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Numerical Simulation and Experimentally Investigation into Forming of Cups using Conical Die Based on an Innovative Deep Drawing Combinations Processes

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Keywords
Deep Drawing Process; Cups; Blank holder; Simulation; and Drawing ratio

Abstract: Deep drawing process is important sheet metal forming processes and is done either with or without blank holder. In this research, there is another innovative method that combines both two modes drawing process at the same time, with the possibility of ironing the thickness for the wall cup produced in the same process. In the first, drawing is done without a blank holder by two inclusion punches, one of which forms an initial cup. Then it creates an inclined blank holder for the drawn cup, and the other punch continues process, followed by wall thinning completing the deformation of the cup. The ironing happens when using several punches with diameters whose clearance is less than the thickness of the blank. A simulation model of the innovative process was built using the ANSYS program, while experimental work was conducted on a general testing machine, also the study effect of the process variables on the produced cups and their characteristics. The results showed that the innovative process of deep drawing led to an increase in drawing ratio that reached 2.24. This is a high percentage compared to the traditional method, also the process variables have a clear effect on the cups produced. The simulation results showed their convergence was observed between the simulation and experimental results at the same conditions. The results also showed that the values of wall thinning reached by 80% from the thickness blank value before drawing.

1. Introduction

The deep drawing process is a commonly employed shaping method in the aerospace, military, automotive, and other sectors. It's among the most significant sheet metal forming techniques utilized in manufacturing, converting a flat piece into a cup, bowl, or cylindrical item. The product is used in various industries and applications. Two methods are commonly used in deep drawing: first method using blank holder, in second method deep drawing free blank holder. Both methods have advantages and disadvantages, which are often related to the cost of production cups and the time required to form the cups. Several studies have investigated several process parameters, blank

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including blank holder force (BHF), punch diameter, die diameter, punch-die and die friction, inhomogeneous material properties, blank thickness, and more. die and punch shapes, die clamping force, and lubrication. Given the complexity of the functions that describe the process output relative to these parameters, optimizing the deep drawing process is a challenging task. Recently, there has been increased interest in the research community in applying optimization techniques to this process. Wifi, A.S., et al. provide a comprehensive review of the optimization techniques used and identify future research directions [1-3]. A key parameter affecting the quality of the goods made by this procedure is the blank holder force (BHF). By managing the BHF during the forming procedure, formability can be enhanced, and energy demands lessened. Tearing is among the most frequent and important defects in this procedure, originating from elevated radial stresses in the cup walls, thereby imposing several constraints in this area. The BHF performs a crucial function in the incidence of tearing, therefore controlling it during the process is critical to avert tearing or even wrinkling. Khaboushani, M., et al. [2] presented a study to compute the tear limit using new standards in analytical plasticity equations based on the plate method. Shah, K., et al. [3] presented a study to identify the most significant process parameters that cause defects and reduction in dies. The deep drawing process relies on a combination of die and punch, generating radial stresses at the edge region and compressive stresses at the center of the base, achieving a permanent shape change. Patel, N.D. et al. [4] introduced a study that reviews multiple theoretical and experimental attempts to relate punch strength, base holding force, distribution in finished products. The study also focuses on the different failure modes that may occur in various product shapes. Dudhat, P.M. et al. [5] presented a study aimed to determine the optimal die shape design for the deep drawing process of randomly shaped cups with a uniform shear margin at the edge, to determine the optimal values for these parameters, it is necessary to understand their impact on the deformation behavior of sheet metal. Joshi, A., et al. [6] presented a study of the three most important parameters in the deep drawing process such as friction coefficient, and the effect of these parameters on the deep drawing properties of a mild steel cup. The market includes a variety of processes used to manufacture large-depth axial cups. Atul S, T., et al. presented an examining the current status and potential future developments of drawing technology. They also reviewed opportunities for improving flexibility in these processes [7]. Arab, N., & Javadimanesh, A. presented a numerical modelling analysis of the drawing of circular blanks into symmetric cylindrical cups. The drawability was theoretically and experimentally correlated with the initial blank diameter and process parameters. They also presented a study of stresses in the radial and circular directions [8]. In the drawing process, if the part is not susceptible to wrinkling due to a small drawing ratio, deep drawing can be performed without a blank holder. Vahdati, M. et al. presented a study of the spherical head drawing process using three different drawing die shapes in three scenarios: (1) increasing die curvature radius, (2) approximate shape, and (3) exact shape. In this study, they introduced the Johnson-Cook model to describe the material flow behavior and used the Johnson-Cook damage model to predict the probability of failure [9]. Akafzadeh, E. et al. presented a study of the deep drawing process of a thin circular blank into an ideal hemispherical cup at the room temperature, using a die without the blank holder, through experiments and numerical simulations. Removing the blank holder may result in defective products due to various failure modes, such as wrinkles or ripples. Therefore, based on previous studies, removing the blank holder in the process is not recommended. They also proposed an improved die design to compensate for defects that may result from removing the blank holder [10]. Dhaiban, A.A. et al. presented a research paper on a new deep-drawing technique for forming oval cups using a conical die, without the need for a blank holder or drawing die edge. A three-dimensional finite element (FE) model was constructed using semi-cone die angle and corner radius, dies with a semi-cone angle of 18° showed the best ductility for this new technique.

A die with an aspect ratio of 2 was used with punches with aspect ratios ranging from 2 to 2.25. Tensile tests were performed to obtain the stress-strain behavior of the material [11]. Ameen, H.A. et al. proposed a new mechanism for the oval deep drawing process to produce an oval cup from a thin circular brass (CuZn37) sheet without using a blank holder. It was observed that a die with a gap of 1 mm and a thickness of 0.8 mm required high ductility for this new technique. Their results showed that a gap between the punch and the die yielded the best results in the oval deep drawing process without using a blank holder [12]. Shaaban, A., et al. [13] presented a numerical and experimental analysis to investigate the factors affecting the deep drawing process of symmetrical products with low depth, such as the die geometry, the punch motion, and the damping system. The numerical and experimental results obtained showed a slight deviation of 3.5% for the maximum stress and 0.92% for the maximum thickness. After validation of the model, it was used to investigate the factors affecting the maximum stress and maximum thinning. It was found that the damping stiffness and the initial base thickness had the greatest influence, while the punch speed showed an insignificant effect. The results were justified, confirming the reliability of the model for further analysis [13]. Mohammed, A.I. demonstrated in their study how to create a complex eight-pointed shape through the deep drawing process using two different approaches. The first, known as the direct method, involves forming the desired shape directly from sheet metal. The second approach, referred to as the indirect method, requires an intermediate step where a cylindrical shape is first drawn and then reshaped into the complex final shape through a redrawing process. They compared the two methods to evaluate their performance in terms of strength, thickness distribution, and stress-strain behavior. The low-carbon steel (1008-AISI) sheets were used in experiments. Their results showed that the maximum drawing force recorded during the direct drawing process was 41 kN (experimental) and 30 kN (finite element simulation) [14]. Kim, J.Y. et al. presented a study on multi-stage deep drawing methods to achieve deep cups [15]. Mohammed, A.I. worked on producing a complex shape during the deep drawing process [16-18]. Candra, S. presented a study on the blank holder gap (BHG) to prevent wrinkles and crack defects in the deep drawing process of 30 mm diameter cylindrical cups made of 0.7 mm thick SPCC low carbon steel. The die and punch dimensions were determined based on standard tooling designs. According to the research, the BHG was set between 100% and 114% of the raw material thickness, corresponding to approximately 0.70 to 0.80 mm. Using this gap value, wrinkle height can be avoided while maintaining the drawing force below a critical threshold, ensuring that the product sample does not develop wrinkles or cracks [17]. Candra, S., et al. presented a study on prevent wrinkling and cracking during the forming of low-carbon steel sheets without the use of lubricants [18]. Susila Candra et al. presented a study aimed at predicting the maximum variable blank holder force (VBHF) during punch movement, with the aim of eliminating cracks in deep-drawn cup products. Constant blank holder force is often insufficient to effectively prevent cracks. The study used steel plates, and the diameter of the cylindrical cup-shaped product was 40 mm. Compared to applying a constant blank holder force, VBHF can be very effective in reducing cracks [19]. To reduce product defects during the deep-forming process, Sugiyanto, D. et al. have implemented a preliminary simulation in the manufacturing industry, which will helps reduce losses due to design errors. The effects of the die holder include three main factors: deep forming without a holder, the gap, and the drawing ratio [20]. Tearing and wrinkling are among the most common problems facing this process, Belguebli, A., et al. introduced the numerical analysis results reduce the problem in industry, especially in mass production areas such as machinery manufacturing [21]. Reddy, R.V. presented a review of the key aspects affecting wrinkling of cylindrical parts during deep forming [22]. The mechanical properties and dimensional stability of aluminum alloy sheet parts are significantly affected by residual stress. However, limited studies have addressed these stresses in

