An Investigation on Punching Process of Circular Hole on Commercially Pure Titanium Sheet

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Abstract: In this study, an experimental study was carried out to the investigation on punching process of the circular hole on commercially pure titanium sheet by a hydraulic punch machine. Sheared face geometry and hardness distribution resulted from punching process were investigated. The commercially pure titanium sheet with 0.4, 0.5 and 0.6 mm thickness were used in the experiment. The diameter of the punch is 1.7 mm and clearance of punch-die is 7.5%. In the experiment, punch speeds used were 1 and 6.5 mm/s. The results show that punching process on the CP-Ti sheet can increase surface hardness, however hardness distribution on the punched hole are uneven. Hardness distribution on punched hole shows as getting closer with a sheared edge, the surface hardness is bigger. Punch velocity and material thickness increases, burnish height increases, while fracture height decreases.

1 INTRODUCTION

The punch process on commercially pure titanium sheets (CP-Ti) is developed to fabricate medical components and equipment. One of the components and medical devices that can be fabricated using a punch process is a jawbone joint plate. In the manufacture of jawbone joint plates, the punch process is applied to fabricate bolt holes. Characteristics of punched holes are influenced by process parameters. Punch speed and material thickness will influent the characteristics of punched holes.

The punch speed increases, surface roughness of the burnish decrease on commercially pure aluminum material (M. Gotoh and M. Yamashita, 2001). In brass material, increase punch speed with Δv = 47.5 mm/s to decrease surface roughness of 0.16 µm and increases burnish height of 28% (J. Xu, B. Guo,et all, 2012), while increase punch speed with Δv = 2400 mm/minute to decrease burr height of 18.2% (I. Ristiawan & M. Mahardika,2017) In copper material, increase punch speed with Δv = 2500 mm/minute to increase burnish height of 7.3% (D. Z. Lubis & M. Mahardika, 2016), while according to Meng et al. (2015) increase punch speed does not always increase surface hardness (B. Meng, M. W. Fu, C. M. Fu & J. L. Wang,2015).

The material thickness increase of 0.5 mm becoming 0.6 mm causing burr height decrease of 0.03% on stainless steel materials, but material thickness increase of 0.5 mm become 0.6 mm on steel material causing decrease of 0.05% burr height (E. A. Momani & I. Rawabdeh,2015). The punching process on double layer sheet with low temperature co-fired ceramic (LTCC) and polyethylene terephthalate (PET) material has been done, the results showed that punch force in hole manufacture at 40 µm material thickness smaller than at 100 µm material thickness (S. H. Rhim, S. W. Baek & S. I. Oh, 2006) causing the material thickness increase and burr height decrease (S. H. Rhim, S. Y. Shin, B. Y. Joo & S. I, 2006).

The punch velocity and material thickness have an influence on the characteristics of different punch holes on each material. However, in the manufacture of components and medical equipment especially jawbone plate, the effect of punch velocity and material thickness needs to be investigated to produce the appropriate characteristics of the criteria in the manufacture of jaw bone plates. This paper aims to investigate the punching process of the circular hole

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on commercially pure titanium sheet. Effect of the difference punch velocity and material thickness on the characteristics of the punched hole in the commercially pure titanium sheet was investigated.

2 MATERIAL AND METHODE

The testing material used was commercially pure titanium sheet with hardness of 160 VHN. Material thickness used were of 0.4, 0.5 and 0.6 mm. Punch type used was a single shear angle with the shear angle of 17° and punch diameter 1.7 mm. Punch material used was high-speed steel (HSS) with hardness of 63 HRC. Punch tool was manufactured by grinding machine with a punch-die clearance of 7.5%. The schematic of the testing apparatus used as shown in Figure 1. Punching machine used was hydraulic drive with force capacity of 100 ton. Punch speed for testing was 1 dan 6.5 mm/s.

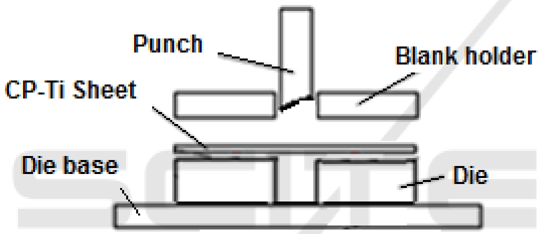


Figure 1: The schematic of the testing apparatus.

