[*Abbas * et al., 6(2): February, 2019*] ISSN: 2349-5197
Impact Factor: 3.765

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

EXPERIMENTAL INVESTIGATION OF PROCESS PARAMETERS ON DIMENSIONAL ACCURACYIN MULTI-POINT FORMING PROCESS USING ANOVA ALGORITHM

Tahseen Fadhil Abbas[*1], Karem MuhsonYounis[2] & Khalida Kadhim Mansor[3]
[*1,2&3]Department of Production Engineering and Metallurgy / University of Technology, Baghdad, Iraq

DOI: 10.5281/zenodo.2560456

Abstract
The multi-point forming (MPF) process is a modern pliable manufacturing technique utilized successfully in many industrial applications. In this work, the effect of many forming parameters was investigated which are blank holder, rubber cushion thickness and forming speed. Also, the influence of these parameters on the dimensional accuracy was studied, where the blank (sheet) material is brass with 0.71 mm thickness. This work concentrated on the development of predicted models to estimate the dimensional deviation using analysis of variance (ANOVA) to minimize the deviation of dimension in the multipoint forming process. Arithmetic minimum dimensional deviation was used as response parameter to assess the dimensional accuracy of multi-point formed parts. The data required was generated, compared and evaluated to the proposed models that obtained from the experiments.

Keywords: Multi-point forming (MPF) process, Forming parameters, Dimensional accuracy, Analysis of variance (ANOVA)

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)..

ISSN: 2349-5197
Impact Factor: 3.765
INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

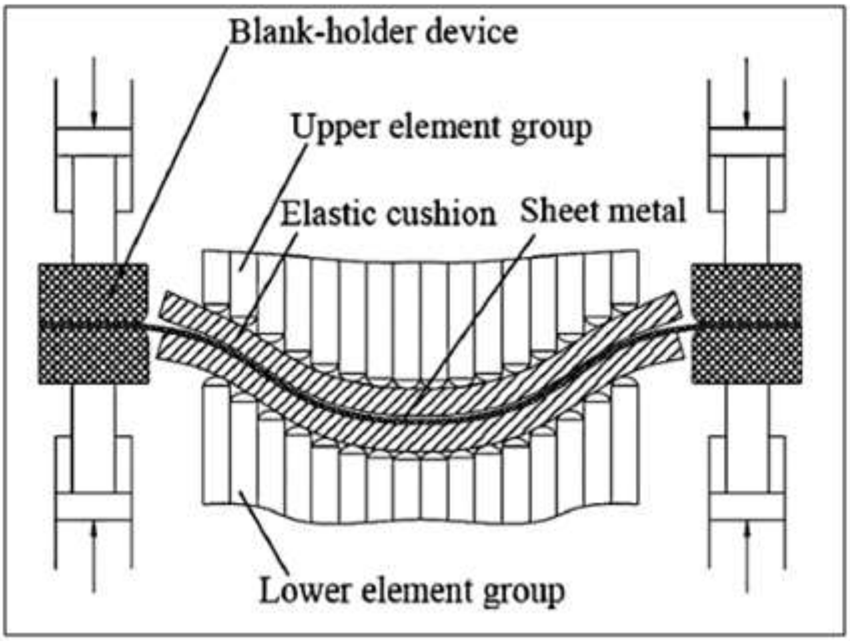


Fig. (1): Schematic diagram of MPF with blank-holder.[4]

Literature Review

A series of experiments has been conducted in the design of experiments for investigating the influence of forming variables, such as blank holder, thickness of polymer and forming speed on the dimensional accuracy.

Wei Liu et al. (2010) [5]investigated the effects of spring-back and elastic cushion non-uniform deformation beyond the unloading upon the accuracy of the formed work-part. Results of simulation depicted the effectively suppress generation of dimples when using elastic cushion, but they have an influence upon the accuracy of the formed work-part. Otherwise, the spring-back beyond the release of load is less, and the influence of the inconsistent elastic cushion deformation on the accuracy of the multi-point forming work-part is greater than the effect of spring-back. An approach depending upon the repeated corrections in accordance with the results of numerical simulation was suggested for compensating the inconsistent elastic cushion deformation and the spring-back to improve the precision of MPF process.

A. A. Tolipov et al. (2017)[6] studied the effect of the cushion pad on the metal formation by its influence on the elimination of defects in this method, and it was obtained that utilizing the cushion A90 led to decrease the wrinkling and the peak deviation.

