International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 07 Issue 05
May 2020

Influence of Single Point Incremental Forming Parameters on 1008-AISI Surface Hardness

Baqer A. Ahmed [1], Saad K. Shather [2] & Wisam K. Hamdan [3]
[1,2,3] Department of Production Engineering and Metallurgy, University of Technology, *Baghdad, Iraq*

Abstract:

This paper is aimed to study the effect of some important factors (incremental step size, product angle and tool rotational speed) on the surface hardness during single point incremental forming (SPIF) of truncated cone made from (1008-AISI) workpiece. In this study the Box-Behnken design of experiment has been used. The obtained results illustrate that the incremental step size has the great significant on surface hardness among the other factors. The contribution percent of (incremental step size, rotational speed and wall angle) on surface hardness were (42.5, 12.5 and 18.13) % respectively.

Keywords

Surface hardness, Single point incremental forming, 1008-AISI, Box-Behnken design

1. Introduction

Incremental sheet metal forming (ISMF) is the process at which the metal blank sheet is clamped simply with a blank holder and hemispherical end of the tool which numerically controlled will form the sheet incrementally to the required shape that will contain a series of locally deformed zones. In 1967 the idea of single point incremental forming was patented by Leszak, named "die less forming" before it was technically feasible [1]. Conventional sheet metal forming (SMF) requires expensive different dies, which contains complex dies, positive and negative dies, etc., furthermore the higher cost and the absences of the flexibility to catch the customer's requirements [2]. Innovative, flexible, and rapid manufacturing processes have been presented to meet the demands of new products with different shapes and materials, small quantities production with minimum cost, etc. One of these processes is the Single point incremental forming (SPIF) [3]. Symmetric and non-symmetric parts can be formed by this process from 100 microns up to several mm thicknesses [4]. ISMF is based on CAD/CAM systems. The geometry of the part and the path of the tool is generated by the applications of CAD after that the process of the sheet forming is completed by a CNC milling machine, were the tool of the machine is replaced by a tool with a hemispherical head which moves over the sheet by positioning system of the CNC machine to form the part layer by layer with little values of Z-interval to avoid the tear in the sheet rely on local sheet deformation [5, 6]. Single Point Incremental Forming (SPIF) and Two Point Incremental Forming (TPIF) are the two types of (ISMF) [7].

S. Kurra et al (2015) have developed a predictive model for estimating the surface roughness during the SPIF process. Three techniques have been used for modeling Surface roughness in SPIF (Artificial Neural Networks (ANN), Support Vector Regression (SVR), and Genetic Programming (GP)). The model variables were (diameter of the tool, step depth, wall angle, lubricant type, and feed rate) using EDD steel workpiece. The optimization of SPIF factors has a good result with 10% error between the obtained and validated surface roughness [8].

Yanle Li et al (2018) have focused on improving the thickness distribution and mechanical properties (e.g., hardness, yield strength, and tensile strength) through process optimization. A set of experiments with 15 tests for pyramid-forming process is performed, and three parameters including step-down size, sheet thickness, and tool diameter are considered. The results show that the maximum thinning rate is lower with larger step down size and larger tools. In addition, compared with the initial sheet, the values of hardness, yield strength, and tensile strength have been increased considerably due to the strain hardening [9].

A. Dabwan et al (2020) have studied the effects of four important single-point incremental forming process parameters on produced surface profile accuracies. The results indicate that the tool diameter (d), step depth (s), and sheet thickness (t) have significant effects on the produced profile accuracy, while the feed rate (f) is not significant [10].

