A Circularity Analysis of Different Clearances in the Sheet Metal Punching Process

V Bram Armunanto, Yudit Cahyantoro NS, Kaleb Priyanto

Abstract— Nowadays, technological development demands efficiency of time and energy in all fields in order to create a product that can compete in the global market. Breakthroughs and innovations are needed merely to survive in manufacturing industry. Punching is the common process of using a cutting punch and die in the manufacturing process. A variety of physical phenomena occur in the metal cutting process such as metal flow, friction between the material and tools, process heat and changes in the microstructure of the material. Much research conerning dimensions, tolerances, cutting angles and cutting force has been carried out. This article discusses and examines the relationship between clearance, punch and dies circularity and circularity of the product of the punching process. Testing has been conducted using various punches with different diameters and different circularity conditions. The Coordinate Measuring Machine (CMM) which has an accuracy of 1 micron was used to measure the diameter of the punch and the dies, the clearance and circularity of the punch and dies, and the resulting product. The question is: is the circularity of the product of punching affected by the clearance or by the circularity of such tools?

Keywords- CMM.

I. INTRODUCTION

The punching process is the process of making a hole using a machine installed with a cutter in the form of a punch and die set, where the machine pushes the punch to cut the material with the dies at the bottom.

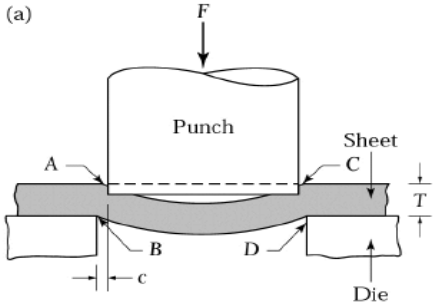


Figure 1 : The Position of the Punch-Dies and Material

Many factors need to be considered in the punching process. These include:

a. The dimensions of the punch and dies used.
b. The angle formed by the punch and dies.
c. The cutting pressure needed.
d. Suitable hardness of the punch and dies material.
e. Other demands such as the smoothness of the surface of the tools.

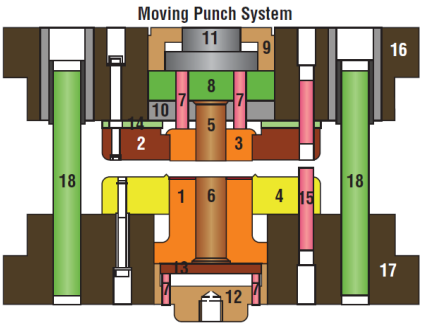


Figure 2 : Mould Punching Machine

Drawing annotation :

1. blanking punch
2. blanking plate
3. ejector
4. guide/ring plate
5. inner punch
6. inner ejector pin
7. pressure pin
8. backup plate
9. holding ring
10. piercing plate
11. pressure pad
12. punch base
13. ejector bridge
14. base plate
15. latch bolt
16. upper frame
17. lower frame
18. column

Clearance is the difference in size between punch and dies in a series of punching processes, measured from one side. The difference in size may vary due to punches and dies having a maximum and minimum size, which means that there are differences in the size of one punch or dies. The amount of clearance in a process of punching ranges between 5% - 7.5% of the thickness of the material being cut. If the clearance is too small (about 3%) it can cause a tear in the material being cut. If the clearance is too large (above 10%) it can cause burr / fracture the tip.

A punch and die set can be round, square, triangular, slot shaped or in another particular shape. Punch and dies have a certain size with a certain tolerance. Good clearance is a difference in size that allows the best result from the punching process.

The effects of clearance on the cutting process include:

= the magnitude of the cutting force required.
= the lifespan of the punch as the upper cutting tool.
= the lifespan of the dies as the lower cutting tool.
= the smoothness of the resulting surface / surface finish.

