Blanking Clearance and Punch Velocity Effects on The Sheared Edge Characteristic in Micro-Blanking of Commercially Pure Copper Sheet

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ABSTRACT

This study aims to identify the influences between clearance and punch velocity on the part edge quality of blanked parts. Experiments have been conducted using material copper, punch-die clearance and punch velocity variations. In order to determine the reachable punch-die clearance and punch velocity required for blanking. The quality of the part-edge characteristics shows that higher punch velocity and decreases clearance value can improve the part-edge quality, resulting in smaller burr height and rollover, and a larger shear zone. Furthermore, it could be observed that the part-edge quality improvement when blanking with high punch velocity is much more distinct for stele than for copper. According to blanking theory, this improvement was expected because copper have much higher heat conduction coefficients. Therefore, the heat dissipates faster and the desired stress relief effect does not take place to the same degree as for stele.

Keywords: Micro PunchClearance, Punch velocity, Copper.

I. Introduction.

Micro-components have been widely used in many industry clusters such as electronics, healthcare, aerospace, biomedicine and automobiles[1]. The miniaturization and weight reduction of various industrial products have become advanced, and higher accuracy and quality are strongly demanded for the parts needed for constructing these products [2].

One of the popular and highly-in-demand forming processes is shearing. Shearinghas been defined as a process employed in the manufacturing of metal parts with a specific design from sheet-metal stock and includes a wide variety of operations such as punching, blanking, embossing, bending, flanging and coining [3]. The process of micro-components is performed by not only shearing, but also by EDM, laser, and etching [4].

The blanking process has long been studied by several researchers for a wide variety of materials or workpieces as well as tool conditions to improve the quality of blanking products, especially the quality of the material surfaceon the micro-hole fabrication by mechanical punching process[5]. The accuracy of the machine from the blanking process is evaluated by the surface quality and dimension accuration. At the same time, the main factors that affect the quality of the blanked edge, according to [6], [7], [3] and [8]are clearance punch-die and punch velocity.

The high-volume production of micro-components should be the main goal for the design of micro-manufacturing [9].However, the blanking process is expected to be widely used, because of its high productivity and machining stability.This study discussesoptimization of clearance and the potential punch velocity as process parameters to influence product quality of tested material.

II. Materials and methods.

A. Micro Punch CNC MachineTools

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

DOI: 10.17977/um016v1i22017p053

shown in figures 1 (a). Press dies can produce a part with uniform quality with minimum machining time. The working principle of press dies is using penetration between punch and d

The alignment accuracy of punch and die Micro Punch CNC machine up to 10 µm with the maximum force of 1663 N. In addition, the blanking process on press dies system has several advantages, including it can produce a uniform sheared edge quality and size products with lower cost in the manufacturing of mass products.

B. Materials

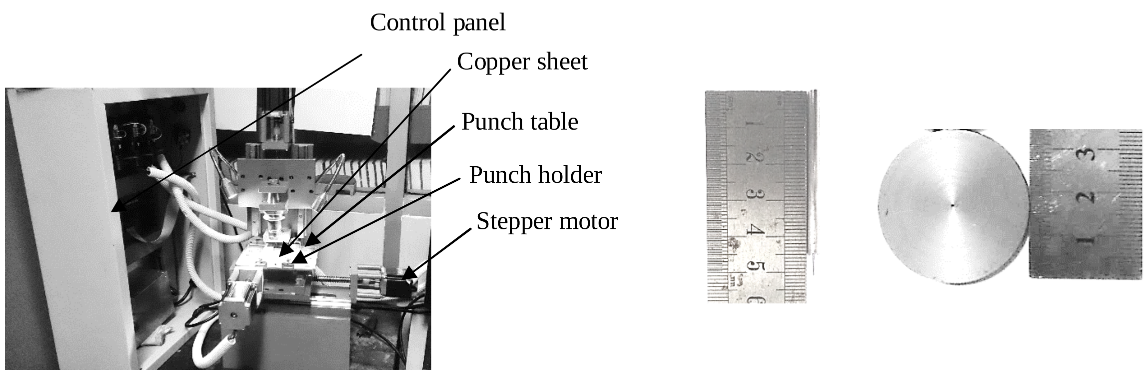
The specimen used for the blanking process were strips of commercially pure copper sheet (99.6%) with thickness of 500 µm. Punch tool using High Speed Steel (HSS) materials type Nachi Standard with a Rockwell C hardness of 64 HRC (figure 1 (b))while the die using Mild Steel (figure 1 (c)). Mechanical properties of experimental setupare shown in Table 1.