Babak Beglarzadeh (2017)[7] used a multi-point forming process to form Al alloy 2024 with a primary dimension of 300 mm × 300 mm sheet to offer a pliable approach to form a metal. Finite elements were simulated through ABAQUS/EXPLICIT 6.14.1. Through increasing of the elastic layer hardness, the minimum required thickness of elastic layer proliferates. Furthermore, the increment of the blank holder force is directly related with the hardness enhancement of polyurethane layer. The MPF experiments of aluminum sheet were conducted, and the forming process comparisons between simulation functions and experimental parts were carried out, which indicated that products of aluminum possess an adequate shape and surface precision. **Tahseen FadhelAbaas et al. (2018) [8]**investigated the multi-point die's performance using pins in a square matrix and a suitable holder for blank. Each pin in the punch holder can significantly move according to the die height and at different loads that applied bya spring with respect to the spring stiffness. The results revealed the reduction in setting time with respect to the traditional single point incremental forming process that leads to (90%).Also, the results manifested that during the forming process, the deformation of the interpolator can create an error in the shape of the formed work-part, and the blank holder can decrease/remove the dimples, which occasionally occur in the work-part.

Experimental Work

3.1. Material and Process

In this work, nine samples of brass (65-35) with thickness 0.71mm were used to perform the experiments. The geometry of forming tool is 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. 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 listed in tables (1 & 2), respectively. Figure (4) elucidates the schematic of a multi-point forming die and the final nine products.

