ANALYSIS OF THE SURFACE QUALITY OF PARTS PROCESSED BY SINGLE POINT INCREMENTAL FORMING

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Abstract: The aim of the current work was to analyse the influence of the process parameters (tool diameter, size of the vertical step of tool, feed rate and spindle speed) on the quality of the processed surface, expressed in terms of roughness and macrostructure in the case of parts processed by single point incremental forming. The analysis was made on A1050 aluminium metal sheets. The obtained results revealed that the process parameters influence differently the surface quality, the worst influence being exerted by the increase of the vertical step of tool.

Keywords: SPIF, process parameters, surface quality

1. INTRODUCTION

Single point incremental forming (SPIF) is an unconventional technology suitable for unique or small series production of components made by metal sheets. It is a flexible forming process that represents an economic alternative to the conventional forming methods since it enables production of complex geometries without costly tools [1-3]. The working principle consists of progressive local deformation of a metal sheet by a simple tool whose trajectory is controlled through CNC programming (Figure 1).

Many studies have been dedicated to this technology over the last decade to make it applicable at industrial level, since different industries as automobile, aerospace or medical industry have shown an increasing demand for prototypes and small series production to face out the diversified customer's demands [1]. Despite its main advantages (flexibility, enhanced formability), single point incremental forming is not yet largely used in industry because there are still unsolved aspects related to the quality of the processed parts and processing time.

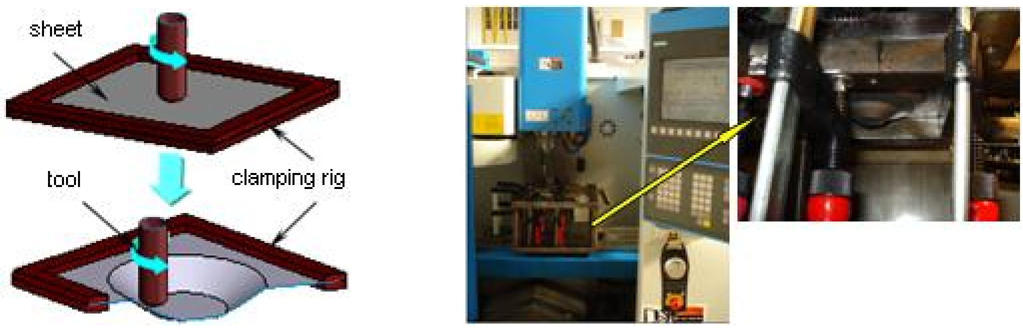

Fig. 1. Principle of the single point incremental forming process.

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2. EXPERIMENTAL SETUP

2.1. Material of samples and part geometry

Samples of A1050 aluminium metal sheets (EN 573-3 standard), 210 x 210 x 0.6 mm, were used to perform the experiments. In addition, 0.8 and 1mm thick metal sheets were used to determine the effect of the sheet thickness on the quality of processed surface. The geometry of part is shown in Figure 2.

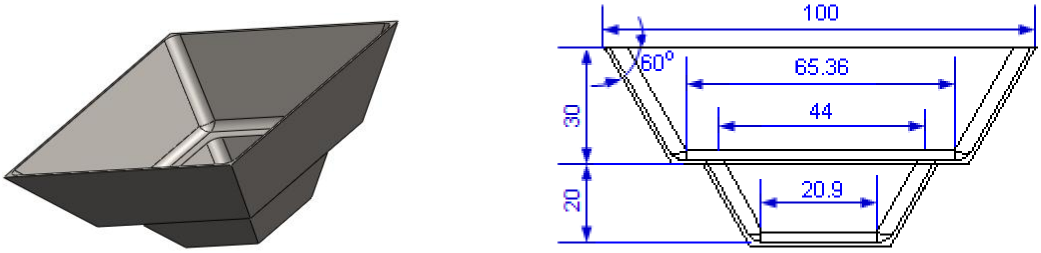


Fig. 2. Geometry of part.

2.2. Experimental equipment and methodology

The metal sheet samples were SPIFed by using a three axis CNC milling machine (RAPIMILL 700), equipped with an 802D Siemens numerical command that assured the spherical-head tool trajectory. A FEM 110 CNC electro discharge machine (Figure 3) was used to prepare the samples whose roughness was measured with a Mitutoyo SJ-20 roughness device (Figure 4). Measurements were performed also on unformed samples, in order to have a comparison basis, by using the same roughness device and an AFM microscope. Three measurements were performed on each sample and their average was used as the roughness value. The macrostructure analysis was performed on a metallographic microscope, on samples previously prepared; the measurements were done on the sheet thickness, at a magnification of 450X.

