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A Review on Deep Drawing of Rectangular Shaped Parts

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***Abstract* - Sheet metal forming is one of the most widely used manufacturing processes for the fabrication with a wide range of products in various industries. Cylindrical, rectangular and some complex shaped parts can be produced with the help of process. Various factors affect this process like die radius, punch nose radius, lubrication, blank size. Rectangular shaped parts are very critical in deep drawing process as stresses induced are not same in all directions. So, this paper is mainly focused on the work done by some researchers on rectangular type of parts.**

Index Terms* – *Sheet metal, Forming, Blank size, Rectangular shape

I. INTRODUCTION

Sheet metal is one of the most important semi-finished products used in the steel industry, and sheet metal forming technology is therefore an important engineering discipline within the area of mechanical engineering. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity, and considerable material saving [1].

The deep drawing is a process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. This process allows obtaining a complex shape part through a simple process, based on the plastic deformation of the metallic sheet. Sheet metal forming is a high productivity manufacturing process that is largely used in industries such as the automotive and the machinery components, to produce products made from metallic flat rolled sheet (blank).

This process involves three main tools, namely: Punch, Blank-holder and Die. It is schematically shown in Fig. 1

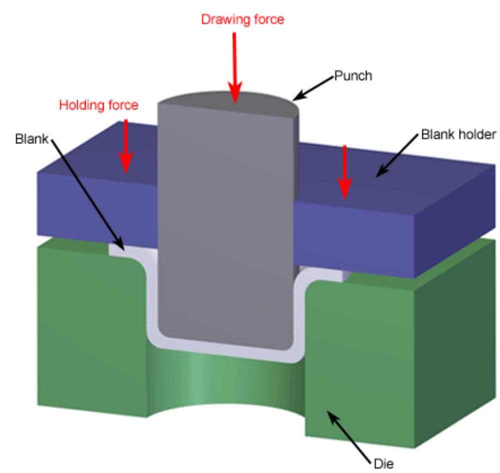

Fig. 1 Schematic of Deep Drawing Process

The die defines the shape of the product to be drawn. The punch is used to move the sheet into the die's cavity and deform the sheet to its final shape. The blank-holder presses the sheet against the die (typically using a constant force or gap), which prevents the wrinkling of the sheet and controls the sheet sliding during the drawing process.

A. Advantages of Deep Drawing process

- A wide variety of both ferrous and nonferrous materials can be used in deep drawing making it a very versatile manufacturing process.
- Deep draw transfer presses have a rapid press time and can produce large quantities of metal components in a short space of time.
- Less wastage of material.
- The deep drawing process is capable of high repeatability which ensures batch to batch consistency in the production of the deep drawn components.
- Cost efficient process.
- Grain orientation is possible.

B. Disadvantages of Deep Drawing process

- The process is not cost effective for smaller quantities.
- The press setup costs associated with deep drawing are very high and require considerable expertise.
- Defects like spring back, wrinkling, tearing may occur in the process.

C. Applications

Deep drawn parts are used in various industries. Mainly in automotive industries, household utensils, beverage cans, aircraft panels and many more. Such industries required parts with lighter weight, complex shape and with mass production availability. These properties can be fulfilled with deep drawing process.

By considering the various aspects of deep drawing process, this paper tries to cover the literature related to the process, particularly for square or rectangular shaped parts.

II. CONTROL OF CRITICAL PARAMETERS FOR SQUARE CUP DEEP DRAWING OF AISI 304 DDQ USING GENETIC ALGORITHM

Bernal-Aguilar et. Al [2] studied the deep drawing process for AISI 304 DDQ for square shaped cups with the help of Genetic Algorithm. They investigated most significant parameters in sheet metal forming with a view of optimizing these parameters. The genetic algorithm is used for the optimization purpose to minimize the force of the deep drawing process and to investigate the roles of other parameters as blank holder force.

A. Drawing load for rectangular pan

The required drawing load for work piece can be determined in two ways, from theoretical equations based on plasticity theory, or by using empirical equations. In scientific literature is possible to find many different equations for calculating the maximum drawing load (F_{dmax}) and Blank Holder Force (BHF) in cylindrical shapes drawing. There no exists a unique equation to calculate required drawing load for deep drawing, in wide ranging shapes, the generalized expression take the form (equation 1)

$$F_{dmax}= f (h, BHF, \mu, n, K, r) \ldots\ldots\ldots (1)$$

Where h represents the drawing height, BHF is the blank holder force, μ the friction coefficient, n the strain hardening exponent, K the material strength coefficient, and r the normal anisotropy coefficient.

