# Study of Various Parameters and Its Effects on Deep Drawing Process – A Review

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*Abstract*— Defects like cracks and wrinkling of deep drawing occur very often in conventional cylindrical deep drawing process because of the lower forming ability of aluminum alloy sheet at room temperature. This paper is highlighting recent research work and results in deep drawing. Different authors have used different approach for their result. With the help of this paper different parameters that are responsible for deep drawing and their effects are shown. After going through different authors, a need is developed for future usage of deep drawing process. In order to avoid the costly, tedious and difficult experiments instead of the experimental set-up, simulation is preferred. In this work, finite element simulation is shown to understand its potential. Thus, simulation process is shown. Using alloy steel at different die angles and their performance are shown. This review paper has given the attention to gather recent development and research work in the area of deep drawing. The result of simulation will be beneficial to the tool designer and the manufacturing industries doing work in this field.

***Key words:*** Blank shape, Punch force, Finite element method, simulation, Sheet metal forming, blank holding force

## I. Introduction

As we know there are a lot of uses of the finite element method, still the simulation of forming process provides great challenges to overcome because of the complex physical phenomena. Failure in sheet metal parts during deep drawing phenomena usually occur in the form of bulging, wrinkling, or necking. After viewing so many research papers it can be seen easily that there are many variables that affect the failure in deep drawing problems. These include material parameters, die design and process parameters like friction conditions, work element of die, the material anisotropy, design of die, height of die depth, the drawing ratio as well as the blank- holder force (BHF), and the effective control of these parameters can reduce the failure of the parts and can produce better end products. Generally, the blank holding force has to increase along with the increase along with the increase of the drawing depth, but we should take into our consideration the process fact that if its value is too large then it may lead to cracks and even a break of the material. The main geometric parameter, wrinkling like phenomena is punch diameter and punch radius. Increase of friction can reduce the defect related to wrinkling. On the other hand very high value of coefficient of friction can cause cracks and material breakage. Phenomena of instability which appears at the end of process of plastic deformation and which lead the modification of the shape of the deformed parts after the deformation forces have stopped. Therefore, the important behaviour of this kind is the process of elastic recovery. The forming processes of sheet metal are technically among the most important metal forming processes. Various end products obtained by sheet metal include a very large variety of different geometrical shapes and sizes, like simple bend to double curvatures even with the deep recesses and very complex shapes as well. Various common examples include aircraft panels, appliance bodies, kitchen utensils and beverages cans. Sheet metal processes are widely used in the manufacturing industries.

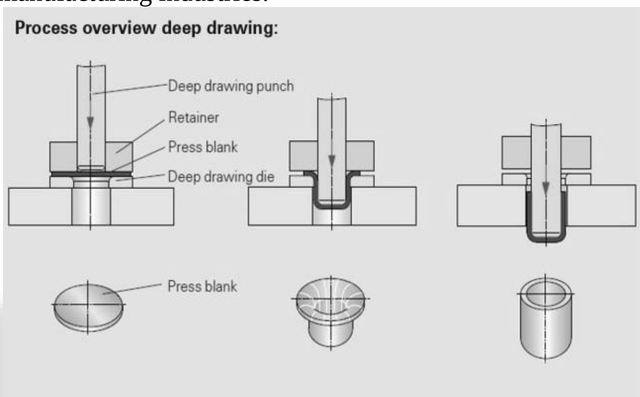


Fig. 1:

### A. Advantages of Deep Drawing

Deep drawing may be a viable solution for any manufacturing process that includes one or more of the following: Seamless parts: deep drawn metal parts are created from a single sheet of metal. Rapid cycle times: large quantities of products are easily manufactured through the deep draw process. Complex geometries: deep drawing delivers exceptional detail and accuracy. Reduced technical labor precision deep drawing can deliver similar results as technical labor in quicker time frames. The finite element method is a numerical technique which is commercially used for the finding approximate solution of partial differential equation as well as integral equation. In solving partial differential equations the first problem is to create an equation that approximate the equation which is to be studied. It means that during calculations the error should not accumulate, thereby causing the output meaningless.

### *B. How FEA does work?*

There is complex system of points used by FEA, called nodes which make a grid called a mesh. It is programmed to constitute the material and structural properties. These properties define behaviour of structure on loading conditions. Nodes are assigned at certain region throughout the material depending on the stress levels of a particular area. The areas having larger stress usually have a higher node density as compared to those which experiences little or no stress. Various points of interests may consist of fillets, corners, high stress areas, fracture point of earlier tested materials. The meshed part will be seen like a spider web in that from each node, and it extends to each adjacent nodes. The concept of finite element analysis is to simplify and solve the solution of complicated problem in relatively easy way. The finite element analysis is a powerful and useful tool for the numerical solution of a wide range of engineering problem. Applications range from deformations to stress analysis of automotive, aircraft, building, defense, missile, and bridge structures to the field of stability, fracture mechanics, dynamic analysis, heat flux, fluid flow, seepage, and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modeled with some other relative case.

