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Material Deformation and Wrinkling Failure in Deep Drawing Process by Finite Element Approach : A Review

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ABSTRACT

Deep drawing is one of the most important process for forming sheet metal parts .It is widely used for mass production of cup shapes in automobile, aerospace and packaging industries. In deep drawing metal sheet is subjected to high punch pressure which causes deformation of material, during deformation stresses are generated in various zones, which leads to various defects. The predominant failure modes in sheet metal parts are wrinkling and fracture. Existence of thickness variation in the formed part may cause stress concentration and may lead to acceleration of damage .Simulation and FEM analysis of the process by varying process parameters can interpret concentration of flowing stresses during deep drawing process in advance before actual production of parts, thus anticipation of defect free product can predicted before actually going for production.

Keywords:Deepdrawing,Wrinkling,Fracture,Simulation,FEM

1. Introduction

1.1 Deep Drawing Process: Sheet metal forming is one of the most widely used manufacturing processes for making wide range of products in many industries. It is due to the ease with which metal may be formed into useful shapes through plastic deformation processes in which the volume and mass of the metal are conserved. Deep drawing is a well-established sheet metal forming process where a deformable blank is hold between rigid die and binder, and punch is given motion to deform the blank into a hollow cup as shown in Fig.1.The sheet metal undergoes different stress state, mainly biaxial stresses at different section of the cup during this deformation. The stress states are mainly tensile in all the section except on the cup flange where the tangential stress is compressive in nature [5] as shown in Fig 1.

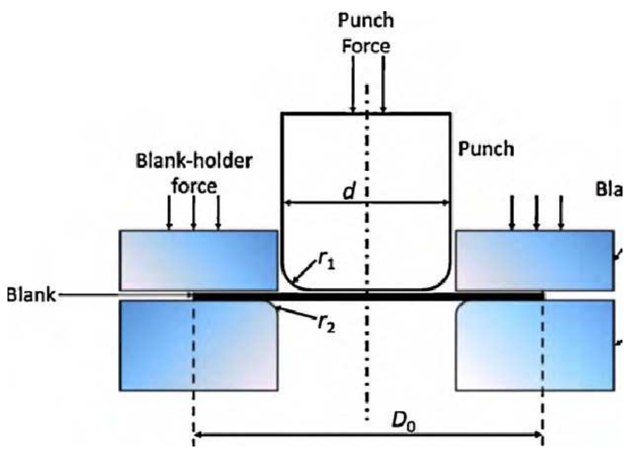

Fig.1 Schematic of deep drawing process showing stress state at different regions.

1.2 Stresses Occur During Deep DrawingProcesses:

During deep drawing process stresses induced are categorized in to various zones as shown in fig2.[19]

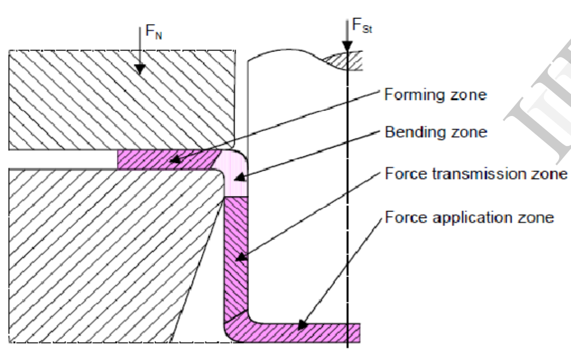

Fig2: Stress zones that occur during deep drawing.

During deep drawing, metal in various zones as prescribed earlier subjected to a plane radial drawing, and the three principal stresses radial stressσ_r , tangential stressσ_t, and the circumferential or hoop stressσ_θ .[5].

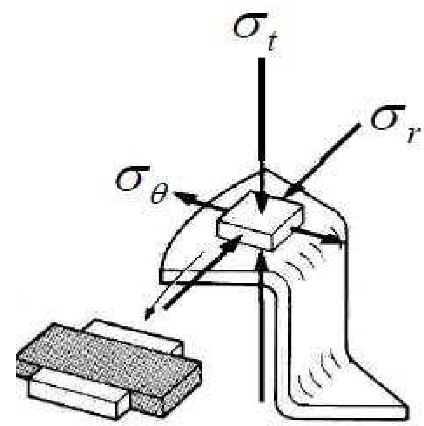

Fig 3: Stresses acting at the forming zone

The three principal stresses occur at the forming zone, the forming zone is also a friction zone. The part of the blank in the forming zone is subjected to a radial tensile stress and a tangential compressive stress. A minimum normal stress must be applied in other to prevent buckling of the sheet.[19]

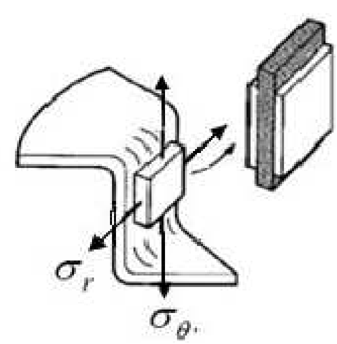

Fig4: Stresses acting on the force transmission zone.