aluminum alloy sheet parts processed by deep drawing at elevated temperatures [23, 25] Many researchers presented development technique for deep drawing a detailed analysis and treatment of these defects. The deep drawing process of a wheelbarrow tray was modeled by finite element (FE) method using Abaqus software [26-28].
As noted in the previous literature, several attempts have been made to simulate and predict the effects of various factors affecting the deep drawing process, particularly with and without a blank holder, in separate studies. However, the research gap was that no previous work has addressed the effects of deep drawing when punch work as a blank holder. This innovative process combines both processes into a single process and a single pass, saving effort and time and improving the cups produced using the innovative method. Furthermore, the current work focuses on an analytical and experimental investigation into the feasibility of introducing an innovative deep drawing process that combines a deep drawing process without a blank holder, while simultaneously having a blank holder as a punch. The effect of this on the deep drawing process with/without a blank holder is also discussed.

2. Material and Methodology for Simulation and Experimental work

To conduct practical experiments for forming cups using the combined deep drawing process, which combines the deep drawing process without a blank holder and with a blank holder, in one process, one journey, and one operation, by demonstrating the benefit of the advantages of each process and combining them in one process. For this purpose, a laboratory setup was designed as shown in Figure 1, 2,3 and Figure 4. In Figure 1. It consists of a conical drawing die, a secondary conical punch/blank holder, and a blank support or blank holder as one part: the primary punch, the die base and holder, the punch/holder, a spring assembly, and the punch centre sleeve.

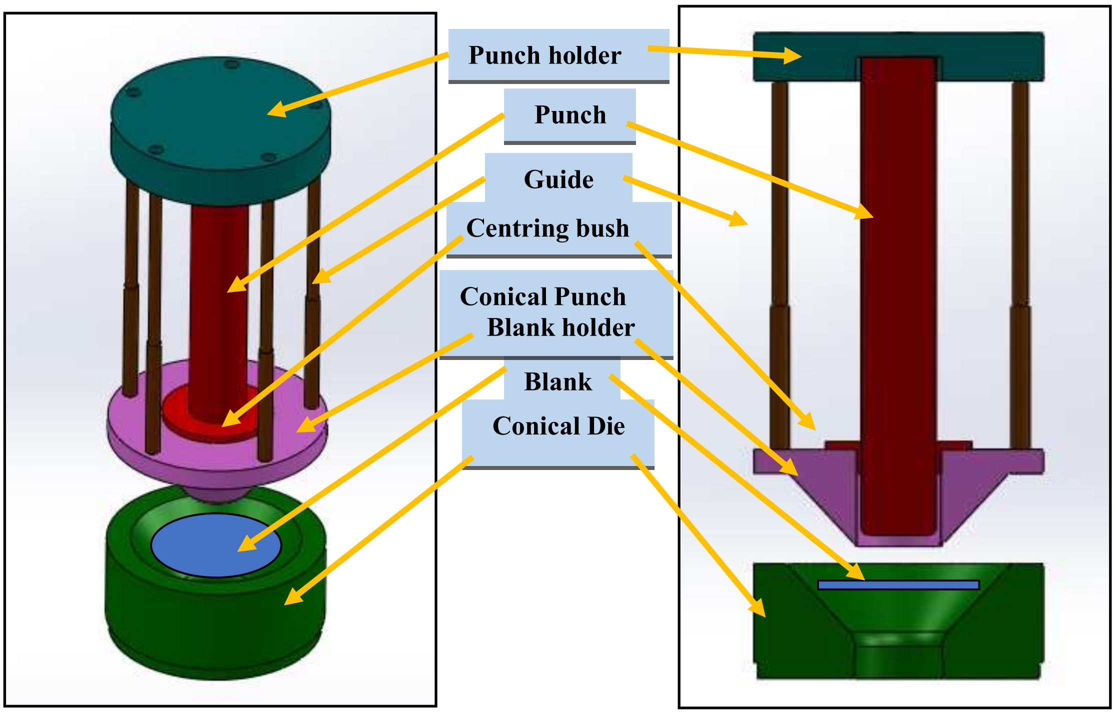

Figure 1 Schematic illustration of the components of the innovative proc

Figure 2 shows a photograph during practical experiments conducted on the universal testing machine. While Figures 3 and 4 show the parts and components of the tool or die used in the innovative deep drawing process. The setup was used with the blank position adjusted completely horizontally using a balance and adjusting the equipment centre with the machine centre. A pressure program was loaded and set to operate. The upper jaw of the universal testing machine acts as a forming machine or as a punch, exerting a force on the blank, displacing the blank so that it passes through the cavity of die. This is done at a specific speed according to a pre-prepared experimental program. As the upper group of the laboratory setup advances, the conical punch forms the blank and transforms it into the first precoup. It then stops and acts as a support or holder for the first cup. The primary punch then moves and transforms the first cup into a final formed cup in its final shape after passing through the cavity of die. As the cup is formed, a mixture of oil and graphite is used to reduce Friction during the forming process. The basic punch is also used, the lower part of which has a groove or roughness to prevent the sample from collapsing and helps in transferring stresses from the base of the cup to the walls, thus reducing the forming loads on the cup material.

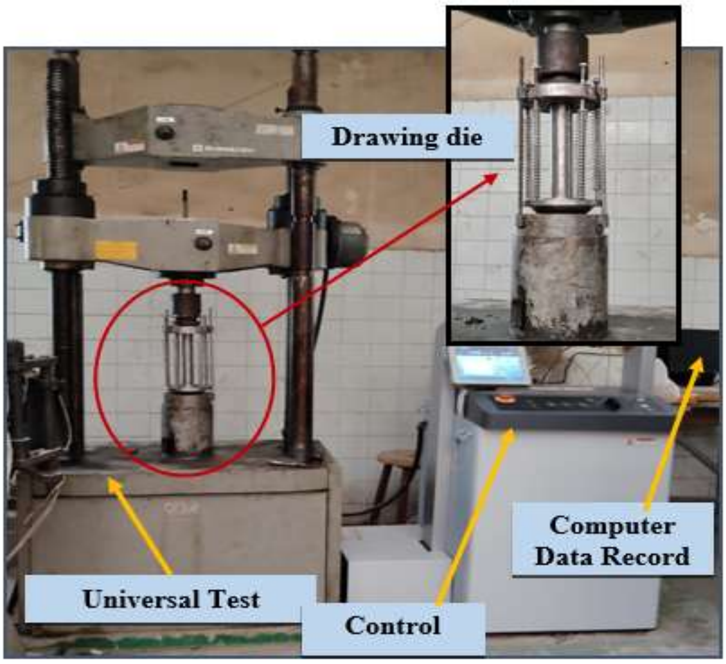

Figure 2 Photograph of experimental components and parts for the innovative process laboratory setup.

