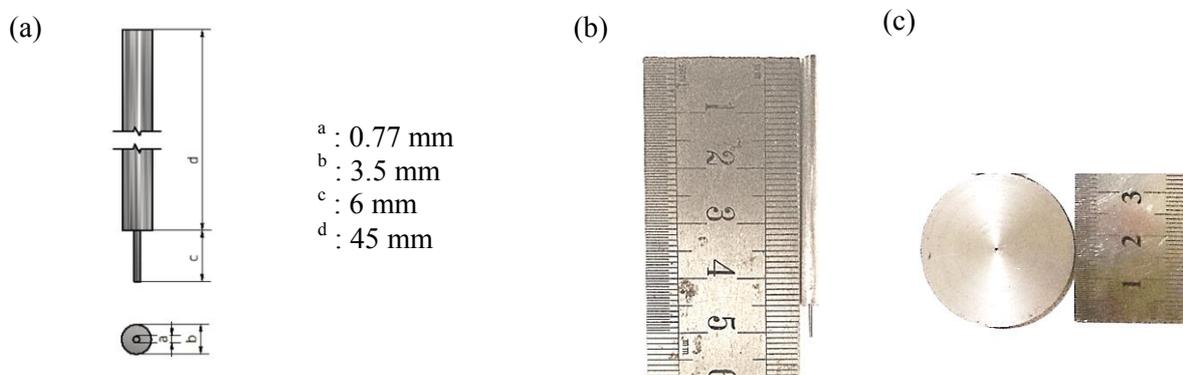


Figure 2. (a) Punch sample, for clearance 2.5%, (b) Punch tool, (c) die

Punch tool using High Speed Steel (HSS) materials type Nachi Standard with a Rockwell C hardness of 64 HRC while the die using Mild Steel (see figure 2). Mechanical properties of experimental setup is shown in Table 1.

Table 1. Mechanical properties of experimental setup

Properties	Material testing	Punch tool (High Speed Steel)	Die (Mild Steel)
Young's Modulus (Mpa)	118 x 10 ³	207 x 10 ³	220 x 10 ³
Poisson's Ratio	0.34	0.27	0.28
Density (kg/m3)	8900	8138	7861
Yield Strength (Mpa)	33.3	3250	207
Tensile Strength (Mpa)	210	172	345

2.3. Clearance and punch velocity setup

The experiment was conducted at room temperature. Punch velocity (*v*) of Micro Punch CNC Machine was 100 (low speed) and 2600 mm/min (high rate). Clearances used for this study were 2.5, 5, 7.5 and 10%. Figure 3 describes clearance punch and die used in the study.

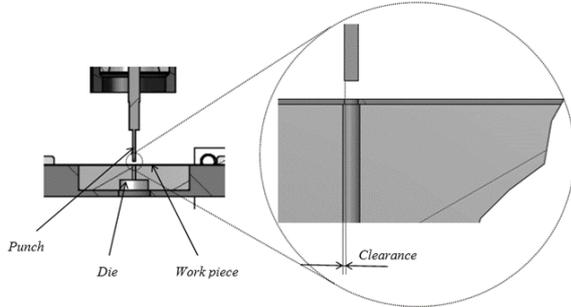


Figure 3. Punch and die Clearance

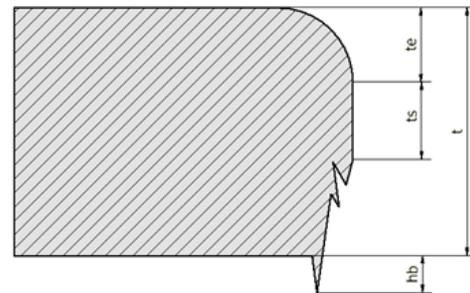


Figure 4. Form errors on sheared workpieces, *t* is the sheet thickness; *te* rolover; *ts* shear zone and *hb* is burr height

2.4. Material testing

This study uses pure copper sheet (99.6%) workpiece with the thickness of 500 μm. On each velocity variation, punching is performed four times to obtain the most valid data, and follow with clearance variation. The equation to measure the total force required to pierce the workpiece with circular section is as follows.

$$P = \pi Dst \tag{1}$$

Known that shear strength (*st*) of the material is 0.7 times the tensile strength (TS) of 210 MPa. The obtained *st* is 147 MPa. It can be obtained that the force (*P*) needed to punching the copper with *t*: 500 μm is 182.3 N. Based on the calculation of the force required for punching process as compare to optimal punching machines, it can be concluded that the maximum force of 1662.8 N may allow punching process on the copper sheet with the required maximum force of 182.3 N.

The calculation of punch size variations based on the following formula.

$$c = \frac{d_d - d_p}{2t} \cdot 100\% \tag{2}$$

where *D_p* is the external diameter of the punch, *D_d* is the internal diameter of the die, and *t* is the thickness of the workpiece. The punch diameter variations are shown in table 2 below.

