The enhancement of thickness distribution and dimension accuracy using hybrid method: multi-point forming process combines with single-point incremental forming process

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Abstract

The multi-point forming (MPF) process and single-point incremental forming (SPIF) process are the modern pliable manufacturing technique utilized successfully in many industrial applications. The main problems of MPF process are wrinkle and dimple that happened in final product, while the main problem of SPIF process is thickness distribution, geometric accuracy and forming time.

This paper focuses on a new hybrid process, the combination of MPF and SPIF. The positive impact of this hybrid process on the process limits. The experimental results show that the hybrid forming process could achieve sheet parts with more uniform thickness distribution, minimum spring back, reduced forming time and without dimple. With addition to distribution of thickness, the local deformation that happened when using SPIF process caused internal problem on structure was elimination and the strain hardening of forming product was decrease. The data required was generated, compared and evaluated to the proposed models that obtained from the experiments.

KEYWORDS: Multi-point forming (MPF) process, single-point incremental forming (SPIF), Hybrid forming process, Thickness distribution and dimension accuracy.

1. Introduction

Normally, a metallic sheet component is shaped by using certain dies produced according to the part's form and dimensions. The design method of a die is a repeated process of trial and error; it causes important lead times and expenses in the dies manufacturing. This traditional process is proper for a higher production rate, since the dies cost can be participated through the mass production of products. Nevertheless, the pliable die and die less forming operations for a tiny size have been evolved, because the need of customer is too varied, thus resulting in a smaller size of lot. [1, 2]

In the process of MPE, the used pins are designed in a method, which is not depending on each other, and are modified simply. Consequently, governing the height of pin may produce an uninterrupted operating surface. In the MPF process, the die's curved surface is produced by using an enormous number of pins. In such approach, independent pins are utilized in place of conventional dies. [3]

The schematic of the MPF process with a blank holder (BH) is shown in figure (1).

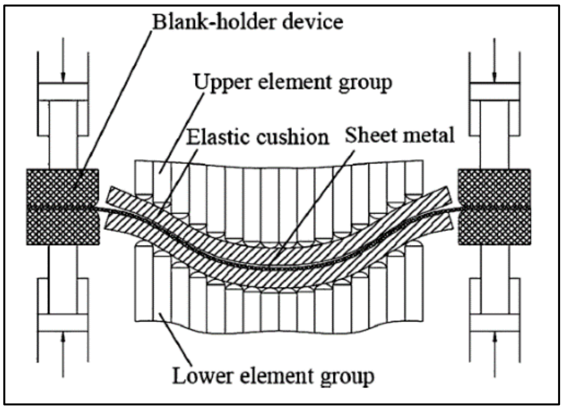

Fig. (1): Schematic diagram of MPF with blank-holder. [3]

Single point incremental forming (SPIF) is a very simple, flexible and cost-saving alternative to the classical forming processes of metal sheets when low volume batches, customized parts or prototypes have to be manufactured. This technology does not require dedicated expensive tools. On the contrary, the metal sheets, tightly held at the periphery by a frame situated on the worktable of a CNC milling machine, is formed by a rigid tool programmed to follow, usually, a succession of planar contours or a single spiral contour. Incremental sheet metal forming is a modern method, which brings new possibilities of sheet metal forming. Nowadays a lot of attention is focused on the single point incremental sheet metal forming, where the dedicated die is not needed. SPIF also has some limitations including long processing time, low geometrical accuracy and coarse surface finish. In order to overcome these limitations, effort has been made to explore a number of variations of the SPIF process.[4]

In this paper, a new hybrid process is analyzed, the combination of MPF process and SPIF process. This new process combination will be motivated in the 'state of the art' section by analyzing the work that has been done so far to overcome the limitations of MPF and SPIF processes. Each of the process limits will be analyzed separately, and hypotheses about the benefit of combining MPF with SPIF will be formulated. A 'spherical cap' is used to analyses and compares the hybrid process and the basic MPF process regarding sheet thinning and interior structure of final product.

2. Literature Review

A series of experiments has been conducted in the design of experiments for investigating the influence of hybrid forming process to elimination the limitation of incremental forming process using other processes.

