Deploying CAE For 'Forming Analysis' of A Sheet-Metal Automotive Component 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 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. OBJECTIVE

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 to analyze stresses involve in forming process and optimize thinning and other defects by iterating suitable parameters out of blank holding force, clearances, material properties, punch velocity, lubrications and many.

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III. FEA RESULTS

3.1 Iteration I: The FEA analysis considering simple crash forming process to evaluate the stresses and potential thinning or other quality defects. The forming process parameters were finalized by analytical calculation. The material of part considered as CRDQ and with 10% die clearances.

The maximum stresses observed is 613.5 MPa at critical radius which is above yield limit i.e. 420 MPa. It is clearly seen that component will fail in crash forming process. Also, at high stresses area maximum strain observed which is 0.471.

Also from the FLD diagram it can be seen that areas where the potential failure happen, it is mostly around where maximum thinning was observed.

The thinning is observed as high as 38% which is much higher than acceptable limit of 20% set by die maker.

It shows that crash forming is not best process for forming the sheet metal part to desired geometry. And hence we move for second run of FEA analysis.

3.2 Iteration II: The FEA analysis considering Single stage forming process on same material CRDQ. Here die clearances are increased to 15% as we observed the more thinning of part in previous iteration. For single stage forming process computed the blank holding force 25kN and run the simulation.

The maximum stresses observed is 612.9 MPa at critical radius which is above yield limit i.e. 420 MPa. Also, maximum strain observed which is 0.437.

The stress and strain reduce compare to crash forming process.

As there is blank holding added the flow of material in die is controlled and hence thinning is drastically reduced to 22% compare to previous 38% in crash forming. The thinning is still higher than acceptable limit of 20% set by die maker. Also, in FLD diagram the component is safe.

3.3 Iteration III: Performed FEA analysis considering same process to improve the percentage of thinning, Also FLD diagram shows the stresses can be improved further so decided to change the material of sheet metal part to Special Engineering Draw quality SPCEN.

The blank holding force kept same as previous and runs the simulation.

The maximum stresses observed is 650.6 MPa at critical radius which is above yield limit i.e. 420 MPa. Also, maximum strain observed which is 0.432. And in FLD diagram the component is safe.

No major change observed in stress and strain compare to second iteration.

But it is observed that % thinning is reduced to 20.94% compare to 22% in second iteration. It is seen that the change in material help to reduce % thinning when we go for better deep draw quality material. The thinning at edge of acceptable limit of 20% set by die maker.

3.4 Iteration IV: Final iteration of FEA analysis performed considering same process to improve the thinning percentage. As observed that change in material help for better forming results and hence the decision is to go with CR-DDQ material for sheet metal and perform the simulation.

The results show that the maximum stresses observed is 556.3 MPa at critical radius which is above yield limit i.e. 420 MPa. Also, maximum strain observed which is 0.383. And in FLD diagram the component is safe.

Good improvement in stress and strain values are observed compare to third iteration.

Also, percentage thinning is reduced to 18.39% which is lesser than expected limit of 20% from die maker.

Fourth iteration parameters are optimum parameter at which die maker can go for die manufacturing and later do the tool trials.

Table 1: FEA simulation results

Iteration no.	Forming Process	Material	Clearance	Blank holding force	Thinning
1	Crash Forming	CRDQ	10 %	-	38.08 %
2	Single stage forming	CRDQ	15%	25000 N	22.02 %
3	Single stage forming	SPCEN	15%	25000 N	20.94 %
4	**Single stage forming**	**CR-DDQ**	**15%**	**25000 N**	**18.39 %**

IV. EXPERIMENTAL RESULTS OF TOOL TRIAL

For experimental trail, die maker has made tool as per tooling specifications which are outcomes from analytical calculations performed in this dissertation.

This experimental trial called as soft tool trial where dies are not hardened which gives freedom to any correction if needed in trial.

As we seen from FEA analysis that iteration III and iteration IV having close results with nearly 2% difference in percentage thinning.

However, the cost of sheet metal is also one of the final decision parameters. So, it was decided that two trials will be performed with two different materials used iteration III and iteration IV.

4.1 Trail I:

The experimental test done on closest available press of 80 Ton with Bloster size of 1000mm x 600mm and throat size 310mm.

- The material of sheet metal is SPCEN.
- Blank holding force 25000N
- The clearances are maintained between punch and die are at 15%.

If in experimental trail, we observe that clearances are non-sufficient and causing any quality issue we can only increase the clearances.

It can be only achieved by milling operation of of die or punch, and foe same reason die and punch inserts are not hardened.

Results-

In visual inspection few light marks were observed of grain structures which indicate thinning. But there are not any major marks of excessive deformation or compression of grains structure which may lead to stress concentration of part during its function.

It confirms that visual test is pass with acceptable deviations.

To measure the percentage thinning of part thickness needs to be measured at different section of part, for quick and effective measurement it is decided to use outside caliper as a measurement devise. It avoids cutting of parts at different section and then do measurement is very time consuming and costlier process.

Total 10 measurement spots are identified where potential thinning might happen and recorded measurement using outside caliper. For better accuracy the recorded thickness by outside caliper is confirm with slip gauges every time.

