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Optimization of Blank Holding Pressure in Deep Drawing Process through FEA

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ABSTRACT: *Deep-drawing is a metal forming method, which is used to manufacture products from sheet metal. It is a very common method in the industry for the applications requiring sheet metal. So this operation is one of the important metal manufacturing processes in different industries. Today's automotive parts are required to be of light weight with high strength and this can be achieved by using available materials having high strength, low density, and corrosion resistibility. This has increased tendency of Wrinkling. Wrinkling is caused by stresses in the flange part of the blank during metal forming operations. It is required that the flange of a work-piece in deep drawing operation should deform in its plane without wrinkling otherwise the final product will be defective. . This paper investigates effect of blank holding pressure on wrinkling using FEM simulations. Results show that wrinkling is heavily influenced by blank holder pressure. An optimum value of parameters can be set to minimize wrinkling.*

Keywords*: Blank-holder Pressure, Deep Drawing, Flange Wrinkling, FEM.*

I. INTRODUCTION

Sheet metal forming problems are typical in nature since they involve geometry, boundary and material non-linearity. Cup drawings involves many parameters like punch and die radius, clearance, lubrication, blank holding force and its trajectories etc. Cylindrical cup formed by deep drawing is very readily used for the production of many round components, that the reason deep drawing is one the most important metal forming in many industries. Gyadari Ramesh et al [1] have investigated that one of the basic problems in deep drawing is wrinkling. Wrinkling can be avoided by using blank holding force. But higher the blank holding force (BHF), higher is the frictional force, so more will be tensile stresses in cup wall there by promote tearing failure at the punch corner. Hence BHF needs to optimized so as to prevent the wrinkling. Wrinkling, caused by compressive stresses. When the radial drawing stress exceeds a certain value compressive stress in the circumferential direction becomes too high, so plastic buckling occurs. H. Gharib et al. [2] suggested that Blank holder force (BHF) is an important parameter in the deep drawing process. It is used to suppress the formation of wrinkles that can appear in the flange of the drawn part. When increasing the BHF, stress normal to the thickness increases which restrains any formation of wrinkles. H. Gharib et al. [3] have determined optimized strategy for the linear blank holder force scheme for a certain cup model that minimizes the maximum punch force without causing wrinkling or tearing in the cup material. For this purpose in this work genetic algorithms (GAs) are used. Genetic algorithms are known to be able to search through all of the function space, thus it can detect the global minimum of the function. The results show that, optimization of the BHF scheme is attempted for two cup models. The first is used to compare the optimized BHF scheme with the constant BHF scheme, while the second is used to analyze the nature of the optimized BHF scheme. H. Gharib et al. [4] have developed an analytical model for the cup drawing process to solve for the induced stresses and strains over the deforming sheet at any stage of deformation until a full cup is formed. This model is used as the solution engine for the optimization of the blank holder force for such cups avoiding failure by wrinkling or tearing. The phenomenon of wrinkling (flange instability) is specific to the process of deep-drawing. Instability in the body of the piece, also called wrinkling of the walls. In deep drawing process the main goal is to obtain defect free end product. Wrinkling is an undesired deformation, so it must be prevented. There are two main methods used in order to prevent wrinkling. The first one is using blank-holder. Second way of prevention of wrinkling is using drawbeads. Blank holder is a tool used for preventing the edge of a sheet metal part from wrinkling. A part wrinkled during the deep drawing process, will not be accepted and most likely become a scrap, a total waste of both money and time. Because of these reasons, wrinkling must be prevented. There are two main methods used in order to prevent wrinkling. The main objective of this study is to investigate the effects of Blank-holder pressure (BHP) and suggest a optimize value for wrinkle free product.

II. RESEARCH METHODOLOGY

In this study, a two-dimensional axisymmetric elasto- plastic Finite Element (F.E.) Model for deep drawing of Mild Steel IS 2062 Grade B sheet has been developed to study the behavior of material under different blank-holder pressure (B.H.P.) for obtaining a good drawing product. The methodology adopted in this study consists of a number of steps and sub steps. Starting from the creation of a 2-D Axisymmetric model and then defining input parameters such as material properties, parameters. The mechanical boundary conditions were then imposed on the model and the solution was done by meshing of the model by using PLANE42 element type. The FE model was made using ANSYS software.