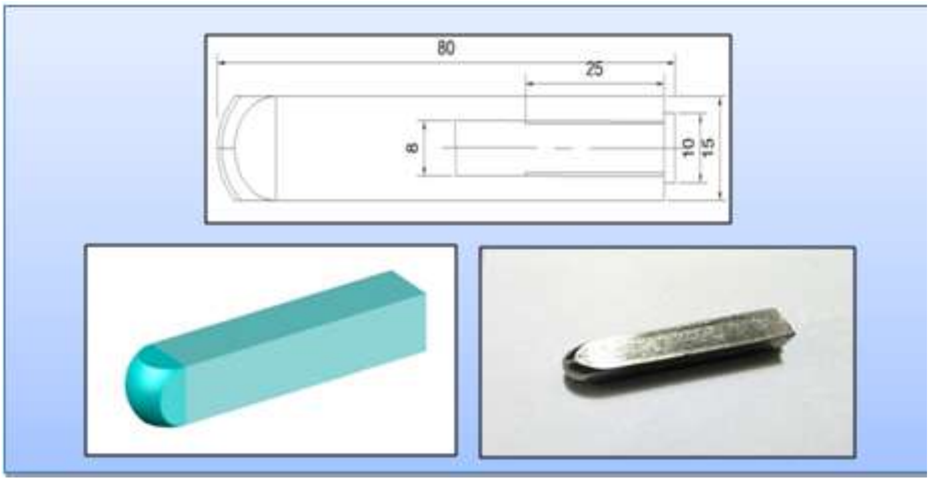


Fig. (2): Geometry of forming tool

ISSN: 2349-5197
Impact Factor: 3.765

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

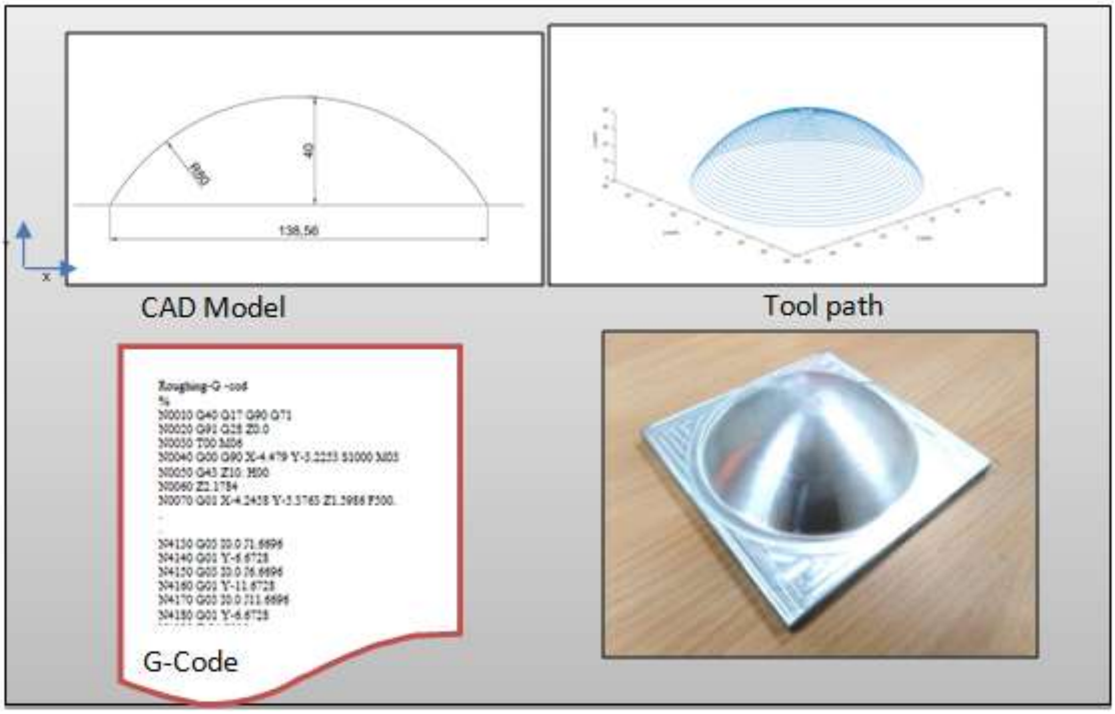


Fig. (3): Geometry of part and part program.

Table (1): Chemical composition of Brass 65-35 sheet (ISOworkpiece- 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	

ISSN: 2349-5197
Impact Factor: 3.765

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

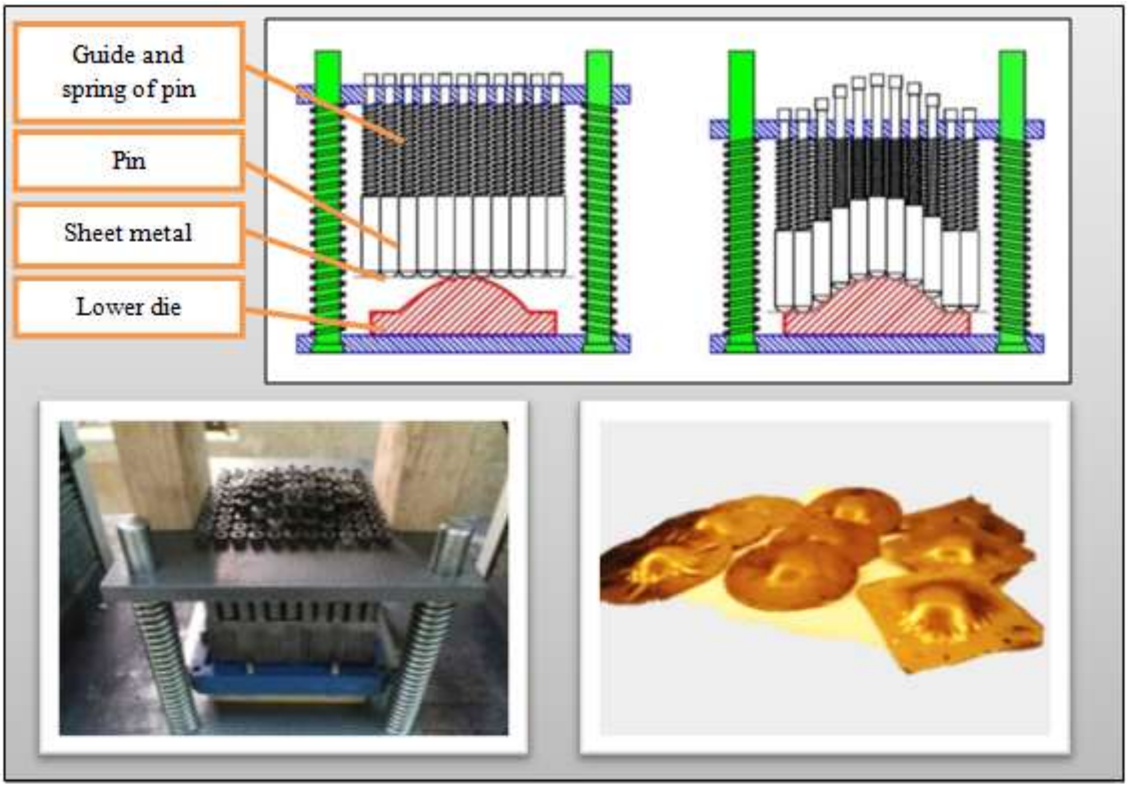


Fig. (4):The experimental setup and nine samples

One of the most important tests of product is the dimensional accuracy that was examined by using NC-milling machine that evinced in figure (5).

Fig. (5):NC milling machine and measurement probe

3.2. Plan of Experiments

The important stage in the response surface model generation by ANOVA is the planning of experiments. The factors having a significant influence on the dimensional deviation were identified by the blank holder types; cushion thickness and forming speed in multi-point process.