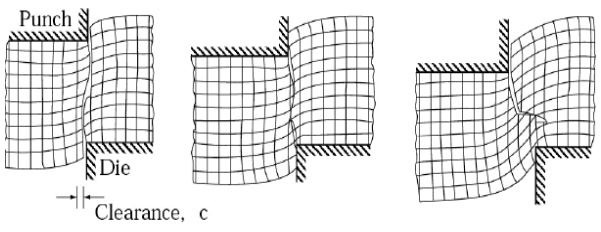


Figure 3 : Punching Process Faults

Manuscript received on December, 2012.

V Bram Armunanto, Mechanical Engineering, Sebelas Maret University, Surakarta, Indonesia.
Yudit CNS, Mechanical Engineering, Sebelas Maret University, Surakarta, Indonesia.
Kaleb Priyanto, Mechanical Engineering Sebelas Maret University, Surakarta, Indonesia.

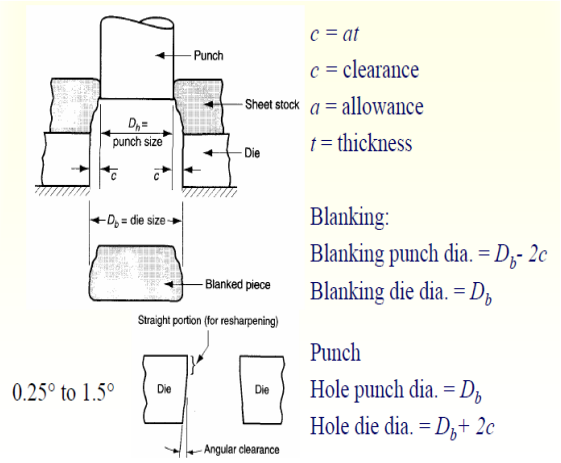
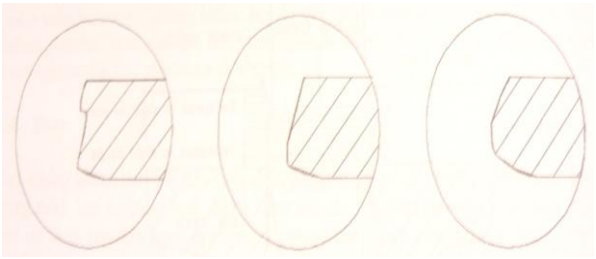


Figure 4 : Specifications of a Punch and Die.



5.1 5.2 5.3

Figure 5 : Resulting Pieces of the Punching Process.

Figure 5.1: resulting pieces of a small clearance.
Figure 5.2: resulting pieces of a suitable clearance.
Figure 5.3: resulting pieces of a large clearance..

The following table shows the thickness of the material used and the amount of clearance in the process of cutting sheet metal in accordance with DIN 1623.

Nr	Material Thickness	Spring Back	Clearance
1	0,10 mm	0,010 mm	0,02 mm
2	0,25 mm	0,020 mm	0,04 mm
3	0,40 mm	0,025 mm	0,06 mm
4	0,63 mm	0,030 mm	0,08 mm
5	1,00 mm	0,050 mm	0,11 mm
6	1,25 mm	0,055 mm	0,13 mm
7	2,00 mm	0,080 mm	0,25 mm
8	2,50 mm	0,100 mm	0,28 mm
9	3,20 mm	0,120 mm	0,30 mm
10	4,00 mm	0,130 mm	0,35 mm

Table 1 : Material – Spring Back - Clearance

Circularity / roundness is a cross-section calculated from the difference between the nearest and farthest distance to a point on the outside of the circle from the center. Geometric characteristics are essential for the suitability of the product. In the manufacturing industry with its accuracy to the micron meter, geometric characteristic circularity means that dimensions and tolerances absolutely must be met, and other associated requirements must also fit.