Table 2. Variations in diameter punch against clearance

die Diameter (μm)	Clearance	Various punch Diameter (μm) t = 500 μm
790	2.5 %	765
	5%	740
	7.5%	715
	10%	690

2.5. Measurement method

The amount of rolover, shear zone and burr height from section of the slug were obtained using an optical microscope camera (Type Olympus C-35AD-4). To observe the validity of rolover, shear zones and burr height, each slug has been measured at 4 different locations around the circumference (see figure 4).

3. Result and discussion

Figure 5 shows the shape of the part-edge characteristic as punching process results. It can be seen that the high rate punching and the smallest clearance shape looked smooth and even glossy. Differ from the shape of the copper with v : 100 mm/min for clearance of 10% figure 5 (d), the shape looks dull and finely fibrous with no reflection of light and with many fine scratch-marks parallel to the punching direction.

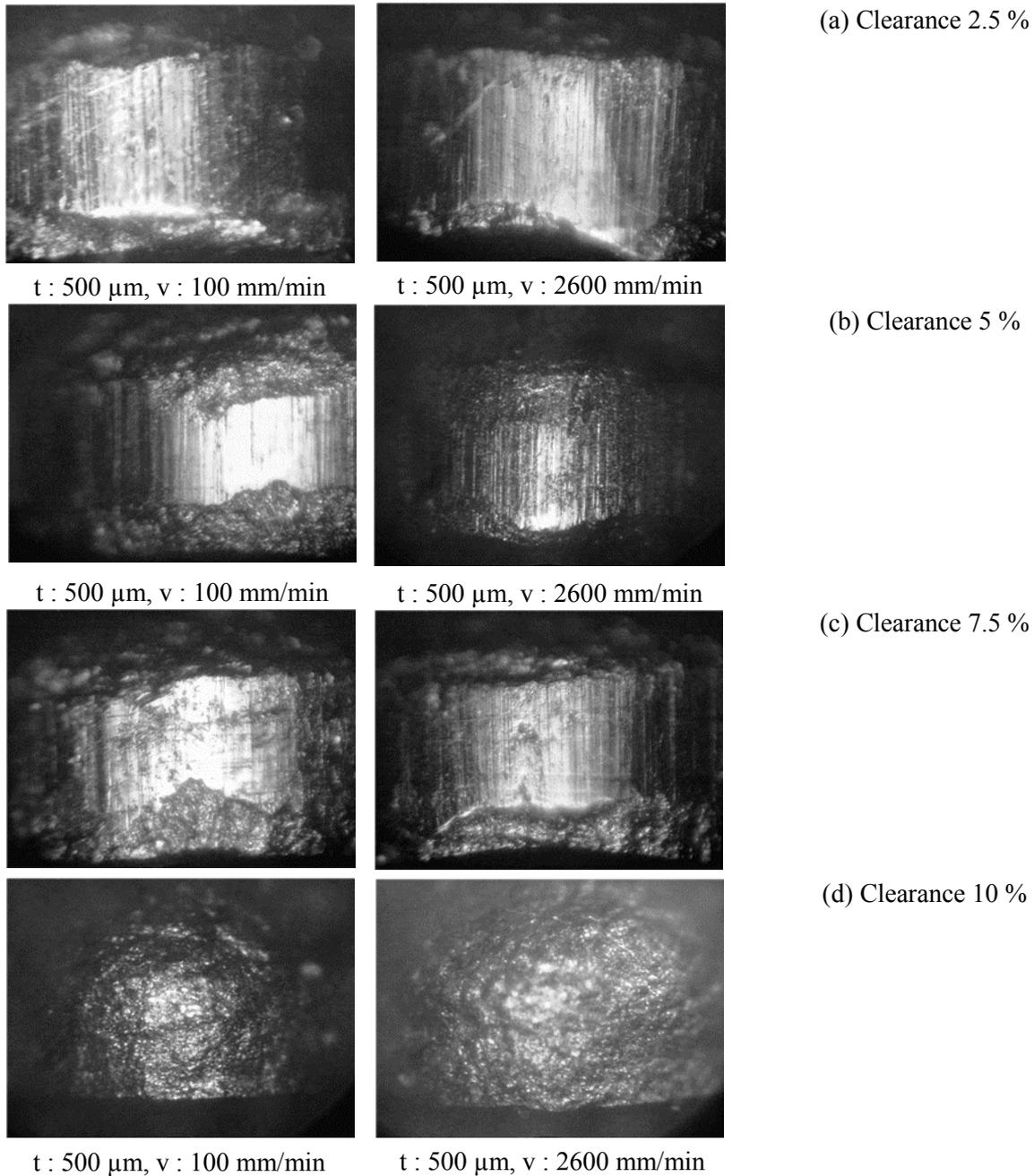


Figure 5. Surface appearance of punched edge surface under various experimental conditions, t : sheet thickness, v : punch velocity

Figure 6 shows the measurement results of a rollover, shear zone and burr height in respect to variations of punch and die clearance for the low speed. Up to 10% clearance, the percentage rollover and burr height of the slugs is constantly increasing. At a clearance of 10% the rollover is about 4 times greater than 2.5% clearance with v : 100 mm/min, while on high rate at a clearance of 10% rollover increase is about 6 times higher (see figure 7).