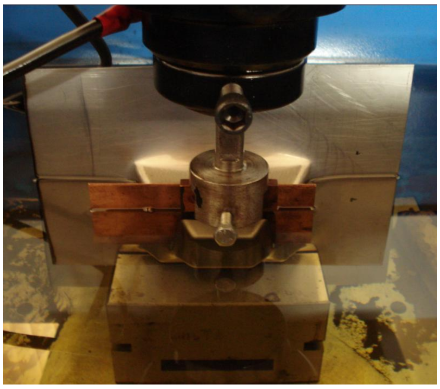


Fig. 3. Cutting samples by EDM.

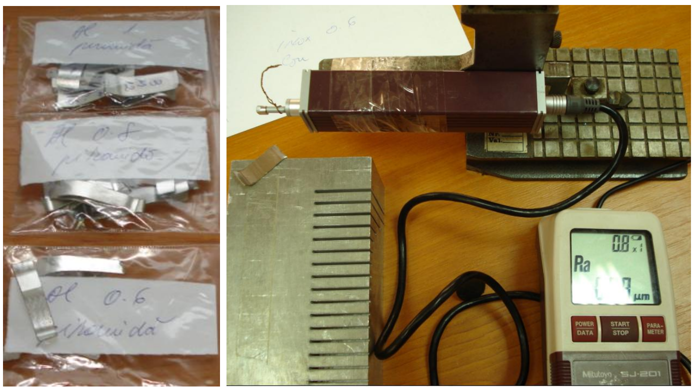


Fig. 4. Prepared samples and Mitutoy SJ-20 roughness device.

The process parameters used for the single point incremental forming of A1050 aluminium metal sheets are presented in Table 1. The lubrication during forming was assured by an industrial oil for metal processing, AGIP ALNUS SSC 608.

Table 1. Variation level of the process parameters.

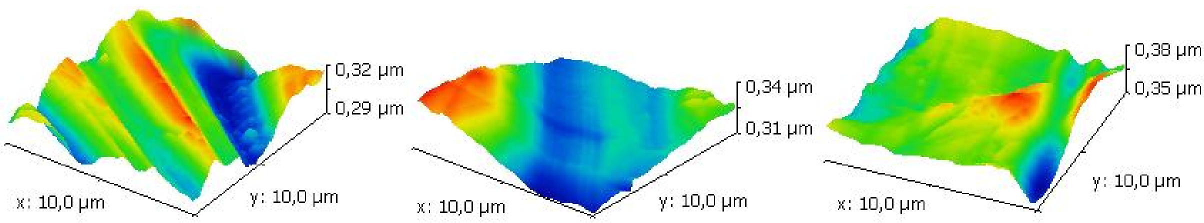
Parameter	Level	
	low	high
Tool diameter [mm]	6	10
Vertical step size [mm]	0.1	0.5

Feed rate [mm/min]	1500	3000
Spindle speed [rot/min]	500	750

3. RESULTS AND DISCUSSION

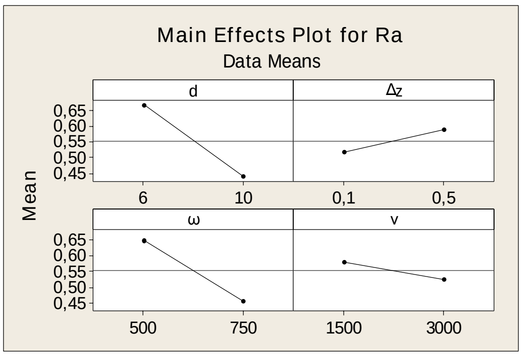
3.1. Surface roughness

The surface roughness of the unformed samples measured with the AFM microscope, for the three investigated thicknesses of metal sheets is presented in Figure 5. The influence of the four process parameters – tool diameter (d), size of the vertical step of tool (Δz), feed rate (ω) and spindle speed (v) – on the surface roughness of the processed parts (the inner side of parts) is presented in Figure 6.

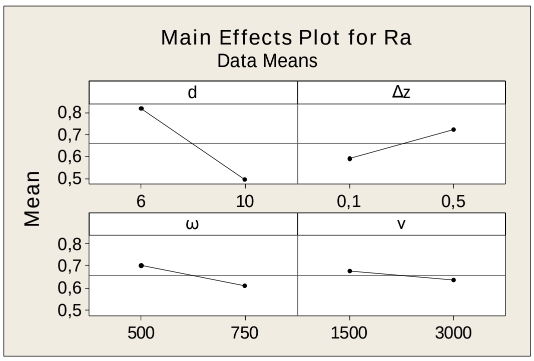


a. aluminium, g = 0.6 mm b. aluminium, g = 0.8 mm c. aluminium, g = 1 mm

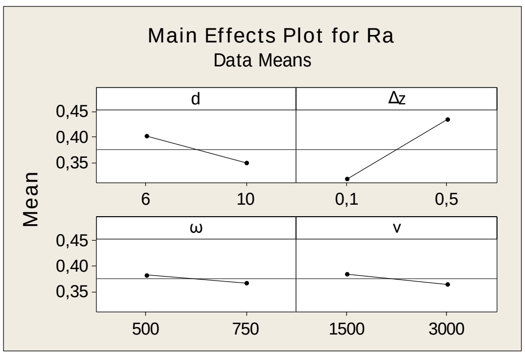
Fig. 5. Surface roughness of unformed samples of metal sheets.



