The 24th Conference of the Mechanical Engineering Network of Thailand
October 20 – 22, 2010, Ubon Ratchathani

The Effect of The Single Point tooling Radius to Roughness of DIN 1.0037 Steel Formed Workpiece in Incremental Forming Process

Kittiphat Rattanachan* and Chatchapol Chungchoo

Mechanical Engineering Department, Faculty of Engineering, Kasetsart University,
Bangkok, 10900, Thailand
*E-mail: r_kittiphat@hotmail.com

Abstract

This published paper concerns about tool radius in single point incremental forming (SPIF) process. Currently, there are insufficient data of SPIF for applying to be used in manufacturing. So in this research, the objective was to study the effect of tool radius on the roughness of DIN 1.0037 steel workpiece formed by the SPIF process to create the specific data to be convenient to use in industry application. The tool was used in the experiment is made of HSS tool steel, 10 mm. In diameter, with edge grinding to submit the radius 2, 4 and 5 mm. respectively. And some other parameters, such as toolpath, tooling speed and feed rate, and tool side overlap and step depth were treated as fixed parameter. The oil SAE 46 was used as lubricant in the experiment. After testing the workpiece was measured its roughness. The result demonstrates that tool radius had a high effect on the roughness of workpiece manufactured by SPIF process.

Keywords*:* Single Point Incremental Forming, Sheet metal rapid prototype, Tool radius

1. Introduction

Single point incremental forming (SPIF) is a new sheet metal forming process with a high potential economic payoff for rapid prototyping applications and for small quantity production. The basic components of the process compose of the sheet metal blank, the fixture and the rotating single point forming tool. The sheet was clamping and holding in the fixture during forming. The tool is move progressively shapes follow toolpath, which was generated by a CNC machining centre. This is dieless process, in this process there is no die required to form the sheet. There is the effectiveness process, but the disadvantage of this process is the very high surface roughness, its make the process is very difficult to apply to the real manufacturing process because the surface roughness of workpiece is very important, the surface must be attractive to the customers, when it used as the commercial part.

2. Literature reviews

G. Ambrogio et al., had studied on the dimensional accuracy of the incremental forming operations by using the tool radius 12 and 18 mm and tool pitch 1 and 2.5 mm to form the frustum of pyramid, with 163 mm side and 50 mm height, the result was compared between the accuracy of designed surfaces and the obtained ones, but unconcern about surface roughness of specimen. [1] E Hagan, J Jeswiet. was studied on surface roughness of annealed Al 3003 sheet which formed by incrementally forming, that using various tool depth increments and spindle speeds. A relationship was defined between peak-to-valley roughness and depth increment, which was then compared to theory for shear forming. [2] G. Hussain et al., was investigated the suitable tool and lubricant, which can be employed to form a commercially pure titanium (CP Ti) sheet by negative incremental forming. The various combinations of tools and lubricants were employed. The effect of each combination of tool and lubricant on the quality of the formed surface was studied by measuring the surface roughness with a surface roughness meter and examining the surface with a scanning electron microscope (SEM), the CP Ti components having good surface quality can be realized by using the surface-hardened high speed steel (HSS) tool and the paste of molybdenum disulphide (MoS_2) with petroleum jelly in a specific proportion. [3] K. Hamilton and J. Jeswiet was studied and analyzed the effects of forming at high feed rates and tool rotational speeds in SPIF. Roughness and forming parameters were used to create models for an equivalent combinatory roughness which characterizes orange peel roughening. [4] V. Oleksik et al., was studied on the surface quality of the medical implants obtained by SPIF to demonstrate the factors that influence its. Those factors compose of the initial roughness of the punch, the punch diameter, and the friction coefficient between the punch and the blank. [5] Hamilton and Kelvin Allan Samuel was studied the effects of step size, angle, spindle speed, and feed rate on the external surface roughening, orange peel effect, observed in SPIF. Forming were performed at very high rotational speeds and feed rates and showed various influences on surface roughness, thickness distribution, and grain size. [6]

3. Research experimental

The surface roughness of SPIF workpiece is depend on the process parameters such as, tool roughness, tool rotational speed and feed rate, workpiece material and lubrication. The aim of this research was to determine the relationship between tool radius and surface roughness of DIN 1.0037 sheet steel workpiece.

