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Modelling, Simulation and Optimization of deep-drawn Cup-Cone Assembly

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ABSTRACT

In present innovative and fast developing industries, it is necessary to deliver best product with high quality, good productivity and optimum cost. All sheet metal forming processes result in permanent plastic deformation changing material properties and hence it is necessary to find the limit to which a material can further be deformed for further forming operations. Traditionally, experimental trial and error methods are used which include adjustment of settings (geometry, loadings, tool direction) accordingly. However, this method is time consuming and is dependent on the experience of the tool designer. To overcome these shortcomings, sheet metal forming simulations have been used instead. This paper highlights development of 'draw' component and the changes made in product design due to manufacturing and assembly reasons considering the design intent; and also the advantages of using Simulation software for deep draw process. Deep drawing process was independently modelled using CATIAV5 and simulated using HYPERFORM. The workpiece material used was steel alloy. For whole simulation process, the punch and die were considered to be rigid bodies made from alloy steel. Deep Draw Simulation was carried out. The critical areas on the workpiece were identified and then optimized as per design conditions. The results obtained using simulations were in good agreement with the experimental results. Thus results help to reduce cost and manpower required during proto phase as all modifications were carried during design and development phase.

Keywords—**Deep Draw, formability, simulation, sheet metal, optimization.**

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I. INTRODUCTION

Sheet metal forming is mostly used manufacturing method in industry that is used to change the geometry of sheet metal of typically about 1.5-2 mm thickness without loss of material. The purpose of sheetmetal forming processes is basically to produce a required shape by plastic deformation. The final part quality is dependent on both the sheet material property and process variables. These variables are dependent on the tool and die design, blank geometry, properties of the lubricant used (such as 13 coefficient of friction and heat capacity) and drawing speed. A deviation in product shape can result due to incorrect combinations of these process parameters. A change in shape is usually caused by elastic spring back of the part after forming and retracting the tool.

It is therefore important to have a good knowledge of the influence of all variables on sheet metal forming process in general and on the deep drawing process in this work, if a proper tool design is to be achieved. Design approach with simulation have been used for forming processes. Using similar approach, a full process modelling and simulation was undertaken in the present work. While FEA serves well for die design and optimisation, it faces unique challenge for process design and optimization for each particular product. Suggestions have been made that at the product development stage, it is possible to model and analyse the whole production process before physical prototyping. With FEA all possible flaws in the production line can be identified and corrected at the design stage. It is necessary to determine the stress/strain state of the sheet metal at every forming stage for easy assessment of formability or work hardening of the material.

The main objective of this research was to accurately simulate and optimize the deep drawing process of sheet metal, specifically. This was expected to enable tool designers to numerically evaluate the sheet metal forming tool and process design and to then enable redesign where necessary in order to meet the requirements of producing desired shapes using deep draw processes.

Deep Draw Process

Deep drawn products in modern industries usually have complicated shapes that require several successive operations to be achieved. The first process that a sheet metal undergoes is usually blanking, the shaping of the sheet metal to optimal size which is followed by the deep drawing process, after which trimming of the resulting flange is done in order to remove the extra material from it to ensure uniformity of the flange shape on all sides of the final product. This extra material is often wavy or uneven formed along the edge of the flange or end of the wall of the cup. This is result of uneven metal flow from different directions, which is due to the presence of planar anisotropy in the sheet. Die design for a full deep drawing production line becomes a challenge if a lengthy and expensive prototype testing and experimentation is used in arriving at a final competitive product.

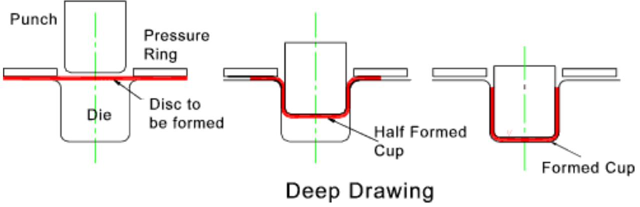


Fig. 1 Deep Drawing

II. PROBLEM STATEMENT

Development of form component is very costly process and it will take lot of time if we work traditionally. For this we can use latest technology such as simulation and analysis during the design phase.This helps to solve errors in forming by easily pointing out through analysis results which will save our work, time and cost. Based on the analysis report tool designer can suggest revisions/ changes in the product design which will help tool designer to design a tool which produce defect free components depending on the given inputs. Without this technique the die design and the processing could be costly and complicated project. As shown in Figure 2, draw Component may face challenges such as, Wrinkling, Tearing, Thinning, Spring-back. The challenge is to capture these defects in initial stages and rectify them before the actual tryouts in order to produce cost effective component.