Characteristic of punched hole shown in Figure 2. Rollover, burnish, fracture and burr height were measured using dino-lite digital microscope of AM4515 series. Surface hardness was measured with BUEHLER Vickers microhardness test with 100-gram load and 15 s load time. The position of surface hardness testing shown in Figure 3.

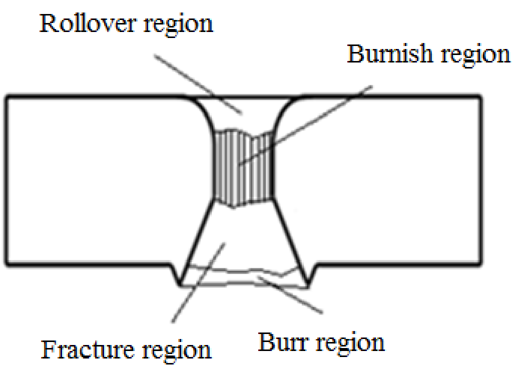


Figure 2: Characteristic of the punched hole.

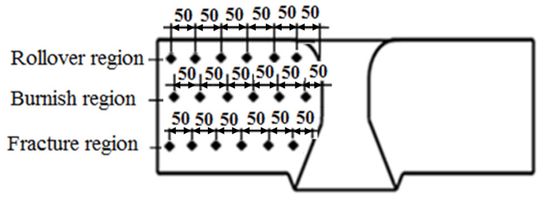


Figure 3: The position of surface hardness testing, with unit of µm.

3 RESULTS AND DISCUSSION

The relationships between material thickness and punch velocity on the rollover, burnish, fracture and burr depth are given in Fig. 4. As the material thickness increases, burnish and fracture depth increases. As the punch velocity increases, rollover, fracture and burr depth decreases while burnish depth increases on the material thickness of 0.4 and 0.5 mm. However on the 0.6 material thickness, punch velocity increases, rollover and fracture depth decreases while burnish and burr depth increases. This result occurs due to impact load on the 1 mm/s punch velocity smaller than 6.5 mm/s punch velocity, where low impact load cause longer elastic deformation and shorter plastic deformation. As the elastic deformation increases, rollover depth increases. As the plastic deformation increases, burnish depth increases. Thus to increase burnish depth can increase punch velocity.

The relationships between material thickness and punch velocity on the surface hardness are given in Figure 6-7. The result of the punching process on material thickness 0.4 to 0.6 mm shows the punching process on the CP-Ti sheet can increase surface hardness, however hardness distribution on the punched hole are uneven. Figure 5 shows the relationships between material thickness and punch velocity on the surface hardness on 0.4 mm material thickness. Hardness distribution on punched hole shows as getting closer with a sheared edge, the surface hardness was got bigger. As burnish region experienced the largest increase in surface hardness compared with rollover and fracture region. The highest hardness in the rollover region at a distance of 50 µm from the sheared face of 173.96 VHN on the 1 mm/s punch velocity and 243 VHN on the 6.5 mm/s punch velocity. The highest hardness in the burnish region at a distance of 50 µm from the sheared face of 226.7 VHN on the 1 mm/s punch velocity and 266.5 VHN on the 6.5 mm/s punch velocity. The highest hardness in the fracture region at a distance of 50 µm from the sheared face of 225.13VHN on the 1

