The Eurasia Proceedings of Science, Technology,
Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 36, Pages 245-252

ICBAST 2025: International Conference on Basic Sciences and Technology

Investigation of Burr Height for Sheet Metal Process of Medium Duty Casters in Industrial Kitchens

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Abstract: Sheet metal processing is a cheap, automated metal processing method that is frequently preferred in many different industries. Holes, slots and gaps of different geometry on sheet metal surfaces are generally required at various processes. These manufacturing are performed with punches and dies. In this study, holes were punched into ASTM A1011 low carbon sheet metal with punches made of AISI D3 tool steel and the maximum burr heights in the flank materials were measured. In general, the quality of the parts coming out of the punch is determined by tool wear and burr height. For this reason, maximum burr height of piercing materials was measured in this study. As a result, it was observed that the burr heights increased with increasing strokes. Intensive plastic deformation and wear in the tool increased the burr height in the blank. The highest burr value was obtained with 118 µm and 60,000 strokes.

Keywords: Sheet metal blanking, Punch, Burr height

Introduction

Sheet metal forming and processing are one of the classical manufacturing methods frequently used in the production of house holding goods, kitchenware, automotive, electrical electronics and communication, logistics and storage, food, medical devices and equipment. Due to mass production and being quite economical, the method attracts great attention especially in the household goods and automotive sectors. Perfect products are obtained by opening holes, channels or cavities with different geometries with the help of punches in sheet metal materials with different chemical components and bending them in the desired shapes and angles. In today's industrial kitchens, supermarkets, product transfer equipment in hospitals, and home moving works, vehicle wheels are used to carry light, medium and heavy loads. On the rim sidewalls of these wheels, there are perforated sheet metal parts produced with progressive or stepped molds of certain thicknesses and also deep-drawn (Hambli, 2003).

Sheet metal, made of low carbon (0.1%) thin steel sheets (DKP) shaped by cold rolling process, is a versatile material used in various industries. Especially being suitable for deep-drawing processes allows this material to have a wide range of use. The durable structure of DKP sheet metal contributes to the long life of the manufactured parts. For these reasons, it is preferred in automotive parts, house holding goods parts, containers and tin cans and furniture parts. Advancements in die design and manufacturing have not only extended die lifespan but also enhanced the quality of punching and cutting by enabling more precise and cost-effective production processes. During the sheet metal piercing process, the material undergoes stages of plastic deformation, cutting, and fracture. Previous studies (Arslan et al., 2015; Arslan & Özdemir, 2016; Arslan, 2020) have shown that punching parameters such as the press machine settings, material type and thickness, die clearance, and piercing forces significantly influence the geometry of the hole edge. To remain competitive in today's tough competition conditions, the life of punches and dies should be very long, and the waste produced should be as little as possible. The quality of the parts coming out of the punch is generally determined by tool wear and burr height. These criteria are affected by the type of material, processing parameters, punch wear and punch geometry (Monteil et al., 2008, Hernandez et al., 2006, Hambli, 2002, Högman, 2002).

High wear in punches directly affects the quality of the final product. This mismatch between the work piece and the punch causes excessive stress increase. This intense friction during cutting causes excessive wear. These tribological events cause adhesion, micro cracks and tool fatigue and lead to premature breakage of the punch or the part. For better results, the punching and cutting parameters of the work piece materials should be selected appropriately. In industrial applications, apart from the examination of the hole geometry of the products, many studies have been conducted on tool life, wear, cutting gap and material thickness (Fang et al., 2002, Çavuşoğlu & Gürün, 2017, Arslan et al., 2013, Çicek et al., 2012). The geometric parameters in the punching process are shown in Figure 1. In Figure 2, the highest burr and other sections in the blank material taken as basis in this study are shown. Therefore, in this study, holes were opened on the DKP sheet materials with three punches on the wheel rim sidewall and the maximum burr heights in each hole were measured and compared.