Fig. 2Defects in forming

III. LITERATURE REVIEW

Literature review is sorted on the basis of the parameters and functions which control forming process. The important parameters and functions are:

a. Blank holder force
b. Punch velocity and punch force
c. Forming Limits
d. Blank shape
e. Stress and Strain Distribution
f. Thickness variation
g. Wrinkling

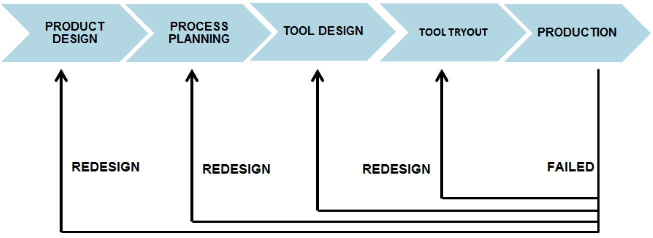


Fig.3 TraditionalProcess

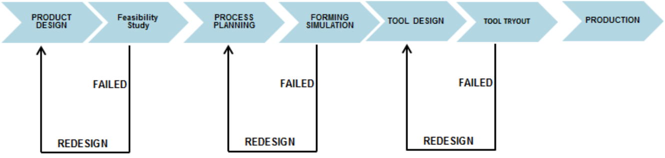


Fig. 4 Conventional Process

The traditional process and effective conventional process can be shown asin the fig3 and fig4 respectively.It can be seen that in traditional process there is no detection of error or defects till the actual product is produced. The process continues from Product Design—Process planning—Tool Design—Tool Tryout—Production. But till that time high cost and manpower is utilised which is wasted if the component fails due to any possible reason.If failure occurs the Redesign of process has to be done and each stage is verified to check the errors occurred. The recovery of costand time is impossible at this stage and one may have to bear heavy loss.

Conventional process is used in order to overcome the ineffectiveness of the traditional process. It includes stages Product Design—Feasibility Study—Processplanning—Forming Simulation—Tool Design—Tool Tryout—Mass Production. At each stage one loop of study is included to check and rectify the errors. This help to reduce the propagation of error in further stages. This method proved helpful in producing cost effective component.

IV. ASSEMBLY MODELLING

A 3-D model was createdusing modelling software CATIA V5 as shown in Fig5. The actual part will be the part of car exhaust system. It is close shaped like tube. Hence it was initially cut in two parts.

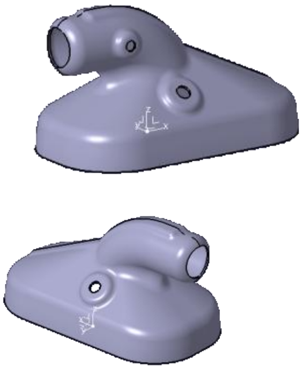


Fig. 5.Actual Part in CATIA

The two sides were to be drawn from single blank.3D was created keeping this concept in mind as shown in Fig 6.

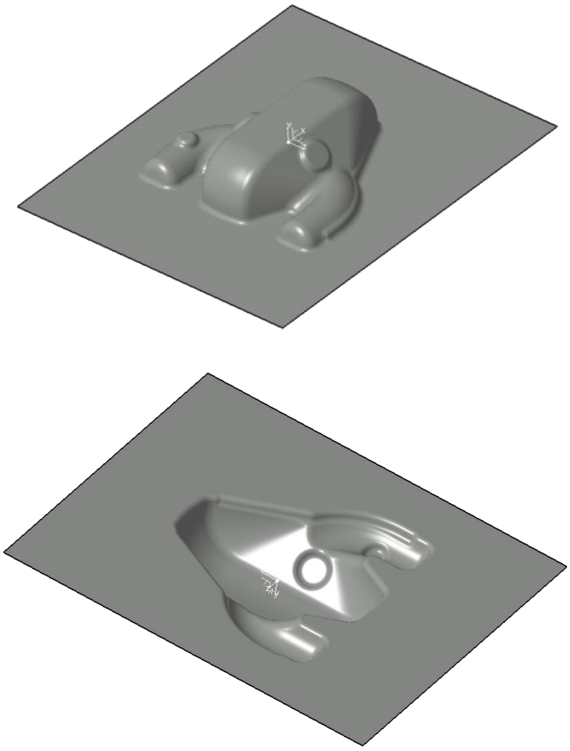


Fig.6. Blank Concept in CATIA

The model shown is a virtual concept of the sheet metal blank after forming process.