The important stages in developing the FE model were:

● Determination of the appropriate model geometry
● Generation of a FE mesh
●Application of boundary conditions and loading
●Determination of material properties
●Choice of the appropriate solution method

An axisymmetric model combines the computational savings of the two-dimensional model with a more complete model representation afforded by a three-dimensional model. Since the geometry and loading conditions of the physical system could be reasonably approximated by an axisymmetric model, the computational expense of a full three-dimensional model was avoided. In the present model of Inner diameter of punch as 250mm, outer diameter of punch as 450mm, inner diameter of die as 250mm, outer diameter of die as 850mm, inner diameter of blank as 250mm, outer diameter of blank 850mm, thickness as 3mm are taken. During deep drawing process, a loose BHP will lead to wrinkling; and on the other hand, an excessive BHP will result in fracture. Therefore, the blank holder pressure has to be properly determined and controlled. Punch pressure evolution law can be represented from the curve of punch force versus displacement, and it can provide a guide for selecting proper press machine. The initial value of both punch pressure and blank holder pressure are taken as 24.516625 MPa and 2.4516625 MPa respectively. The blank was modeled as a flat round disk. The thickness and diameter were input geometric parameters used to generate the FE mesh. The element used to model the blank was Element type PLANE42, a quard-free, axisymmetric element. This element was chosen because it supported elastic-plastic behavior, high deformation and large displacements. Mesh was generated with a uniform element mesh size . A mesh refinement study was conducted to determine the optimal mesh. The circular plate is assumed to behave as an elasto-plastic material with a Young's Modulus of 210000 MPa and a Poisson's ratio of 0.30.The values of the plastic strains & the corresponding yield stresses were taken from the stress- strain curve obtained from the research paper of Schuler [5].The density of the Mild Steel is taken as 7850 Kg/m^3.

In this work, the blank-holder, die and punch contact surfaces are modeled as rigid bodies. The Mild steel blank is modeled as a deformable body. The ANSYS contact wizard requires a number of steps at each increment of the analysis. The surface-to-surface contact element type was used which determined the blank (work piece) and the rigid surface (punch, die and blank-holder).Simulation results are critically examined in terms of von Mises stress, equivalent plastic strain.

A body that is subjected to a system of loads in three directions, a complex three dimensional system of stresses is developed. That is, at any point within the body there are stresses acting in three different directions and the direction and magnitude of the stresses changes from point to point. The Von Mises criterion combines these three stresses into an equivalent one, which is then compared with the yield stress of the material. The present study aims to predict optimum value of BHP to produce wrinkle free product, von-Mises stresses and equivalent plastic strain are the criterion to get optimize value of BHP. The result validation of the present study (at 21,0000 MPa Young modulus) is done by research paper of GAO En Zhi.

III. RESULTS

Following graphs show von-Mises stress and equivalent plastic strain at different BHP. A small change of blank-holder pressure will result in a different wrinkle pattern. When the BHP is very low than the wrinkling produces; and if the BHP is increased than cracks are developed.

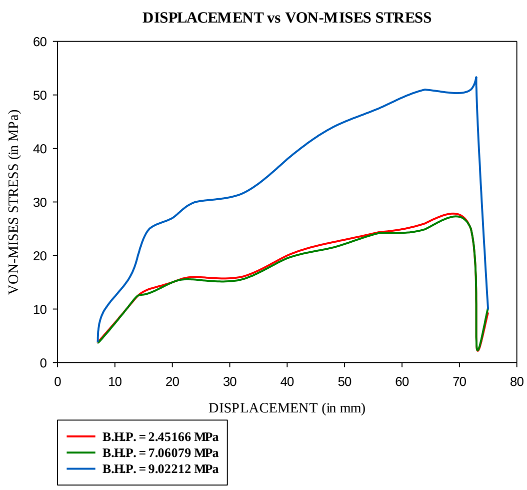

Fig.1: variation of minimum von-mises stress at different b.h.p.

Above graph give detail about variation of minimum Von-Mises stress with respect to increase of displacement atvariation of blank-holder pressure. The Von-Mises stress increases and suddenly decreases with increasing the value of displacement. For three case von-mises stresses the pattern is approximately same.