The fixed parameters are tool diameter of 10mm, tool rotational speed of 100 rpm and feed rate of 3140 mm/min follow equation 1 (mean linear speed at the surface of tool), side and depth step of 1.5 and 3 mm respectively, workpiece of 0.8 mm thick DIN 1.0037 steel (see Table 1.), the dome shell of 100 mm. tested configuration, and lubricant are SAE 46 oil. Other parameter such as, toolpath is a “Plane spiral, center to edge and depth” [7, 8]

$$f = \pi d n \qquad (1)$$

while

f = feed rate (mm/min) it is equivalent to the mean linear speed at the surface of tool.

d = tool diameter (mm)

n = tool rotational speed (rpm)

The variable parameter was tool radii and tool geometry. The radiuses are 2.5, 4 and 5 mm respectively, and tool geometry is 5 mm half sphere and 5 mm hemisphere as shown in Fig. 1

Table 1 The mechanical property of DIN 1.0037 steel.

No. of test specimen	Tensile strength (Nmm^{-2})	Yield stress (Nmm^{-2})	% Elongation (mm/mm)
1	355.50	272.50	18.36
2	350.93	265.83	18.49
3	357.41	275.67	19.99
Ave	354.61	271.33	19.94

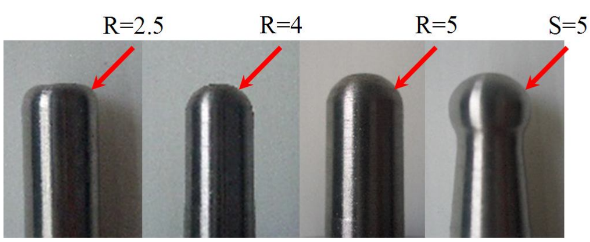


Fig. 1 Tool radius and configuration

The testing machine, tool and apparatus which used in experiment were shown in Fig 2. There are 3 axis CNC machine tool “Bridgeport VMC 600X” lowest spindle speed is 100 rpm, and the apparatus is clamped on its table.

The toolpath and tool direction were selected to avoiding surface rubbing between tool and sheet metal surface. (see Fig 3-4)


Fig. 2 Machine and apparatus

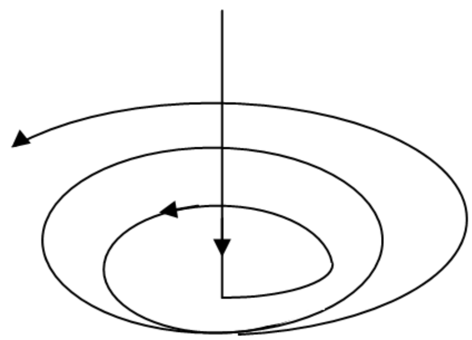


Fig. 3 Toolpath configuration

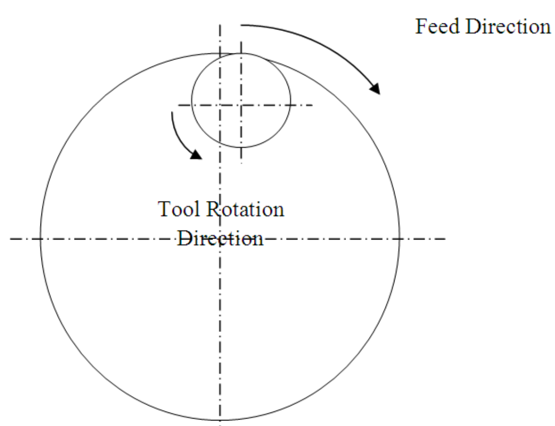
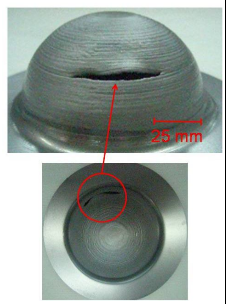
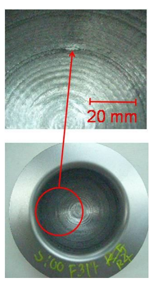
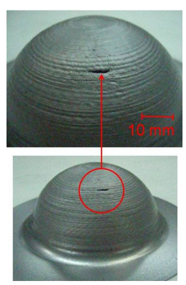
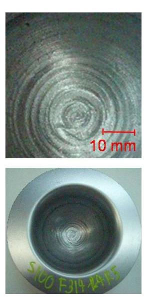
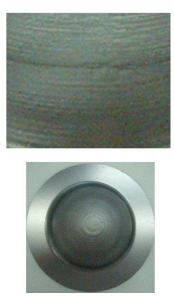
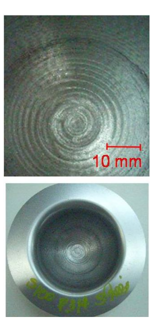
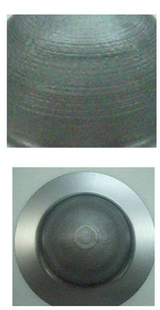


