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An experimental Investigation Study of application various shapes in Incremental Sheet Metal Forming (ISMF) Process

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Abstract- Incremental sheet metal forming is adaptable rapid manufacturing in sheet forming process that lead to cost and time effective and good quality products, more flexible and less set up cost to any complexity parts, so that it is highly versatile nowadays. Therefore, incremental sheet metal forming technology solving many problems found in conventional sheet forming. More than researchers continue in studying improvement (ISMF) process. In this work, simple and complex shapes manufacture by Single Point Incremental Forming process (SPIF) without using a dedicated die depending on helical tool path was generated by Unigraphics-NX10 (UGS-NX10) programing system. The aim of the presented work is to investigate the feasibility of the incremental forming process for different geometry shapes by using computer numerical control (CNC) depending on zero spindle speed using 1050 aluminum sheet material. The results from this work gives good indication about the complexity of using different shapes in (ISMF). Therefore, improvement of this process by using different shapes as a design tool for incremental sheet forming very important things.

Keywords: Single Point Incremental Sheet Forming, Helical Tool Path, Springback, Sheet Thickness.

1-Introduction

It is known that the traditional forming processes need a long time and very high costs because it depends mainly on the use of dies and punch depending on the dimensions of the product manufactured. In view of the development and needs of the market for more appropriate and less expensive process, it required the emergence of a technologically advanced process compared to the conventional process. [1]

With the beginning of the nineties of the last century, and depending on customers requirement a group of researchers was able to find a new method for the processing sheet metal formation namely incremental sheet metal forming (ISMF), as a new developing technique [2,3].
in recent decades, (ISMF) attracted more and more attentions and this method required simple shape of tool (single shape usually hemispherical) to produce the sheets to its final shapes using CNC machine. [4,5]
This process suitable for rapid prototyping or small shape technology process and parts can be directly formed using CAD model that mean ability of fast design shape and controlling in complexity of the design. [6,7]
Because of incremental sheet metal forming is modern technique, so its remain to be develop and study all difficulties to enhancement in industrial fields. Incremental sheet metal forming is slow process because of locally deformation through the successive points. Elastic springback, sheet thinning and shapes accuracy negative effect in this process because of sheet material attach to the clamped in frame without any dies. [8,9]
For this above reason, it is important to make an investigation for this technology in experimental fields for continues development of this process. This work aims study feasibility of the incremental sheet forming process for different geometry shapes (simple and complex shapes) by SPIF process without using a dedicated die depending on helical tool path.

2-Gometric Modling

Geometric modling is the method for represnts of an object. There are many geometric models manufactured in this study such as truncated pyramid, truncated cone, cross hexagonal, 5 lobes shape and V shaped tube as shown in figure (1). They are modeled using wire frame method by AutoCAD program through the two-dimension geometric entities. Thereafter, a model transforms into UG-NX10 program under same file extension (.dwg) to create surface for side walls within CAD system, where the wire frame models form the basis for surface models.