V. MATERIAL PROPERTIES

The Material Properties which are Important with respect to the Forming Simulation are displayed below.

Table 1: Properties of the Material of the Wheel

Properties	Sample 1	Sample 2
Thickness(mm)	1.5	2.0
Ultimate load (KN)	15.3	22.77
Yield Stress(N/mm2)	284.42	354.15
Tensile Ultimate Strength(N/mm2)	464.67	555.37
% elongation	29.12	27.5

VI.MESHING PROCESS

Deep drawing process is characterized by a large number of processparameters and their interdependence. These are material properties, machineparameters such as tool and die geometry, workpiece geometry and working conditions. The drawing force can be determined by the empirical formula [Sharma,2003]

$F = Ax * Ys * \{(D/d) - C\}$ …………Equation

Where,

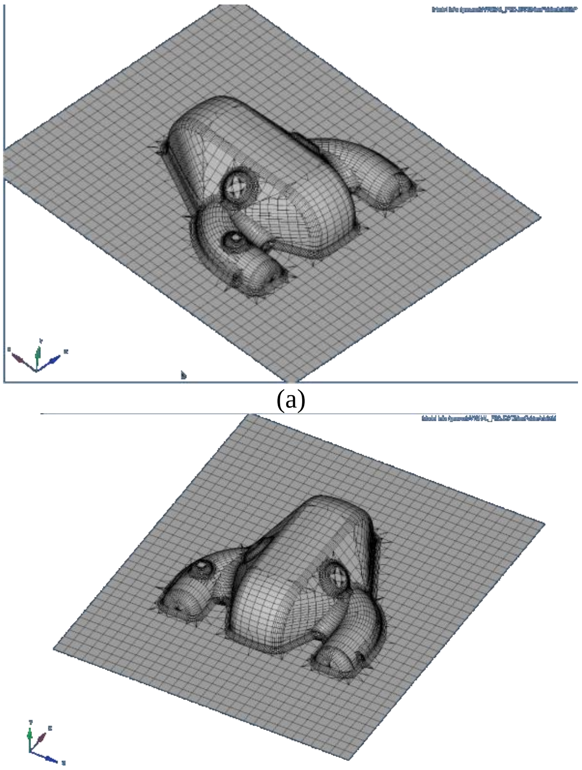
D= blank diameter,

d = shell diameter,

Ys = yield stress of the materialand

c = 0.6 .

The drawing ratio D/d takes into account the relation between theblank and the shell diameters. The drawing ratio depends on factors such astype of material and amount of friction present. The usual range of themaximum drawing ratio for mild steel is 1.6 to 2.3. The constant C accounts forfriction and bending effects and ranges from 0.6 to 0.7 [Sharma, 2003].



(a)

(b)

Fig.7 Auto mesh output in Hyperform

VII. SIMULATION RESULT

Following results were obtained for first Trial.
The result obtained mainly highlighted the region showing

a. Variation in thickness

The area shown in Fig 8 in red colour indicates thinning of material which needs to be improved to avoid cracking of sheetmetal

b. Stress Concentration

The area shown in Fig 9 in red colour indicates stress concentration which may result in crack initiation.

c. Plastic strain

The area shown in Fig 10 in red colour indicates plastic strain on the draw component. Area in red is undergoing more material flow compared to other regions. Hence plastic strain is more in that area.