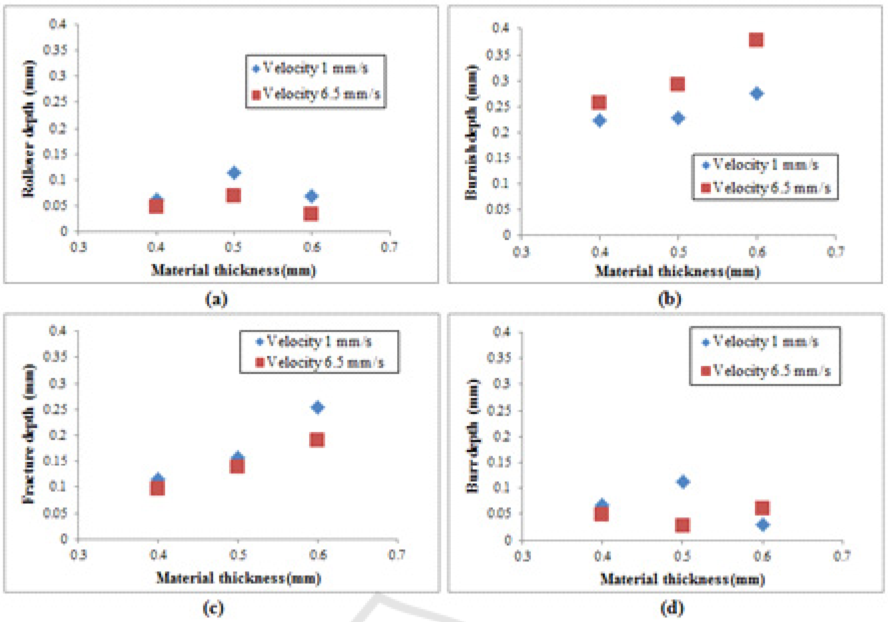


Figure 4: The relationships between material thickness and punch velocity on the: (a) rollover, (b) burnish, (c) fracture and (d) burr depth.

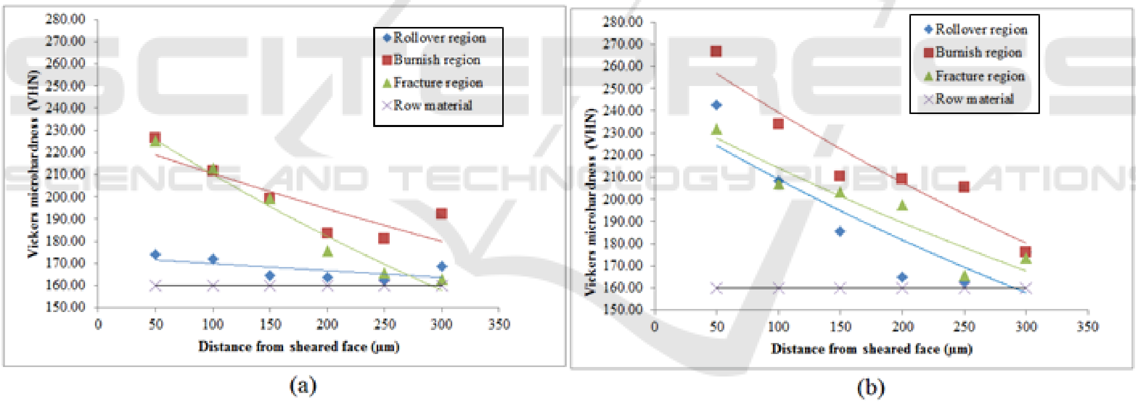
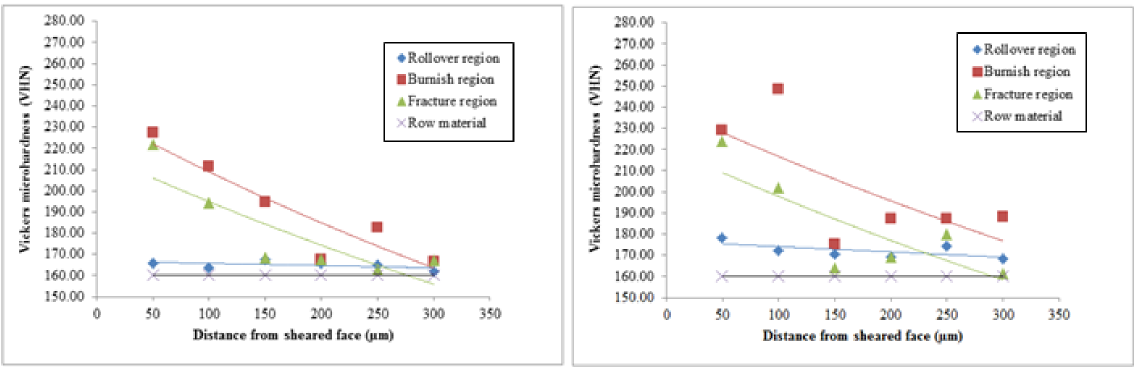


Figure 5: Hardness distribution on the rollover, burnish and fracture region on 0.4 mm material thickness with punch velocity: (a) 1 mm/s dan (b) 6.5 mm/s.

mm/s punch velocity and 231.8 VHN on the 6.5 mm/s punch velocity.