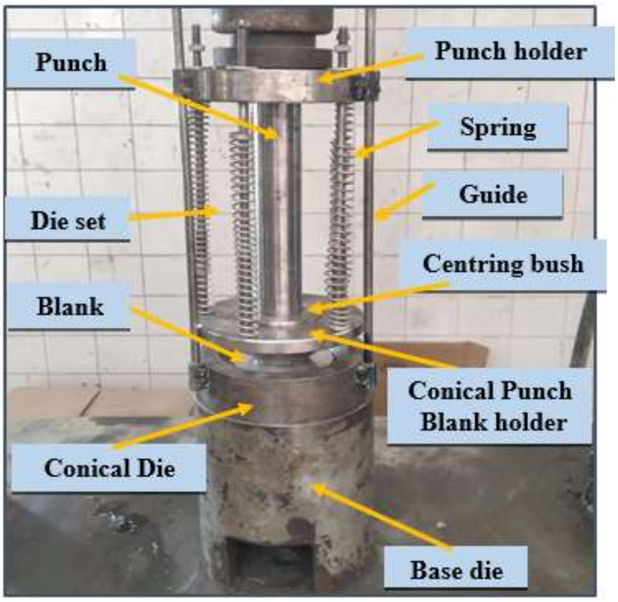

Figure 3 Components and parts for set assembly of the innovative deep drawing tool

Figures 5 and 6 Illustrative Steps and shots of the innovative deep drawing process in this process, aluminium was used with the properties shown in Table 1. And Table 2. Before the experiments, an annealing process was carried out for the blanks before drawing them by placing the blank in the oven at a temperature of 450 degrees Celsius for two hours, then leaving them to cool and reach room temperature for a period of 24 hours without opening the oven. Thus, they are ready for forming. All blanks were prepared and cut according to the dimensions specified in the experimental program shown in Table 3. The measuring devices used in this research include a dimensional measuring device, a hardness measuring device, a tensile testing machine, and a thickness change measuring device. Some measurements were taken before the forming process to determine the mechanical properties to understand the behaviour of the metal during forming. Some measurements were taken during the forming process, such as the stress-strain curve or the forming load-drawing curve. Other measurements were taken after the forming process, such as the thickness and hardness of the sample at various locations within the formed cup. After collecting all measurements, curves, and the formed cup samples, they were subjected to examination, analysis, and discussion, as follows in the Results and Discussion section.

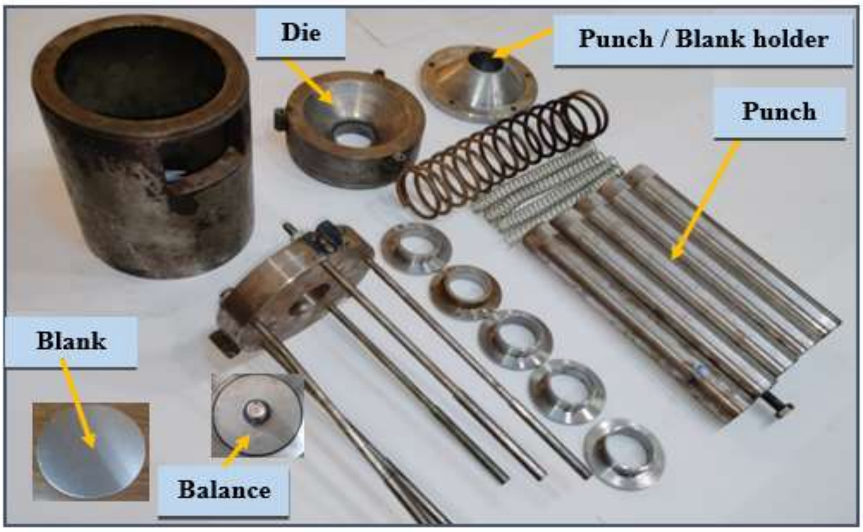

Figure 4 Components of the deep drawing tool and Conical die with Punch / Blank holder

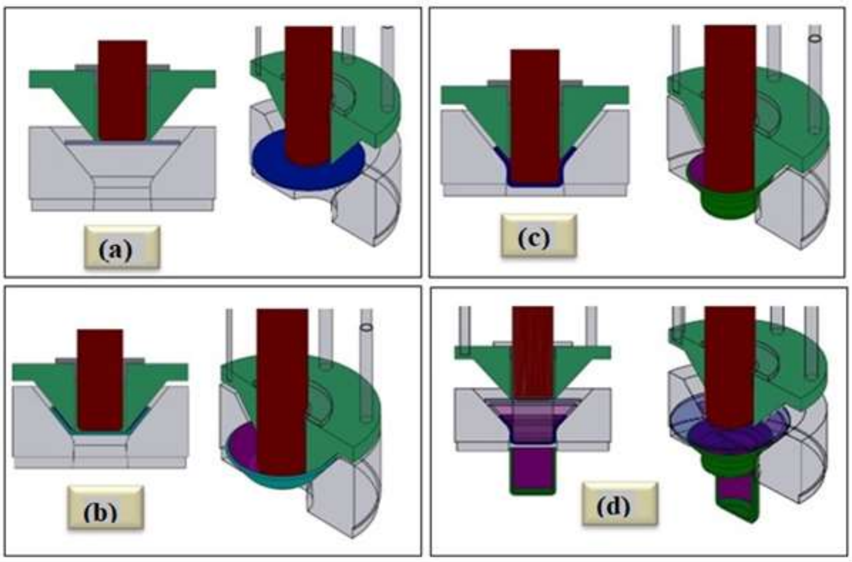

Figure 5 Illustrative shots of the innovative deep drawing process

Figure 6 shows several positions for the sequence of the deep drawing process in the innovative way, which is done in one step. The process is analyzed by placing the sample or disk, then moving the punch down, which works to draw the sample into the first cup, then works as a support for the disk, and the other punch completes the rest of the drawing process. Part of Figure 6 is a snapshot from the simulation program that was used to carry out the drawing process.

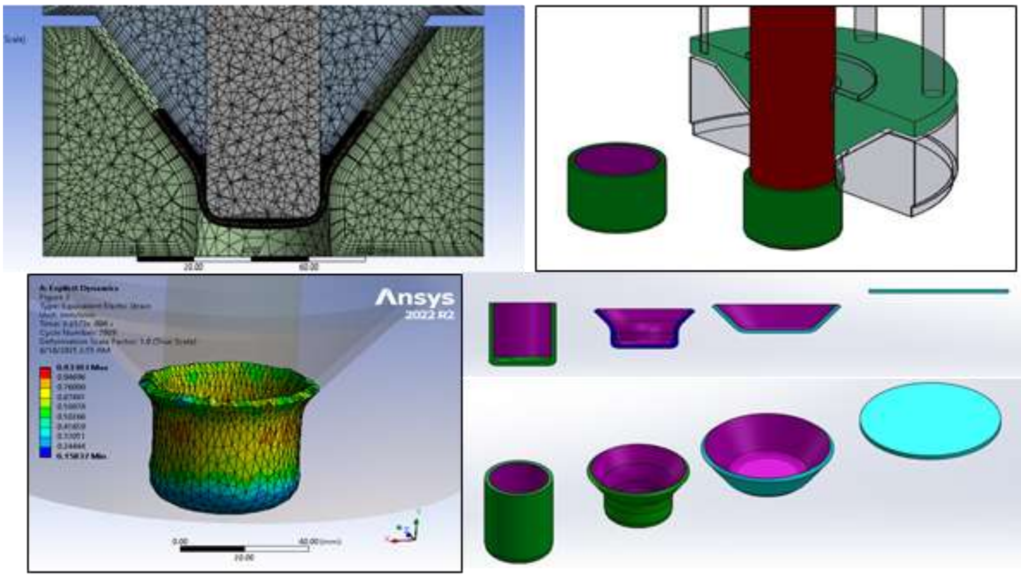

Figure 6 Steps to the innovative deep drawing process to produce cup

Table 1 Chemical composition of tested Aluminium blanks (AL1055).

Element	Al	Si	Fe	Cu	Mn	Mg	Zn	Cr
Percent	96.7	0.1844	0.071	2.54	0.0288	0.08046	0.094	0.1266
Element	Be	Ca	Pb	Sn	Sr	V	Bi	Ni
Percent	0.001	0.005	0.00288	0.00243	0.001	0.00203	0.00997	0.01
Element	Cd	Co	Ag	In	Ga	Ti	B	Zi
Percent	0.0042	0.0643	0.0137	0.0213	0.0139	0.0172	0.004	0.00183

Table 2 Measured plastic behaviour of the tested material.