ISSN: 2349-5197
Impact Factor: 3.765
INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

The powerful tool for improving the productivity is Taguchi method that has been extensively used during the research and development in the recent years with lower cost for producing good quality parts quickly. In this method, a special design of orthogonal arrays with a small number of experiments is employed. Taguchi method for (3) input factors with(3) levels was utilized for the applied experiments. To define the nine trial conditions, (6) degrees of freedom (dof) needed for this study and Taguchi's (L9) orthogonal array were employed. The used levels and process parameters are given in table (3).Table (4) presents the results of testing nine products (nineteen samples for each one), whereas table (5) demonstrates the dimensional deviation for each sample. The average response and replicated twice values for each of the nine trials or process designs were used for this work. Table (6) depicts the present work and the average of dimensional deviation, and figures (6, 7 and8) clarify the relationship between experimental data and product design (CAD model) for nine products and the location of (nineteen samples).While figures (9 and 10) exhibit the relationship between process parameters and average deviations.

Table (3): Multipoint levels and parameters

Parameters	Units	Level -1-	Level -2-	Level -3-
blank holder type (B)	-	1	2	3
Cushion thickness (R)	mm	2	4	6
Speed (D)	mm/min	2	5	10

Table (4): The average values of dimensions of nine products.

Radius	Products								
	1	2	3	4	5	6	7	8	9
90	0	0	0	0	0	0	0	0	0
80	1.7	2.42	2.275	2.25	2.195	2.19	2.59	2.465	1.095
70	2.385	3.38	3.175	3.1	3.06	2.93	3.69	3.46	1.925
60	11.835	13.575	13.1	13	12.95	12.745	13.745	13.535	13.835
50	24.78	25.035	23.875	23.555	23.5	21.595	21.51	21.535	21.595
40	28.365	29.13	28.01	28.755	28.05	28.565	28.05	28.28	28.585
30	33.8	34.705	34.3	34.45	33.205	34.005	33.35	33.85	35.275
20	36.7	36.985	36.78	36.7	36.71	37.61	36.85	36.92	36.92
10	38.38	38.38	38.38	38.38	38.38	38.85	38.85	38.85	38.45
0	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.127

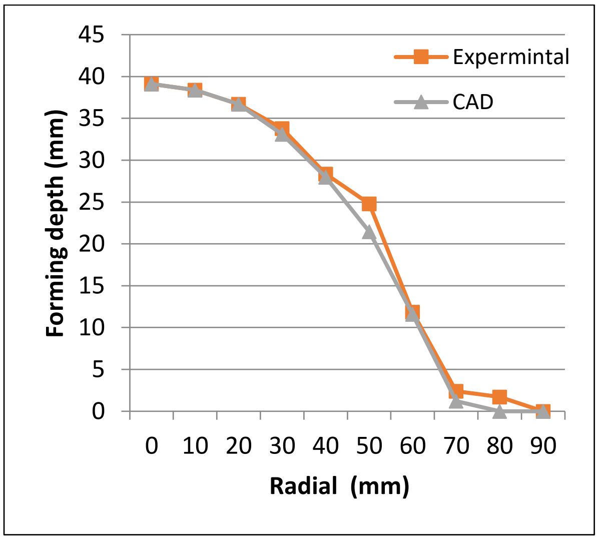
Table (5): The dimensional deviation for each product

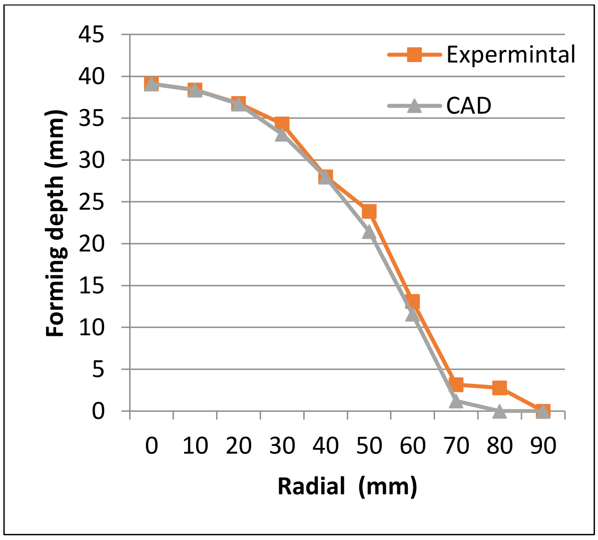
Radius	Products								
	1	2	3	4	5	6	7	8	9
90	0	0	0	0	0	0	0	0	0
80	1.7	2.42	2.275	2.25	2.195	2.19	2.59	2.465	1.095
70	2.385	3.38	3.175	3.1	3.06	2.93	3.69	3.46	1.925
60	0.268	2.008	1.533	1.433	1.383	1.178	2.178	1.968	2.268
50	3.311	3.566	2.406	2.086	2.031	0.126	0.041	0.066	0.126
40	0.39	1.155	0.035	0.78	0.075	0.59	0.075	0.305	0.61
30	0.712	1.617	1.212	1.362	0.117	0.917	0.262	0.762	2.187
20	0.007	0.292	0.087	0.007	0.017	0.917	0.157	0.227	0.227
10	0.016	0.016	0.016	0.016	0.016	0.486	0.486	0.486	0.086
0	0	0	0	0	0	0	0	0	0.027
Average Deviation	0.9251	1.5214	1.1567	1.16144	0.9362	0.98252	0.9977	1.0251	0.8986