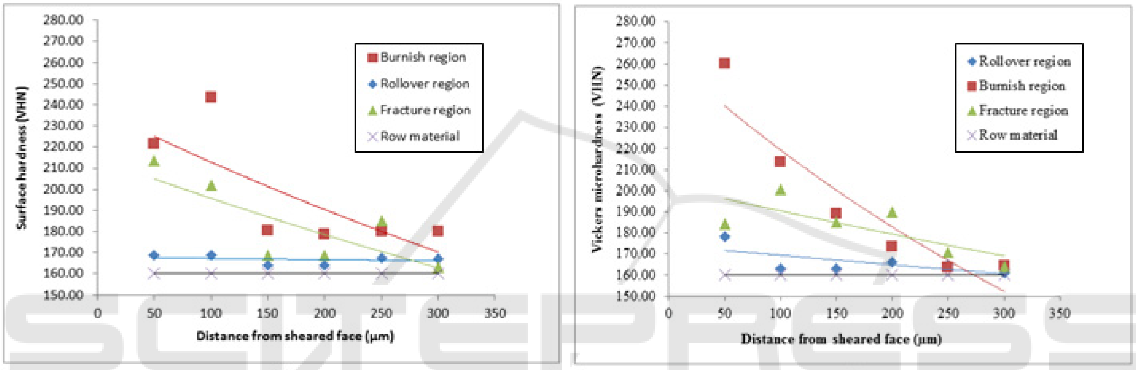
Figure 6 shows the relationships between material thickness and punch velocity on the surface hardness on 0.5 mm material thickness. As burnish region experienced the largest increase in surface hardness compared with rollover and fracture region. The highest hardness in the rollover region at a distance of 50 µm from the sheared face of 165.73 VHN on the 1 mm/s punch velocity and 178.30 VHN on the 6.5 mm/s punch velocity. The highest hardness in the burnish region at a distance of 50 µm from the sheared face of 227.51 VHN on the 1 mm/s punch velocity and a distance of 100 µm from the sheared face of 248.82 VHN on the 6.5 mm/s punch velocity. The highest hardness in the fracture region at a distance of 50 µm from the sheared face of 222.03 VHN on the 1 mm/s punch velocity and 223.57 VHN on the 6.5 mm/s punch velocity.

Figure 7 shows the relationships between material thickness and punch velocity on the surface hardness on 0.5 mm material thickness. As burnish region experienced the largest increase in surface hardness compared with rollover and fracture region. The



(a) (b)

Figure 6: Hardness distribution on the rollover, burnish and fracture region on 0.5 mm material thickness with punch velocity: (a) 1 mm/s dan (b) 6.5 mm/s.



(a) (b)

Figure 7: Hardness distribution on the rollover, burnish and fracture region on 0.6 mm material thickness with punch velocity: (a) 1 mm/s dan (b) 6.5 mm/s.

highest hardness in the rollover region at a distance of 50 µm from the sheared face of 165.73 VHN on the 1 mm/s punch velocity and 178.30 VHN on the 6.5 mm/s punch velocity. The highest hardness in the burnish region at a distance of 100 µm from the sheared face of 243.44 VHN on the 1 mm/s punch velocity and a distance of 50 µm from the sheared face of 260.12 VHN on the 6.5 mm/s punch velocity. The highest hardness in the fracture region at a distance of 50 µm from the sheared face of 213.81 VHN on the 1 mm/s punch velocity and a distance of 100 µm from the sheared face of 200.66 VHN on the 6.5 mm/s punch velocity.

4 CONCLUSION

Punching process on the CP-Ti sheet can increase surface hardness, however hardness distribution on the punched hole are uneven. The biggest increase of surface hardness occurs in the burnish region. Punch velocity increase, surface hardness and burnish height increase on the other hand fracture height decreases. Material thickness increase, burnish height and fracture height increase.

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