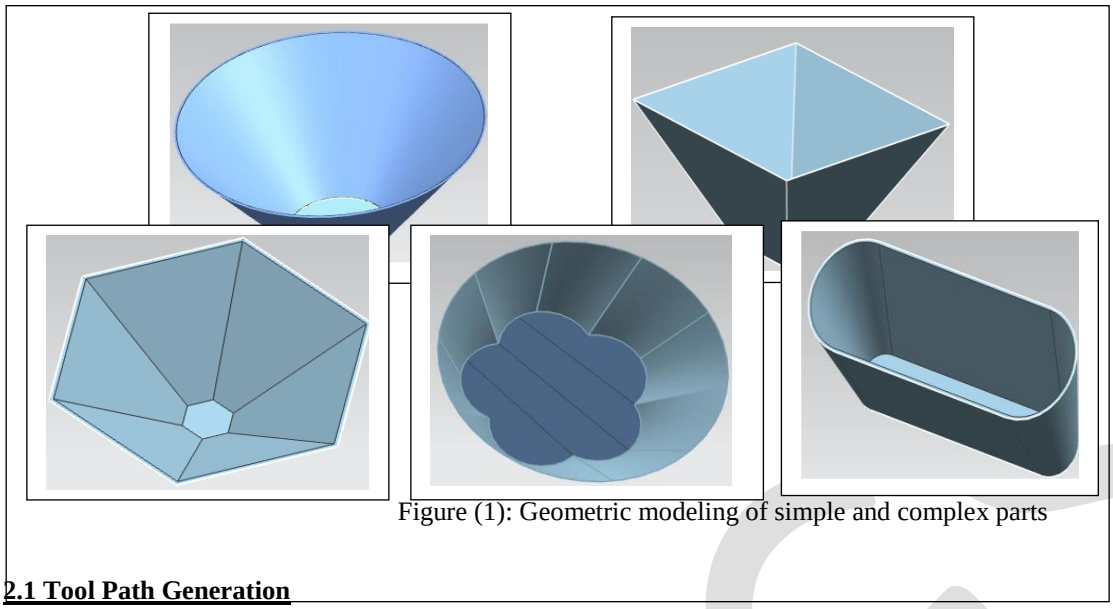


Figure (1): Geometric modeling of simple and complex parts

2.1 Tool Path Generation

According to geometry complexity tool path was applied, sheet thickness, materials of sheet, surface finish requirement and CNC [10]. UGNX10 programming system used for tool path generated, then post-processing generate G-code used appropriate 3-axis CNC milling.

Z-increment responsible in sheet forming were tool moved down in Z-direction by a stated quantity. continuous line mark by tool on the formed part not desired phenomena, if the location not shifted, this is critical when the part to be forming includes of 3D surface and artistic of all the surface is significant. So that, the increment line must be diverted along edges or corners, concealed increment location effects. Helical tool path also evades like this problem, because Z-direction increment of loop cycle is evenly circulated along that cycle and absent increment mark line. Therefore, to minimizing the increment line effect, some typical tools engage motions before beginning a cycle can be used.

If using planer forming, tool forming should remain in consistent contact with the blank sheet during forming process. highly contact is inconsistent, the spring back affected the accuracy of sheet formed parts [10,11]. Figure (2) an Scheme summarizes the integration of CAD / CAM system.

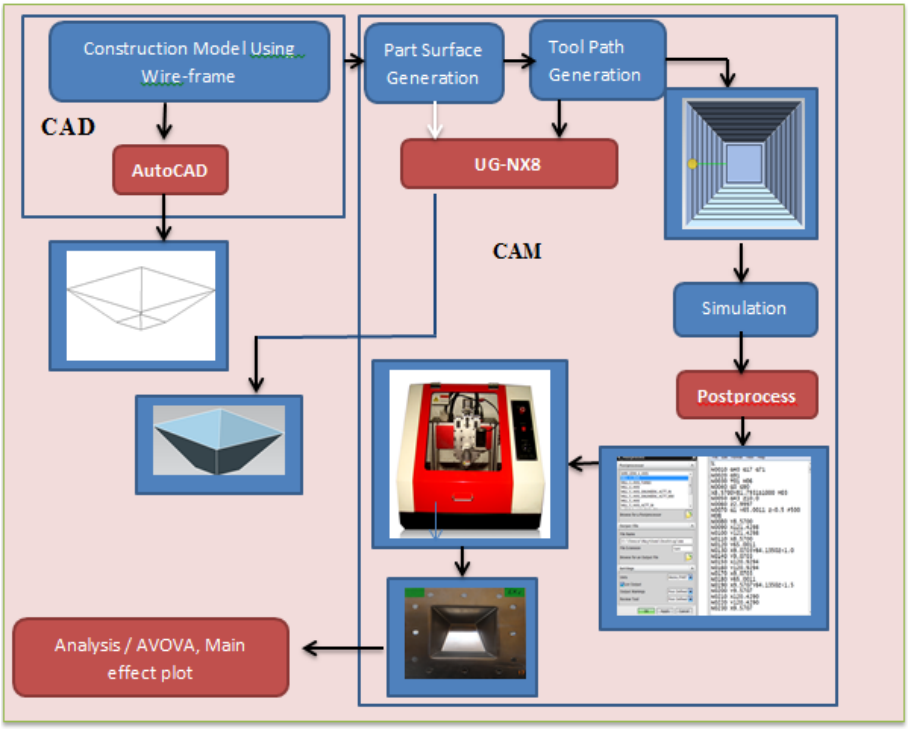


Figure (2): Scheme summarizes the integration of CAD / CAM

3-Materials and equipment's

3.1 Sheet Material

Material used in this feasibility was a 1050 aluminum of 0.5mm in thickness. A formed part produced from a square area of a blank sheet (230×230 mm^2) was investigated using SPIF process technology, while the working area is 180×180 mm^2 according to the blank holder size as shown in figure (3).