B. Taleb Araghi et al. (2009) [5] focused on a new hybrid process, the combination of Asymmetric incremental sheet forming (AISF) and stretch forming. First results are presented that show the positive impact of this hybrid process on the process limits. The results show that SF and AISF has the advantage that the simulation of the stretch forming can be completed in a relatively short time, even for a larger part, which makes it possible to simulate and optimize at least the first forming stage.

B. Lu et al. (2014) [6] developed flexible sheet forming approach with better sheet thickness distribution and reduced processing time comparing to the conventional incremental sheet forming. In the approach, a two-step forming process has been proposed: multi-point forming as preforming is employed to achieve an initial shape and designed thickness distribution; after the preforming, incremental sheet forming process is then applied to finalize part geometry with desired thickness distribution. a numerical model for predicting the thickness distribution of the final part is developed by integrating finite element simulation and analytical prediction of ISF process.

Khalil I. Abass (2016) [7] presented the data and main results of a study on effect of using pre-forming blank in SPIF through FEA. The considered SPIF has been studied under certain process conditions referring to the test work piece, tool, etc., by applying ANSYS 11. The results show that the simulation model can predict an ideal profile of processing track, the behavior of contact tool-workpiece, the product accuracy by evaluation its thickness, surface strain and the stress distribution along the deformed blank section.

Adil S. Jabber (2018) [8] studied the effect of some parameters on the strain distributions of the product over the length of deformation is the aim of this study. In order to achieve this goal, three factors (tool forming shape, feed rate and incremental step size) are examined depending on three levels on the strain distributions over the wall of the product. Strain measurement was accomplished by using image processing technique using MATALB program. The significance of the control factors are explored using two statistical methods: analysis of variance (ANOVA) and main effect plot (MEP).

3. Experimental Work

3.1. Material and Process

In this work, four samples of brass (65-35) with thickness 0.71 mm were used to perform the experiments. The geometry of forming tools are shown in figure (2), while the geometry of final product is illustrated in figure (3). The experimental work was applied using oil lubricant on a C-tek three-axis CNC milling machine (KM-80D) having a peak rotational speed of (6000) rpm and a feed rate of (10) m/min. The required CNC programs for the part and the tool path were achieved to manufacture the CAD model that used as the lower die and used the same part program in single point incremental forming process. The experimental work was conducted on a workpiece having a hem-spherical shape. Chemical analysis and mechanical properties of blank sheet (brass 65-35) are presented in figure (4) using Energy dispersion spectrograph (EDS) test and listed in tables (1 & 2), respectively. While, Figure (5) elucidates the schematic of a multi-point forming die and single point forming process.