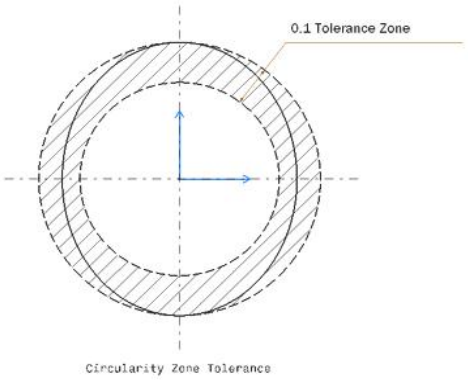


Figure 6 : Product Circularity

Specifications related to circularity tools and products for the punching process with 9 mm diameter: (Ø 8-13 mm)

Fine circularity: Circularity of the punch < 0.002 mm.
Circularity of the dies < 0.002 mm.
Circularity of the product < 0.004 mm.
Middle circularity: Circularity of the punch < 0.005 mm.
Circularity of the dies < 0.005 mm.
Circularity of the product < 0.012 mm.
Rough circularity: Circularity of the punch < 0.015 mm.
Circularity of the dies < 0.015 mm.
Circularity of the product < 0.025 mm.

II. PUNCH AND DIES USED FOR TESTING

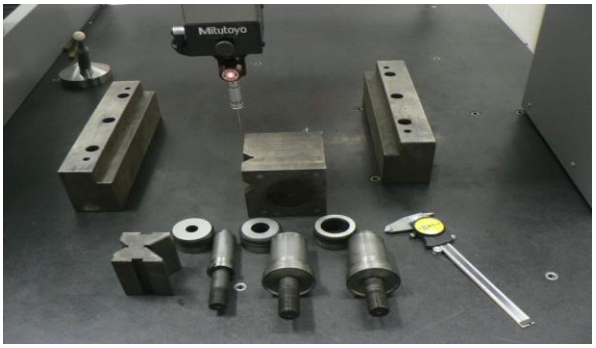


Figure 7 : Punch and Dies

One die and three punches made of SpKNL and XW5 of varying tolerances were used for testing. All of punch and dies diameters were 9 mm. The tools used met manufacturing standards related to surface smoothness = N6, hardness of the end product HRC = 62 and occuring corner formations. The tools used and their specifications are shown in table 2.

Tool Name	Min Ø (mm)	Max Ø (mm)	Circularity (mm)	Clearance (mm)
Dies 01	9.326	9.328	0.008	---
Punch 01	9.005	9.006	0.007	0.161
Punch 02	9.012	9.012	0.014	0.158
Punch 03	9.017	9.018	0.022	0.155

Table 2: Analysis of Tools Used.

III. DESIGN ANALYSIS OF PUNCH AND DIES

A. Modelling of the Punch

The punch is the male part of the cutting tool and works with an up and down movement from above. The shape of the surface intersection depends on the shape desired.

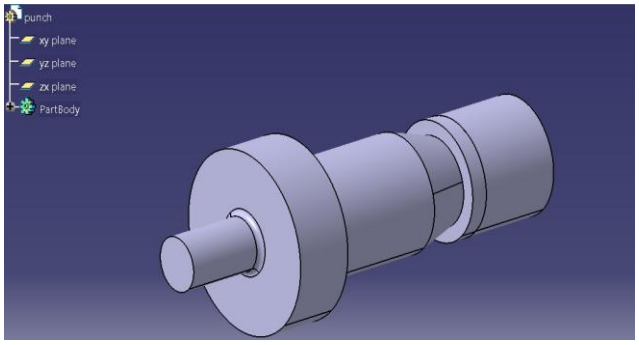


Figure 8 : Punch Tools.

Specifications applicable to the punch size:
Piercing punch, **d1 = d + f**
Blanking punch, **D1 = D – f – 2c**

d1 : punch diameter for piercing process.
d : piece diameter from the piercing process.
f : material spring-back.
D1 : punch diameter for the blanking process.
D : piece diameter from the blanking products.
2c : 2x clearance between punch-dies.

B. *Modelling of the Die*

The die is the female cutting part located on the under side. It has notching hole profiles in a similar shape to that of the punch. The die form can be made as an intact die plate or plate insert or mounted in a circuit of holders.

