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Die Defects Analysis Using Taguchi Method

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ABSTRACT:

Deep drawing is one of the widely used sheet metal forming operations. Cup shaped objects, utensils, pressure vessels, gas cylinders, cans, shells, kitchen sinks are some of the products of deep drawing of good strength and light weight. There are many process parameters and other factors that affect quality of product, produced by deep drawing. Deep-drawing operations are performed to produce a light weight, high strength, low density, and corrosion resistible product. These requirements will increase tendency of wrinkling and other failure defects in the product. Parameters like as blank-holder pressure, punch radius, die radius, material properties, and coefficient of friction affect deep drawing process. So a great knowledge of process is required to produce product with minimum defects. This review paper has given the attention to gather recent development and research work in the area of deep drawing.

KERWORDS: deep drawing, defect, material properties, sheet metal, process parameter

INTRODUCTION:-

Deep drawing is a compression-tension forming process. In this process a flat sheet metal blank is formed into a cylindrical part by means of a punch that presses the blank into a die cavity with a small radial clearance, typically of 2mm [1]. Although the process is called deep drawing, meaning deep parts, the basic operation also produces parts that are shallow or have moderate depth. Deep drawing is one of the extensively used sheet metal forming processes in the industries to have mass production of cup shaped components in a very short time [2]. In deep drawing, a flat blank of sheet metal is shaped by the action of a punch forcing the metal into adie cavity. Deep drawing products in modern industries usually have a complicated shape, so these have to undergo several successive operations to obtain a final desired shape. It is used to manufacture complicated parts from sheet metal and in many industries such as automobile, aerospace, appliance and so on. One of the primary defects that occur in deep drawing operations is the wrinkling of sheet metal material, generally in the wall or flange of the part [3]. The flange of the blank undergoes radial drawing stress and tangential compressive stress during the stamping process, which sometimes results in wrinkles. Wrinkling is preventable if the deep drawing system and stamped part are designed properly. Wrinkling in the flange occurs due to compressive buckling in the circumferential direction tearing occurs because of high tensile stresses that cause thinning and failure of the metal in the cup wall. Other factors, such as die temperature and the metal alloy of the blank, can also affect the drawing process. A variation in any of these factors influences the potential for wrinkling or cracking in the deep-drawn part. The blank holder, as the name implies, holds the edges of the sheet metal blank in place against the top of the die while the punch forces the sheet metal into the die cavity-the sheet metal deforms into the proper shape, instead of simply being pulled into the die cavity. The blank holder, however, does not hold the edges of the blank rigidly in place. If this were the case, tearing could occur in the cup wall. The blank holder allows the blank to slide somewhat by providing frictional force between the blank holder and the blank itself. Blank holder force can be applied hydraulically with pressure feedback, by using an air or nitrogen cushion, or a numerically controlled hydraulic cushion. The greater the die cavity depth, the more blank material has to be pulled down into the die cavity and the greater the risk of wrinkling in the walls and flange of the part [4]. The maximum die cavity depth is a balance between the onset of wrinkling and the onset of fracture, neither of which is desirable. The radii degrees of the punch and die cavity edges control the flow of blank material into the die cavity. Wrinkling in the cup wall can occur if the radii of the punch and die cavity edges are too large. If the radii are too small, the blank is prone to tearing because of the high stresses. In this work tooling parameters die profile, punch profile are investigated and the wrinkling limit in deep drawing process is determined [5].

The material used in the present work was the commercially available AA 6061 aluminum alloy sheet shown in Figure 1.1. The thickness of the sheet was 3mm. The mechanical properties and the composition (wt%) of the AA 6061 are given in Table 1.1 and Table 1.2

Figure 1.1AA 6061 aluminium alloy sheet.

Table 1.1: Mechanical properties of AA 6061

Ultimate Tensile Strength (MPa)	125
Tensile Yield Strength (MPa)	57
Elongation (%)	15-20

Table 1.2: The composition (wt.%) of AA 6061.