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

Table (6):Methodology of Taguchi's (L9) orthogonal array and response value

	Process Parameters			
Exp. No.	Blank holder type	Cushion thickness	Speed	Average deviation
1	1	1	1	0.9251
2	1	2	2	1.5214
3	1	3	3	1.1567
4	2	1	2	1.16144
5	2	2	3	0.9362
6	2	3	1	0.98252
7	3	1	3	0.9977
8	3	2	1	1.0251
9	3	3	2	0.8986





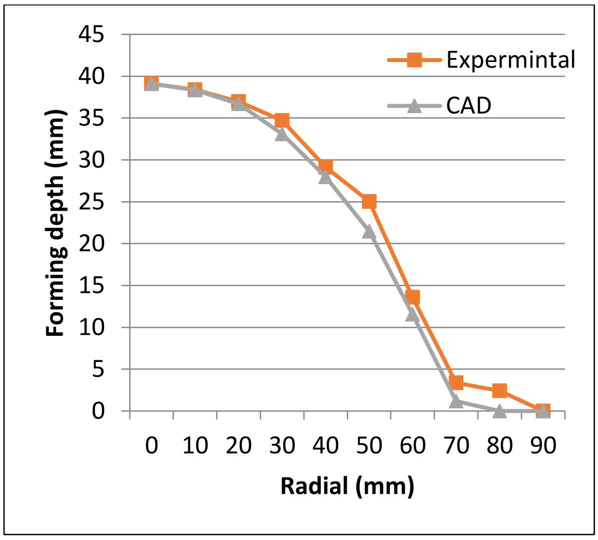
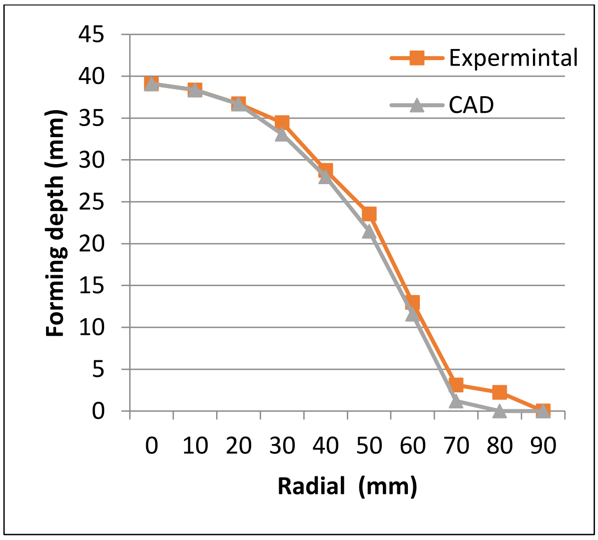
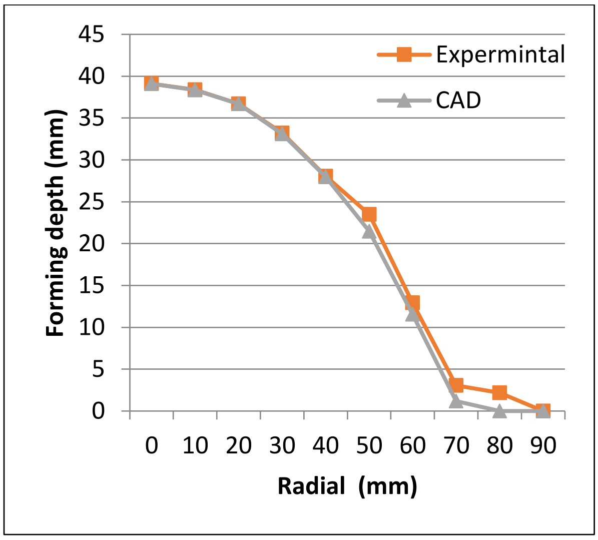


Fig. (6):Dimensional accuracy of radial displacement using blank holder (1) with different cushion thicknesses (2,4 and6)