Several alternate configurations can be tried out on a computer before the first prototype is built. The solution region in FE method is considered as built up of many small, interconnected sub regions called finite elements. The need is to predict the behavior of structure the designer takes three types of tool such as analytical, numerical and experimental methods. The method of finite element is very much popular because of its favorably usage of computers. The FE method gives the component behavior at desired accuracy for any complex structure and any irregular geometry. In finite element analysis (FEA) though exact equations are formed but approximate solutions are obtained, unlike to that of classical methods in which exact equations are formed and exact solutions are obtained. In this FEM solutions obtained are not limited too few standards only; here solutions can be obtained for all problems by finite element analysis. FEM can handle structures with anisotropic material properties also without any difficulty. FEM has also advantaged that if structure consists of more than one element, it is easy to use it without any difficulty. Also, the problems with material and geometric non-linearity are not to be handled by classical methods. There is no difficulty in FEM. FEM makes piecewise approximating function i.e., it ensures the continuity at node points as well as along the sides of the element. FEM can give the values at any point. However, the outcome occurs at points other than nodes by using interpolation formulae. FEM can consider the slopping boundaries exactly. If curved elements are used, even the curved boundaries can be handled exactly. Also, FEM have advantage to get good results by using fewer nodes as compared to FDM.

### *C. Field variables*

In engineering problems there are some basic unknowns. If they are found the behavior of the entire structure can be predicted. These unknowns are called field variables in FEA.

For example: -

- Displacements in structural mechanics, Temperature in heat flow processes,
- Velocities in fluid mechanics,
- Electric and Magnetic potentials in electrical engineering etc.

In a continuum, these unknowns are finite. The FE procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements. In FE procedure the unknown field variables are expressed in terms of assumed approximating functions within each element. The approximating functions are defined in terms of field variables of specified points called nodes or nodal points. This function which relates to the field variable at any point within the element to the field variables of nodal points is called shape function.

## II. Literature review

The applications of the finite element method to the numerical simulation of the deep-drawing process has evolved in efficient and significant way in the course of the last few years. Many of the problems associated with numerical simulation of this process have been solved or at least are better understood.

Reviewing the research papers of various authors available on simulation of drawing of cylindrical product. Relatively a few research works has been done for finite element simulation conical product. The conical shaped product made on hydraulic power press was extensively used in the engineering and day life.

Various related literature such as transactions, proceeding of various national and international conferences and other journals which were available are reviewed.

Existing Related Researches

1) Marek Hauptmann, the aim of his paper was to describe the capabilities of variable blank holder force trajectories for improve the distribution of wrinkles and the quality of 3 D structures. The results showed that the blank holder force should be adapted to the punch position keeping the highest possible force level. The force can increased during the drawing process and needs to be strongly reduced short before the blank is drawn out of the blank holder completely. The induced force trajectories lead to an optimized visual quality increasing the initial height where wrinkle occur encouraging fiber to fiber movement at the beginning of the process. The results further more contribute to a better understanding of the rupture behavior.
2) Sachin S Chaudhary, In this paper the effects of reverse deep drawing process parameters was determined by FEA study with the use of Design Experiment method and analysis of variance (ANOVA) using Minitab software for CRDQ steel in order to reduce the amount of spring back. Finally confirmation test showed optimized spring back effect. Improved spring back quality characteristics of weld joint obtained.
3) V Hari Shankar, according to this paper short run productions are the current scenario for batch productions are considered. He considered the metal forming process in this scenario, die and punch costs plays very important role in making the process costlier. Polymer composite material, Renshape 5166 dies made by rapid tooling techniques are shown to be good a good solution. FE simulations are carried out to predict the fatigue life of these dies during deep drawing process. The results of the simulation indication showed that dies can be used or softer material like aluminum for 1000 cycles, but when stronger materials are used like Cu or SS, the life is limited to around 100 cycles.
4) Martinez-Martinez, Transformation induced plasticity (TRIP) steels, which were made initially for automotive applications, have attracted a growing interest due to

the fact that they exhibit a combination of high strength and ductility through their multi-phase microstructure that includes ferrite, bainite and retained austenite. This one transforms to martensite under the external tensile stress. Electron Back Scatter Diffraction (EBSD) technique could be used successfully for determining the texture and fiber components in the body centered cubic (BCC) and face centered cubic (FCC) Phases and try to establish the role of deformation in the microstructure transformation. The main aim of the presented work was to evaluate the changes in the microstructure and texture of TRIP sheet steel by EBSD technique due to the multiaxial stresses taking place during stamping operations.