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 07 Issue 05
May 2020

2. Experimental Procedure

SPIF is performed on CNC milling machine, where it used to control and assign the tool movement according to the desired paths. A hollow cylindrical frame is manufactured from medium carbon steel by metric turning machine with outer diameter (220 mm) and inner diameter (190 mm) and height of (200mm). A ring with radii equals to the radii of the forming frame has been used as a blank holder. As shown in Figure 1, the blank holder has nine holes uniformly distributed along the circumference of blank holder and the frame. Nine studs (M8) are utilized in order to fix the blank sheet between the frame and the blank holder. In this work, a hemispherical head of the cylindrical tool manufactured from tool steel with diameter (12 mm) is utilized in order to form the required shape which illustrated in the Figure 2. The Samples of (1008-AISI) sheets with dimensions (250x 250 x 0.5) mm, were used to perform the 15 experiments. The experimental work was applied using oil lubricant SAE 30 on RAPIMILL 700 CNC milling machine, equipped with a 802D Siemens numerical command. The single point incremental forming (SPIF) is performed with hem-spherical tool to produce the truncated cone illustrated in Figure 3. The chemical composition of workpiece illustrated in Table1.

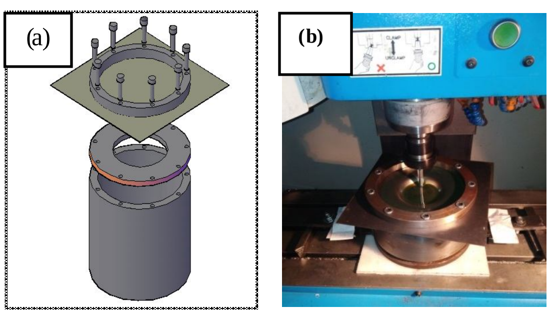


Figure (1): The forming frame being used for experiments,

(a) Graphical frame.

(b) Physical frame.

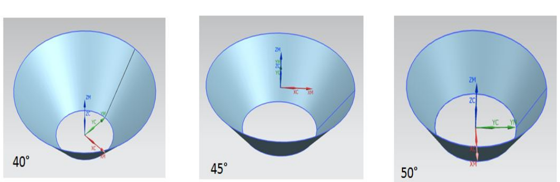


Figure (2): The geometry of part

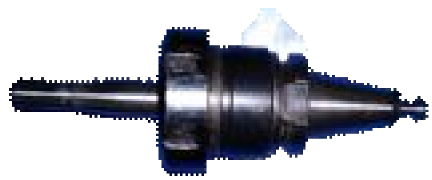


Figure (3) SPIF tool with tool holder

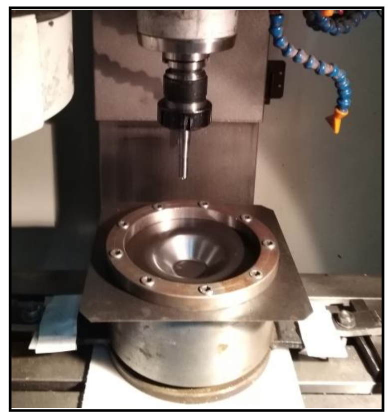


Figure (4) the produced truncated cone shape

Table1. Chemical composition of workpiece (1008-AISI)

element	Weight%
C	0.08
Si	0.02
Mn	0.32
S	0.024
P	0.014
Cr	0.035
Ni	0.032
Mo	0.002
V	0.001
Cu	0.072
Al	0.044
Fe	Remain

3. Plane of Experiment

In this work a special design of orthogonal arrays with a small number of experiments Box-Behnken method was used to study the entire parameter space. The methodology of Box-Behnken for three factors at three levels is used for applied of experiments. The levels and process parameters are illustrated in Table

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 07 Issue 05
May 2020

2. Table 3 illustrated the present work and the test results.

Table2. Process parameters and their levels

Parameters	Unit	Level 1	Level 2	Level 3
Rotational Speed (S)	Rev/min	600	700	800
Wall angle (α)	degree	40	45	50
Incremental step size (ΔZ)	mm	0.3	0.5	0.7

Table 3. Experimental layout using Box-Behnken design and corresponding results

NO.	Incremental step size (mm)	Rotational Speed (Rev/min)	Wall angle (α) (degree)	Micro hardness (Hv)
1	0.3	600	45	210.0
2	0.7	600	45	337.4
3	0.3	800	45	200.8
4	0.7	800	45	250.5
5	0.3	700	40	160.3
6	0.7	700	40	220.7
7	0.3	700	50	188.7
8	0.7	700	50	309.3
9	0.5	600	40	260.6
10	0.5	800	40	175.7
11	0.5	600	50	283.2
12	0.5	800	50	270.0
13	0.5	700	45	280.5
14	0.5	700	45	280.2
15	0.5	700	45	281.8