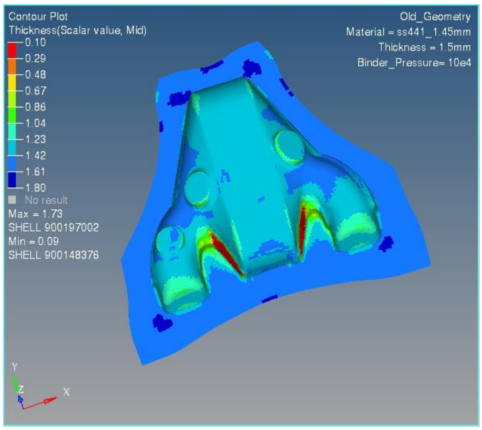


Fig.8 Thickness simulation

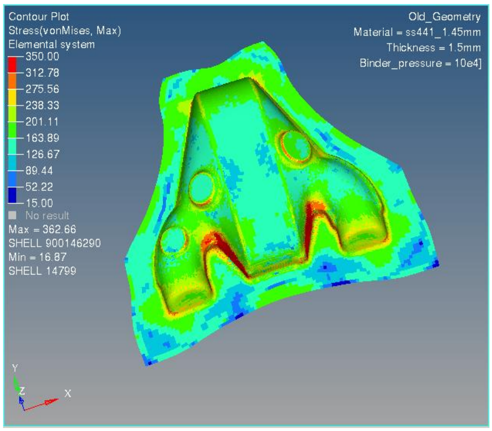


Fig.11Stress simulation

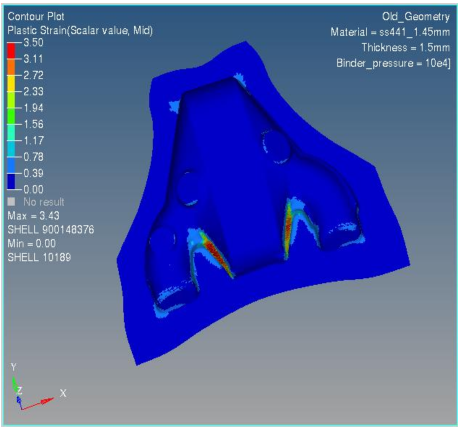
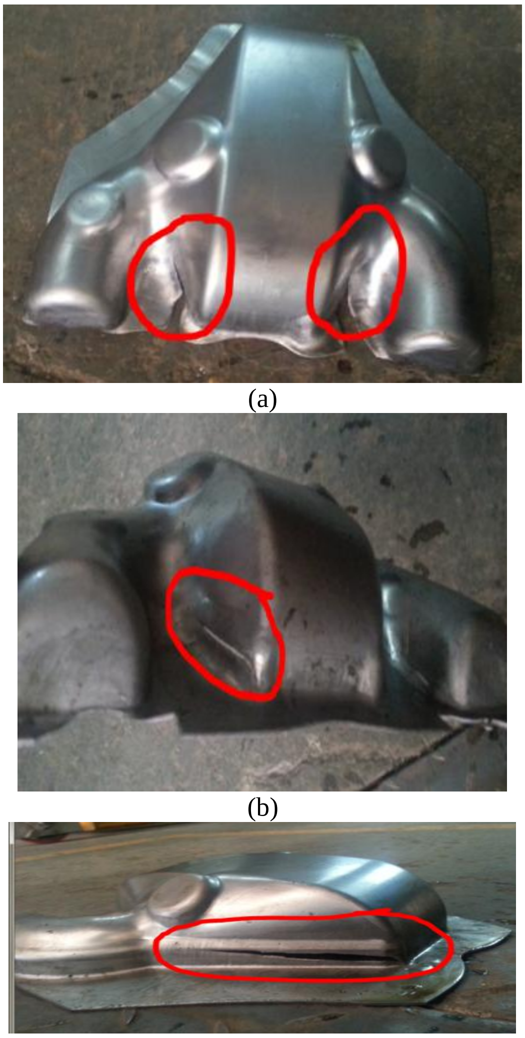


Fig.10Plastic Strain simulation

VIII. PHYSICAL TRYOUT

After the First trial simulation the die and punch geometry was finalised and physical tryout were done. Fig 11 (a)(b)(c) shows the defects in draw component due to excess stress concentration and thinning in particular area.


(a)

(b)

(c)

Fig.11Trial 1Observations in actual tryout component

IX.FINAL RESULT COMPARISON (Expected)

Thus by following the Simulation process and using optimization method it is expected that we get final results with defect free component. Also the software results must be in conformity with actual try-out results thus increasing the trustworthiness of the software. Thus the objective of the study to optimize the Deep Draw process could be achieved.

X. CONCLUSION

This was an attempt has been made to simulate the deep draw process for given sheet metal alloy. It was observed that, the results of simulation and actual try-out were similar. Thusif we have adequate inputs for the software the result can be trusted for complicated components without physicaltry-outs. Thus we can save the cost involved in proto phase. Simulations can be carried out for many combinations. By changing different variables we can finally achieve the best combinations considering design and manufacturing feasibility.

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