5) M. Huseyin Cetin, Temperature is the effective parameter which is used in the warm deep drawing (WDD) process to make it better for the formability of light-weight engineering tools, and this feature requires very accurate means of calibrations and observation of temperature for process stability. In this study, an evaluation of the WDD process was conducted according to the forming temperature curves characterized from work-piece temperatures otherwise of tool temperatures, as usual. The characteristic behavior of these curves was experimented under non-isothermal WDD of AA 5754-O. In the experimentation stage, the process parameters, namely FTC, blank holder force and punch velocity, which assure successful deep drawn ability, were determined according to the failure-free cups by analyzing the wrinkling and tearing conditions and minimum cup height parameter as output. As the next step optimum conditions were investigated by evaluating the volume of cup and its spring back parameters. As a general conclusion, approximately 330$^{o}$ C in the Flange-die radius region and 100$^{o}$ C in the cup wall-punch bottom region are the optimum temperatures for the warm deep drawing process.

6) Minsoo Kim, in his work, an additional 1$^{st}$ stamping tool with a 2-step stamping model was used to minimize stamping flaws in the curved parts of dimple, which is used in nuclear fuel spacer grids. Firstly, the strains are analyzed and compared with solution of strains for pure bending. A reference model (2D FE) is designed and corresponding strains were obtained. The solution obtained by FEA for 1$^{st}$ stamping was used in 2$^{nd}$ stamping. Strains are expressed as a function of process variable on the basis of these obtained solutions after applying RSM (Response Surface Method). This helped in evaluation of optimum variable values of a process. Finally, he confirmed the optimized formability of the proposed 2-step stamping model, by transferring the obtained optimized value to 3D FE model.

7) Jay N. Mistri, A blank holding force, punch force, material property of sheet metal, thickness of sheet, velocity of punch, these are all affecting parameters in deep drawing process to regulate wrinkling effect, tearing effect and fracture defect. Nowadays composite material is extensively used in manufacturing industries due to its better strength. Therefore with the help of experimental and simulation tools investigation of stress and strain distributions in the deep drawn cup were also done the finite element results can be predicted the sample of tearing and wrinkling error for bimetal cup as occurred in experimental tests.

8) Sachin Ramdas Jadhav, as we know that sheet metal forming problems is typical in nature since they involve geometry, boundary and material non-linearity. Drawings part involves many parameters like punch and die radius, clearance, lubrication, blank holding force and its trajectories etc. thus designing of tools for part drawing involves a lot of trial and error method. This paper was relevant in the context of developing a cost effective die with a lower lead time through the phase of design, development, trials and testing, pilot lot production & regular supply. The deep drawing process being critical for calculate offers higher scope for study and research while addressing the most effective design for the drawn die. Sheet metal die was an inseparable constituent of the development process of any given automotive or consumer appliance. In most of the cases, this accounts for a high proportion in the tooling needed of the large size and structural member in any automotive lie the chassis and the BIW.

9) R. Venkat Reddy, in this paper it was shown that how wrinkling and fracture defects can be prevented using blank holding force (BHF) which has to be optimized as lower BHF promotes wrinkle formation and higher BHF promotes fracturing. Hence the limits of wrinkling and fracture had to be established. Dependency of these limits is on tooling and process parameters. In his work the effect of tooling parameters like die corner radius and punch corner radius on wrinkling and fracture limits were investigated using a finite element explicit solver LS-DYNA. And for the analysis he used constant blank holding force.

10) Bharat Kumar A. Modi, in his work, he has designed an experimental set up. And deep drawing has been performed using aluminum sheets of ally AA5182 with the help of developed experimental set-up. Through finite element method an optimum blank shape has been found. A methodology is used in order to find blank force path for successful hydro forming of the cups. Better formability is achieved in terms of minimum corner radius. Dependency of process parameters peak pressure, blank holding force and pressure path is checked with numerical simulations and experimental work.. Taguchi method is used for the experiments. For the prediction of minimum thickness in the cup and corner radius regression models have been developed. Also it has shown that high peak pressure can be withstood by lubricated conditions with Teflon. To predict forming limits by modifying Stoughton's stress based criterion using Barlat's 3-parameter yield function some analytical procedure is developed.

### *A. Study of Parameters*

- Blank Holding Force: Higher BHF is always desirable to elimination of wrinkling phenomenon in deep drawn product, but always it is aimed to predict a minimum BHF.