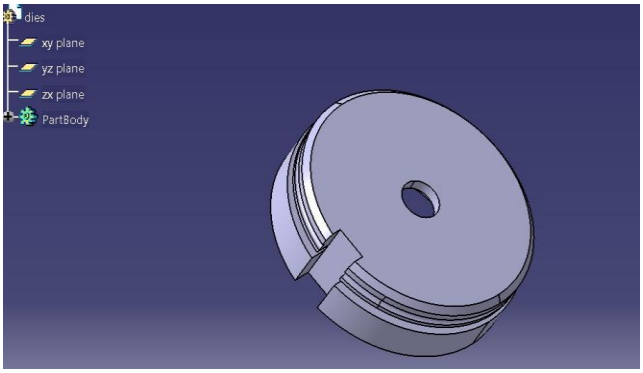


Figure 9 : Die Tools.

Specifications applicable to the die size:
Piercing die, **d2 = d + f + 2c**
Blanking die, **D2 = D – f**

d2 : die diameter for the piercing process.
d : piece diameter from the piercing processs.
F : material spring-back.
D2 : die diameter for the blanking process.
D : piece diameter from the blanking product.
2c : 2x clearance between punch-dies.

IV. MANUFACTURING REQUIREMENTS

A. *General Requirements*

For the manufacturing industry in general, dimensions and the tolerances are the two key factors. Clearance between the punch and dies are major factors associated with:

a. The thickness of the material.
b. The type of material.
c. The dimensions of the material to be cut.
d. The types of material for the cutting tools.
e. The surface finish and cutting results.

For industry using conventional machinery of this type, feeding, cutting speed or strokes per minute are not the main objective.

B. *Specific Requirements*

In industries that use Fine and Progressive Stamping Dies, speed and product performance are essential. The surface smoothness of the tools, the centricity, cylindricity and circularity of the punch and dies are also very important.

We can imagine that with a movement of materials and tools at a speed of about 500 strokes per minute, if demands outside of these dimensions are neglected, tools will quickly wear out, the product will not perfect, or tools may break because the hole is not round / off center.

Fulfilling the demands of the tools and equipment in the punching process is expected to reduce the number of errors and reject products which will both increase productivity and create a precise mold development that meets all the requirements of the industry in all fields.

V. RESULTS AND DISCUSSION

A. *Figures and Tables*

After running multiple tests, the results of the punching process can be observed in the following table :

No	Øpunch,mm (circularity)	Ø Dies,mm (circularity)	Ø Product (mm)	Product Circularity
1	**9.006 (0.007mm)**	**9.328 (0.008mm)**	**9.033**	**0.014**mm
			9.042	**0.016**mm
			9.036	**0.017**mm
			9.041	**0.018**mm
2	**9.012 (0.014mm)**	**9.328 (0.008mm)**	**9.049**	**0.021**mm
			9.042	**0.024**mm
			9.043	**0.028**mm
			9.045	**0.032**mm
3	**9.018 (0.022mm)**	**9.328 (0.008mm)**	**9.053**	**0.029**mm
			9.052	**0.033**mm
			9.053	**0.034**mm
			9.056	**0.035**mm

Table 3 : Diameter and Circularity of the Product.

From the test results can be computed average circularity product and made the following table:

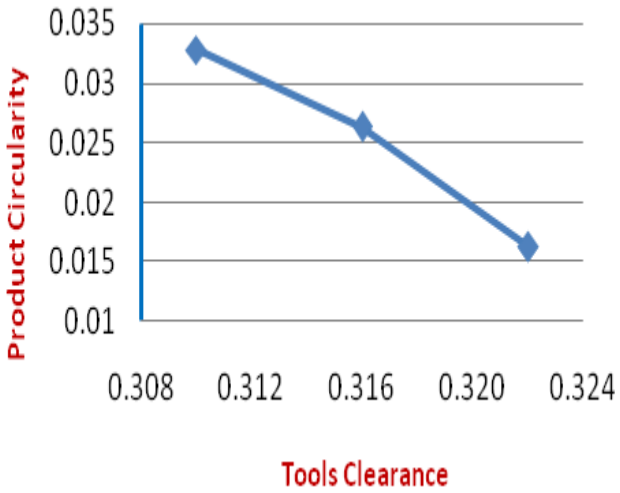


Table 4 : Tools Clearance – Product Circularity Graph.

