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Formability Analysis of Crca-IS2 Sheet to Eliminates the Defects during Deep Draw

Satpal Singh[1], Gurmeet Singh[2*], Simardeep Singh[3]

[1]Thapar Polytechnic College, Patiala, Punjab India
[*2]Thapar Institute of Engineering and Technology University, Patiala, Punjab India
[3]Honda Motorcycles and Scooters India Pvt. Ltd, Gurgaon, India
Corresponding author: gurmeet.singh@thapar.edu

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Abstract
Metal forming operations in industries are performed by the sheet metal processes. In sheet metal work deep drawing plays a major role to form the desired shapes. Improper design process leads to defected parts which are not acceptable due to ergonomics as well as aesthetics. Enormous defects during drawing have been discussed in the literature. FEA of sheet metal drawing was performed by using a blank. During the drawing operation wrinkling and tearing were observed experimentally. FEA as an effective tool has been concluded for this technique. The results will help in optimizing the process by changing the input parameters and help the industry to perform hit and trial on simulator rather than virtual environment.

Keywords- Finite Element Analysis (FEA), Sheet Metal Bending, Drawing, Simulation, Wrinkling.

1. Introduction

Sheet metal is a metal forming process in which a sheet is transformed into preferred shape by means of die and punch. Sheet metal parts are used in numerous applications where aesthetic look is more dominant compared to properties of materials for example panels, bonnet, etc. So, any kind of defects like wrinkles or tearing are unacceptable. Various important parameters which are the integral part of drawing operation are blank holder force, punch die clearance, draw bead design, corner radius, die entry radius, coefficient of friction, etc. (Yang et al., 2008; Singh and Agnihotri, 2015).

In sheet metal deep drawing is an integral part of the metal forming to produce axis symmetrical drawing (Sen and Kurgan, 2016) or axisymmetrical rectangular drawing (Kang et al., 2010). An optimize die design is required so that the deep drawing operation can be executed successfully. Certain equations are available to calculate the blank holder force required, but for some parts the exact classification cannot be done because of some complex design. It has been detected from literature that the blank holder force plays a major role on the metal distribution during the deep draw. If blank holder of large value is given to blank metal resist flowing wherever low forces support the flow of metal. A similar kind of pattern is observed in the case of friction coefficient (Ramezani and Ripin, 2012; Reddy et al., 2012a). The die entry radius, corner radius and the punch die clearance are some parameters which further

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affect the flow of metal (Özek and Bal, 2009; Alin et al., 2013). Complex shapes of the draw bead have a large impact on the distribution of metal. Optimal values of the parameters are important to properly design the die as well as the process for the successful drawing operation (Wei et al., 2008). A proper draw must be excluded from the wrinkles nor should it tear out during forming. An optimum size of blank can be used to produce a part with minimum of material (Wang et al., 2009; Reddy et al., 2012b). In a nutshell, if the design of the die is properly made and the process is studied before the forming can result into a defect free part. For the analysis of the drawing operations FEA is an important tool (Altinbalik and Tonka, 2012). To reduce the computational cost and expenses in the simulations six sigma approach has been used on the basis of CAE (Madake et al., 2013; Mayavan and Karthikeyan, 2013). Some other expert systems have also designed to validate feasibility of the production and the die design. (Vosniakos and Giannakakis, 2013; Wifi and Mosallam, 2007).

2. Material and Model

An industrial panel which is small bumper was taken for case study of sheet metal drawing process. The specification of the material of sheet blank was Extra Deep Draw grade Cold Rolled Closed Annealed IS(2): 440x380x4.00 mm The flow curve defining the material was taken as $\sigma = \max[S, C(\varepsilon)^N]$ where σ is flow stress, S & C are constants, ε is strain and N is strain exponent. The Coulomb friction model $F = \mu N$, is used where F is the frictional force, μ is the coefficient of friction and N is the normal load in contact. This model defines the friction in mechanical contacts.

3. Finite Element Model

FEA works on the basis of quantum mechanics and in case of sheet metal; it is a non-linear problem. To formulate the proper functioning of the problem variational approach is applied and it depends on specific equations. It is a necessity of the admissible velocities and the compatibility, incompressibility and boundary conditions. The most basic form of constitutive equation is described in terms of virtual displacement vector δu_i.

$$\int_V pu_i \delta u_i dV + \int_V Ku_i \delta u_i dV + \int_V \sigma_{if} \delta\varepsilon_{if} dV = \int_V f_b^i \delta u_i dV + \int_S f_s^i \delta u_i dS + \int_C f_c^i \delta u_i dS \tag{1}$$