C. Force Calculation

The equation to measure the total force required to blanking the specimen(copper) with circular section is as follows.

$$P = \pi D \tau_u t \tag{1}$$

Known that shear strength (τ_u) of the material is 0.7 times the tensile strength (TS) of 210 MPa. The obtained (τ_u) is 147 MPa. It can be obtained that the force (*P*) needed to blanking the specimen 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 1663 N may allow blanking process on the specimenwith the required maximum force of 182.3 N.



(a) (b) (c)

Fig. 1.(a)Micro Punch CNC Machine, (b) punch tool, (c) die

Table 1. Mechanical properties of experimental setup

Properties	Specimen (Copper sheet)	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/m^3)	8900	8138	7861
Yield Strength (Mpa)	33.3	3250	207
Tensile Strength (Mpa)	210	172	345

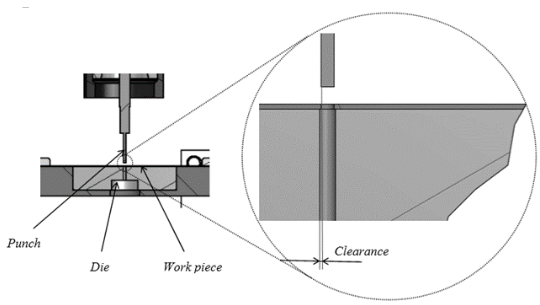


Fig. 2. Punch and die Clearance

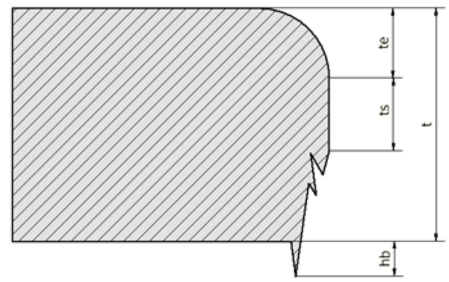


Fig. 3. Form errors on sheared specimen, t: sheet thickness, te: rollover, ts: shear zone and hb: burr height

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

D. Punch-die Clearance

Clearances used for this study were 2.5, 5, 7.5 and 10%. Figure 2 describes clearance punch and die used in this study.

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

$$c = \frac{d_d - d_p}{2t} \cdot 100\% \quad (2)$$

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 specimen. The punch diameter variations result are shown in table 2 below.

E. Testing Parameters and Measurement Method

The experiment was conducted at room temperature.Punch velocity (υ) of Micro Punch CNC Machine used 100, 500, 2000 and 2600 mm/min. In order to complete the accurate analysis of the blanking process there are performed four times to obtain the most valid data, and follow with clearance variation. 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 sheared edge on the circumference of a circle.

The amount of shear zone from section of the slug were obtained using an optical microscope camera (Type Olympus C-35AD-4). To observe the validity of shear zones each slug has been measured at 5 different locations around the circumference (see figure 4).