Mg	Si	Mn	Zn	Cr	Mo	Ti	Cu	Fe	Al
0.80-1.20	0.40-0.80	0.15	0.25	0.04-0.35	0.012	0.15	0.15-0.40	0.7	Balance

Experiment:-The deep drawing was conducted using a double action hydraulic press with a maximum load capacity of 60 ton. The experimental setup is shown in Fig. 1.2. A schematic illustration of deep drawing process is shown in Fig. 1.3.

Fig. 1.2. Photograph of experimental setup.

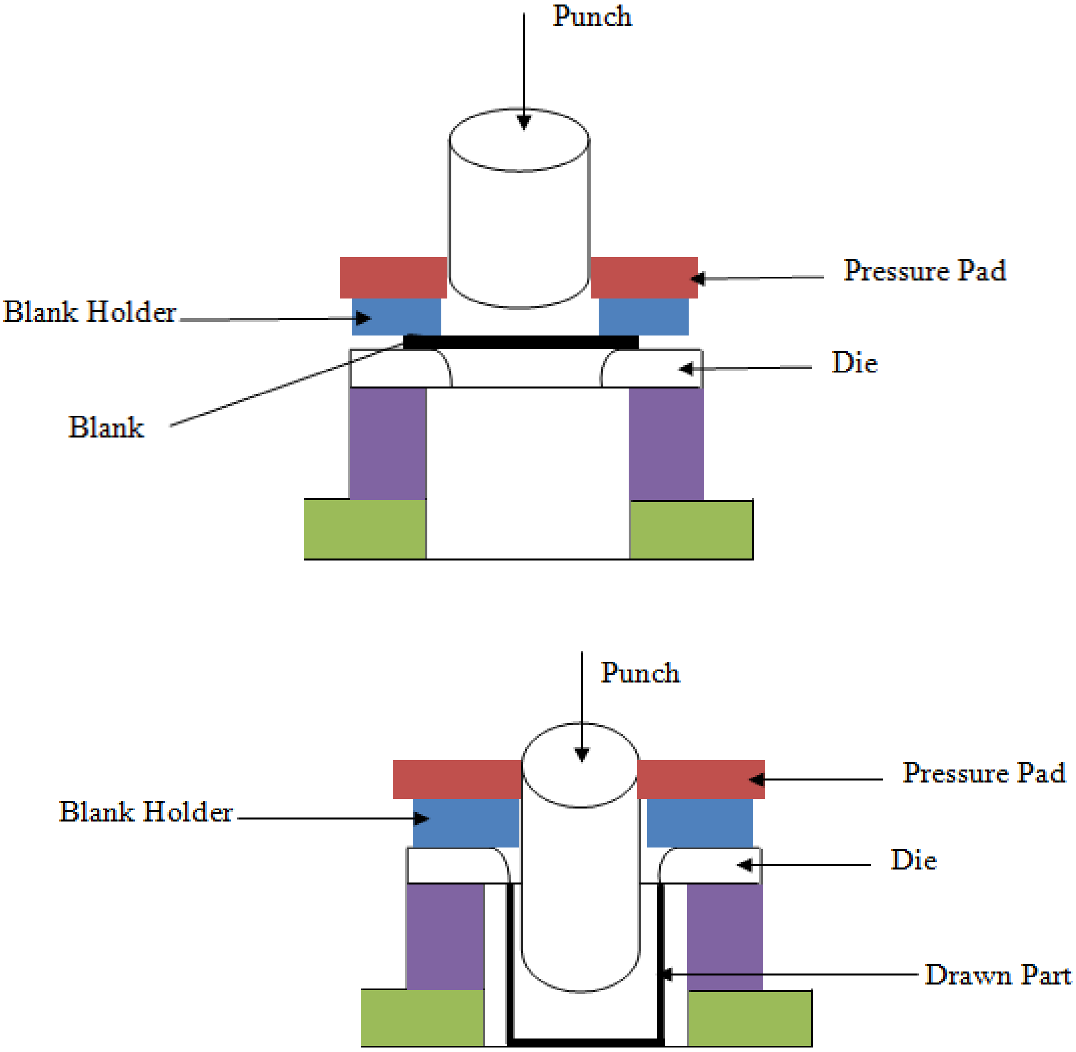

Fig. 1.3. Deep drawing process

There are many factors, both process and material parameters that influence the deep drawing process. Among all process parameters, blank temperature, die arc radius and punch velocity play an important role in the formability of aluminium material and hence the above parameters were considered in this study. The levels are selected based on the process window. Other process parameters such as die temperature (30°C), punch radius (30mm), coefficient of friction (0.25) were fixed. The blanks of 100 mm in diameter were cut from the sheet and cups were drawn according to the experimental design.