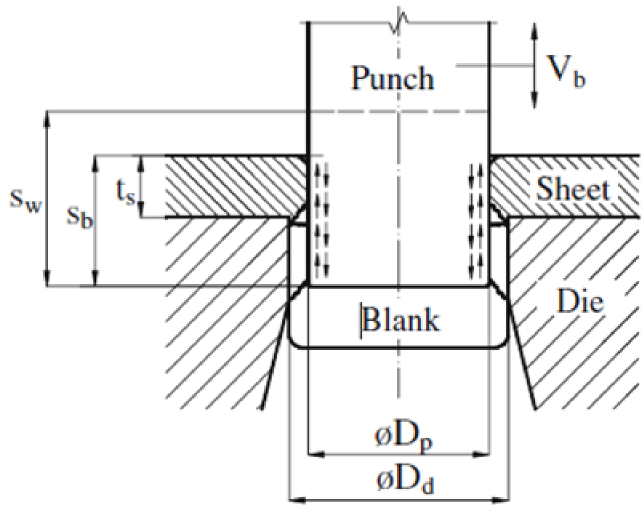


Figure 1. Procedure of blanking process (Mucha, 2010).

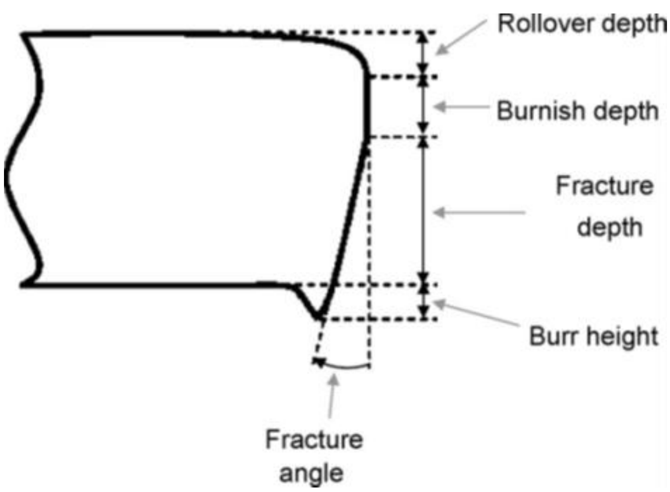


Figure 2. Parts and deformation of blank material (Husson et al., 2008).

Method

In this study, a 1 mm thick steel sheet material known as DKP characterized by its cold formability and a carbon content ranging from 0.15% to 0.2% was used. These types of sheets are commonly employed for storage and transportation applications. The cutting punch used had a diameter of 5.5 mm, a length of 100 mm, and a head diameter of 7 mm, and was made from AISI D3 tool steel. The experiments were conducted using a 500-ton conventional hydraulic press. The key process parameters included a die clearance of 10% (0.1 mm), a die cutting force of 610 kg, a stroke rate of 8 strokes per minute, a stroke length of 60 mm, and a punch speed of 900 mm/min. The chemical composition of the DKP material (ASTM A1011) is provided in Table 1, while its typical mechanical properties are shown in Table 2. The chemical composition and mechanical properties of the AISI D3 punch material are listed in Tables 3 and 4, respectively. The hydraulic press used in the punching process is illustrated in Figure 3, and the device used for measuring the manufactured parts and burr heights is shown in Figure 4. To measure the geometry of the cut surfaces, a contour measuring machine with a precision of 1×10^{-3} mm was used, ensuring that no damage was caused to the control arm parts. Measurements were taken after every 5,000 strokes, with samples collected at each interval. Burr height was evaluated based on the maximum burr height observed. For each sample, three regions around the hole perimeter were measured, and the results were averaged. Burr height was determined by taking measurements at predefined points along the perimeter of each blanked sample, with the maximum value recorded for analysis.

Table 1. Chemical composition of ASTM A1011 sheet

Weight, (wt %)	**C**	**Mn**	**S**	**P**	**Si**
	0.12	0.246	0.0072	0.0045	0.002

Table 2. The mechanical properties of ASTM A1011 sheet

Max. Tensile strength (MPa)	Yield strength (MPa)	Elastic Modulus (GPa)	Density (gr/cm^3)
390	295	200	8,80

Table 3. Chemical content of AISI D3 tool steel

Weight, (wt %)	**C**	**Cr**	**V**	**Mo**	**Si**	**Mn**	**P**	**S**
	1.5	12	1	0.7	0.36	0.3	0.024	0.0006

Table 4. The strength values of AISI D3 steel

Max.Tensile strength (MPa)	Yield strength (MPa)	Hardness (HRc)	Elastic Modulus (GPa)
1090	850	62	209

Figure 3. Experimental equipment of blanking sheet metal process

Figure 4. Manufactured product and burr height measurements

Results and Discussions

Typical microstructure of AISI D3 tool steel is given in Figure 5. The microstructure of the tool steel contains martensitic structure with presence of carbides and ferrites. The equal fine grain can be seen and distributed uniformly in same macrograph.


