Deploying CAE For 'Forming Analysis' Of A Sheet-Metal Automotive Components While Validating Through Physical Experimentation

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Abstract- *Sheet metal parts involve cutting and non-cutting operations. This work shall focus on 'forming' as a non-cutting operation that accounts for a significant volume of parts processed using this operation. Forming, being a tricky operation to deal with, is best approached using CAE solvers. The behavior of the material during this operation depends upon the material properties and is manifested by the Forming Limit Diagram Curve. The feature like radius on the die-block, velocity of ram, use of lubricant, blank holding pressure, etc plays a key role in delivering a defect-free component.*

Hyper Form shall be deployed as a solver for the given problem case. Mathematical tools shall be used for preliminary investigation for finding tonnage. Validation shall be realized using physical experimentation during trials or testing.

Keywords- Forming, Draw, FLD, Hyper Form, Tonnage.

I. INTRODUCTION

Forming processes are particular manufacturing processes which make use of suitable stresses (like compression, tension, shear or combined stresses) to cause plastic deformation of the materials to produce required shapes. In sheet metal forming, the final shape of a part is made from a flat metal sheet. The desired shape is achieved through plastic deformation, without undergoing any machining like milling. In most cases, a certain amount of elastic deformation leads to spring back which occurs after forming is complete.

Most Automotive parts are made up of sheet metal which is manufactured by using Forming processes. Different type of reinforcements, body parts and door parts are manufactured in sheet metal scope. Thus sheet metal forming plays a very important role in automotive industry. With every manufacturing process there are some defects associated with it. In forming process also there are some types of defects arises, but the most common defects related to automotive body parts are: Spring back, wrinkles, tearing, thinning. These defects have many cost effective impacts like Material loss, loss of productivity, rejection, rework, Quality issues, etc. To avoid these losses analysis of forming processes is important. The feature like radius on the die-block, velocity of ram, use of lubricant, blank holding pressure, etc plays a key role in delivering a defect-free component.

II. CHALLENGES IN PRESS TOOL FORMING COMPONENTS

Modern NPD processes are banging on to reduce the cost, time and resources to deliver excellent products. Day by day as products gets better the complexity in shape of components increasing in sheet metal parts and challenges arising in forming processes. For better quality one should overcome defects like wrinkle, thinning, spring back and surface defects. To achieve the same lots of trial and error done in tool design, process parameters and material selection of the blank. But CAE technique are overcoming these challenges by virtual analyzing different process parameters like ram speed, blank holding force, tooling parameters like punch and die clearances, surface finish and draw bid also with material properties.

Using CAE tools sheet metal defects can be substantially reduced by changing multiple parameter or it gives the feasibility check of part at very first design stage. It reduces risk of potential failure of component after heavy investment in tooling at T0 trials and saves both Time Money and. The other advantages are reducing dependency of expertise in tooling by experience and get reliable on facts and figure. The attempt is given to provide solution to sheet metal forming automobile component by deploying CAE and doing analysis to reduce defects in safe range which is acceptable to quality and verifying it though experimentation.

III. DIE DESIGN CALCULATIONS

The case study considered for forming analysis of sheet metal automotive is named Upper cross member of automobile and this is sponsored by company "ADVENT TOOL TECH PVT. LTD. Pune". Through calculations we will recommend suitable die by investigate required tonnage for forming the component. Using industrial practices for assigning blank holding force, selection of spring, bush, guide-pillar and press selection as shall be suitable for the component and the operation.

Material: Available commercial material to suit manufacturability of component.

Grade	C	Mn	S	P	Iron
Commercial (O) (CR1)	0.15	0.60	0.04	0.05	Rest
Drawing (D) (CR2)	0.12	0.50	0.035	0.040	Rest
Deep Drawing (DD) (CR3)	0.10	0.45	0.030	0.025	Rest
Extra Deep Drawing (EDD) (CR4)	0.08	0.40	0.030	0.02	Rest

Grade	Yield Strength N/mm2	Tensile Strength N/mm2	% Elongation Min. L_0= 80mm	Hardness Max. HR (30T)
Commercial (O) (CR1)	280	410	27	-
Drawing (D) (CR2)	240	370	30	60
Deep Drawing (DD) (CR3)	220	350	34	55
Extra Deep Drawing (EDD) (CR4)	210	350	36	50

Ref: IS 513 : 2008 Cold reduced low carbon steel sheet and strip (Fifth Revision)

- The 2D drawing and Specification component provided by sponsor:

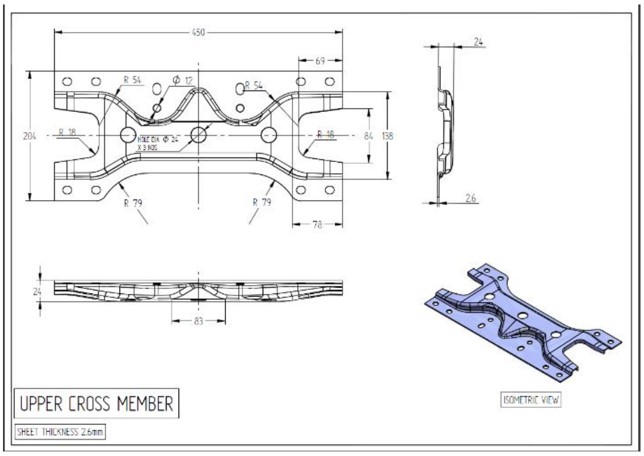

Fig 1: 2D drawing of Upper Cross Member

- Thickness: 2.6mm.

1. Draw Ratio

At this component, the Draw ratio wrt Length is
= d/l
= 24/450
= 0.053

The Draw ratio wrt width is,
= d/w
= 24/204
= 0.118

Here,
l= Length of component
w= Width of component
d= Depth of draw

It indicates the draw is simple & may require only one st age for completion because draw ratio 0.053 and 0.118 are less than limiting ratio 0.75.

2. Draw Force

Draw Force can be computed from knowing the shear strength of material and before and after blank dimension, by empirical relation,

$$P = 2\,(Lf + Bf) * t * \sigma s \left\{ \frac{Lb + Bb}{Lf + Bf} - C \right\}$$

Here,
P = Draw Force in Tons
Lf= Final part length in mm= 450 mm
Bf= Final part width in mm= 204 mm
Lb= Blank length in mm= 450 mm
Bb=Blank width in mm=250 mm

t = Thickness of metal in mm = 2.6 mm

σs = Shear strength of Metal in Kg/mm2 = 40 Kg/mm2
C = Constant (Take 0.6 to 0.7)

$$P = 2\,(450 + 204) * 2.6 * 40 \left\{ \frac{450 + 250}{450 + 204} - 0.7 \right\}$$

= 50377.6 kg
= 50.38 Tons

To encounter unaccounted forces due to imperfection 15% general factor of safety to be consider.

Safe draw Force (P_s),

= 50.38 * 1.15
=57.94 T
(P_s)≈ 58 Tons

3. Blank holding force

Blank holding force control metal flow around a shape to be formed in draw operation. It creates restraining force by friction between the tools and blank. In general, blank holding force 25% of draw force. For better results it can vary during analysis.

Blank holding force (Pbh),
= 25 % of Draw Force
= 25 % * 58
= 14.5 Tons

Material for blank holder:
Used EN-353 or 20MnCr5

Hardness :
Blank Holder should be hardened up to 30 to 35 HRC

4. Press Tonnage or Press capacity

The capacity of the press is the ability to deliver enough force necessary to perform the metal working operation. It includes draw force and blank holding force. For safer side available capacity press higher than this force is selected.

Press Tonnage,
= Draw Force (P) + Blank holding force (Pbh)
= 58 + 14.5
= 72.5 Tons

Press Capacity of 72.5 Ton shall be suitable.

To design die suitable to available standard pressed select press based on required press capacity.

The next tonnage available in standard presses from Xuzhou Metal Forming Machines is 80Ton press with following details.

Press capacity	Bolster size (mm)	Throat size (mm)	Die height adjustment (mm)
80 Tons	1000 x 600 T slot pitch = 100	310	80

5. Die Block Design:

Die block is main part which holds and locate die. It also transmits the load of comes on die.

Material for Die block should be use HCHCr & OHNS Hardness. Die block should be hardened up to 60 to 62 HRC. Hardened dies can be safely stressed up to 160N/mm2 compressive stress and 240N/mm2 shearing stress. We can compute minimum thickness of die block from shearing area.
Shearing area= 2(L+W) * Tb

If we consider 15mm base (Tb) after locating die in die block with support up to 40 mm. Total die block thickness would be 25mm.

Permissible shear stress,

= Total draw force/ Shear area
= 72.5*10^4 / 2 (450+204) * 15
= 36.95 N/mm2

The permissible shear stresses for Tb 15mm is 36.95 N/mm2 witch is lower that 160N/mm2.

Die block dimensions:
Ldb = 450+50+50= 500 mm
Wdb = 204+48+48 = 350 mm
Tdb = 15+40 = 55mm

6. Punch holder

Punch holder holds the punch and guide Blank holder. The thickness of punch holder should be sufficient enough to accommodate blank holder during strokes.

Punch Holder dimensions:
Lph = 450+50+50= 500 mm

Wph = 204+48+48 = 350 mm
Tph = 20+25 = 45mm

7. Top Plate & Bottom plate

Top Plate Dimension = 700 mm X 450 mm
Thickness for Top Plate should be 30 mm

Bottom Plate Dimension = 700 mm X 450 mm
Thickness for Bottom Plate should be 30 mm

8. Draw & Punch radius

The Draw radius usually ranges from 4 to 10 times the Blank thickness,
Radius of Draw Die=Rd=4.5 x 2.6=11.7 mm.