As shown in the above figure it is seen that in the transmission zone, only the radial and hoop stress are active. The radial stress stretches the material around the die cavity, while the circumferential stress pulls the material into the die cavity.[19]

1.3 Defects In Deep Drawing:

Wrinkling and tearing are two major issues that induce irregularities in the formed part. Tearing is caused by excessive tensile stresses leading to fracture of the sheet while excessive compressive stresses during forming cause wrinkling. Wrinkling is a wavy condition obtained in the blank while drawing due to unbalanced compressive forces set up in the flange area. This can be achieved by using a blank holder force just above wrinkling threshold from the beginning of the deep-drawing process. The wrinkling phenomenon in draw die forming has been considered as a major obstacle in limiting the ability of the die maker to produce good parts. In spite of its practical importance in sheet metal forming applications, the wrinkling instability phenomenon has received very little attention in the industry. Much of the activity in the last two decades has been directed toward analyzing tensile instabilities in sheet metal forming processes. Less attention has been given to the compressive type of wrinkling instabilities encountered in automotive stamping operations.[17].

1.4 Finite Element Analysis

Finite element analysis is a simulation technique which evaluates the behavior of components, equipments and structures for various loading conditions. It is a computerized method for predicting how a real object will react to forces by mesh of simpler interlocking structures, the simpler structures or finite elements being agreeable to mathematical analysis.In the finite element analysis the structure is modeled by the assemblage of small pieces of structure, These pieces with simple geometry are called finite elements. The word "finite" distinguishes these pieces from infinitesimal elements used in calculus. In the finite element analysis (FEA), the variation of the field variable on the element is approximated by the simple functions, such as polynomials. The actual variation on the element is almost certainly more complicated, so FEA provides an approximate solution. The value of field variable and perhaps also its first derivatives are defined as unknowns at the nodes. Solving a structural problem by FEA involves following steps : Learning about the problem; Preparing mathematical models; Discretizing the model; Having the computer do calculations; Checking results (Generally an iteration is required over these steps.) Finite element simulations are often required to reduce the experimental cost and time by reducing number of trials in the product development cycle. Metal forming is one of such area where a lot of trials are required to arrive at the die design to produce defect free parts. There is a body of literature that demonstrates finite element method can be used as a powerful analytical tool in simulation of deep drawing processes. If the finite element method is used properly in regards to reliable input data as well as correct modeling technique and appropriate analysis approach, then the results can be reliable enough to predict the outcome of drawing processes and thus direct the design of tools[18]

3. Forming Limit Diagram (FLD)

A forming limit diagram, also known as a forming limit curve, is used in sheet metal forming for predicting forming behavior of sheet metal. The diagram attempts to provide a graphical description of material failure tests.In order to determine whether a given region has failed, a mechanical test is performed. The mechanical test is performed by placing a circular markon the work piece prior to deformation and then measuring the post-deformation ellipse that is generated from the action on this circle. By repeating the mechanical test to generate a range of stress states, the formability limit diagram can be generated as a line at which failure is onset. Sheet metal is marked with small circles ,stretched over a punch, and deformation is observed in failure areas. FLD shows boundary between safe and failure zones[1].

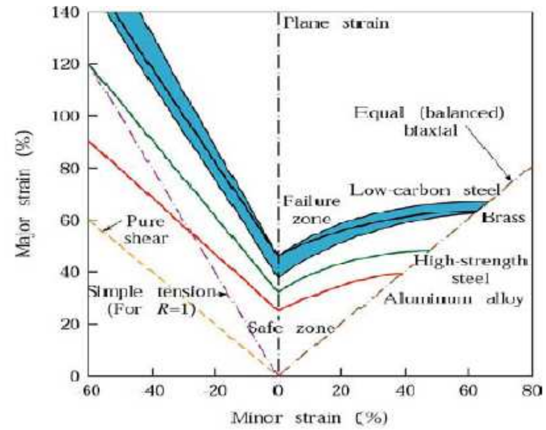

Fig.2 Forming-limit diagrams (FLD) for various sheet metals.

Literature Review

Literature review is an assignment of previous task done by some authors and collection of information or data from research papers published in journals to progress our task. It is a way through which we can find new ideas, concept. There are lot of literatures published before on the same task; some papers are taken into consideration from which idea of the project is taken.