a. g = 0.6 mm



b. g = 0.8 mm



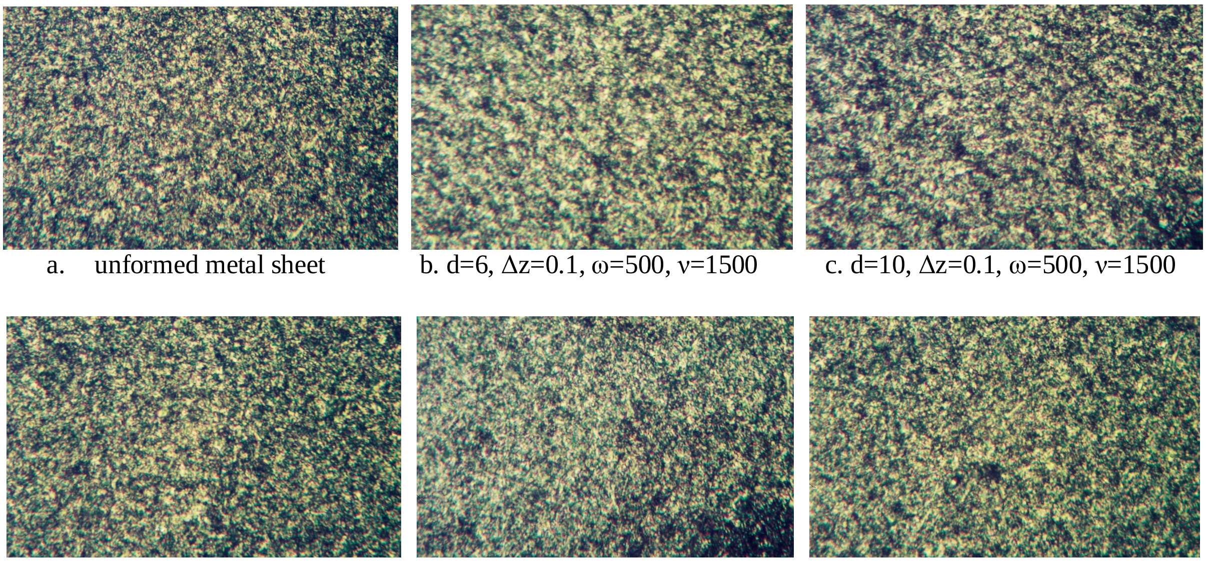
c. g = 1 mm

Fig. 6. Influence of the process parameters on the surface roughness for different thicknesses of metal sheet.

By analyzing the above presented graphs, it can be observed that the process parameters influence differently the surface roughness of the processed parts: it is smaller when the tool diameter and tool speeds increase and bigger when the vertical step of tool increases. From the sheet thickness point of view, the smallest roughness resulted for the metal sheet of 1mm; an increase of thickness from 0.6 mm to 0.8 mm led to an increase of roughness. However, this influence should not be considered separately but in relation with the influence of the process parameters.

3.2. Microstructure of parts

The metallographic analysis of samples emphasized that the structural changes of material as result of forming are not so visible; this fact could be explained by the lack of alloying elements into the material composition (it contains 99.58% aluminium) which could indicate preferential direction of deformation, separation or precipitation of phases, etc. [4]. However, a slight elongation and refining of grains were observed when higher values of the process parameters were used, except for the vertical step of tool - its high values gave a rough structure. For exemplification, in Figure 7, the microstructure of samples cut from parts made from 0.8 mm thick metal sheets is presented.



a. unformed metal sheet

b. d=6, Δz=0.1, ω=500, ν=1500

c. d=10, Δz=0.1, ω=500, ν=1500

d. d=10, Δz=0.5, ω=500, ν=1500

e. d=10, Δz=0.5, ω=500, ν=3000

f. d=10, Δz=0.5, ω=750, ν=1500

Fig. 7 Microstructure of 0.8mm metal sheets at 450X.

4. CONCLUSIONS

The surface quality of parts processed by single point incremental forming was investigated as a function of four process parameters: tool diameter, size of the vertical step of tool, feed rate and spindle speed. Two quality characteristics were taken into account: the surface roughness (Ra) and the microstructural modification of material as result of forming. The obtained results revealed that both characteristics were improved when high value of the process parameters were used, excepting the size of the vertical step of tool that led to an increase of roughness and a coarse microstructure of material. This influence is valid and slightly more accentuated in the case of thicker metal sheets. Therefore, the constraint to use smaller vertical steps to obtain a good quality for the surface of processed part could be compensated by using high speeds of tool; in this sense further studies must be performed to find out an optimum working regime.

Acknowledgments

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