Taguchi technique is a powerful tool for design of high quality systems based on orthogonal array experiments that provide much-reduced variance for the experiments with an optimum setting of process control parameters. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance and computational cost. From a scientific viewpoint, these experiments are either one or a series of tests to either confirm a hypothesis or to understand a process in further detail. Experiments from a manufacturing point of view, however, are concerned with finding the optimum product and process, which is both cost effective and of a high quality. In order to achieve a meaningful end result, several experiments are usually carried out. The experimenter needs to know the factors involved, the range of these factors are varied between, the levels assigned to each factor as well as a method to calculate and quantify the response of each factor. This one factor at a time approach will provide the most favourable level for each factor but not the optimum combination of all the interacting factors involved. Thus, experimentation in this scenario can be considered as an iterative process. Although it will provide a result, such methods are not time or cost effective. But the design of experiments is a scientific approach to effectively plan and perform experiments, using statistics. In such designs, the combination of each factor at every level is studied to determine the combination that would yield the best result. The advantage of such design schemes is that it will always determine the effect of factors and possible interactions (between factors) on the result.

Taguchi design of experiment is a powerful analysis tool for modeling and analyzing the influence of control factors on performance output [6]. The most important stage in the design of experiment lies in the selection of the control factors. Therefore, initially a large number of factors are included so that non-significant variables can be identified at earliest opportunity. In the present work, the impact of four such parameters is studied using L_{16} orthogonal design. The operating conditions under which experiments are carried out are given in Table 1.3.

Table 1.3: Levels for various control factors for drawn part height and thickness analysis

Control factor	Level I	II	III	IV	Units
A: Die Radius	4	8	12	16	mm
B: Blank Temperature	225	300	375	450	°C

Two parameters viz., die radius, blank temperature, each at four levels, are considered in this study. In Table 1.4, each column represents a test parameter and a row gives a test condition which is nothing but combination of parameter levels. Five parameters each at three levels would require $3^4 = 81$ runs in a full factorial experiment whereas Taguchi's factorial experiment approach reduces it to 16 runs only offering a great advantage. The deep drawing tests for AA 6061 are conducted as per experimental design given in Table 1.4.

This method achieves the integration of design of experiments (DOE) with the parametric optimization of the process yielding the desired results. Taguchi's method uses a statistical measure of performance called signal-to-noise ratio (S/N), which is logarithmic function of desired output to serve as objective functions for optimization.

Table 1.4: Experimental design (L_{16} orthogonal array)

S. No.	Die Radius (A) (mm)	Blank Temperature (B) (^{o}C)
1.	4	225
2.	4	300
3.	4	375
4.	4	450
5.	8	225
6.	8	300
7.	8	375
8.	8	450
9.	12	225
10.	12	300
11.	12	375
12.	12	450
13.	16	225
14.	16	300
15.	16	375
16.	16	450

The S/N ratio considers both the mean and the variability into account. It is defined as the ratio of the mean (signal) to the standard deviation (noise). The ratio depends on the quality characteristics of the product/process to be optimized. The S/N ratio can be calculated as logarithmic transformation of the loss function as shown in Eq. (1.1). Smaller is the better characteristic:

$$\frac{S}{N} = -10\log\frac{1}{n}\left(\sum y^2\right) \qquad (1.1)$$

Where; n the number of experiments and y the observed data (drawn part height or thickness)

$$\overline{\frac{S}{N}} = \frac{1}{16}\sum_{i=1}^{16}\left(\frac{S}{N}\right)_i \quad (1.2)$$

The sum of squares (SS) due to variation about the overall mean is

$$SS = \sum_{i=1}^{16}\left(\left(\frac{S}{N}\right)_i - \overline{\frac{S}{N}}\right)^2 \quad (1.3)$$