Figure 5. Optical microscopy picture of typical AISI D3 tool steel

Optical microscopy picture of worn punch surface is given in Figure 6. During the blanking process, the cutting edge of the punch, made of AISI D3 tool steel, has been plastically deformed. This caused the burr height on the product edge to increase significantly.

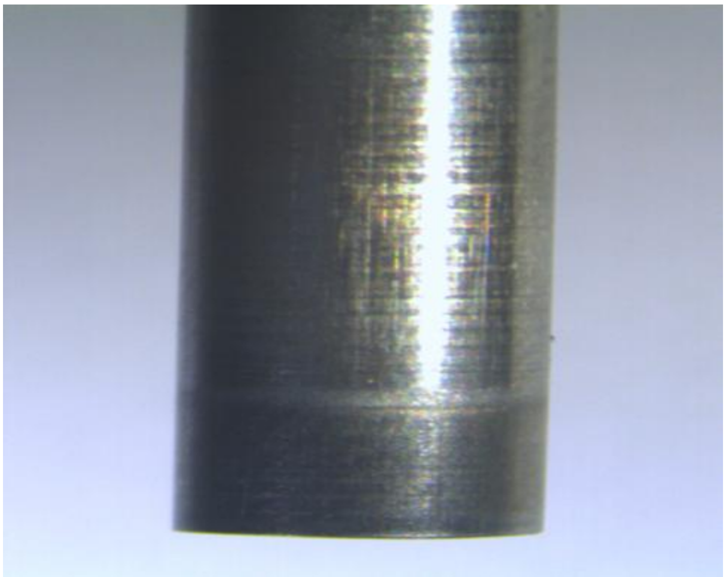
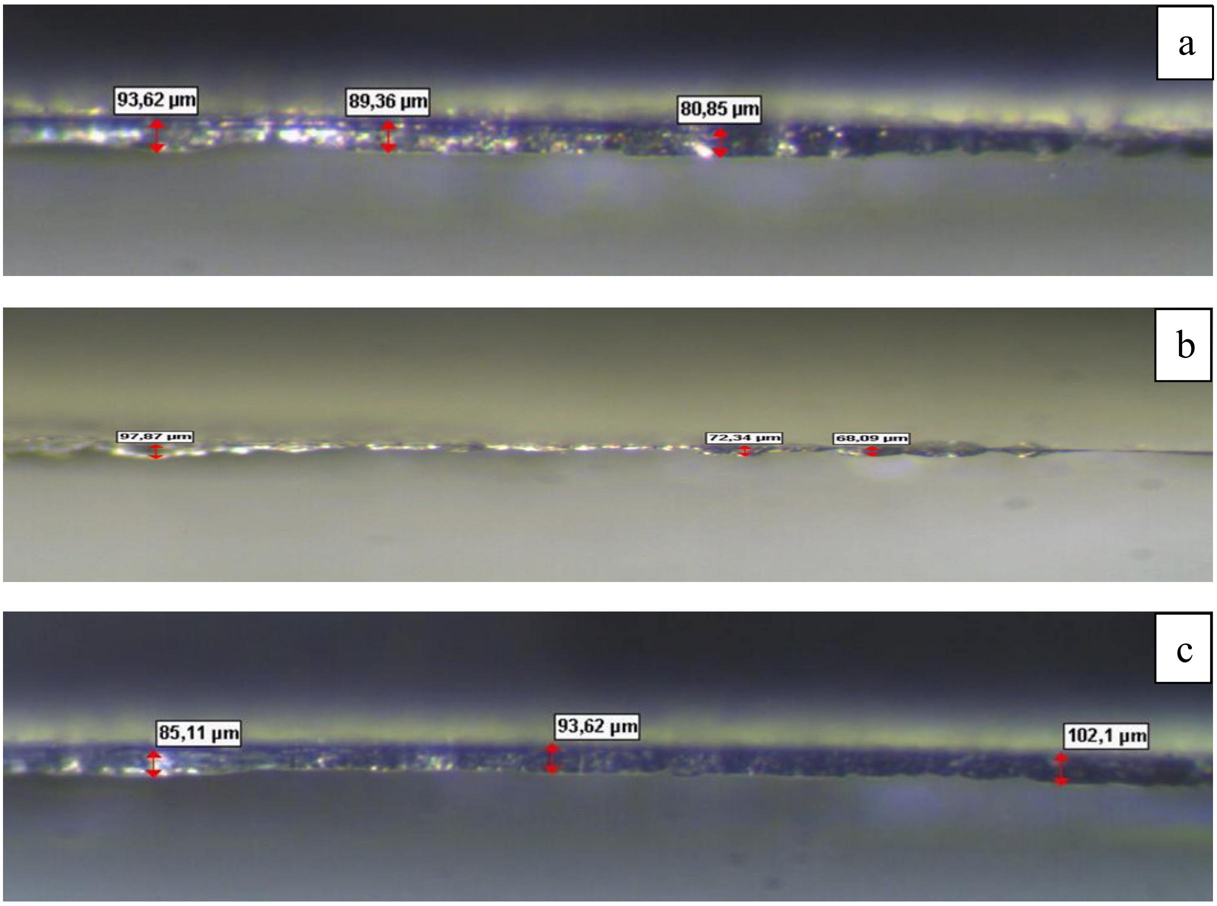