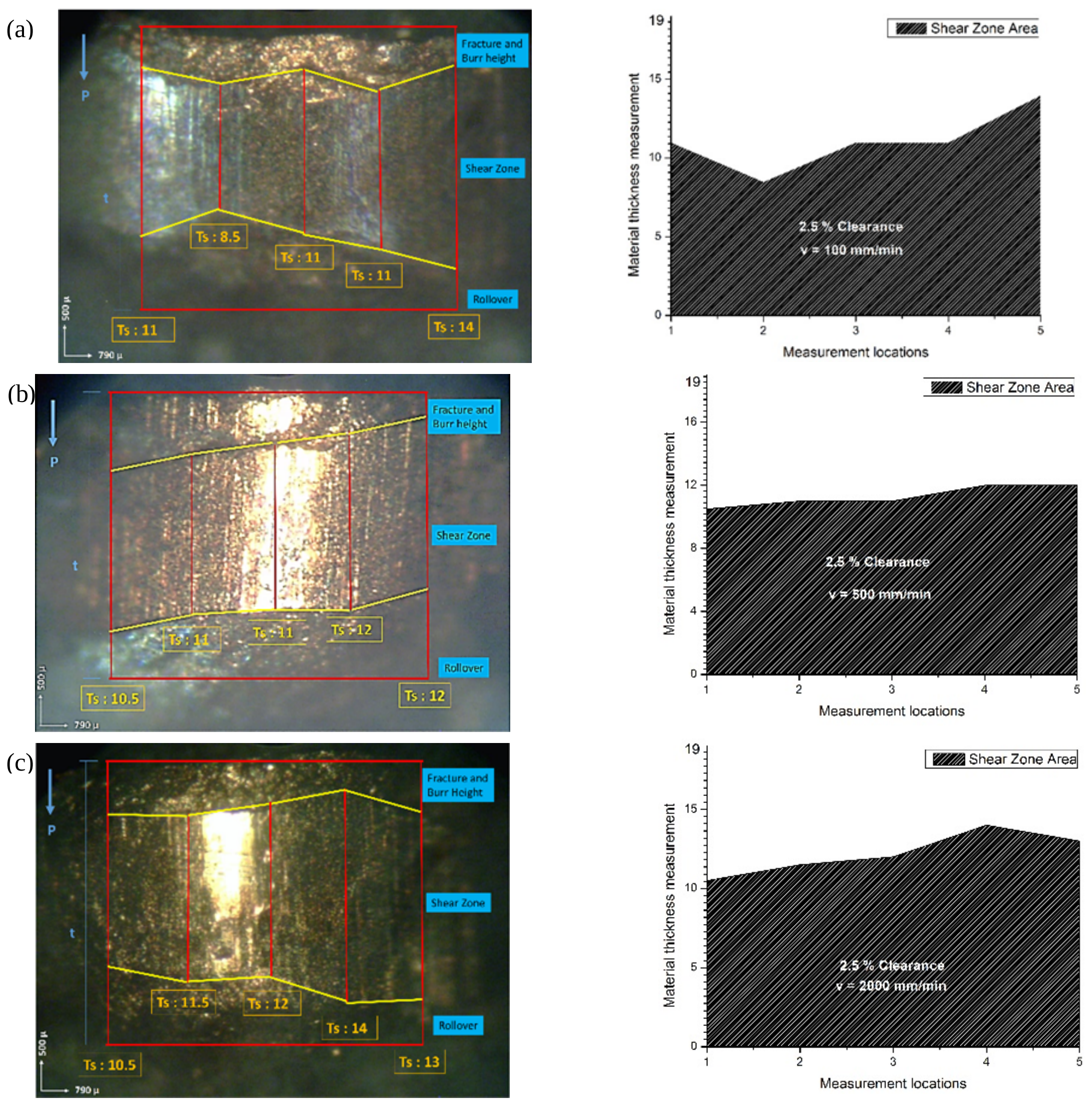
III. Results and discussion.

Table 1 shows that shear zone increases according to the increasing of punch velocity and decreasing the clearance value. At the highest speed (2600 mm/min) with the 2.5% clearance the shear zone up to 71.58%. Consequently, the sheared surface is smoother and exhibits less burr formation.At low speed (100 mm/min) with the same clearance value indicates shear zone value of 58.42%. At the clearance value of 10% does not show the surface of the shear zone at all.

Table 3. The shear zone results of the experimental measurement for commercially pure copper sheet

Clearance	Shear Zone (%)			
	100 (mm/min)	500 (mm/min)	2000 (mm/min)	2600 (mm/min)
2.5 %	58.42	59.47	64.21	71.58
5%	19.47	25.79	44.74	48.42
7.5 %	0.00	0.00	0.00	4.74
10%	0.00	0.00	0.00	0.00

Edge quality can be improved with increasing punch velocity, speeds may be as high as 2000 to 2600 mm/min. In Figure 4 (c), (d) sheared edges can undergo severe cold working due to the high shear strains involved.