	Strength Coefficient, (k)	Strain Hardening Exponent, (n)
Before annealing	K = 137 MPa	n=0.142
After annealing	K = 83 MPa	n=0.215

Finite Element Analysis Before performing a wired element analysis, it is necessary to draw an analysis model in soft drawing program. SOLIDWORKS was used to draw the models under various parameter conditions. ANSYS Explicit Dynamics was then used to perform finite element analysis simulations. The forming parameters were adjusted according to the final product. The obtained optimal geometric parameters for the model were used in the die unloading process. A test model was drawn to verify the accuracy of the analysis program's predictions. The simulation of the model drawing and the model are shown in Figure 1. Before performing finite element analysis, it is necessary to draw the analysis model using SOLIDWORKS and import the STL file for the model. In this case, the material properties of the part were set to plastic. The calculations were based on the following assumptions and estimates: (i) Strain hardening fluctuations during the forming process can be ignored. (ii) The rebound effect can be ignored. (iii) The processed material is homogeneous and uniform. (iv) It is possible to disregard the spring-back impact and during the deformation, the influences of temperature can be ignored. The mesh setting values are suitable. If the analysis value remains consistent when the mesh count is raised, the analysis time will elevate as the number of meshes continues to increase. Here, 50000 to 85,500 meshes were used. Material properties apart from the workpiece are rigid. The punch blessing curve setting is a function that employs paths, and custom coordinate functions. The friction setting uses Coulomb friction with a value of 0.01 to 0.03, while constant shear friction is suitable for the analysis of drawing operations. After the part is defined, the simulation setup is run. It's intended to define the total stroke of punch for the analysis according to deformed cup. The set value is 160 mm, each 0. 1 second is 1 reding is record, stop setting the definition of time used, when the set value is 20 seconds it stops. Mold temperature set point is 25°C to finalize the simulation setting.

Table 3 clarifies the experiments executed and operating parameters for the innovative deep drawing process

No	variable	The value of variable					
		State 1	**State 2**	**State 3**	**State 4**	**State 5**	**State 6**
1	Hole die diameter, mm	46 mm					
2	Punch diameter, mm	40	41	42	43	44	45
3	Blank thickness, mm	4	3.5	3	2.5	2	---
4	Linear velocity, mm/min.	V1, V2, V3 and V4					
5	Lubrication	A mixture of oil with graphene powder					
6	Blank material	Aluminium					
7	Blank diameter, mm	92	94	96	98	100	102
8	State	Under constant clearance or under constant pressure					
9	The thickness after forming, mm	3	2.5	2	1.5	1	0.5

3. Results and Discussions

3.1. The experimental and simulation results of innovative process

Figure No. 7, 8 and 9 shows some of the cups that were formed using the innovative deep drawing process in this research. It is clear from the visual inspection that the process succeeded in forming cups and obtaining a drawing ratio that reached a value of 2.24, which is a large value compared to the drawing process without a blank holder, which has a drawing ratio of 1.7, meaning that the increase in the drawing ratio is about 30%. Also, the drawing ratio with the blank holder is 2.1 in the case of a horizontal or vertical blank support. Therefore, the drawing ratio in the innovative method is also 20% higher than using the blank holder alone. This may be due to the analysis of the forming forces and load in the innovative method into two components of forces, one of which is the vertical component, which is part of the total forces and acts as the blank holder, and the other component is the horizontal component, which increases the cohesion of the disc to the punch walls and reduces the reaction of the disc on the punch and vice versa, which reduces the stresses that cause disc brakes. Therefore, the limits of success in forming the disc increase when using discs with large diameters, which increases the deep drawing ratio compared to its counterpart. This indicates the success of the innovative method in the deep drawing process using and without the use of the blank holder at the same time. Also in Figure 9, some samples are shown in the position of a full section of a sample with wall thinning and others without thinning and a half section of a sample showing the regularity of the change in thickness, and this is due to the balance of the sample during forming.

Figure 7 The successful forming cups using by an Innovative Deep Drawing Processes

Figure 8 the formed cups for different parameters

Figure 9 The successful cups and section in some sample at different drawing ratio

Table No. 4 and Figure No. 10 illustrate the process of thinning the wall of cups produced by the proposed deep drawing process during the drawing process directly. It is clear from the table that the maximum percentage of thickness reduction achieved was up to 85% with the use of a 45 mm diameter bench and a 4 mm original thickness sample. Also, in some cases there is no change in the thickness of the sample, for example, when using a 40 mm punch and a 2 mm thickness sample, in this case there is no thickness reduction, and so on (see negative sign). Regardless of other variables affecting the draw ratio in the deep drawing process, for samples with a thickness of 2, 2.5, 3, 3.5 and 4 mm, the value of the reduction ratio

(Corrective ironing) for the sample thickness differs, which is known as the value of the sample thickness after the drawing process divided by the sample thickness before the drawing process. The table shows calculated percentage values. Also, the punch dimeter used has an effect. In On the other hand, in this work, a simulation model was built using the ANSYS program, where the basic parts were drawn using the SolidWorks program, then the simulation model was built as shown in Figure 4, which shows the position of the forming process at the beginning of the process with the forming process variables as shown in Table 3. Here, the projection values were made large in number and very small in size so that the simulated results are as close as possible to practical reality. Figure 11, 12, 13, 14 and 15 shows several snapshots of the simulation result. This images, was taken at several locations from the beginning of the forming process until the end of the forming process. It is clear that during the forming stage, the stress is concentrated on the walls instead of being concentrated at the base, which works to tearing of the cup. This tearing is shown in Figures 11, 12 and 13, in which the load increase across the conical punch, so the forces increase at the end of the cup as if it were a support, while the forming load is downward. The following equations clarify this, as the sample is balanced between the two sides of the equation shown. If the right side of the equation increases, the sample is cut, and if the left side of the equation increases, which is difficult, the blank will not be pulled inside. The model and the successful case are in balance between all the effective forces to pull the disc inside the model and to complete the pulling journey without interruption. However, by conducting several experiments,

Table 4 The value of Corrective ironing (Thinning in % from original thickness)

The value of Corrective ironing (Thinning in % from original thickness)							
		Punch Dimeter in mm					
		40	**41**	**42**	**43**	**44**	**45**
Blank thickness in mm	**2**	-50	-25	0	25	50	75
	2.5	-20	0	20	40	60	80
	3	0	16.6667	33.3333	50	66.6667	83.3333
	3.5	14.2857	28.5714	42.8571	57.1429	71.4286	85.7143
	4	25	37.5	50	62.5	75	87.5