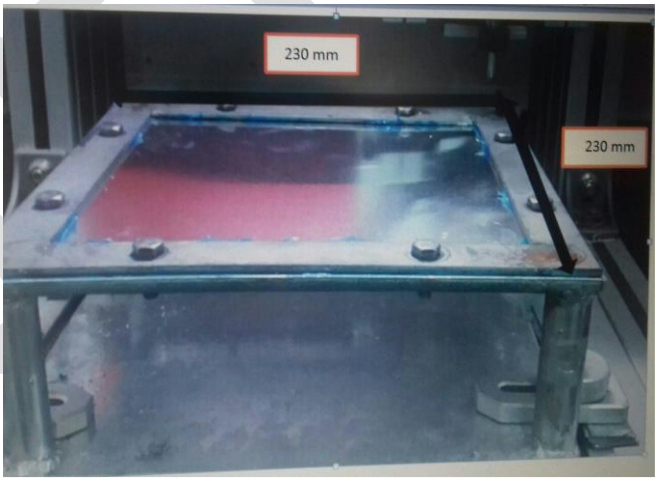


Figure (3): Aluminum blank sheet.

3.2 Forming Tool

Hemispherical head tool with diameter (6 mm) made of low carbon steel is used in this work. The tool is utilized to form or sculpture the sheet metal according to tool path generation. Several authors recognize that the formability in SPIF increase with decrease the tool size as well as the tool size of tool is the important parameter in this process [12]. In fact, large radius using tools permit gives good metal flow and reduced time of forming process, smaller tool radius on other hand is important to enhance the

geometrical features of the part to be formed. Therefore, on this basic selected this diameter. Also, application of lubricant in ISMF is important to obtain a smooth surface and to reduce the wear of the tool.

3.3 Forming Frame and Blank Holder

Based on the machine table area, the forming frame was designed and constructed as illustrated in Figures (4.a and 4.b), The frame fixed and rests on the machine table by using traditional fixture as demonstrated in figure (4.b).

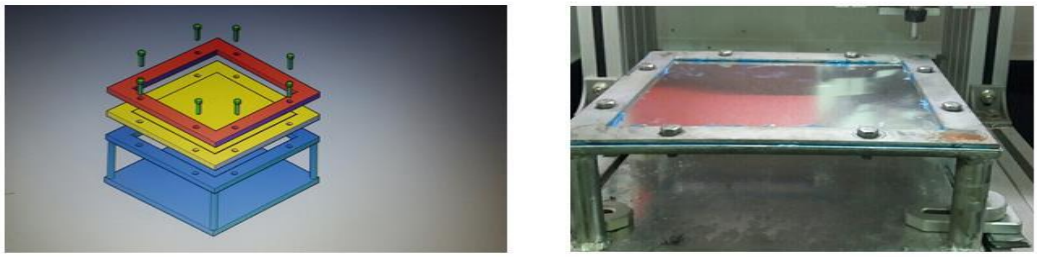
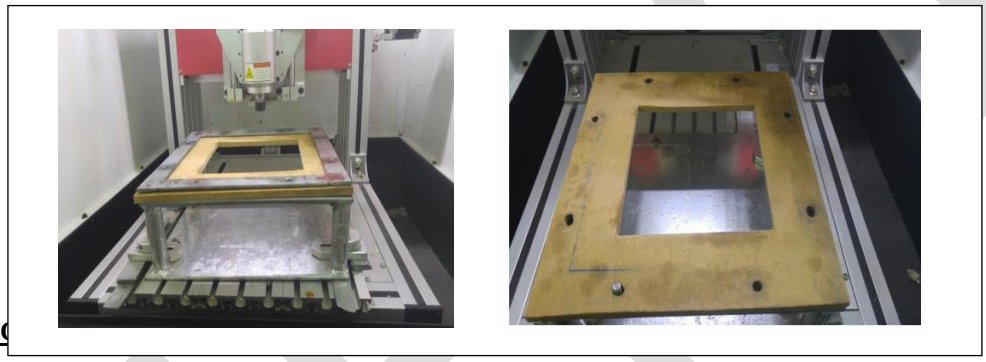