Figure 6. Optical micrographs of the worn punch after 70.000 strokes

Typical measurement of Maximum burr height values and optical microscopy pictures are shown in Figure 7. It can be seen that three different measurements were taken and maximum burr heights were detected on the blanked surface edge. Maximum burr height was 94 µm at 5000 stokes, 98 µm at 25.000 strokes, 102 µm at 35.000 strokes and 106 µm at 55.000 strokes. As the punching strokes increases, the burr height also increases, which is directly proportional to the wear on the punch.



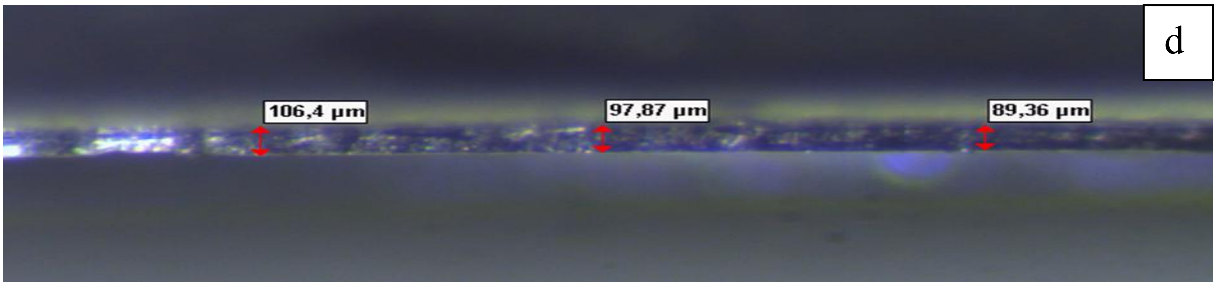


Figure 7. Measurements of maximum burr heights: a) 5.000 strokes for 3. punch, b) 25.000 strokes for 1. punch, c) 35.000 strokes for 2. punch, d) 55.000 strokes for 3. Punch

The relationship between burr height and the number of holes is a critical parameter in manufacturing processes, especially in punching operations. Burrs, which are unwanted protrusions that appear after multiple punching operations, significantly affect product quality, performance and the overall cost of finishing operations. Maximum burr height values were shown as a graph of produced materials in Figure 8. It can be seen that increase in number of strokes resulted in higher values of burr height. The important factor in the hole quality of the piercing is the hole diameter, circularity, rollover depth, fracture depth, burr height, fracture angle and smooth-sheared depth (Arslan, 2020, Fang et al., 2002). Also, it can be seen from same figure that there is no effect on the different location hole geometry and number, similar results can be observed from the same graph. Tool wear increases burr formation with continuous use, resulting in higher burr heights as cutting edges become less effective. It can also be said that burr formation is caused by excessive friction between the number of punches and the interaction of the tool with the material, which ultimately affects the applied cutting forces, changing the burr properties and increasing the temperature on the surfaces. Increased heat causes decreasing the yield strength both the punch material and, more importantly to the sheet material, and leading to more plastic deformation. Thus, burr height is significantly increased with increasing strokes. Optimum control of punch parameters is crucial to minimizing burr formation and is an important quality and control parameter in precision machining applications.