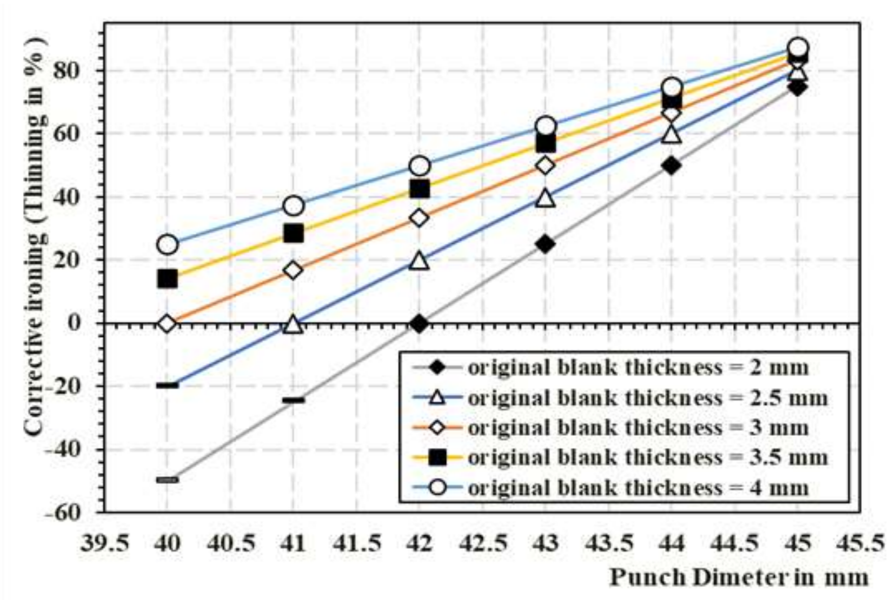

Figure 10 The value of Corrective ironing against the punch diameter

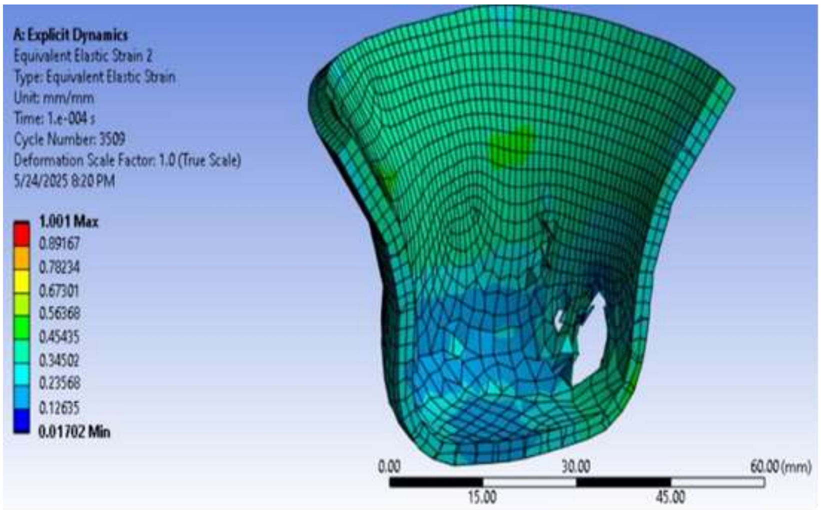

Figure 11 The unsuccessful simulation cups at different parameters of deep drawing process

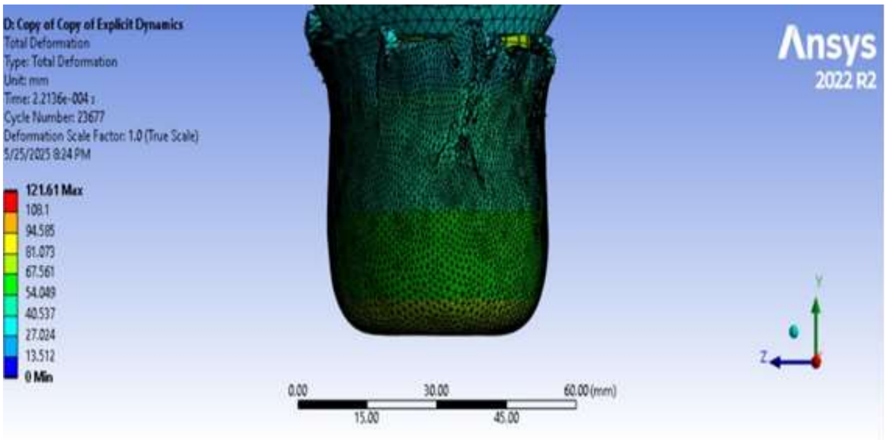

Figure 12 The successful simulation cup at drawing ratio 2.24

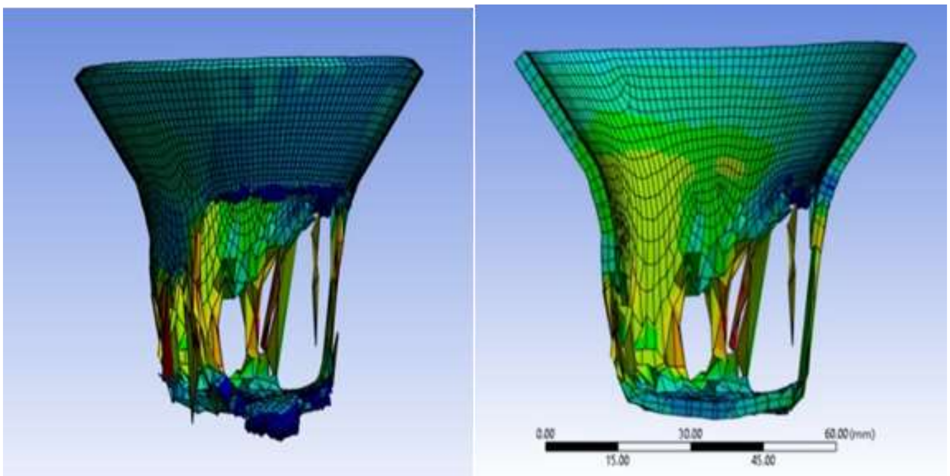

Figure 13 The successful and unsuccessful simulation cups at drawing ratio upper 2.24

Figure 14 and 15 shows the successful simulation cups during deep drawing process at different variable values affecting the process, as shown in the figure and as agreed upon by references and previous research. It is very important to review and discuss the results, for example, from the following images, which show that part of the stress is transferred from the base to the wall of cup, which may be the reason for reducing the tearing and cutting of the samples. Here, in the suggestion new work, the blank hold has an additional function in the deep drawing without blank holder or support, which is adding other forces to the drawing process. These forces are analyzed into two components: a component that works as a support for the sample during the drawing process, and the other component works to move the sample from top to bottom and works with other forces resulting from the sagging or roughness between the sample and the punch, so the stresses are transferred from the base to the wall, reducing the possibility of cutting the sample and increasing the drawing percentage. The new process was observed to provide a higher draw ratio and overcome some of the drawbacks of the conventional deep drawing process. Cups with a higher draw ratio were produced, compared to references [27], [28] and [29], which achieved draw ratios of 0.09, 1.14, and 1.68, respectively. This process was concluded to be suitable for aluminium. Another comparison of the deep drawing ratio with previous works (see Table 5)

Table 5 Comparison of the deep drawing ratio with previous works

Material type	Drawing ratio	The proposed method	References
Low-Carbon Steel	3.8-5.5	Friction force between blank and blank holder i.e. at the flange	[30]
Soft aluminum	4.0	Experimental (new friction-aided deep drawing process)	[31]
Unknown	3.76	Friction-aided deep drawing with segmented tapered blank holder	[32]
Unknown	3.0, and 3.3	Experimental observation on wall thickness uniformity	[33]
aluminum	2.1 – 2.2	Conventional deep drawing	[34]
Unknown	3.5 – 4.0	Hydro forming, hydro mechanical, counter-pressure, etc.	[35]