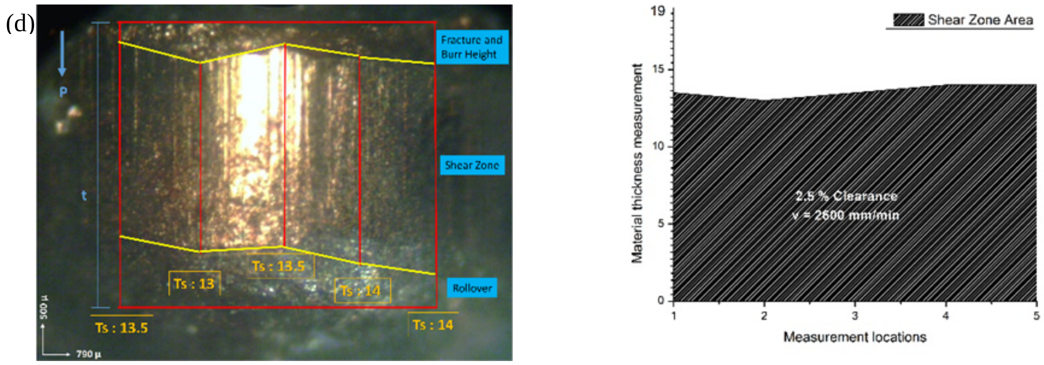
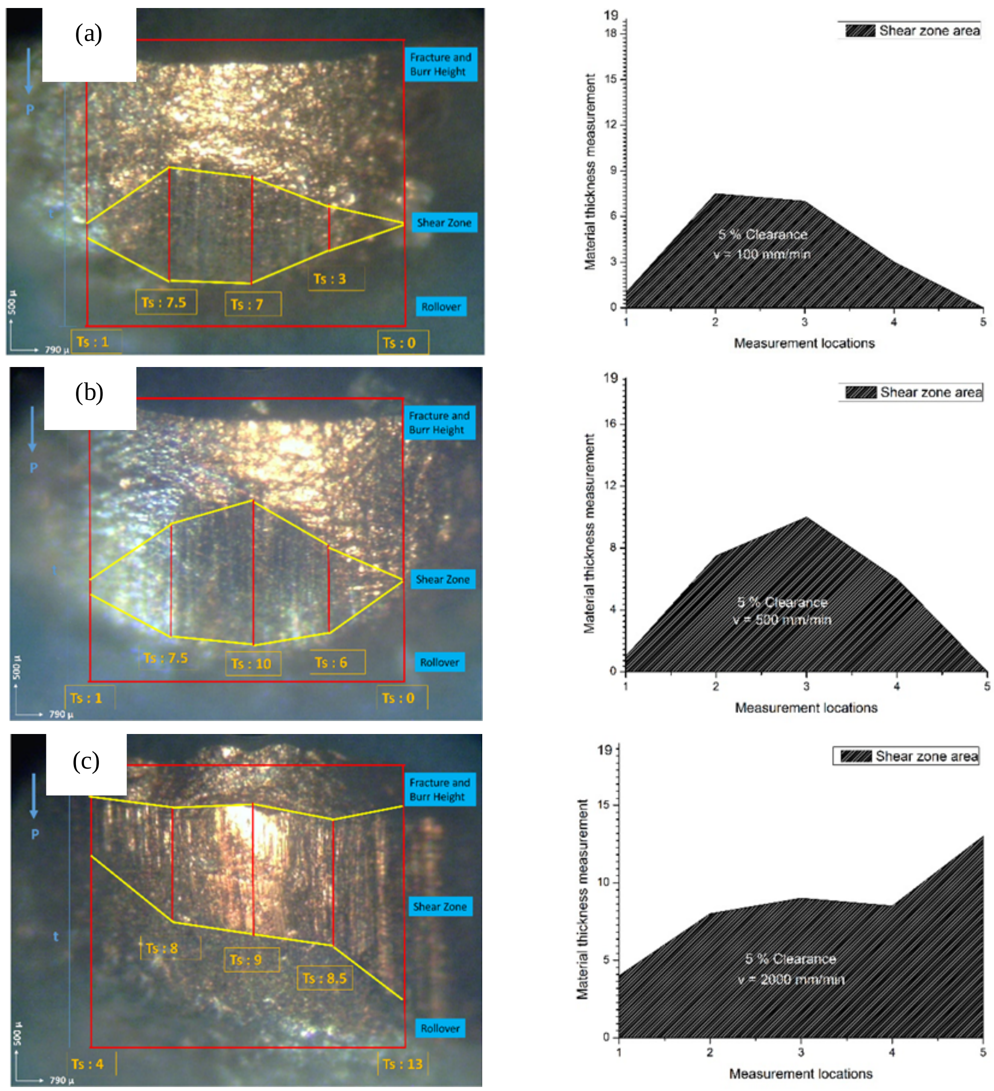