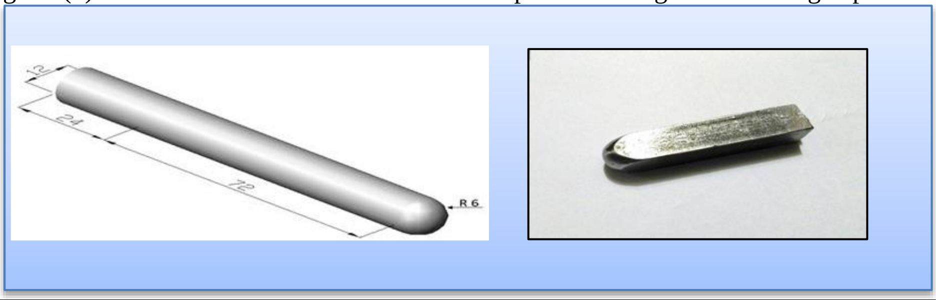

Fig. (2): Geometry of forming tool

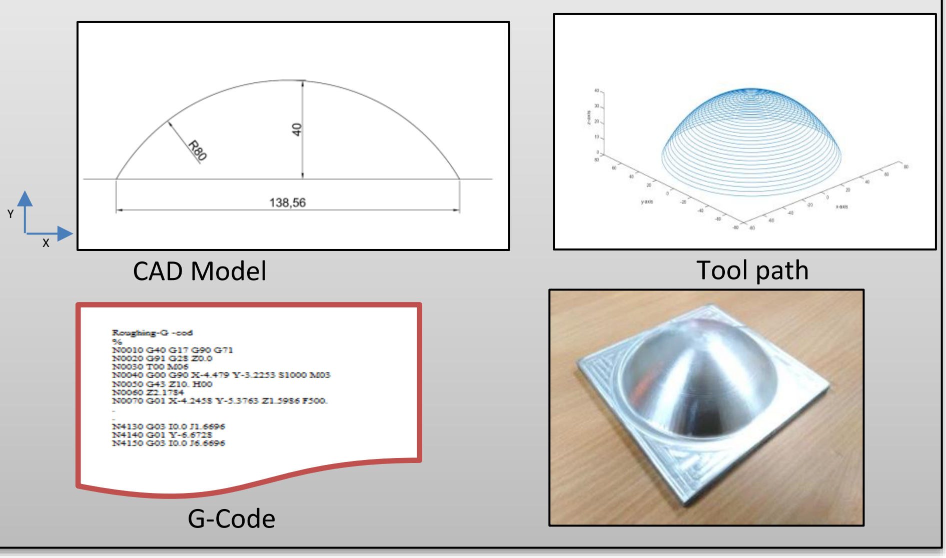

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Fig. (3): Geometry of part and part program.

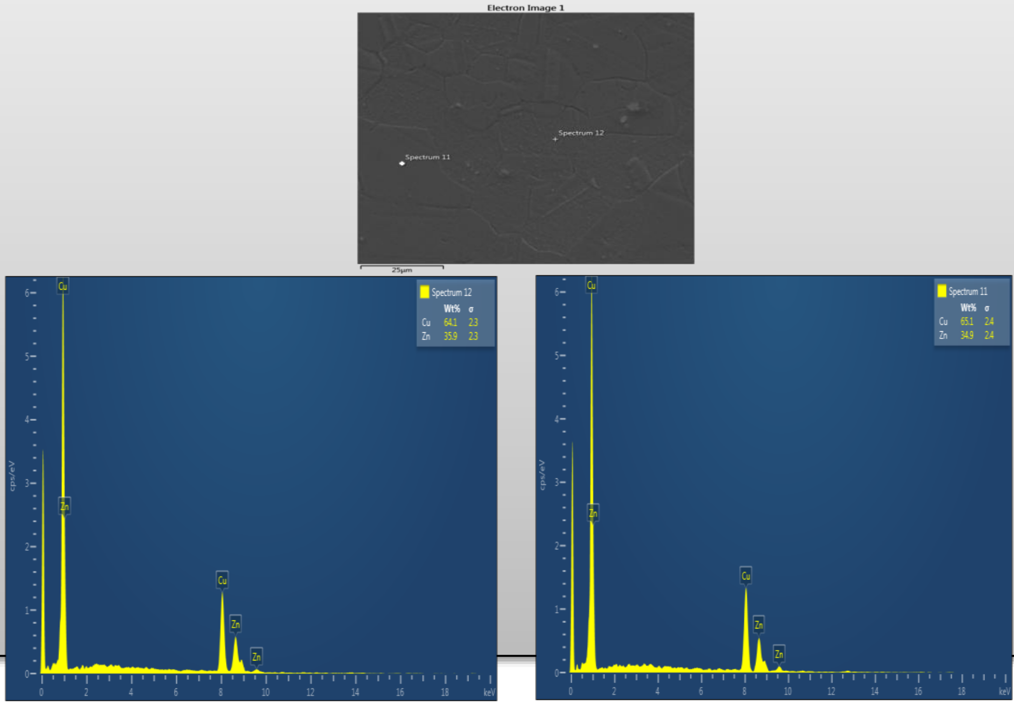


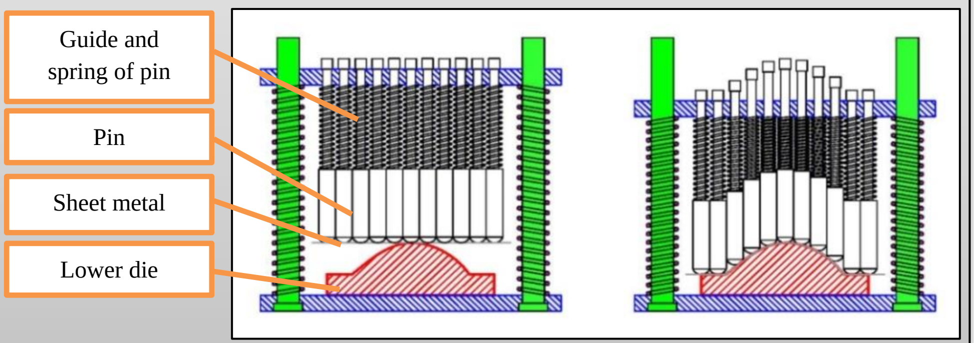
Fig. (4): Energy dispersion spectrograph (EDS) test