4. Results and Discussion

The main effect plot of micro hardness during SPIF is illustrated in Figure (5) it's observed that the hardness is directly proportional to (ΔZ). Increasing the (ΔZ) will causes to improve of the sheet hardness because of the material will gained high plastic deformation which causes notable strain hardening, where the strain hardening majorly denote to the phenomena that the material strength and hardness to increase on the other hand the material toughness reduces due to increase of plastic deformation the reason is that when stress increase till more than one slip system starts at same time, dislocations intersect with each other so the dislocation are pinned and difficult to move, resulting the increase of strain hardening and hardness. Also, it's observed that the hardness is inversely proportional to the rotational speed (S). Increasing the spindle speed will causes increasing of the generated heat that increase the formability and yield strength in tool-blank contact zoon will reduced. The hardness increases with decreasing the rotational speed and vice versa. The increasing of wall angles from (40° to 45°) the hardness increases, where the contact radius with the sheet also increases which cause the material suffers repeated squeezing action which influence the surface hardness, and no change in hardness from (45° to 50°). The contribution percent of forming parameters (incremental step size, rotational speed, and wall angle) on micro hardness were (42.497, 12.498, and 18.131) % respectively. The response surface plot and contour plot of micro hardness are illustrated at Figures (6, 7) respectively, from these Figures its concluded that the lowest micro hardness can be achieved with a higher rotational speed of forming tool and 40° of product wall angle, smaller micro hardness is attainable at S at the highest level and ΔZ at lowest levels, the highest micro hardness can be achieved with a higher level of ΔZ and α. The residual plot of the normal probability for micro hardness is shown in Figure (8).

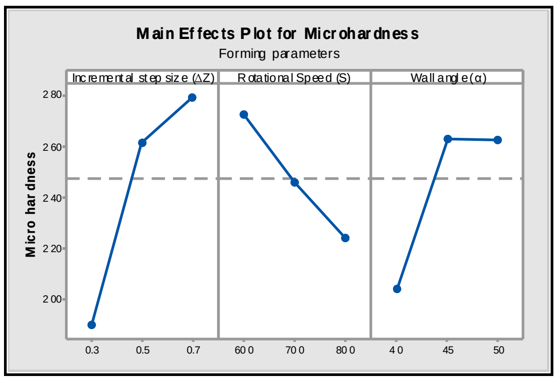
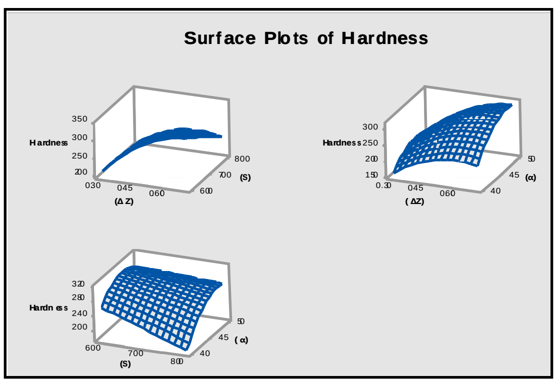