Figure (4): The forming frame used for experiments, (a) physical forming frame and (b)schematic representation

3.4 Backing Plate

The backing wood plate used in this work. Backing plate is fixed between the frame and blank holder to reduce bending and springback. Figure (5) backing plate illustration.



3.5 CNC

Experimental work done by using three-axis motion milling machine "CNC" in materials engineering department laboratories -University of Kufa. The experimental setup, specifications and technical parameters of the CNC milling machine being used are shown in figure (6).

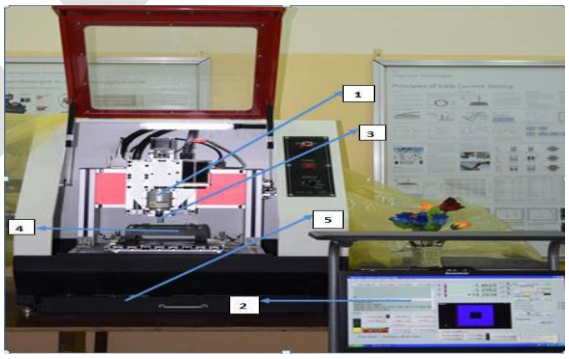


Figure (6): (CNC) milling machine used in this work; 1. Movable head, 2. Machine controller, 3. Tool holder, 4. Forming frame, 5. Machine table.

4-Plan of Experiments

The experimental study consists of the manufacturing simple and complex shape (truncated pyramid, truncated cone, hexagonal, 5 lobe shape and V shaped tube). This study included five experiments shown in table (1), after that accuracy an final sheet thickness measuring using suitable tools.

Table (1): Plane of experiments.

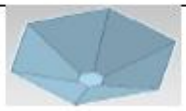
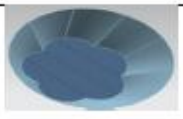
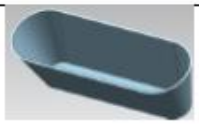
Experiments	Feed Rate (mm/min)	Z-increment (mm)	Tool Path	Geometry Shape
EX 1	1500	0.2	Helical	Truncated cone
EX 2	1500	0.2	Helical	truncated pyramid
EX 3	1500	0.2	Helical	hexagonal
EX 4	1500	0.2	Helical	5 lobes shape
EX 5	1500	0.2	Helical	V shaped tube

For all experiments in table (1) the spindle speed (N) is 0 rpm. In this work, selection the feed rate, tool diameter and Z-increment depended on previous researches. Using small tool size diameter and lower tool depth lead to a significant enhancement of the dimensional accuracy. Therefore, the best parameters should be selected to help in tool path improvement to produce desired results for geometric accuracy and thickness variation.

5-Results and Discussions

Feasibility of the incremental forming process for different geometry by SPIF process without using a dedicated die depending on helical path for machining process are tested to forming the parts. Five experiments for the shapes carried out using 3-axes CNC milling machine as earlier mentioned. Further details of the variables and measured aspects for the shapes are presented in Table (2). FR= 1500 mm/min, Día = 6 mm, N = 0 rpm.

Table (4.1): CAD model &final products of `different shapes

Experiments	*Geometry*	*CAD Model*	*Final product*
EX 1	cone		
EX 2	Hexagonal		
EX 3	5 lobe		
EX 4	V shaped tube		
EX 5	pyramid		

5.1 Feasibility of (SPIF) for different geometry

There is a good possibility to apply different shapes in SPIF process. It has been found through this work the shapes with circular sections have a better possibility of forming than square sections shapes where the decline of the bending and springback in the form of the cone for example, while increasing bending and springback in the pyramid shape (without using backing plate) as illustration in figure (7).