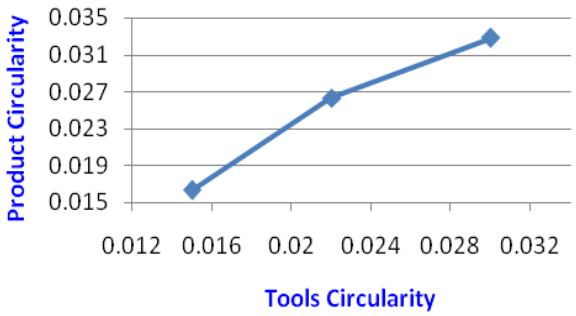


Table 5 : Tools – Product Circularity Graph.

VI. CONCLUSION

The results of the analysis of the punching process and measurements are as follows:

1. The circularity of the product is smaller than the clearance between the punch and dies.
2. The circularity of the product is always greater than the circularity of the punch and dies.
3. The diameter of the product hole is always larger than the diameter of the punch.
4. The diameter of the product hole is always smaller than the diameter of the dies.
5. Increasingly tight / small clearance between the punch dies does not guarantee the product circularity punching the smaller / stable.
6. The main effect on the product's circularity is the circularity of the tools used, the punch and die.

As such, while it was previously assumed that the tolerance and size of the punch and die were the main determinant of product circularity, this research indicates that the circularity of the punch and die are in fact the more influential factors.

REFERENCES

[1] Donald F Eary, "Techniques of Pressworking Sheet Metal Prentice - Hall, Inc., Englewood Cliffs, New Jersey 1974, pp. 15–24.
[2] Hermann W Pollack, Tool Design, Reston Publishing Company, Inc., Virginia, 1976, pp. 23–35.
[3] Donaldson Lecain Gold, Tool Design, Tata Mc Graw – Hill Publishing Company Ltd., New Delhi, 1978, ch. 4.
[4] Heinrich L Hilbert, "Stanzereitechnik," Schneidende Werkzeuge, Carl Hanser Verlag, Muenchen, 1971.
[5] J R Paquin, "Die Design Fundamentals," Industrial Press Inc., 200 Madison Avenue, New York, N.Y.10016, 1962.
Anthony Davidson, "Handbook of Precision Engineering, Vol.10.
N.V Philips, Gloeilampenfabrieken, London, 1974.
[6] J.B Moerbani, "Punching Tools 1 and 2," ATMI Polytechnic Lab., ATMI Solo Press, Indonesia 2005, pp. 7-14.
[7] B Sudibyo and Djunarso, "Tolerance," ATMI Polytechnic Lab. *ATMI Solo Press, Indonesia, 1991.*
[8] VB Armunanto, "Industrial Metrology" ATMI Polytechnic Lab., ATMI Solo Press, Indonesia, 2004.
[9] D. Brokken, "Numerical Modelling of Ductile Fracture in Blanking" PhD Thesis, Eindhoven University of Technology, Netherland, 1999.
[10] Chang T.M. "Shearing of Metal Blanks" Institute of Metals, 1951. pp. 393-414.
[11] Xiao Jingrong and Jiang K, "Stamping Technology" Mechanical Industry Press, Beijing, 1993. pp 137-143.

V Bram Armunanto Magister Mechanical Engineering, Sebelas Maret University, Surakarta, Indonesia, Industrial Metrology HandBook for Polytechnic ATMI, Manual Book for Small Measuring Tools.

Yudit Cahyantoro NS Magister Mechanical Engineering, Sebelas Maret University, Surakarta, Indonesia.

Kaleb Priyanto Magister Mechanical Engineering, Sebelas Maret University, Surakarta, Indonesia.

Figure 10 : Raskin Punching Machine.

Figure 11 : CMM Measuring Machine.