Table (1): Chemical composition of Brass 65-35 sheet (ISO workpiece - Cu Zn 65-35 426/1).

Material		Zn%	Pb%	Sn%	P%	Mn%	Fe%	Ni%	Si%	Al%	Cu%
Brass	Exp.	35.23	0.007	0.001	0.007	0.000	0.021	0.001	0.001	0.002	64.7
	Iso	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0

Table (2): Mechanical properties for Brass 65-35 sheet (ISO - Cu Zn 65-35 426/1).

Material		Tensile Strength Mpa	Modulus of Elasticity Gpa	Poissons Ratio	Elongation % on 50 mm G.L.	Vickers Hardness VPN	Iso
65/35 Brass 'O'	Exp.	230	110	0.375	31.5	≤ 100	Cu Zn 35 426/1
	Iso	230	110	0.33	56	≤ 90	



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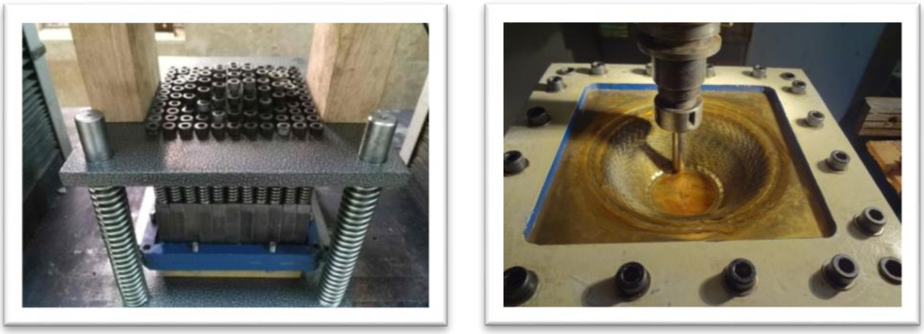

Fig. (5): design of MPF die and the experimental setup.

3.2 Thickness deviation test

It is important to know the thickness distribution because it has a big role in the failure of the product, especially as it is one of the most important problems in the process of incremental formation. The thickness of the samples was tested by a digital micrometer after it was modified so that one could measure the curves, as shown in figure (6).

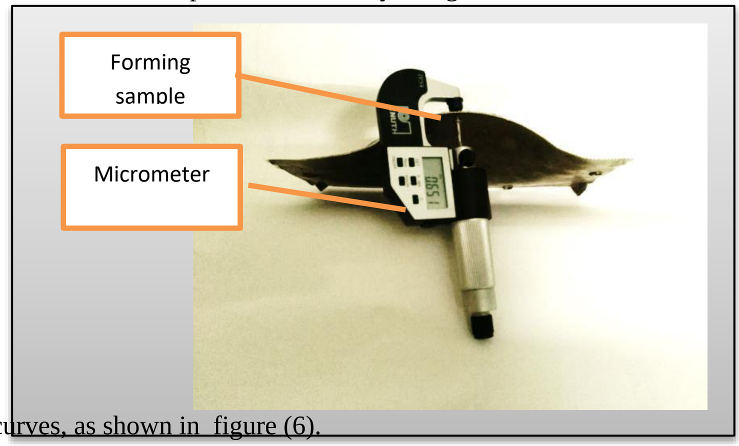

Fig. (6): Micrometers measurement device

3.3 Dimensional accuracy

One of the most important tests on the product is the accuracy of dimensions that examined by using the NC milling machine located in the metal cutting laboratory, was illustrated in figure (7).