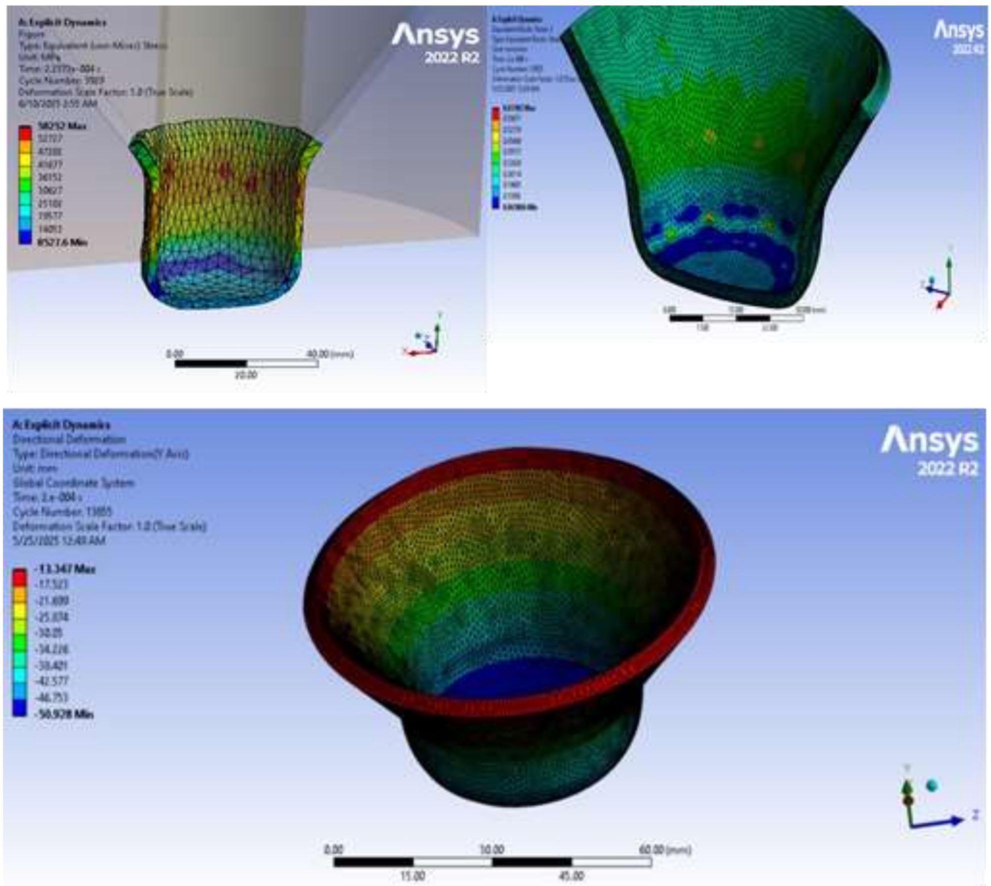

Figure 14 The successful simulation cups during deep drawing process

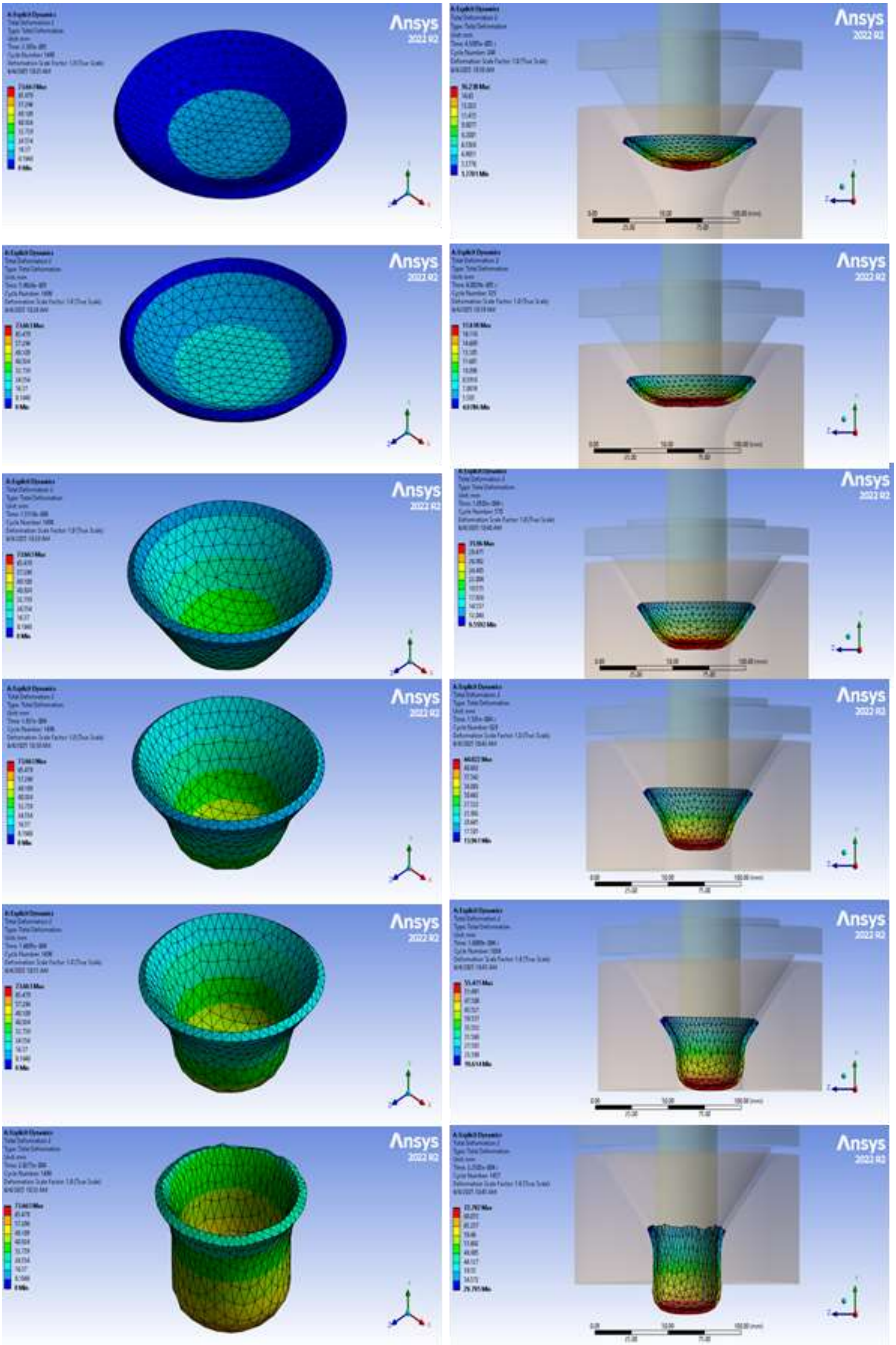

Figure 15 Simulates results at the stages of forming cup using the innovative deep drawing process.

3.2. The effect of innovative process variables on drawing load

The following figures, numbered from Figure (16) to Figure (22), illustrate the effect of innovative process Variables on drawing load. Such as the blank diameter, the thickness of the blank, or even the thinning values that occur during the innovative drawing process. In Figure (16), we find a general relationship between the deep drawing forces and the punch stroke. From this general curve, we can see that it is divided into three stages: the first is the initial pre-cup formation region. Then the cup formation area was followed by the wall thinning process as a second and third stage together and in a certain area the forces reach their highest value in the drawing process and then decrease as a result of approaching the end of the drawing process. As for Figures 17, 18 and 19, they show the drawing forces at a blank diameter of 95 with a thickness of 2.5, 3, 3.5 and 4 mm for different samples. Table (6) shows the values of these changes and it is noted that the figure takes the same trend or the same behaviour, except that some samples, as a result of the increase in values and wall thinning, the forces increase and after that the drawing process is greater than the others, as by working with the principle of the size stability or constant volume of the sample before and after the drawing process, when thinning increases, the length of the produced cup increases,

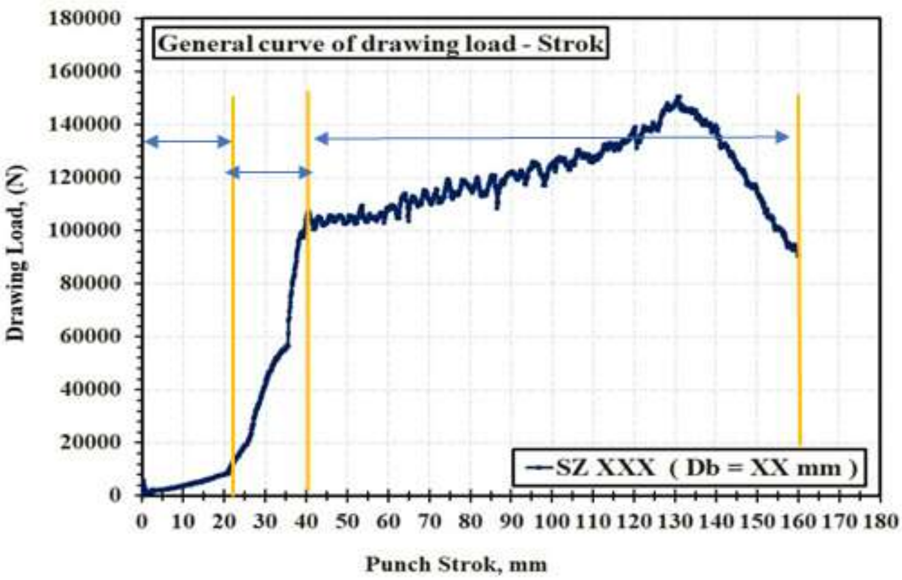

Figure 16 General curve of drawing load against punch stroke

Table 6 Som the value of variables foe the experiments for the innovative deep drawing process