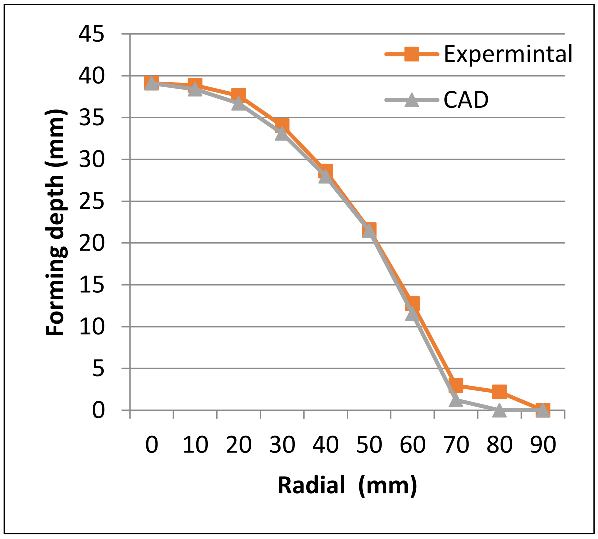
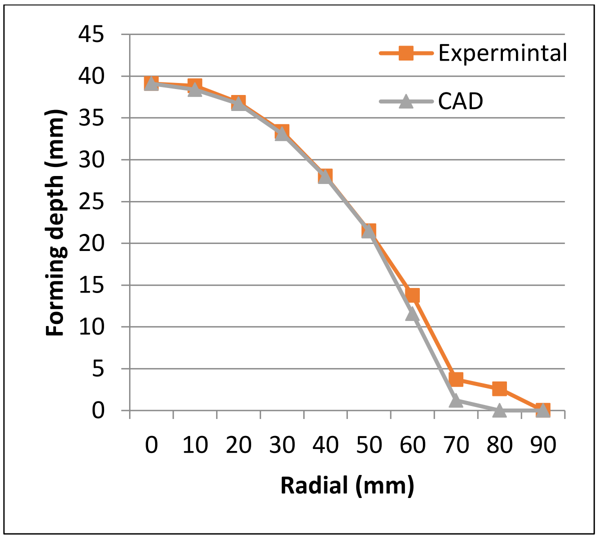
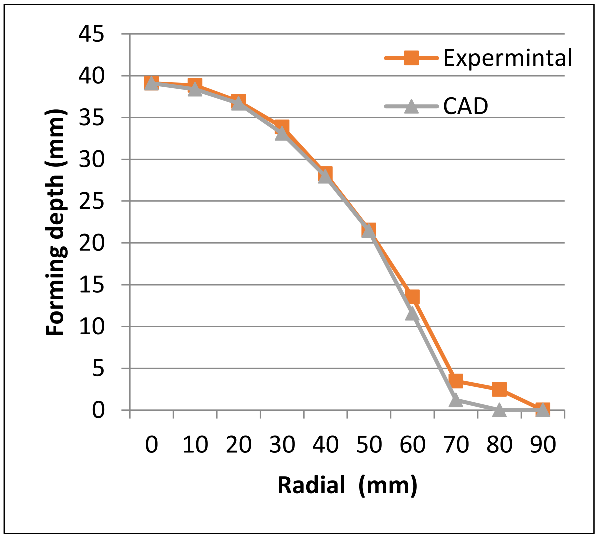


Fig. (7):Dimensional accuracy of radial displacement using blank holder (2) with different cushion thicknesses (2,4 and6)


45
40
35
30
25
20
15
10
5
0
Forming depth (mm)
Expermintal
CAD
0 10 20 30 40 50 60 70 80 90
Radial (mm)


45
40
35
30
25
20
15
10
5
0
Forming depth (mm)
Expermintal
CAD
0 10 20 30 40 50 60 70 80 90
Radial (mm)