Fig. 4. Shear zone measurement result with deference punch velocity on 2.5 % punch-die clearance using optical microscope camera, p: punch force, t: sheet thickness, v: punch velocity, ts: shear zone



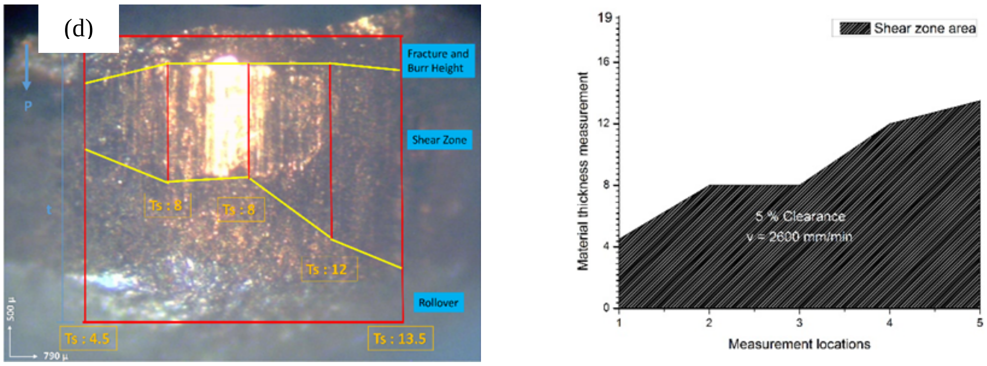
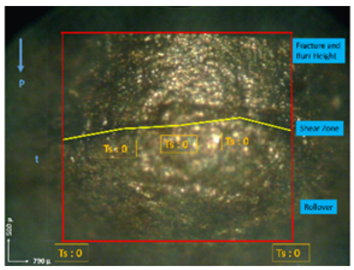
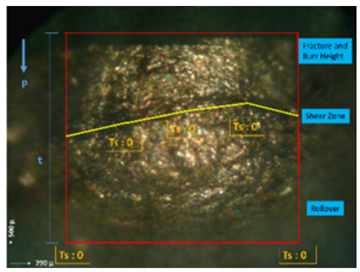


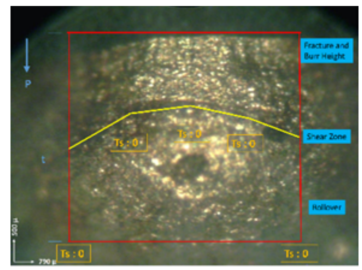
Fig. 5. Shear zone measurement result with deference punch velocity on 5 % punch-die clearance using optical microscope camera, p: punch force, t: sheet thickness, v: punch velocity, ts: shear zone