ID Sample	The value of Variables Dp (mm), t (mm), S (mm/min), Db (mm)				ID Sample	The value of Variables Dp (mm), t (mm), S (mm/min), Db (mm)			
SZ 78	45	2.5	15	98	**SZ 2**	40	4	6	104
SZ 209	45	3	9	98	**SZ 9**	40	3.5	15	104
SZ 264	45	4	15	95	**SZ 336**	45	3	12	95
SZ 186	45	4	9	101	**SZ 49**	42	4	9	104
SZ 116	45	4	6	98	**SZ 266**	41	4	15	101
SZ 251	45	2.5	6	104	**SZ 211**	43	2.5	15	104
SZ 160	41	3	12	104	**SZ 81**	42	4	12	98

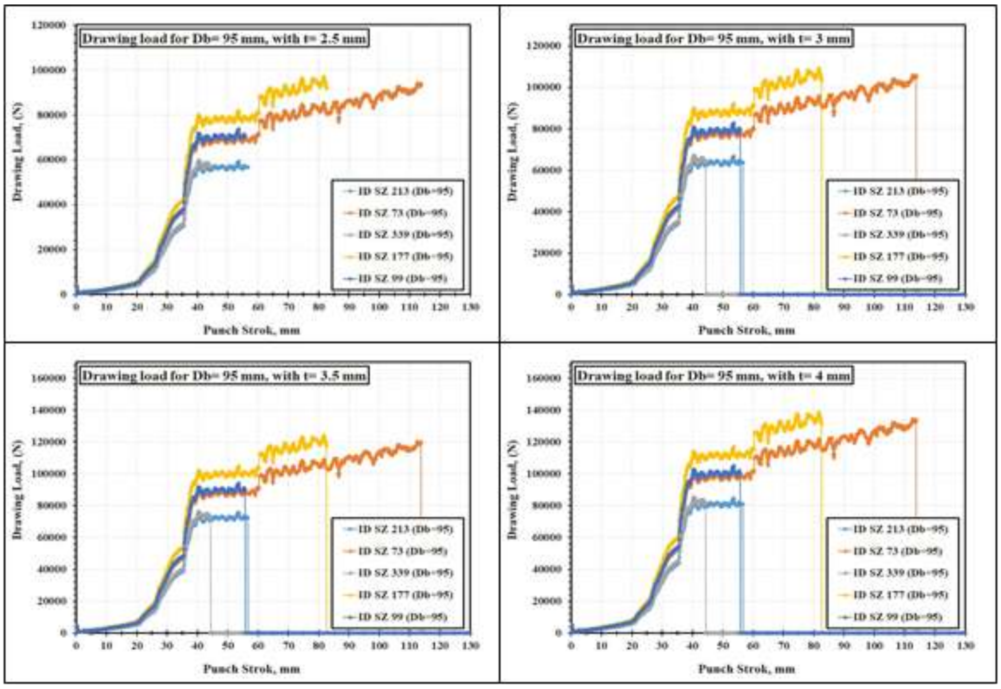

Figure 17 Drawing load for Db = 95 mm with t = 2.5, 3, 3.5 and 4 mm

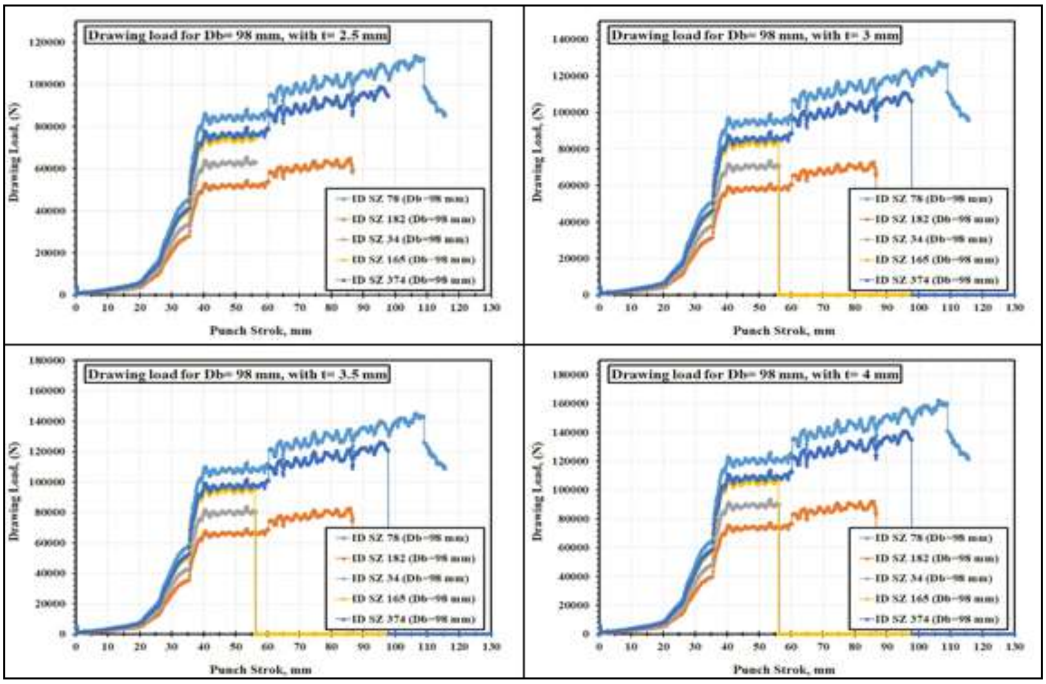

Figure 18 Drawing load for Db = 98 mm with t = 2.5, 3, 3.5 and 4 mm

In Figure 16, the forming load curve with the punch stroke for four samples at thicknesses of 2.5, 3, 3.5 and 4 mm. Each of the four curves has five curves for five different samples numbered as in Table 4. According to the sample number, the sample thickness, the diameter of the used punch, the speed, and the diameter of the blank differ. Figure 16 shows load curve of the blank diameter as 95 mm, while Figure 17 shows load curve of the blank diameter 98 mm, Figure 18 shows 101 mm and Figure 19 shows 104 mm. From this, it appears that the larger the sample diameter, the longer the punch stroke, the longer the formed cup length, and the higher the drawing ratio. Also, when using a punch with a larger diameter, the percentage of wall thinning increases. This is agreement with the reference [1, 18 and 24]. This appears in the horizontal axis of the figure, which expresses the punch stroke, which increases in samples with a larger diameter or with a larger wall thinning. Figures 20 and 21 express the use of wall thinning in samples with the same blank diameter, but with different punch diameters, to give a value of a thinning ratio of 20, 33, 42 and 50% of the value of the sample thickness before drawing. It is also clear from the figure that the higher the thinning ratio, the greater the drawing force and the longer the length. The punch stroke, i.e. the longer the wall cup produced, It is also clear that the set of curves numbers 16 to 19 has the same trend as the set of curves numbers 20 to 22. the same behaviour as curve in Figure (20) (21) (22), but with different thicknesses or different blank diameters. In cases of large diameter samples, the drawing ratio is high, the length of the cup is large, and the punch stroke strokes longer to complete the drawing process than in cases of smaller diameter samples.