For the ith process parameter, the sum of squares due to variation about the mean (SS_i) is

$$SS_i = \sum_{j=1}^{4}\left(\left(\frac{S}{N}\right)_{ij} - \overline{\frac{S}{N}}\right)^2 \quad (1.4)$$

The percentage contribution of individual process parameter on the deep-drawing process can be calculated by

$$(contribution, \%)_i = \frac{SS_i}{SS}\times 100$$

Result and discussion:-The deep drawing of AA 6061 was conducted using a double action hydraulic press with a maximum load capacity of 60 ton.Drawn part (as shown in Fig. 1.4a) were sectioned at the middle and measured for height and thickness as shown in Fig. 1b. Thethickness of the drawn part was measured at five points.

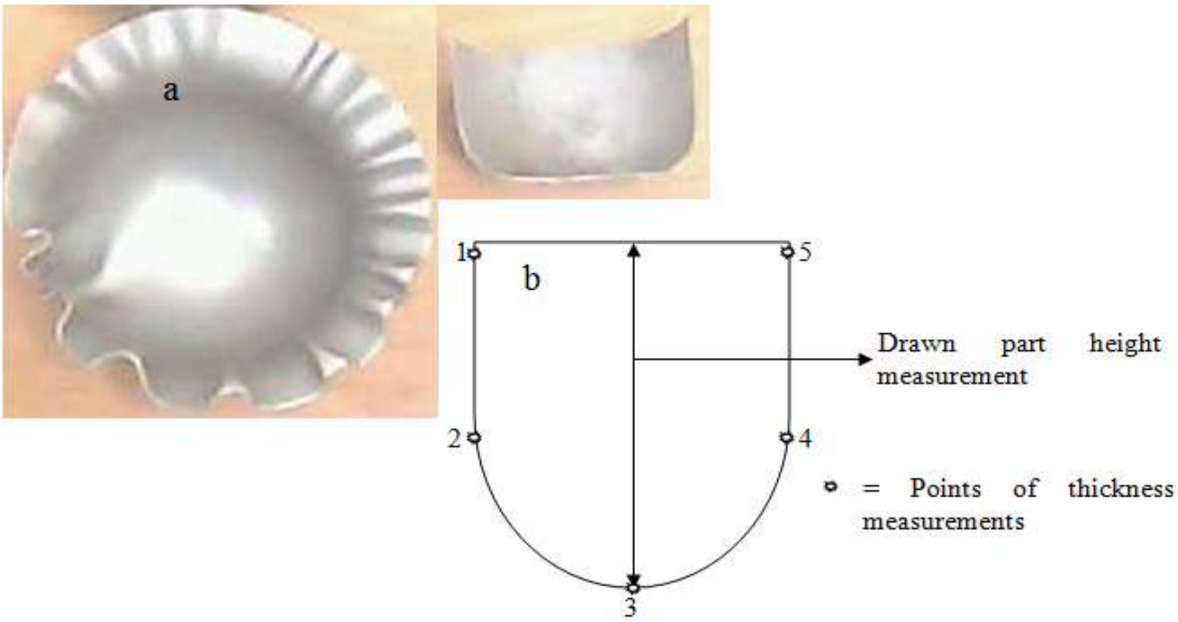

Fig. 1.4 a) Drawn part and b) Points of height and thickness measurements

INFLUENCE OF PROCESS PARAMETERS DRAWN PART HEIGHT:

The drawn parts were sectioned at the middle and the height was measured from bottom to top of the cup, as shown in Fig. 1b. The measured values for height against four experiments for each level are shown in Table 4.1 respectively. The $\frac{S}{N}$ is usedto measure the deviation in drawn part height and calculated by using Eq. 3.1. The overall mean $\overline{\frac{S}{N}}$ is calculated as per Eq. 1.2 and shown in Table 1.5

Table 1.5: ANOVA data table for drawn part height.