Inertia force is defined by

$$\int_V pu_i \delta u_i dV$$

where ρ is the mass density of sheet and $\ddot{\mu}_i$ is acceleration vector over volume V. Damping force defined by

$$\int_V Ku_i \delta u_i dV$$

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where k is damping factor and u_i is velocity vector over volume V. Internal nodal force vector is the virtual work done by stresses and is given by

$$\int_V \sigma_{if}\,\delta\varepsilon_{if}\,dV$$

where σ_{ij} is Cauchy stress tensor and $\delta\varepsilon$ is the virtual strain vector due to virtual displacement vector $i\ \delta u$. External nodal force

$$\int_V p\phi^T\phi dV + \int_V K\phi^T\phi dV + (F_i)^T\delta U = \int_V f_b\phi^T dV + \int_S f_s\phi^T dS + \int_C f_c\phi^T dS \quad (2)$$

where M is the mass matrix, C is the damping matrix, F_i is the internal node force vector, F_e is the external node force vector and F_c is the contact force vector. The speed of the sheet metal operation is high so the inertia and the damping effect can be cancelled out. The complex partial differential equations are discretized into large sparse linear systems, which can be solved for solutions. Marc solver was utilized taking into consideration the nonlinearity of the system. It uses Updated Lagrangian formulation to give the incremental form of solution because of the large deformation involved in the sheet metal forming operation.

4. Numerical Simulation

For simulation on simulator, the dies and the sheet blank models were designed in solid works 2012 and then saved in the form of parasolid file. The sheet was meshed using sheet mesh element with 3 mm element size. Automatic contact procedure in ANSYS 15.0 LS DYNA was assumed for the complex interaction between the punch, blank and die. For rigid-flexible (tool set-blank) contact, 3D 8-node quadrilateral target element (TARGET 17.0) was used to represent 3D target (tool set) surface which was associated with the deformable body (blank) represented by 3D 8-node contact element (CONTA174). Conventional shell elements have to be applied with the special care where in significant deviation from plane-stress behaviour is expected. The sheet mesh element automatically detects the thickness of sheet and divides it into optimal mesh with 3D elements which gives accurate results and a good prediction of thickness variations. The following table (Table 1) gives the values of other parameters considered for drawing operation.

After the material properties, meshing and loading conditions, the analysis was performed. In analysis the total deformation and total strain effects is to be analysed. Using the actual loading values was also assigned i.e. when the impact loading rate is applied on the punch the wrinkles generate. The velocity with which the punch moves down towards the blank holder and the pressure on the blank as measured was also assigned. Velocity 75 mm/sec and rate of loading 470 MPA was assigned. The analysis shows the wrinkles on the same area. Figure 1, 2, 3 and 4 shows the analysis of the impact loading conditions. The results of simulation are given

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below.

By changing the loading conditions, punch velocity was assigned as 15 mm/sec and load on the blank holder was assigned as 470 MPa. So the analysis was performed and the wrinkles were eliminated and draw was properly seen.

The speed of the punch is changed and found that the proper draw was obtained. It was observed in Figure 4 that the thickness distribution of the metal was fairly gradual at most of the regions. But, the local thickening of metal at the corners implied that the pressure from the punch is important part. The effective stress was maximum when the speed of the punch was more than required. When the speed of the punch was optimized the wrinkles disappeared and the part can be easily drawn. So the simulation can save time of the production and also expenditure of the die changes. So, it may be concluded that the simulation results are valid.

5. Conclusion

It can be analysed that the compressive forces produced during the drawing operation were unstable which resulted in wrinkles. This implies that the material was not properly draw due to improper pressure on the part. The material distribution during drawing could be controlled through a proper pressure on the sheet. The parameters can be varied to prevent the thickening or thinning of the material in any part of the panel. Further, the anisotropy of the material has not been taken into consideration. FEA has successfully simulated the drawing operation and can be used for the optimization of the process saving a lots of time, money and labour expenditure.

S.No.	Parameters	Value used
1	Blankholder Force	150 KN
2	Friction Coefficient	0.01
3	Die Entry Radius	8 mm
4	Drawbead Height	4 mm
5	Die Punch Clearance	2 mm
6	Corner Radius	20 mm