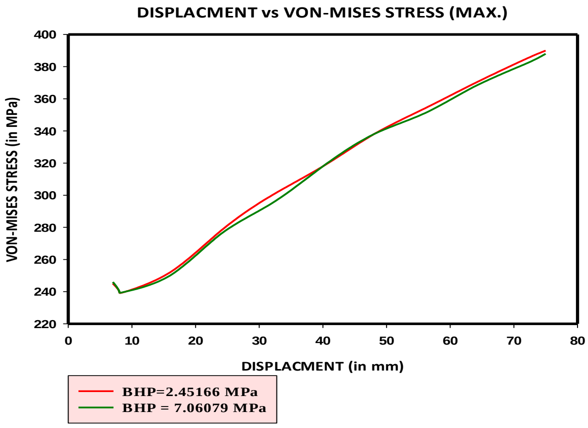

Fig. 2: variation of maximum von-mises stress at different b.h.p.

Above graph give detail about variation of Von-Mises stress with respect to displacement at different blank-holder pressure. The von-Mises stress increases with increasing the value of displacement. Von - Mises stress pattern for the both casesis approximately same. At optimized pressure 7.06079 MPa Von-Mises stress decreased compared to 2.45166 MPa.

The graph below give detail about variation of 3rd Principal stress with respect to displacement at various blank-holder pressures. 3rd Principal stress pattern for all cases is approximately same. In three pressure cases 3rd Principal stress increases with increase in displacement value.

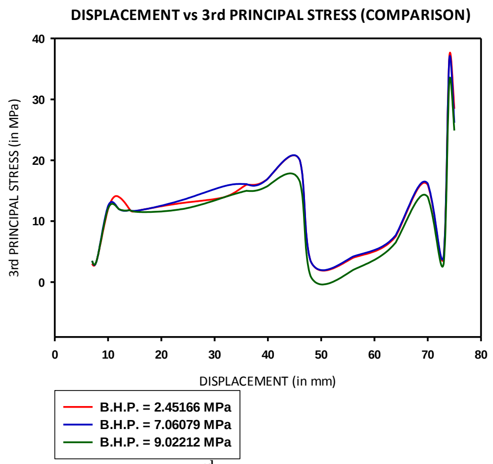

Fig3: variation of max. 3rd principal stress at different b.h.p.

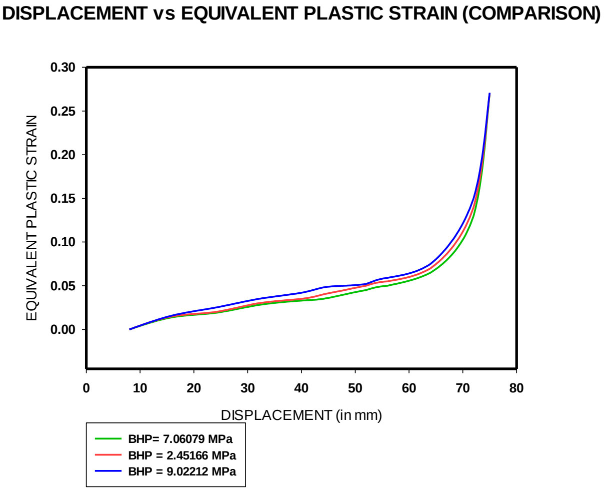

Fig 4: variation of maximum plastic strain at different bhp.

Above graph give detail about variation of equivalent plastic strain with respect to displacement at different blank-older pressure. The strain increases with increasing the value of displacement. Equivalent plastic strain pattern for the three cases is approximately same. At optimized pressure 7.06079 MPa strain decrease compared to 2.45166 MPa.

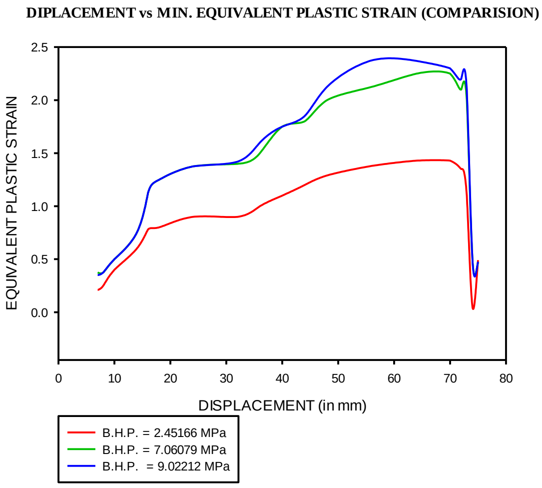

Fig 5: variation of minimum plastic strain at different bhp.