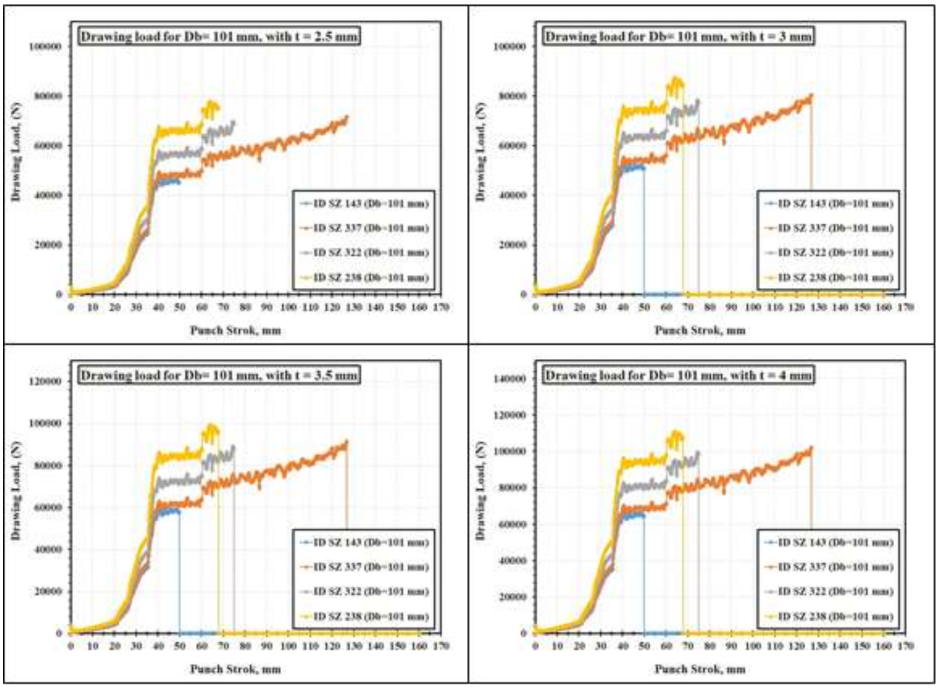

Figure 19 Drawing load for Db = 101 mm with t = 2.5, 3, 3.5 and 4 mm

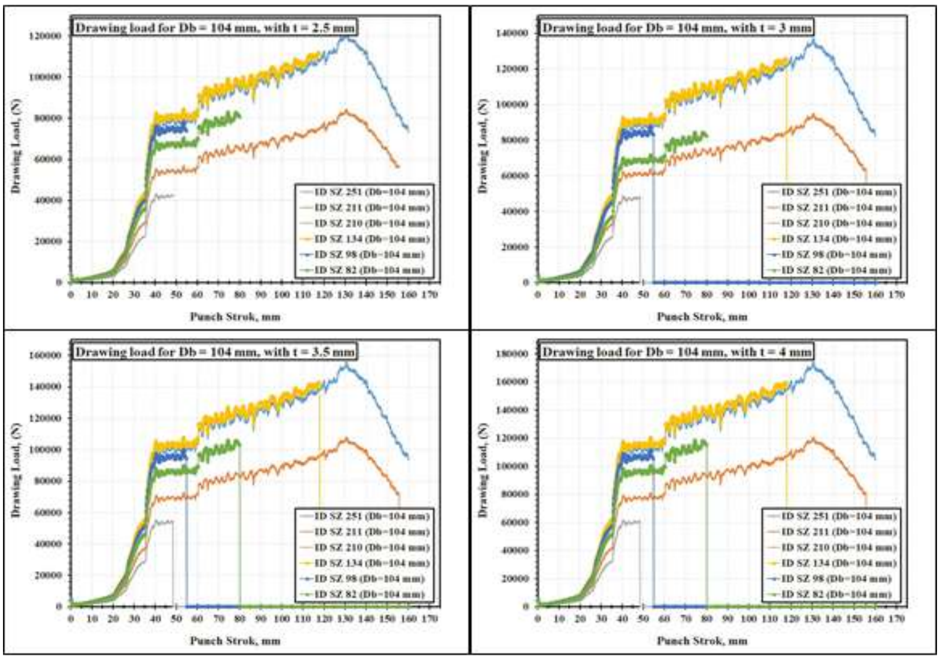

Figure 20 Drawing load for Db = 104 mm with t = 2.5, 3, 3.5 and 4 mm

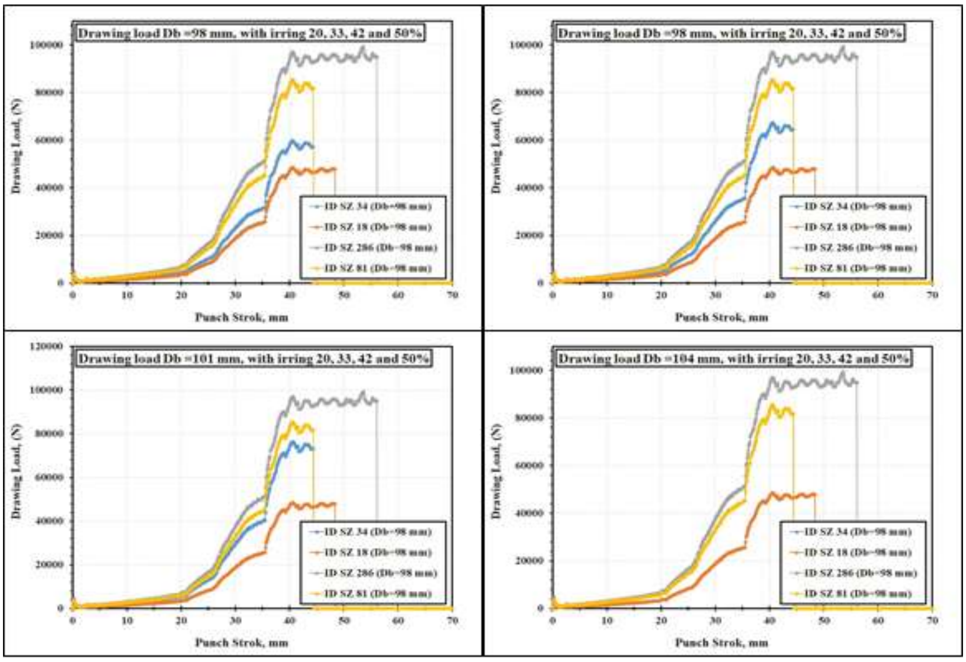

Figure 21 Drawing load for ironing = 20, 33, 42 and 50%

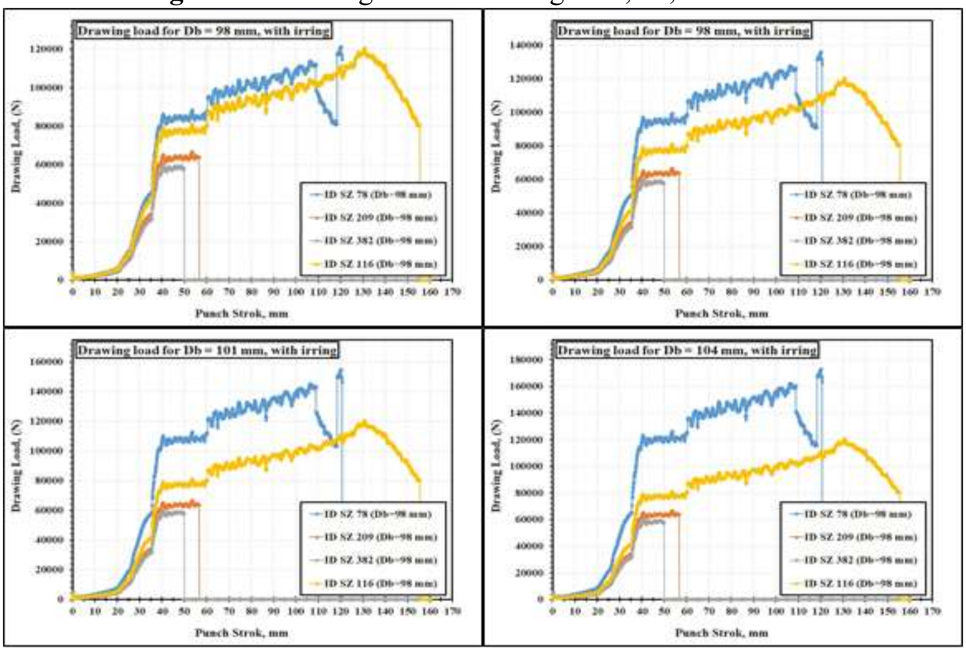

Figure 22 Drawing load for ironing at Db = 95, 98, 101 and 104 mm

4. Conclusions

In this current study, an investigation was conducted into the production of cups using an innovative method that combines the use of a blank holder as a punch and a blank holder simultaneously. The results were analyzed conceptually to arrive at some important conclusions. Some of the conclusions drawn from the discussion of the results are listed below:

- The innovative method was successful for producing cups using deep drawing processes with a conical die and a blank holder.
- achieving a drawing ratio of 2.24. Also,
- the results of the simulation model using ANSYS software are in agreement with the experimental results.

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