The Punch radius usually ranges from 3 to 4 times the Blank thickness,
Therefore, Radius of Punch = Rp =3 x 2.6 = 7.8 mm

9. Tool shut height:

Tool shut height = Top plate + Punch thk + Blank holder projection + Gap + Blank holder Thk + Bottom Plate.

= 30 + 45 + 30 + 10 + 55 + 30
= 200 mm

10. Die Punch clearances:

To facilitate smooth flow of material during drawing operation sufficient clearances are desired. The clearances can be computed from following formula and its depend on material where constant K changes.

$$C = t + K * \sqrt{(10*t)}$$

For Deep draw grade K=0.06 and for commercial grade K=0.07.

$$C = 2.6 + 0.06 * \sqrt{(10 * 2.6)} = 2.9\text{mm}$$

Clearance between Punch and Die, C = 2.9mm. In draw / form tool, Punch is the master, which means the Punch shape will perfectly match the part surface / profile. The clearance is given to die surface. The clearances can be altered for refining the results during analysis.

IV. HYPERFORM ANALYSIS

To compute blank size and analyze component for thinning, stress- strain plot and FLD diagram CAE software HyperForm used which is manufacturing solution from Hyper Works. For preprocessing like controlled meshing Hyper Mesh and for solver OptiStruct used.

Component analyze for different parameters like Die-Punch clearances, Material of component and forming process (Blank holding force) and try to bring thinning in acceptable level where quality can be ensured.

Itera-tion no.	Forming Process	Material	Clear-ance	Blank holding force	Thinning
1	Crash Forming	CRDQ	10 %	-	38.08 %
2	Single stage form-ing	CRDQ	15%	25000 N	22.02 %
3	Single stage form-ing	SPCE-NEDD	15%	25000 N	20.94 %
4	**Single stage forming**	**CR-DDQ**	**20%**	**25000 N**	**18.39 %**

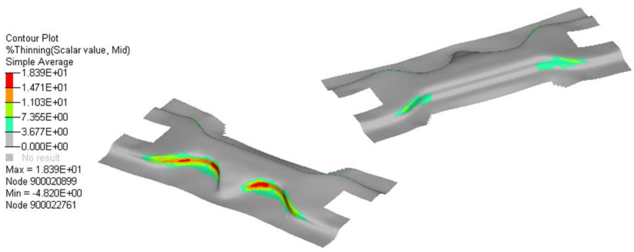

Fig. 2: Result of Iteration 4, Thinning plot and maximum thinning observed is 18.39%

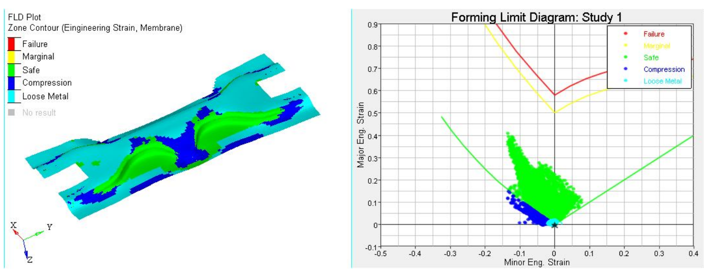

Fig. 3: Result of Iteration 4, FLD curve shows that component is safe.

Observations: Opting Single stage forming process with CR-DDQ grade material with good elongation property under Die-Punch clearances 20%, minimum thinning observed which is 18.39% which is under acceptable limit.

V. CONCLUSION

Deploying CAE software support (HYPERFORM) has offered a feasible solution to the problem at hand. Practice method of designing die and selection of materiel like HCHCr (High carbon High Chromium) & OHNS (Oil Hardening non Shrinkage) grade for both punch and die block to suit the components having CRCA grade material which are practically used in industries. This exercise done to reduce thinning and make component safe Formability and to achieve this multiple parameter worked out in analysis. The Single stage forming with sufficient blank holding force preferred over crash forming for better formability and to avoid wrinkles. The iteration table shows varying parameter Die-Punch clearance allows better flow of material in drawing or forming operation which facilitate lesser thinning. Material selection is governed by this analysis where practice grades of CRCA (EDD) having 36% elongation gives better yield in terms of % reduction in thinning and component get safe in Formability Limit Diagram. The iteration 4 is the recommended variant among the alternatives. The percentage thinning observed about 18.39. The component is safe in forming limiting diagram. In true meaning deploying CAE in such cased reduce trials and errors after tooling to achieve quality product and save time. The future scope of the work is to apply this develop process in more complicated case studies.

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