Above graph give detail about variation of minimum Equivalent plastic strain with respect to increase of punch displacement at variation of blank-holder pressure. The strain increases and suddenly decreases with increasing the value of displacement. For three cases equivalent plastic strain the pattern is approximately same.

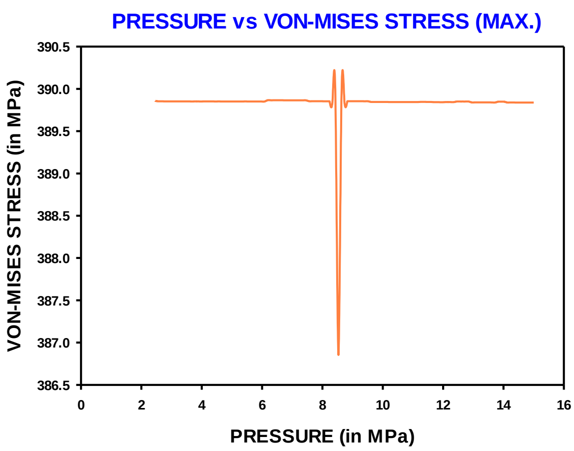

Fig 6: variation of von- mises stresses at different pressure.

Above graph give detail about variation of von-Mises stress with respect to increase of pressure. It is shown in the fig that the von-Mises stress are minimum at a pressure of 7.06079 N/mm^2.

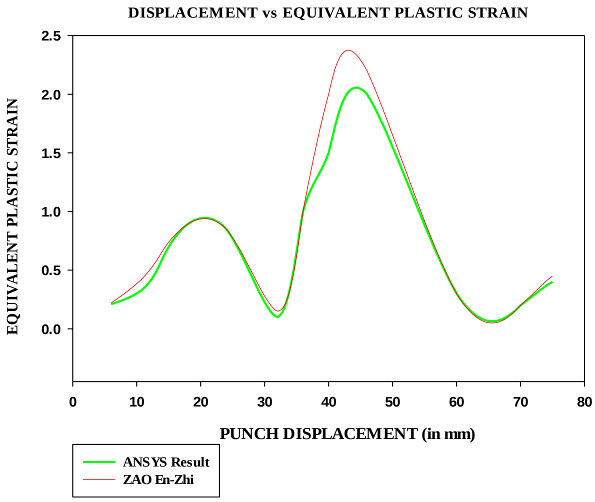

Fig 7: validation of result.

The result of the present study (at 21,0000 MPa Young modulus) is varified by research paper of GAO En Zhi [6], that finds the maximum value of equivalent plastic strain value with respect to punch displacement. In this study, equivalent plastic strain curve follow the same pattern. And this pattern gives the validation of present study.

IV. CONCLUSIONS

All tooling was modelled as a rigid surface uses 2-dimensional curves. The work piece was modelled as a deformable body using quadrilateral axisymmetric element type PLANE 42.The work piece was modelled as an isotropic material using an isotropic hardening rule, and assumed to obey the elastic-plastic flow rule. IS 2062 Grade B Mild steel circular sheet are used.

In case of von-Mises stress, at B.H.P. 2.45166 N/mm^2, a noticeable wrinkle pattern was attained, and a maximum stress level of σ_{max} = 389.895 MPa was obtained, for a minimum value of σ_{min} = 9.323 MPa. By increasing the B.H.P. 7.06079 N/mm^2, The maximum stress now achieved was around σ_{max} = 389.865 MPa while the minimum value being equal to σ_{min} = 10.285 MPa.At B.H.P. 15.5926 N/mm^2, the maximum stress now achieved around σ_{max} = 389.865 MPa while the minimum value being equal to σ_{min} = 10.285 MPa.

In case of Equivalent plastic strain, At B.H.P. 2.45166 N/mm^2 the maximum strain achieved around 0.270227 while the minimum value being equal to 4.91E-05. And at B.H.P. 7.06079 N/mm^2, the maximum strain around 0.2701 while the minimum value equal to 4.98E-05.

Present Study suggests a optimize value of BHP as 7.06079 N/mm^2 for wrinkle free product.

The result of the present study (at 21,0000 MPa Young modulus) is varified by research paper of GAO En Zhi (2009).

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