They mainly focused on reducing the drawing load and for that they used Genetic Algorithm (GA) method. The GA search process is generally governed by the size of population, the number of generations, the probabilities of crossover and mutation, and probably the generation gap or proportion to be replaced with new solutions in the next generation. They observed that the intelligent control in deep drawing of sheet metal can be successfully used in the field of parameters optimization by reducing the load by 16.9%

III. DETERMINATION OF THE OPTIMUM BLANK SHAPE IN RECTANGULAR CUP DRAWING

Amra et al. [3] investigated the deep drawing process of rectangular cups with the help of simulation on Abaqus CAE. The blank sheet was discretized by quadrangle elements, representing the material with an elasto-plastic constitutive law. Model consisted of 3800 elements. For the material hardening determination the Krupkowski law was used.
Other material data were:
Young′s modules E=2.1×105 N/mm2;
Poisson′s ratio ν=0.3 and Density ρ=7800 kg/m3. A Coulomb friction law was used with a friction coefficient of 0.1.

They determined an optimum blank shape that did not cause earing. By determining the optimum blank shape, the loss of material due to trimming can be minimized. They concluded that the reduction of forming load and the increase of maximum forming limit are also possible. The optimal blank not only prevents the wastage of material or reduces product development period but also improves product quality and reduces occurrence of defects like wrinkling and tearing to some extent. Also they observed that the blank of octagon form more favorable than the rectangular. Drawing force of optimized initial form is 33% smaller than the initial material of a rectangle form, and 22% smaller than the initial material of octagon shape. Also, using the initial blank of rectangular form occur a thinning of material, which is on critical limit of given part.

IV. EXPERIMENTAL AND THEORETICAL STUDY OF SQUARE DEEP DRAWING

Younis and Jaber [4] have studied square deep drawing process experimentally and theoretically. They worked on effect of process parameters used in square deep drawing operation such as ; die and punch profile radius, blank size, blank shape, on produced cup wall thickness, strain distribution across the wall of the drawn part, punch force, earing shape and height of the drawn cup. The material used was Low carbon steel (AISI 1008) and the dimensions of part was 41.4X41.4 mm with 0.7 mm thickness. They performed the simulation on ANSYS 11 and the numerical results were compared with experimental work.

In this work, three types of blank shape (circular, square, and octagonal), with different sizes, four types of punch profile radii of 3, 5, 6, and 7mm and three types of die profile radii of 3, 5, 7mm were used to form a square cup. Accordingly they performed the simulation and experiments. They found various conclusions from these experiments.

1) Almost earing defect is concentrated at cup corners.
2) The position of ear which appears along the perimeter of the square cup is varied according to initial blank shape, planar anisotropy, and conditions which when effect on the flow rate of the metal.
3) The worst results are obtained from the square blank used; the best results are obtained from the circular blank, according to useful drawing height and earing.
4) The punch force increases with increasing blank size.

V. ANALYSIS OF THE ALLOWABLE DEEP DRAWING HEIGHT OF RECTANGULAR STEEL PARTS

Medellin-Castillo et. al [5] presented the paper which consists of a theoretical, numerical and experimental analysis of the allowable (maximum) deep drawing height (DDH) of rectangular cups made of steel. They proposed a new expression to calculate the allowable DDH of rectangular deep drawing, based on the equivalent diameter concept and the volume conservation principle.

For experimental purpose, they used the material steel AISI 1015. A constant blank holder force was considered in the simulation. For each part, the applied blank holder force was calculated using the expression used for cylindrical cups and considering the equivalent diameter concept. The numerical simulation of the deep drawing process was carried out using FEM by means of the LS-DYNA.

They concluded that new expression considers the blank, cup and punch dimensions and is based on the combination of the equivalent diameter concept and the volume conservation principle. A comparison analysis between the new expression and those reported in the literature has been conducted based on FEM simulations and experimental data obtained from industry. They found that lowest prediction error is obtained with the new proposed equation, and therefore it can be used to calculate, with superior accuracy, the allowable DDH of rectangular steel drawn parts. Thus, the new expression represents a reduction of the trial and errors methods commonly can be used at industry.

VI. PARAMETRIC FINITE ELEMENT ANALYSIS FOR A SQUARE CUP DEEP DRAWING PROCESS

Ayari and Bayraktar [6] dealt with FEA of the sheet metal forming process that involves various nonlinearities. They developed a parametric study that can lead mainly to predict accurately the final geometry of the sheet blank and the distribution of strains and stresses and also to control various forming defects, such as thinning as well as parameters affecting strongly the final form of the sheet after forming process.

They used Abaqus Explicit to carry out FE analysis. The material used was Mild Steel and the initial blank used was 150X150 mm with 0.78 mm thickness. The simulated punch velocity is kept constant and equal to 1.66 mm/sec while the considered minimum nodal distance is less than the blank thickness. They considered various parameters in simulation like punch radius, die radius, die aspect ratio, blank aspect ratio and blank thickness. On the basis of simulation results obtained they concluded that the increase in die radius leads to diminishing of the maximum thinning in general.

VII. CONCLUSION

From the literature survey it can be seen that the deep drawing process has been topic of interest for many researchers. There are standard procedures available for cylindrical shaped parts, but such is not the case for rectangular shaped parts. Various factors like punch radius, die radius, blank holding force etc. affect the process. Researchers studied these parameters and studied their effects on the process experimentally and with the help of simulation. The defects like wrinkling, tearing, earing and spring back can be considered as response parameters.

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