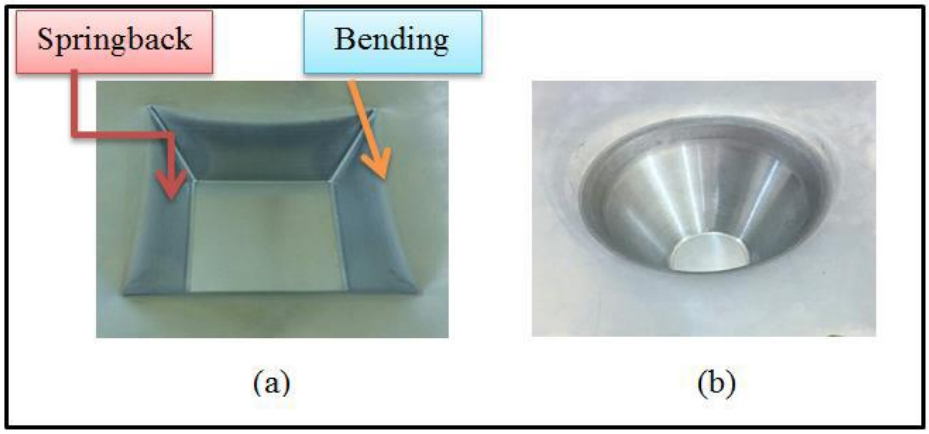


Figure (7): Difference in formability of square cross section and circular cross section; (a) pyramid (b) cone

5.2 Effect of Helical Tool Path (HTP)

Helical or spiral tool trajectory has a suitable choice for incremental forming technology, the important feature in HTP is gabs between successive cycles. The nature of helical tool path motion results in reducing the gap of a given cycle. Therefore, non-deformed regions between cycles were reduced so that the geometrical deviation will also be reduced. Figure (8) illustration generated tool path and final product using (HTP).

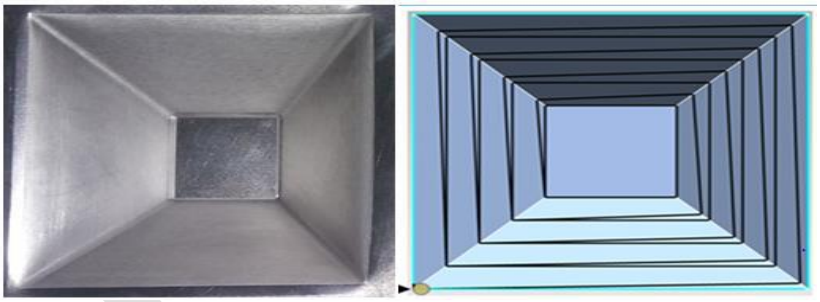


Figure (8): Generated tool path and final product.

5.3 Effect of Angle on Thickness Variation

Thickness of formed part can be measured using sin-law. This law was originally developed for the shear forming process and simply states that [13]:

$$t_1 = t_o \sin(\pi/2-\alpha) \ldots. (1)$$

t_0 and t_1 are the initial and final thickness respectively and α is the angle of wall measured depending on horizontal direction. It describes the thickness distribution well and shows that parts with drawing angles greater than 60-80° in one stage are not achievable. So that a large angle may cause failure such as cracking as shown in figure (9) when angle of 5 lobe shape was 63°.

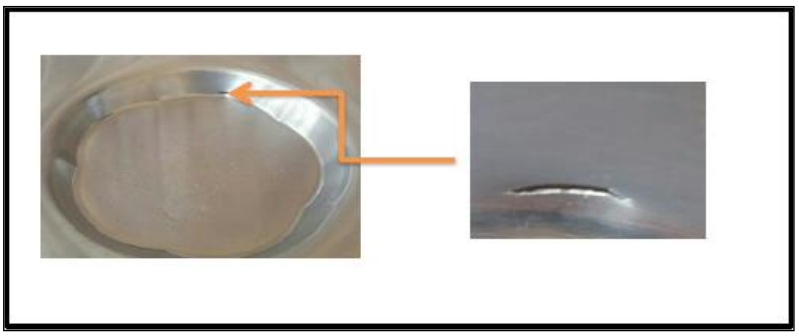


Figure (9): Effect of large angle causing failure (crack) in 5 lobe shapes.