Parameter	**Level**	**Experiment No.**	**Height**	$\frac{S}{N}$	$\frac{S}{N_{ij}}$
Die Radius	4 mm	1	7.66	17.685	20.753
Level 1		2	9.86	19.878	
		3	11.54	21.244	
		4	16.23	24.206	
Level 2	8 mm	5	12.78	22.131	20.620
		6	10.35	20.299	
		7	7.55	17.559	
		8	13.32	22.490	
Level 3	12 mm	9	10.50	20.424	21.540
		10	11.45	21.176	
		11	12.67	22.056	
		12	13.34	22.503	
Level 4	16 mm	13	9.68	19.718	21.513
		14	8.90	18.988	
		15	14.58	23.275	
		16	15.98	24.072	
Blank Temperature	225 °C	1	7.66	17.685	19.989
		5	12.78	22.131	
Level 1		9	10.50	20.424	
		13	9.68	19.718	

Level 2	300 ^oC	2 6 10 14	9.86 10.35 11.45 8.90	19.878 20.299 21.176 18.988	20.085
Level 3	375 ^oC	3 7 11 15	11.54 7.55 12.67 14.58	21.244 17.559 22.056 23.275	21.033
Level 4	450 ^oC	4 8 12 16	16.23 13.32 13.34 15.98	24.206 22.490 22.503 24.072	23.318

The level average response analysis by $\frac{S}{N_{ij}}$ ratio is shown in Table 1.5 Fig.1.4 (a). Although the physical meaning of $\frac{S}{N_{ij}}$ ratio is not as straight forward as simple level average response analysis by values, it is more objective towards the target because the $\frac{S}{N_{ij}}$ ratio reflects both the average (mean) and the scatter (variance). For optimum values of the selected parameters, the level that gives the highest S/N ratio was chosen.

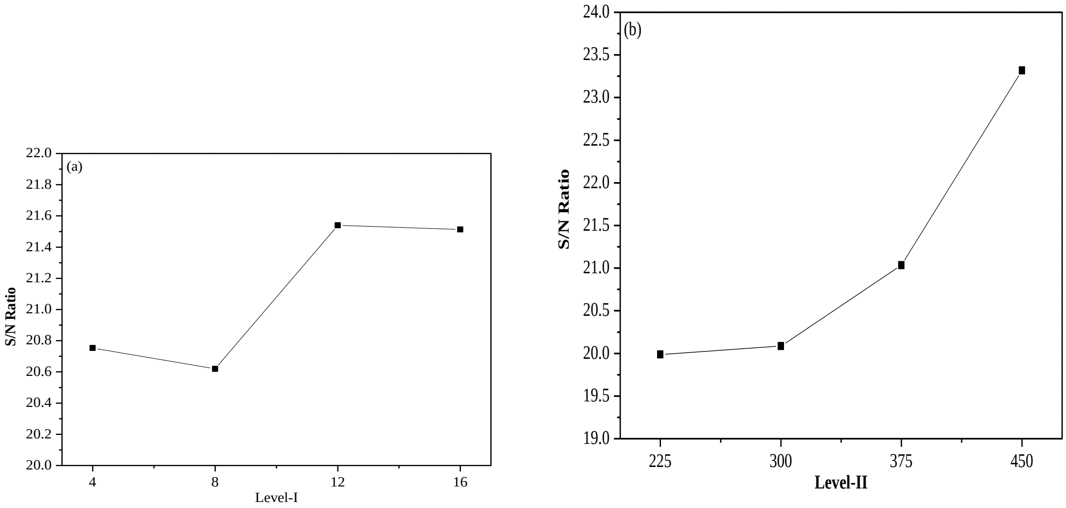

Fig. 1.6. Plots of overall mean ($\frac{S}{N_{ij}}$) of four parameters: (a) Die radius; (b) Blank temperature

CONCLUSION:

The two process parameters such as die radius, blank temperature, with four levels were used to optimize the formability (in terms of height and thickness) of AA 6061.By adopting these parameters the following conclusions are drawn in the present investigation.

1. For drawn part height the parameter settings are die radius of 12mm, blank temperature of 450^{o}C.
2. Blank temperature has greatest influence on the drawn part height with 49.20% and the die radius with 4.90%.
3. Die radius has greatest influence on the drawn part thickness with 51.73% the blank temperature with 9.88%.

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