- Punch Force: If axial pushing force is exerted on the side walls, this reduces radial tensile stress and the risk of rupturing reduces to a great extent.
- Friction: Friction is very important factor for deep drawing process. The presence of a good lubricating film between the contacting surfaces has lot of dependency in end product life.
- Blank Shape: If proper blank is selected for the deep drawing process then end products quality, various forming limits, distribution thickness can be improved to a great extent. It influences forming load and reduces wrinkling and tearing defects
- Stress and Strain distribution: Lots of differences have been observed in thickness distribution, in strain and stress in circumferential direction and radial direction also. Higher radial and circumferential strains have been observed on normal stress. For this strain hardening models should be taken into consideration.
- Thickness variation: Wall thickness is quite uniform except the area near the nose radius of punch with drawing ratios 3.0, 3.3 and 3.5 (according to Thiruvarudchelvan et. al. 1998). Drawing ratio is directly proportional to the thinning.
- Wrinkling: The most severe defect in the deep drawn product. It is nothing but the formation of waves on the surface to minimize the compression stresses. Two areas of wrinkling are flange and cup wall. Side wall wrinkling cannot be minimized by a single parameter. Many authors have suggested that different parameter in combination are needed to take care of this defect.

### B. *Study of Existing Types of Forming Techniques*

- Bulging: In this process from the surrounding geometry a portion of the part's diameter is forced to protrude.
- Coining: In this material is displaced to form specific shapes in a part. Typically coining should not exceed a depth of 30% of the material thickness.
- Stamping: This process is basically used for identification on a part, such as a part number or supplier identification. It is also known as marking.
- Threading: here threads are formed into a part. It is done using a wheel and arbor. In this way threaded parts can be produced within stamping press.
- Trimming: in this process excess metal that is necessary to draw a part is cut away from the finished part.

### C. *Selection of Material for Sheet Metal*

Most researchers have used different alloy steel materials for their study like alloy steel AISI 1008 for deep drawing purpose.

### D. *Simulation Process*

It is the imitation/ representation of the operation of any real world-world process or a system over time. It can be used to represent the eventual real effects of alternative conditions and course of action. It can be used for performance optimization, safety engineering, testing etc. One of the important issue related to simulation include valid source of information and relevant selection of key characteristics and behaviors.

## III. CONCLUSION

It can be concluded that increasing the slopes of die and blank holder up to an optimum amount, wrinkling can be minimized. Increased blank holding force, reduce friction, large radius at tool edge and reduce deep drawing depth could minimize wrinkling. It has been concluded that optimum blank shape reduces forming load, increases forming limits and reduces possibilities of wrinkling and tearing. This paper is highlighting recent research work and results in deep drawing. Blank holder force is one of the important process parameter that needed to be selected very carefully during deep drawing process. Blank holder force controls metal flow, it also affects thickness variation, strain path, stress path and wrinkling behavior. Strain path is well affected by blank holder pressure. By maintaining an optimum blank holder pressure, precise thickness variation in drawn cup and strain path can be maintained. Blank holding force and punch speed affects product quality and production rate. Blank holder force also controls wrinkling. Blank shape is an important parameter in deep drawing process as the quality of deep drawn product. Blank shape influences forming load, material requirement and possibility of defects.. Forming limits depends on various process parameters such as friction between blank and blank holder. Higher LDRs can be obtained with uniform strain hardening. FE analysis may be used as an efficient tool to determine upper and low forming limits that refer respectively to the initiation of rapture and wrinkling of the sheet metal. Friction is one of the most influential parameter in deep drawing process. Friction affects relative thickness distribution and surface quality in micro multi point forming process. The punch/die radii have the greatest effect on the thickness of the deformed material. If lubricating oil film of definite thickness is provided in deep drawing an expected surface finish could be obtained on final product. An effective lubrication can prevent direct contact of the surface asperity, which enhances the draw-ability of deep drawing. Drawability of metal sheet increases as coefficient of friction increases. Coefficient of friction increases with increasing test specimen strain, increases with increasing local contact pressure, decreases with increasing stretching speed, i.e. strain rate, and decreases with increasing pin radius. In deep drawing process strain path varies with variation in process parameters. To achieve successful deep drawn product, strains and strain path has to be controlled. Finally, a useful conclusion is obtained regarding the behavior of parameters responsible for deep drawing process. Various new materials are coming up nowadays and that too with lot of new properties. In future lot of composite materials will be used in order to improve the deep drawing operations. Lot of industrial parts will be made using this deep drawing material. The blank holding force has maximum effect on thinning strain. Due to blank holder force there will also be thickening of sheet metal at flange. Thickness variation at wall inclination and wall curvature has been very critical. The wall thickness does remain uniform for the area near the punch nose radius and the thinning increases as the draw ratio increases. Defects will be minimized. Many other fields will be using deep drawing process in order to manufacture their parts. This review paper has given the attention to gather recent development and research work in the area of deep drawing.

 

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