P V R Reddy et al.[2] studied the effect of blank holding force, die corner radius and friction coefficient on the limit strain of aluminum(AA1100) in deep drawing process using a finite element method, forming limit diagram are plotted for various blank holding forces, die corner radius and friction coefficient and study conducted reveals that ,the limit strains can be obtained in simulation by taking the principal strains at ultimate tensile strength and even though the safer deformation zones decreases with the increase of blank holding force ,the limit strains are independent of blank holding force when the ratio of principal strains are low whereas it plays an important role in deep drawing for affecting wrinkling of flange of deep drawn part. It is also observed that with the increase of die corner radius, the limit strains increases. Whereas friction coefficient has no interaction with the blank holding force. **Sandeep Patil et al [8]** studied the effect of blank holding force and friction force on CRDQ steel sheet of 1 mm thickness and their effect on wrinkles and wall thickness distribution is analyzed by using HyperForm software ,their analysis reveals that as the blank holding force increases from 2 KN to 20KN no. of wrinkles form on flange reduced, experimentation is done by using various values and from that it is conclude that friction coefficient have great influencse on thickness distribution in deep drawing. **Abdulla Mohammad Gous Shaikh et al. [1]** simulated stamping tool used in production of girder used in truck assembly, the conclusion from the simulation result is as the blank is stretched over the tools. Since the blank, for the most part, only is in contact with the tooling on one side, no through-thickness compression is present. The flow stress in the sheet is generally much larger than the contact pressure, and thus, it is assumed that there is no through-thickness compression, which leads to problem like fracture in deep drawing process. **Mayavan. T et al.[15]** studied effect blank holding force ,punch force , punch speed on the formability of low carbon deep drawing steel sheet of 0.8 mm thickness and the formability of the sheet is indicated by Liming Drawing Ratio (LDR). It is the ratio of maximum blank diameter that can be formed into cup without the flange to the diameter of the punch. The blanks of progressively increasing diameters (Do) are drawn into cups using a punch of diameter dp. The maximum diameter of the blank (D0max) just before the first defect occurs is used to find the LDR value. This LDR value determines the deep drawability of the material Experimental Results shows that best forming characteristic were found at a punch stroke of 50 mm with LDR value of 2.2. similar experimentation is carried out by using finite element method which shows the validation of experimental result. **Hakim S. Sultan Aljibori et al.[14]** studied the finite element (elastic-plastic) analysis of sheet metal forming process using the finite element software. LUSAS simulation was carried out to gain accurate and critical understanding of sheet forming process. Simulation of elastic, plastic behavior of aluminum sheet was carried out under non-linear condition to investigate sheet metal forming process. An attempt base on computational experiments is made to explore the effect of process variables on stress distribution and punch load, **R. Padmanabhan et al.[17]** studied the effect of punch force ,blank holding force and friction conditions on thickness distribution of LPG bottles during deep drawing process. A constant blank holder force scheme induces larger deformations in the initial stages of deep drawing leading to an increased thinning at the bottom of the cup, whereas, the proposed variable blank holder force scheme and friction condition reduces the thinning of the deep drawn part. A low-constant blank holder force in the initial stage prevents necking failure between punch and die radius. The magnitude of the blank holder force at initial stages of deep drawing plays a vital role in the thickness distribution in the drawn part. When the punch force remains constant, an increasing blank holder force restrains the wrinkling tendency and enables a smooth flow of material into the die cavity. In addition, localized variation in contact friction condition at the die radius enhances the flow of material. The proposed variable blank holder force scheme and friction condition resulted in an increased minimum thickness in the deep drawn part .**E. Chu et al.[10]**studied the effect of strain hardening exponent and anisotropy coefficient on the formability of sheet. According to Chu it is apparent that the work hardening index has a much greater effect on the critical drawing stress causing wrinkling than the material anisotropy which has only a slight influence. Nonetheless, the critical drawing stress increases with both work hardening index and plastic anisotropy. Similarly, anisotropy has little or almost no effect on wave number, but it increases significantly with decreasing strain hardening. **Milos Tisza et.al [6]**studied the effect of strain hardening exponent 0n formability of steel and he conclude that formability is increased with increasing value of strain hardening exponent.

Conclusion

From the above review ,it is clear that in deep drawing process, finite element simulation analysis is better tool for investigating the effect of various parameter on stress distribution among various zone and to study various problems such as wrinkling and fracture that are common during deep drawing process can be predicted by simulating followed by analysis using a finite element method, otherwise it required tremendous practical experimentation which is costly affair and time consuming.

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