Figure (5): The main effect plot of micro hardness



p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 07 Issue 05
May 2020

Figure (6) response surface plot of micro hardness

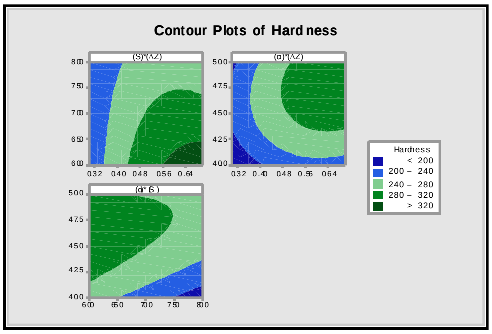


Figure (7): Response contour plot of micro hardness

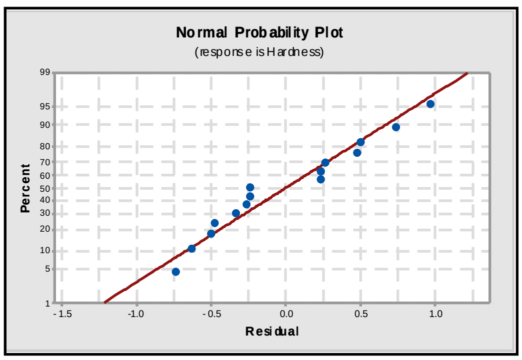


Figure (8): Normal probability plot for micro hardness.

5. Conclusion

From this experimentation the following conclusions can be drawn:

1- The surface hardness of the single point incremental forming (SPIF) product is affected by the forming parameters (incremental step size, spindle speed, and wall angle of the product).
2- The most significant parameter influencing the hardness is the incremental step size.
3- The contribution percent of forming parameters (incremental step size, rotational speed, and wall angle) on micro hardness were (42.497, 12.498, and 18.131) % respectively.

6. References

[1] Jigar Pathak, "A brief review of Incremental sheet metal forming", International Journal of Latest Engineering and Management Research (IJLEMR), Volume 02 - Issue 03, PP. 35-43, 2017.

[2] S.H.Wu, Ana Reis, F.M. Andrade Pires, Abel D. Santos, and A. Barata da Rocha, " Study of tool trajectory in incremental forming" Advanced Materials Research Vols. 472-475 , pp. 1586-1591, 2012.

[3] Wissam K.H. Sarraji , Dr.Jamal H. Mohamed , and Dr.Wei-Xin Ren, "An Experimental Investigation of Some Relevant Process Parameters Affecting Formed Thickness in ISMF Process" Eng & Tech. Journal, Vol.28, No5, 2010.

[4] Saad Arshad, "Single Point Incremental Forming: A study of Forming Parameters, Forming Limits and Part Accuracy of Aluminium 2024, 6061 and 7475 Alloys", A thesis, Department of Industrial Engineering And Production, KTH Royal Institute of Technology, 2012.

[5] G. Hussain and L. Gao, "A novel method to test the thinning limits of sheet metals in negative incremental forming" International Journal of Machine Tools & Manufacture, pp. 419–435, 2007.

[6] A. Petek, K. Kuzman , and J. Kopaè,"Deformations and forces analysis of single point incremental sheet metal forming", International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering, Vol. 35, pp. 107-116, 2009.

[7] Amar Kumar, Johan Verbert, Bert Lauwers, and Joost R.Duflou, "Tool path compensation strategies for single point incremental sheet forming using multivariate adaptive regression splines", Computer Aided design – Elsevier, vol. 45, pp. 575-590, 2013.

[8] S. Kurra, N. Hifzur Rahman, S. P. Regalla, and A. K. Gupta, "Modeling and optimization of surface roughness in single point incremental forming process" , Journal of Materials Research and Technology, vol. 4, no. 3, pp. 304–313, 2015.

[9] Yanle Li, Xiaoxiao Chen1, Weidong Zhai, Liming Wang, Jianfeng L, and Zhao Guoqun," Effects of process parameters on thickness thinning and mechanical properties of the formed parts in incremental sheet forming", The International Journal of Advanced Manufacturing Technology, doi.org/10.1007/s00170-018-2469-9, 2018.

[10] Abdulmajeed Dabwan, Adham E. Ragab, Mohamed A. Saleh, Saqib Anwar, Atef M. Ghaleb, and Ateekh Ur Rehman ," Study of the Effect of Process Parameters on Surface Profile Accuracy in Single-Point Incremental Sheet Forming of AA1050-H14 Aluminum Alloy" ,Advances in Materials Science and Engineering Volume 2020, Article ID 7265941, 14 pages, 2020.