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

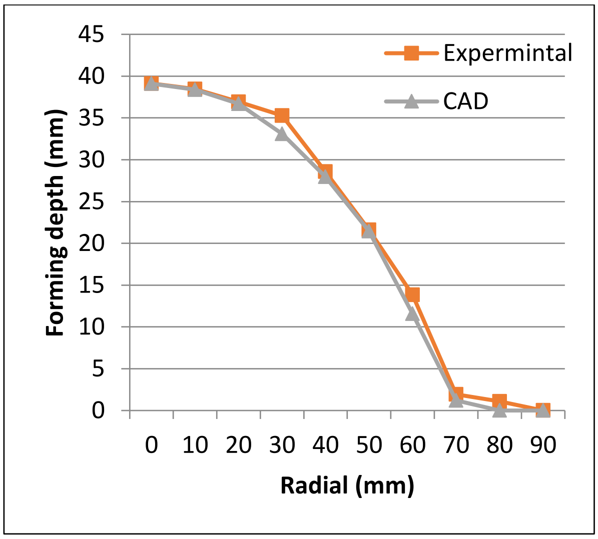
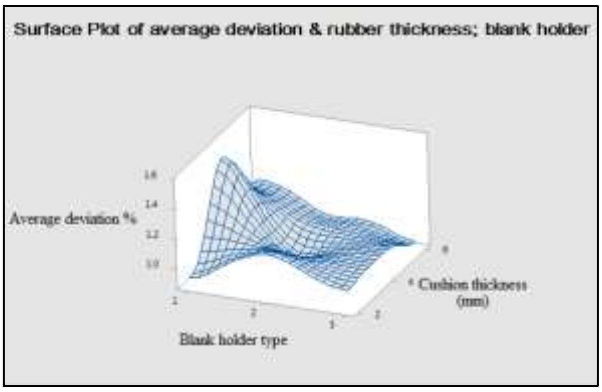
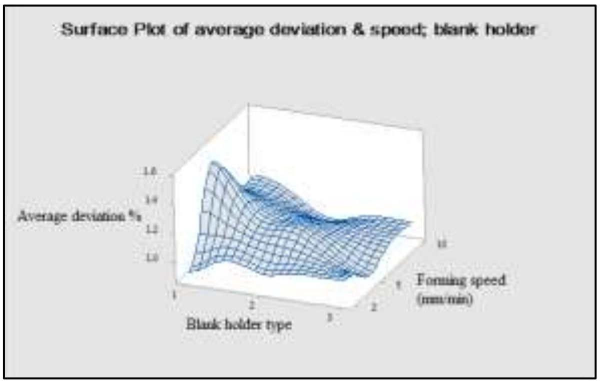


Fig. (8):Dimensional accuracy of radial displacement using blank holder (3) with different cushion thicknesses (2,4 and6)





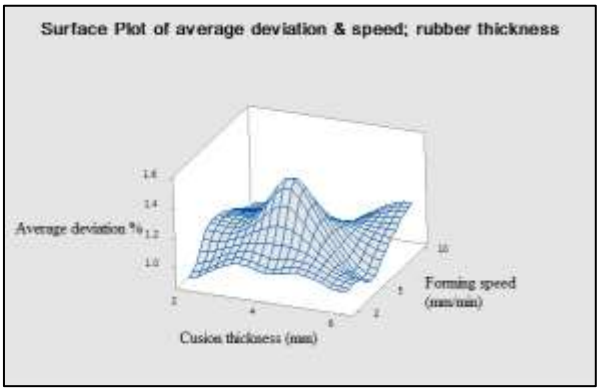


Fig. (9):The relationship between process parameters and average deviations.

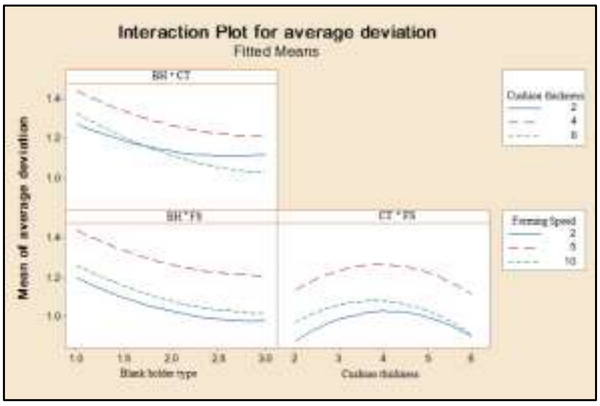


Fig. (10):The relationship between each process parameter and the mean average deviation.

3.3 Prediction of forming process parameters

Taguchi's algorithm has been used to predict the influence of input parameters on the response value, estimate the equation that contributes between each forming parameter and the average response value in second order,as illustrated in equation (1), and to optimize the present work from the given data (blank holder (BH), cushion thickness (CT) and forming speed (FS)) with respect to the dimensional deviation. Table (5) lists the final prediction value using Taguchi's algorithm, while table (7) present the analysis of variance using ANOVA algorithm.

Average deviation = 0.455 - 0.274 BH + 0.3286 CT + 0.1773FS + 0.0607 BH^2- 0.03514 CT^2 - 0.01310 FS^2- 0.01841 BH*CT - 0.00163 BH*FS- 0.00257 CT*FS …..(1)

Level of confidence (F-value) =95% =0.95

Level of significance (P-value) =5% = 0.05

1- P-value

$P < 0.05 \rightarrow$ Significant

$P > 0.05 \rightarrow$ Non- Significant

2- Fisher value (F-value)

F > FT (from table) Critical tabulated

FT=4.4513

Percent of contribution % = $\frac{Adj\ ss}{Total\ Adj\ ss} * 100\ \%$ ….(2)

Percent of contribution %

Blank holder =94.303%

Cushion thickness = 0.645 %

Forming speed= 5.054%

Results and Discussion

Results of the present work represent the effect of various variables of forming parameters (blank holder (BH), cushion thickness (CT) and forming speed (FS)) with respect to the dimensional accuracy in forming parts of Brass (Cu Zn 65-35) using multi-point forming process. The results from the experimental work using ANOVA algorithm are indicated in Figures (9 and 10). The influence of two input parameters are represented in each curve; otherwise the parameter was kept constant.