Fig. 4 Tool direction

4. Experimental result

The experimental result was shown in Table 2.

Table 2 The experiment result

Tool	Radius	Result	
		Inside	Outside
half sphere	r=2.5		
half sphere	r=4		
half sphere	r=5		
Hemisphere	S=5		

The results demonstrate the contribution of tool radius to the surface roughness, the smaller tool radius, the higher surface roughness.

The surface of specimen formed with the smaller tool radius had the highly wear mark than formed with larger tool radius, the surface roughness is too rough then it can not measure with the surface measuring machine and there are not show the quantitative data in this paper.

The hemisphere tool formed the lower surface roughness part than the half sphere tool with the same diameter

5. Conclusion

In this result demonstrate that the smaller tool radius which used in SPIF process trend to higher the opportunity of wall tearing, then at the same forming condition this is better to choose the larger tool radius

The smallest radius that formed without wall tearing was 5 mm, because the bending stress effect in combine stress at the wall local forming process was lower than formed with 2.5 and 4 mm radius tool.

The hemisphere of 5 mm radius tool formed the lower wear surface than the half sphere tool, because there is a straight line at the connection of tool radius and tool body of half sphere 5 mm of radius tool, then it rubbing the sheet metal workpiece with this sharp area of tool while the hemisphere is not.

The largest strain was the strain in the center line of dome that approximation value was 150 %. And compared this value with 19.94 % strain of material (table 1), which demonstrate advantage of SPIF process for very high elongation over the strain limitation of material from tensile testing.

6. References

[1] G. Ambrogio, I. Costantino, L. De Napoli, L. Filice, L. Fratini, and M. Muzzupappa (2004). Influence of some relevant process parameters on the dimensional accuracy in incremental forming: a numerical and experimental investigation, Journal of Materials Processing Technology, Volumes 153-154, 10 November 2004, pp. 501-507

[2] E Hagan, J Jeswiet (2004). Analysis of surface roughness for parts formed by computer numerical controlled incremental forming, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Volume 218, Number 10 / 2004, pp. 1307-1312

[3] G. Hussain, L. Gao, N. Hayat, Z. Cui, Y.C. Pang and N.U. Dar (2008). Tool and lubrication for negative incremental forming of a commercially pure titanium sheet, Journal of Materials Processing Technology, Volume 203, Issues 1-3, 18 July 2008, pp. 193-201

[4] K. Hamilton and J. Jeswiet (2010) Single point incremental forming at high feed rates and rotational speeds: Surface and structural consequences, CIRP Annals - Manufacturing Technology, Volume 59, Issue 1, 2010, pp. 311-314

[5] V. Oleksik, A. Pascu, C. Deac, R. Fleacă, O. Bologa and G. Racz (2010) Experimental study on the surface quality of the medical implants obtained by single point incremental forming, International Journal of Material Forming, Volume 3, Supplement 1 / April, 2010 pp. 935-938

[6] Hamilton and Kelvin Allan Samuel (2010). FRICTION AND EXTERNAL SURFACE ROUGHNESS IN SINGLE POINT INCREMENTAL FORMING: A study of surface friction, contact area and the 'orange peel' effect. Queen's University, 2010

[7] Kittiphat Rattanachan and Chatchapol Chungchoo (2009). Primary Study of Incremental Forming Process Parameters that Affect to Formability of DIN 1.0037 Steel, 6th Conference in Materials Processing Technology, 6-7 January 2009, BANGKOK, Thailand, pp -

[8] Kittiphat Rattanachan and Chatchapol Chungchoo (2010). An Experimental Study of Formability in Single Point Incremental Forming of Dome Specimen, Technology and Innovation for Sustainable Development International Conference (TISD2010), 4-6 March 2010,
Khon Kaen, Thailand, pp 415-419