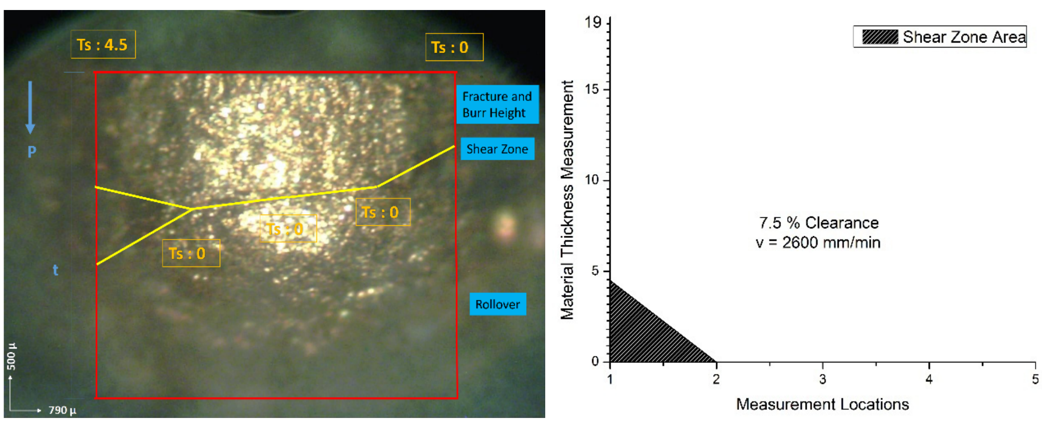
C: 7.5%, υ: 100 mm/min



C: 7.5%, υ: 500 mm/min



C: 7.5%, υ: 2000 mm/min



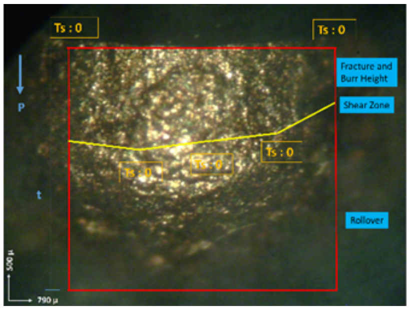
C: 7.5%, υ: 2600 mm/min

Fig. 6. Shear zone measurement result with deference punch velocity on 7.5 % punch-die clearance using optical microscope camera, p: punch force, t: sheet thickness, v: punch velocity, ts: shear zone

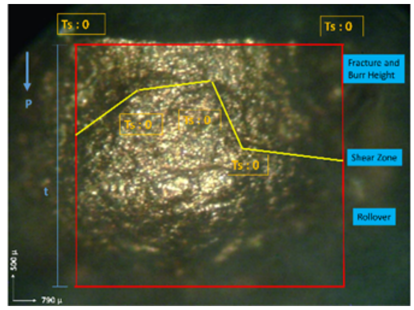
Figure 5 shows at 5% clearance the surface of the shear zone has a proportion below 50%. This is because the clearance value ratio is too large for copper sheet thickness of 500 µm, thuspart edge characteristic for the burr height and rollover will have a high enough proportion.

The study with clearance 7.5% (figure 6) was only 1 sample test at a speed of 2600 mm / min which has a smooth surface, the other velocity samples do not show any sheared edge, the surface looks rough and dull.

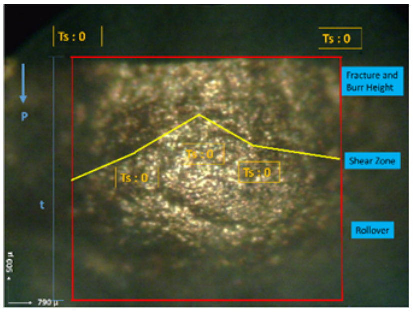
It can be noted from figure 7 that the shear zone is null for 10% clearance in all punch velocity value. As the clearance value increases the zone of deformation becomes larger and the sheared edge becomes rougher. The sheet tends to be pulled into the clearance region, and the perimeter or edges of the shear zone become rougher.