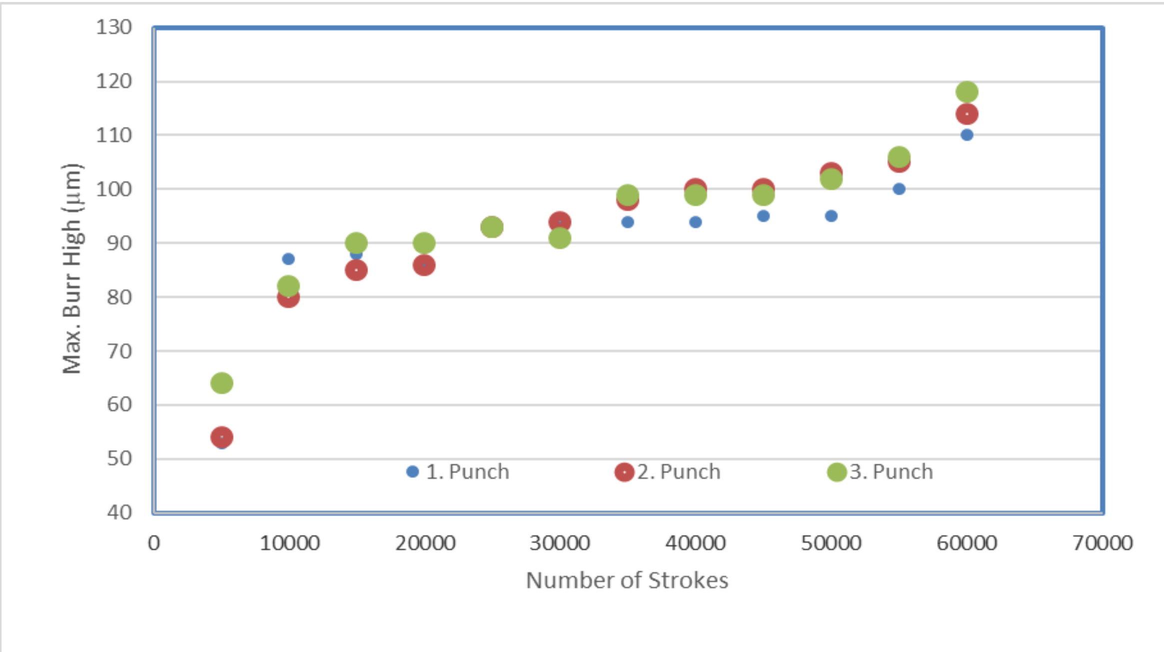


Figure 8. Average maximum burr height values of geometry of the cut surface of the holes of manufactured parts.

Conclusion

In this study, holes were shaped into the lower wheel table of ASTM A1011 metal sheets with AISI D3 punch, and three different burr heights were measured in three different punch holes, and the following results were obtained.

1. Hole operations with a large amount of punch could be successfully performed with minimal punch deformation.
2. Similar burr heights were obtained in drilling operations with punches located in three different locations.
3. Burr heights increased with increasing punch hole amount. The highest burr value was obtained with 118 µm and 60,000 strokes.
4. Excessive plastic deformation on the punch caused an increase in burr height.

Scientific Ethics Declaration

*The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

*The authors declare that they have no conflicts of interest

Funding

*No funding.

Acknowledgements or Notes

*This article was presented as an oral presentation at the International Conference on Basic Sciences and Technology (www.icbast.net) held in Budapest/Hungary on August 28-31, 2025.

*Authors thanks to Gunes Plastic Cooperation in Kocaeli/Türkiye for support and opportunities.

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To cite this article:

Uygur, I., Oktem, H., Karasungur, H., & Gerengi, H. (2025). Investigation of burr height for sheet metal process of medium duty casters in industrial kitchens. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 36,* 245-252.