The effect of blank holder on the dimensional accuracy at the different cushion thicknesses and forming speeds was found with respect to the range of forming parameters used at the cushion thickness (6mm), and the third type of blank holder gives the best dimensional accuracy, see figures (6 ,7 and 8). The final result was estimated, and the empirical model of each forming parameter with respect to the dimensional accuracy was obtained using Taguchi's algorithm. The contribution of blank holder types, cushion thickness and forming speed with respect to the dimensional accuracy is (94.303, 0.645 and 5.054) %, respectively.

Table (7):Analysis of variance using ANOVA algorithm

Analysis of Variance					
Source	Df	Adjss	F-Value	P-Value	F_t
blank holder	1	0.232425	49.53	0	✓
cushion	1	0.001593	0.34	0.568	×
speed	1	0.012457	2.65	0.122	×
Second order					
blank h*blank h	1	0.022101	4.71	00.044	✓
cushion*cushion	1	0.118536	25.26	0	✓
speed*speed	1	0.22693	48.36	0	✓
2-Way Interaction					
blank h*cushion	1	0.01626	3.47	0.080	×
blank h*speed	1	0.000521	0.11	0.743	×
cushion*speed	1	0.00516	1.10	0.309	×
Error	17				
Total	26	0.704881	0.24646		

Conclusions

The current research reviewed some important aspects related with surface quality in sheet metal forming with special emphasis on the brass alloy. Based on the results of this work on the surface quality in multi-point forming process using ANOVA algorithm, the following conclusions can be drawn:

1. In multi-point forming process, the process parameters (blank holder types, cushion thickness and forming speed) are the main factors that effect on the dimensional accuracy.
2. The results of ANOVA Algorithm and the effectiveness experiments confirm that the developed empirical models for the output responses provide the predicted values and show an excellent fit of these response factors that are close to the experimental values, at (95%) confidence level.
3. The blank holder type (2) gave the minimum dimensional deviation up to (94.303%).
4. The low forming speed gave the low dimensional deviation, because it gives enough time for the metal to reorganize the atoms and thus reduce the strength of the metal resistance to the forming force, and the effectiveness range is up to (5.054%).
5. The effect of cushion thickness on the dimensional accuracy was the lowest, and the effectiveness range is up to (0.645%).

Nomenclature
BH: Blank Holder.
CT: Cushion Thickness.
FS: Forming Speed.

References

[1] Zhong-Yi Cai, Ming-Zhe Li,and Xi-Di Chen, Digitized die forming system for sheet metal and springback minimizing technique, Int. J. Adv. Manuf. Technol., (2006) 28: 1089-1096.
[2] Mingzhe Li, Yuhong Liu, Shizong Su, and Guandgquan Li, Multi-point forming a flexible manufacturing method for a 3-d surface sheet, Journal of Materials Processing Technology, 87 (1999): 277-280.
[3] Cai Zhongyi, and Li Mingzhe, Optimum path forming technique for sheet metal and its realization in multi-point forming, Journal of Materials Processing Technology, 110 (2001): 136-141.
[4] Tan Foxing, Li Mingzhe, Cai Zhongyi,and Li Xiangji, Formability analysis on the process of multi-point formin for titanium alloy retiary sheet,Int. J. Adv. Manuf. Tecbnol., (2009) 41:1059-1065.
[5] Wei Liu, Yu-Yong Yang and Ming-Zhe Li, Numerical simulation of multi-point stretch forming and controlling on accuracy of formed workpiece, Int J Adv Manuf Technol (2010) 50:61–66.
[6] A. A. Tolipov, A. Elghawail, M. Abosaf, S. Shushing, D. Pham and K.Essa, Experimental research and numerical optimisation of multi-point sheet metal forming implementation using a solid elastic cushion system, Conference Paper, Department of Mechanical Engineering, School of Engineering, University of Birmingham, UK, July 2017.
[7] Babak Beglarzadeh, An experimental and numerical study of forming parameters affection on multi-point deep drawing process, International Journal of Advanced and Applied Sciences, 4(1) (2017): 90-95.
[8] Tahseen Fadhel Abaas, Karem Mohsen Younis and Khalida Kadhim Mansor, Die Design of Flexible Multi-Point Forming Process, Al-Khwarizmi Engineering Journal, Vol. 14, No.2, (June 2018): 22-29.