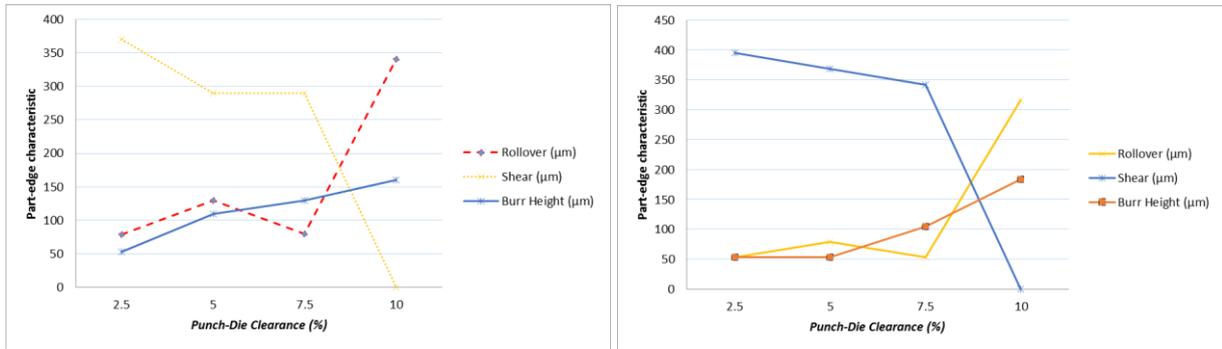


Figure 6. Various punch-die clearance with v : 100 mm/min **Figure 7.** Various punch-die clearance with v : 2600 mm/min

However, with the increasing value of clearance, shear zone is getting lower. At 10% clearance shear zone was not developed see figure 5 (d), the shape of punched edge looks rough and dull. The sheet tends to be pulled into the clearance region, and the perimeter or edges of the shear zone become rougher. Unless such edges are acceptable as produced, secondary operations may be required to make them smoother.

At high speed of v : 2600 mm/min, the shear zone was increase (see figure 7). When punching with small clearance (2.5%) at the high rate a shear zone of up to 395 μm or about 79% of the material thickness could be reached (Table 3). This is because when the high rate punching, the kinetic energy will be greater than the energy required for punching process, so that the heat generated will disappear quickly. Although there is an increase in the percentage of shear when using high rate, it is not enough to compensate the decrease of percentage shear which is caused by an increasing clearance. This means that in order to obtain the shape of the part-edge characteristics of 75% shear, the clearance should be 2.5 to 5%.

Table 3. Percentage of Shape Characteristics

Clearance (%)	Rollover		Shear		Burr Height	
	100 mm/min (%)	2600 mm/min (%)	100 mm/min (%)	2600 mm/min (%)	100 mm/min (%)	2600 mm/min (%)
2.5	15.8	10.6	73.6	79	10.6	10.6
5	26.4	15.8	52.6	73.6	21	10.6
7.5	15.8	10.6	57.8	68.4	26.4	21
10	68.4	63.2	0	0	31.6	36.8

Figure 8 shows the average test results for low speed and high rate. At high rate, burr heights is found to be constant at 2.5 and 5% clearance. When the clearance increase, the height of the burr increases linearly.

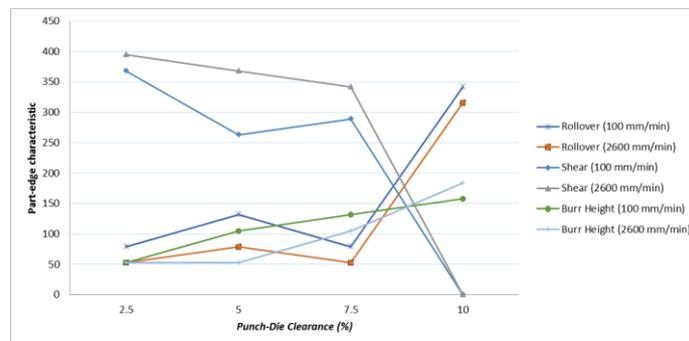


Figure 8. Comparison result between v : 100 mm/min and v : 2600 mm/min

4. Conclusion

In this paper, it can be noted that a positive influence of high rate punching on the quality of the part-edge is more obvious, especially regarding shear zone. At low speed or high rate, it produces similar

part-edge characteristics. If the clearance value increases, the shape of the shear zone decreases with the increase in rollover and burr height and vice versa. When clearance value decreases, the shear zone will increase, and it is followed by the increasing height of the rollover and burr. When the clearance value increase, the deformation area becomes larger and shearing zone becomes rough. Rough shearing zone can be accepted as a product, but further machining may be needed to refine the punched edge, and it may increase the production cost.

Basically, the ideal outcome of part-edge characteristics is having small rollover and burr and having at least 75% of shear zone. This can be achieved with clearance value of 2.5%.

Acknowledgment

This study was carried out with the financial support of DIKTI. Work facilities was supported by Gadjah Mada University. Gratefully acknowledgment.

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