Table 1. Value of parameters using during the deep draw operation

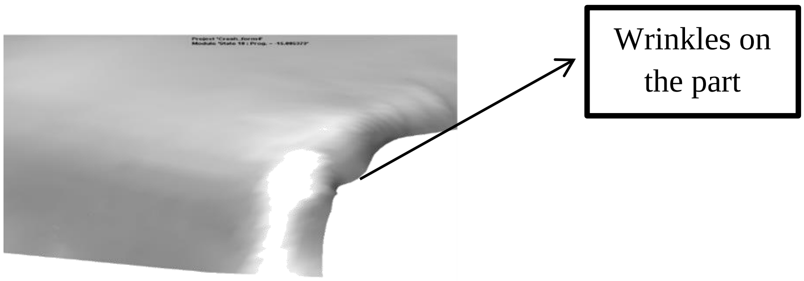

Figure 1. Shows the wrinkles on the part

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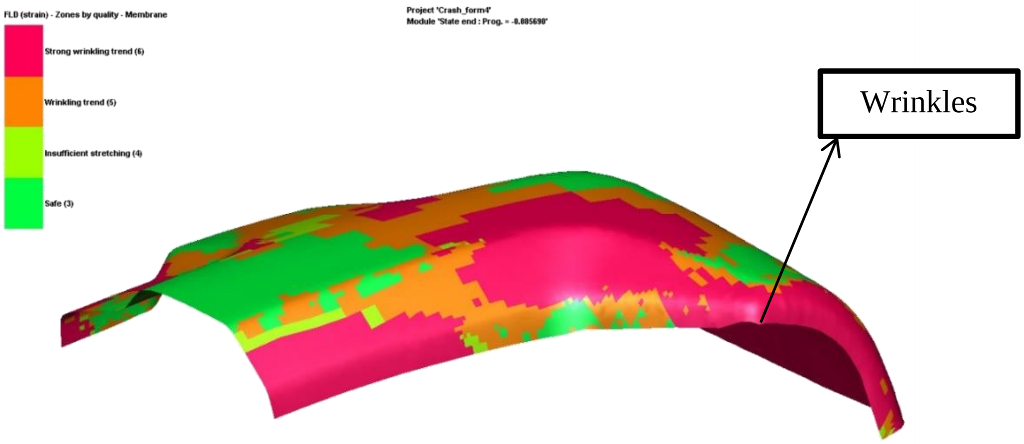

Figure 2. Shows the wrinkles during simulation

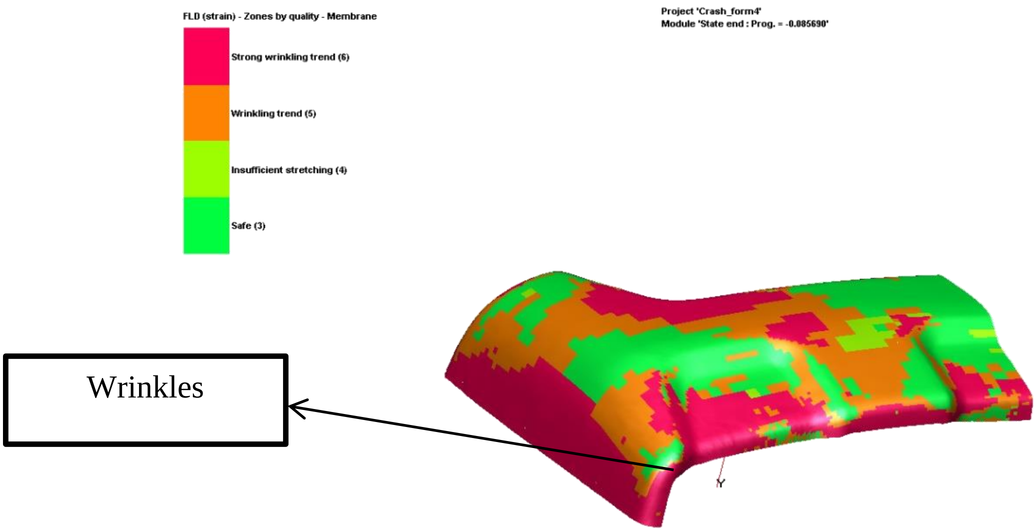

Figure 3. Shows the wrinkles during simulation

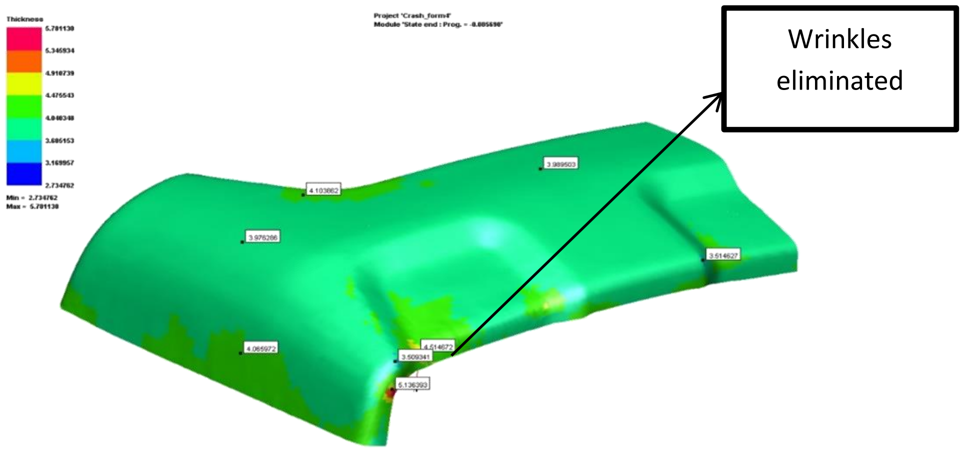

Figure 4. Shows the wrinkles removed

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