5.4 Effect of backing plate.

Bending of sheet material during forming process resulted in sheet fixed in a frame. therefore, bending effect can be reduce using backing plate that reduce the deviation and it does not influence in pillow and springback deviation effects. As shown in figure (10) bending of the pyramid shape can be reduce when the backing plate used.

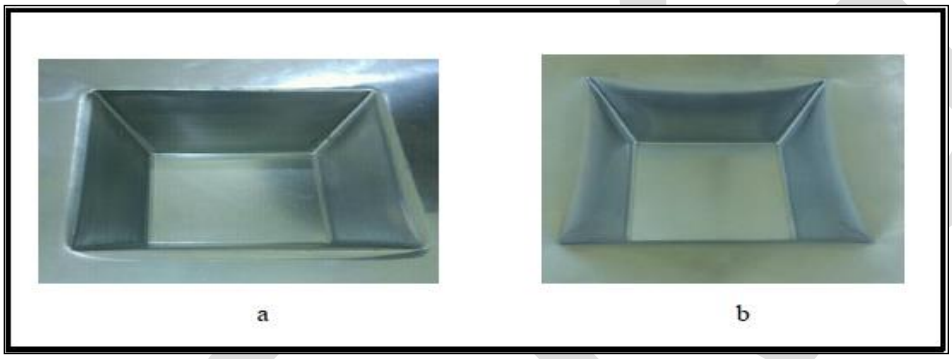


Figure (10): Effect of backing plate; (a): With using backing plate
(b): Without using backing plate

5.5 Effect of springback

Formed parts accuracy was changed because of springback effected. So that, a challenged with some manufacturing process difficulties appeared: Firstly, estimation the final part accuracy after the effect of springback and secondly, compensation this effect by using suitable tool designed for minimized the bending sheet effect close to the start tool contact location.

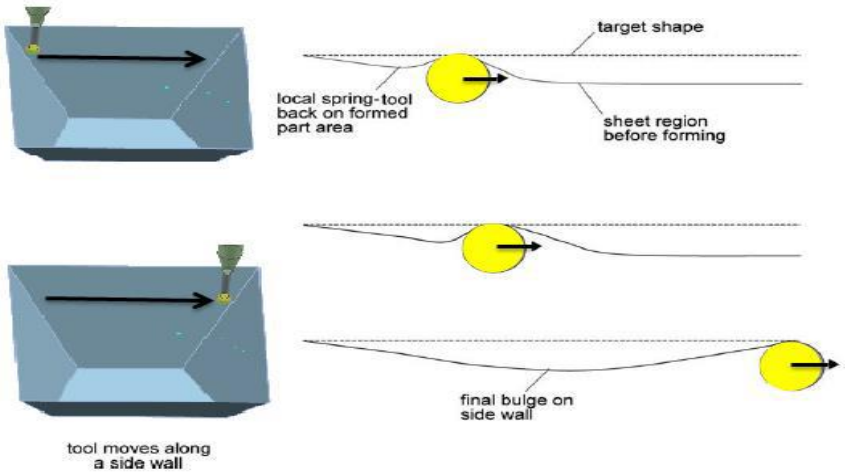


Figure (11): Illustration of local springback in ISMF. [13]

Conclusions

Development of production and prototyping technologies is becoming more important. ISMF implementation technologies of rapid prototyping and small batch production was very important in recent years. Using this technology, time needs for prototyping process can be shortened. The following remarks resulted depending on this work:

1. Helical tool path (HTP) is the suitable tool path to achieve higher geometrical accuracy for most simple and complex shapes.
2. The vertical pitch has major effects on the accuracy and thickness distribution.
3. Bending and springback Shapes with circular cross section will be lower than for square cross section.
4. There is a good possibility to apply different shapes in SPIF process that gives good indication about complexity of this technology.
5. Using of backing plate will reduce the bending and springback.
6. Using zero spindle speed can be depended on it with using effective lubrication and suitable tool path in ISMF process.

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