Table 2: Experimental trial I- thinning measurements

Sr no.	Sheet thickness Measurement (mm)	Percentage thinning (%)
1	2.58	0.8
2	2.41	7.6
3	2.53	2.8
4	2.12	19.2
5	2.28	12.8
6	2.09	20.4
7	2.06	21.6
8	2.11	19.6
9	2.12	19.2
10	2.23	14.8

4.2 Trail II:

The experimental test done on same press of 80 Ton same die without doing any changes, as there is need to change the clearance and

- The material of sheet metal is CR-DDQ.
- Blank holding force 25000N
- The clearances are maintained between punch and die are at 15%.

In visual inspection no marks were observed of excessive deformation or compression of grains structure which may lead to stress concentration of part during its function.

It confirms that visual test is pass.

Similarly, total 10 measurement spots are identified where potential thinning might happen and recorded measurement using outside caliper.

Table 3: Experimental trial I- thinning measurements

Sr no.	Sheet thickness Measurement (mm)	Percentage thinning (%)
1	2.55	2
2	2.48	4.8
3	2.58	0.8
4	2.21	15.6
5	2.35	10
6	2.19	16.4
7	2.13	18.8
8	2.18	16.8
9	2.16	17.6
10	2.34	10.4

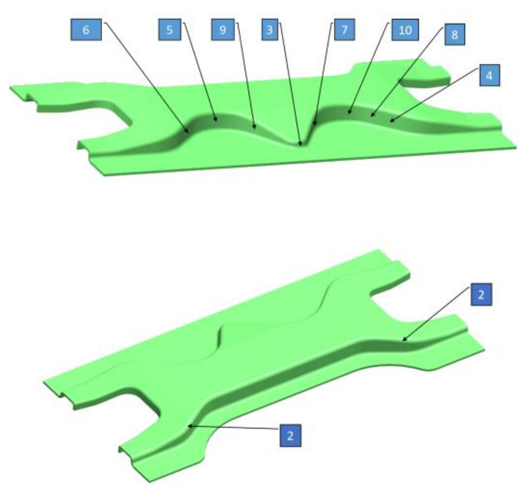

Fig. 1: Location of thinning measurement

V. VALIDATION

The analytical calculations and FEA simulation of forming analysis results are shared with Die maker so tool to be made with the specification recommended from this dissertation.

The experimental trial done to validate the results from FEA simulation and deliver forming tool to OEM.

The results from experimental Trial I compared with FEA simulation results of Iteration III of SPCEN material.

There are light marks of grain deformation which are up to acceptable limit by Die maker.

The percentage thinning in experimental Trial-I observed 21.6 % at preidentified measurement spot 7 which is maximum in 10 measurement spots. While maximum percentage thinning from FEA results of iteration III is 20.94 %. The results are closely matching.

Validation of Trail I with SPCEN material done with percentage error of 3.05% error between results of FEA simulation and experimental trails.

Similarly, the results from experimental Trial II compared with results from FEA simulation of Iteration IV of CR-DDQ material.

There are visible marks of grain deformation the part is accepted to Die maker.

The percentage thinning in experimental Trial-II observed 18.8 % at preidentified measurement spot 7 which is maximum in 10 measurement spots. While maximum percentage thinning from FEA results of iteration III is 18.39 %. The results are closely matching.

Validation of Trail I with CR_DDQ material achieved with percentage error of 2.18 % error between results of FEA simulation and experimental trails.

Table 4: FEA simulation and Experimental trial results comparison

Trail no.	FEA simulation results maximum thinning (%)	Experimental trial result maximum thinning (%)	Error (%)
I	20.94	21.6	3.05
II	18.39	18.8	2.18

The results of FEA simulation and Experimental trial are closely matching and satisfactory to Die maker as percentage of error in results is not more than 3.1%.

VI. CONCLUSION

Predicted thinning percentage from FEA simulation of forming process was close to results from experimental trail with error of 3% which is safe and accepted in industry.

Change in material of sheet in FEA simulation iteration helps to bring the thinning percentage within accepted limit, it facilitates the design team to think on proposal and take a decision before going for actual tool manufacturing.

Single stage forming process is right process for this part and crash forming is not correct method thought it would-be cost-effective method for production.

The blank holding force calculated from analytical calculation yields good results in forming which is confirm in FEA simulation and experimental trial as well.

FEA simulation results of different plots gives better idea of potential failures and what factor of safety we may achieve for final part with different process, material, and manufacturing specifications.

- FEA simulation predicts the which results helps Design and tooling and production team to experiment with digital prototype and arrive at decision much faster with agility.
- Performing FEA simulation before going for actual tool helps to strategies the complete tool design and experimental trial with soft tool.
- Methodology of FEA simulation for forming process is useful to reduce the expensive tool trails and save Design to manufacturing cycle time. This is achieved by simulating multiple possibilities in virtual environment at early stage of design and narrow down the experimental trails.

VII. SCOPE AND FUTURE WORK

Future work may be done in this project work are,

The dissertation work was limited to forming process only and tooling optimization goal was not considered, as most of the tool parts were rescued from old tool. For better life of the tool and optimum cost combine FEA simulation can be done and predict the results.

Existing tooling method is composite tool for each operation like forming, piercing and banking. FEA simulation with freedom of new tool design without using parts of existing tool could open possibility of combining these separate tools in one.

One can further optimize the forming process using same FEA simulation methodology if we know end application and load condition to optimize the parts design and achieve the results from forming process for final part.

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