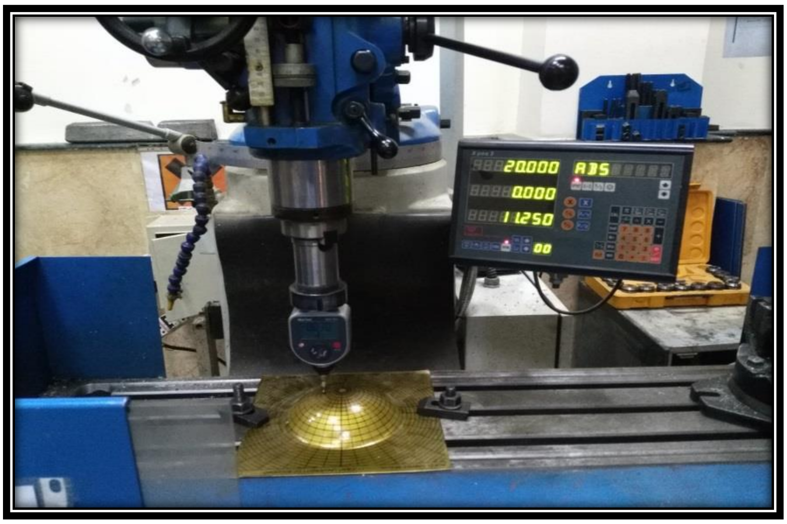

Fig. (7): NC milling machine assist to measure the forming parts.

4. Hybrid concept combining of MPF with SPIF:

During this work a procedure of combining two formation process which are MPF and SPIF was adopted and implemented then the final formed models were tasted and compared with those formed by SPIF ., which has a square blank holder and thickness of rubber of 4 (mm) and speed of 2 (mm/min) on which compared with the following specimens of Brass metal:

1. Single point incremental sheet forming.
2. Multi-point forming process.
3. Hybrid Multi point forming (depth 15) mm and single point incremental forming.
4. Hybrid Multi point forming (depth 25) mm and single point incremental forming.

Figure (8) presented the hybrid forming parts.

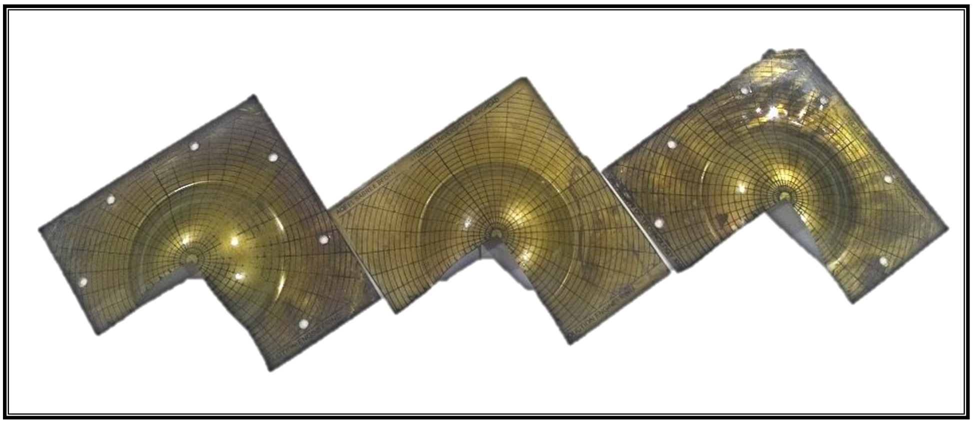

Fig. (8): forming parts using the proposal method

4. Results and discussions:

The results showed the improvement in the product by improvement thickness distribution as shown in table (3) and figure (9).and reducing the spring-back and dimensional accuracy which are the most important defects of the single point incremental forming, as shown in table (4) and figures (10).