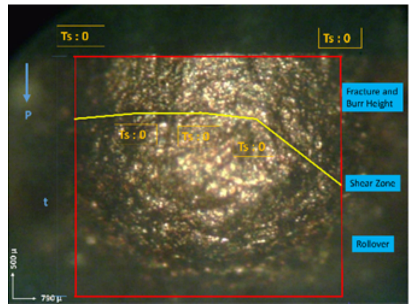
C: 10%, υ: 100 mm/min



C: 10%, υ: 500 mm/min



C: 10%, υ: 2000 mm/min



C: 10%, υ: 2600 mm/min

Fig. 7.Shear zone measurement result with deference punch velocity on 10 % punch-die clearance using optical microscope camera, p: punch force, t: sheet thickness, v: punch velocity, ts: shear zone

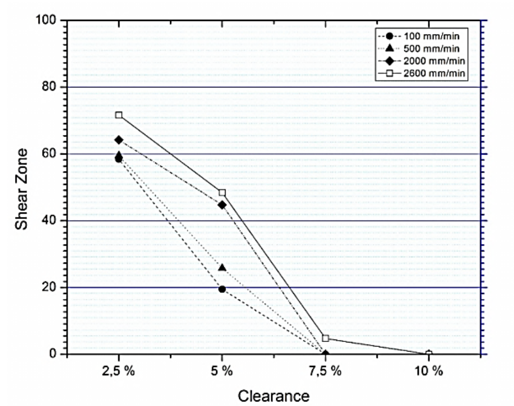


Fig. 8.Shear zone area with difference punch velocity against punch-die clearance

Figure 8 shows a comparison graph between clearance and shear zone at each punch velocity (100, 500, 2000, 2600 mm/min). The graph clearly shows that the highest punch velocity and the lowest clearance value produce the highest shear zone, and vice versa the lowest punch velocity with the highest clearance value yields a zero value.

This present Research conducted in accordance with research that has been done previously by [4], [10] and [11]increasing clearancevaluebetween punch-die has an effect: a) rollover increase; b); small shear zone; c) bigger ruptureand; d) increasing burr. With increased on clearance, the deformation area becomes larger and the shearing zone becomes rough. A rough shearing zone can be accepted as a product, but continued operation may be needed to make the blanked edge smoother, this may increase production costs.

IV. Conclusion

A good clearance design not only increasing the quality of product manufactured, but also reduces burr height. Influence clearance and potential punch velocity in this research showed good agreement with [4]. 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%.

Acknowledgments

The authors would like to thank the DIKTI and Universitas Gadjah Mada for the support given to this research.

References

[1] T. Masuzawa, “State of the Art of Micromachining,” Ann. te CIRP vol. 49/2/2000, vol. 49, no. 1, p. 473, 2000.

[2] J. Jeswiet et al., “CIRP Journal of Manufacturing Science and Technology Metal forming progress since 2000,” vol. 1, pp. 2–17, 2008.

[3] S. R. Schmid, “MANUFACTURING ENGINEERING Illinois Institute of Technology".

[4] Y. Kibe, Y. Okada, and K. Mitsui, “Machining accuracy for shearing process of thin-sheet metals — Development of initial tool position adjustment system,” vol. 47, pp. 1728–1737, 2007.

[5] B. Joo, S. Rhim, and S. Oh, “Micro-hole fabrication by mechanical punching process,” vol. 170, pp. 593–601, 2005.

[6] K. Lange, “Handbook of Metal Forming -Society of Manufacturing Engineers.” McGraw-Hill Companies, 1985.

[7] S. Ivana, Handbook of Die Design Second Edition. McGraw-Hill Companies, 2006.

[8] H. Y. Chan and A. B. Abdullah, “Geometrical Defect in Precision Blanking / Punching : A Comprehensive Review on Burr Formation,” vol. 8, no. 9, pp. 1139–1148, 2014.

[9] A. R. Razalia and Y. Qin, “A Review on Micro-manufacturing , Micro-forming and their Key Issues,” Procedia Eng., vol. 53, pp. 665–672, 2013.

[10] Z. Tekiner, M. Nalbant, and H. Gürün, “An experimental study for the effect of different clearances on burr, smooth-sheared and blanking force on aluminium sheet metal,” Mater. Des., vol. 27, no. 10, pp. 1134–1138, 2006.

[11] C. Husson, J. P. M. Correia, L. Daridon, and S. Ahzi, “Finite elements simulations of thin copper sheets blanking: Study of blanking parameters on sheared edge quality,” J. Mater. Process. Technol., vol. 199, no. 1, pp. 74–83, 2008.