Table (3): The thickness reduction for SPIF and MPF for brass

Testing Points	Thickness reduction		
	SPIF Brass	Hybrid*Brass	Hybrid**Brass
1	0.704	2.112	2.863
2	1.596	3.333	6.760
3	38.215	28.169	25.539
4	28.873	25.539	19.718
5	18.497	21.971	14.600
6	10.892	14.929	12.957
7	5.117	8.873	11.643
8	2.535	6.619	8.403
9	1.408	4.835	5.633
10	0.234	3.004	9.295
11	2.629	4.507	6.713
12	5.821	5.070	10.046
13	10.281	7.746	13.849
14	14.553	9.342	16.995
15	21.455	13.474	21.690
16	22.816	16.244	27.276
17	38.732	22.582	22.629
18	3.333	31.737	3.004
19	0.751	7.042	2.863
*brass(MPF(d=15mm)+SPIF)		**brass(MPF(d=25mm)+SPIF	

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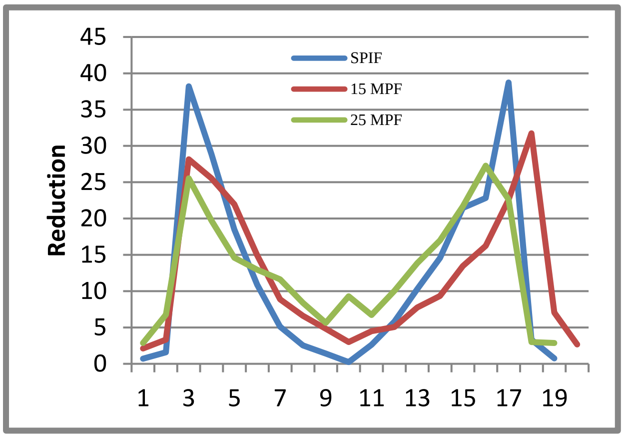

Fig (9): Distribution of thickness reduction percentage along the forming profile for SPIF and MPF for Brass

Table (4): Dimensional average deviation in comparison between SPIF and MPF for brass and aluminum

Radius	Products		
	SPIF$_{Brass}$	Hybrid*$_{Brass}$	Hybrid**$_{Brass}$
90	0	0	0
80	0.185	0.58	0.725
70	2.21	2.705	2.89
60	5.535	6.14	6.45
50	10.29	11.155	11.68
40	17.055	18.06	18.34
30	26.895	27.12	27.675
20	36.85	37.19	37.61
10	37.82	38.525	39.2
0	37.82	38.7	39.2
Average Dev.	3.3623	2.8108	2.4513
*(MPF(d=15mm)+SPIF)		**(MPF(d=25mm)+SPIF)	

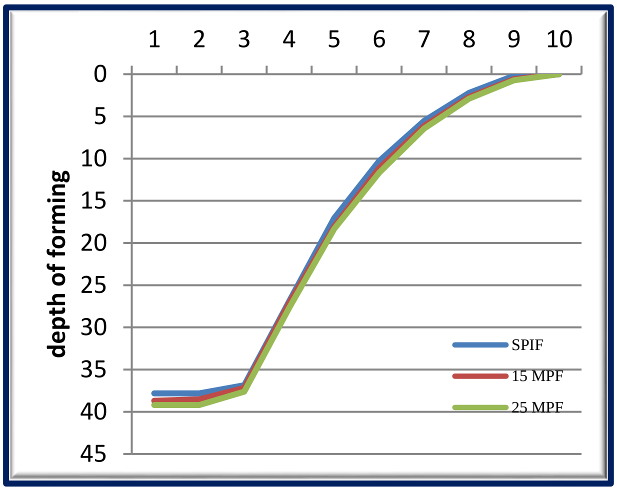

Fig (10) Depth of cut impact on dimensional Accuracy for SPIF and MPF for Brass

5. Conclusions

The current research reviewed some important aspects related with thickness distribution and dimension accuracy in sheet metal forming with special emphasis on the brass alloy. Based on the results of this work in MPF, SPIF and hybrid of these forming processes, the following conclusions can be drawn:

1. Using hybrid forming method between MPF and SPIF processes take a good result and eliminate the defect or limitation for each method such as thickness reduction and springback.
2. The main limitation of SPIF process is high thickness reduction due to local forming that occurs in this process, so using hybrid method that enhancement of thickness reduction to 34%.
3. The spring back that happened in SPIF process is high due to free forming that happened using this method, so the dimension accuracy improved using hybrid method to more than 5%.
4. The additional to the enhancement in SPIF process using hybrid method, the improvement occur in MPF process by elimination of dimples and wrinkle of final product.

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