# Design Analysis of a Cross Member Panel for Eliminating a Wrinkling

Sushama Satish Bobade
Research Scholar,
Department of Mechanical Engineering,
Late G.N. Sapkal College of Engineering,
Nashik, India

Tushar Y. Badgujar
Associate Professor,
Department of Mechanical Engineering,
Late G. N. Sapkal College of Engineering,
Nashik,

***Abstract*— Sheet metals widely used for industrial and consumer parts because of its capacity for being bent and formed into intricate shapes. Sheet metal forming process obtain the required shape and size of the raw material by subjecting the material to plastic deformation through the application of tensile force, compressive force, bending or shear force or combinations of these forces. The cross member is an essential structural component of a vehicle formed by sheet metal forming process. It supports the underside of a car and carries the weight of the engine and transmission system. Several defects can occur like wrinkling in the flange and cup wall, tearing and surface scratches. While forming of the cross member, wrinkling is one of the most severe defect observed. Present study focuses on a cross member panel part to eliminate wrinkling defect observed in it. This wrinkling elimination carried by the study of existing design, simulation analysis, and necessary corrections followed by actual panel analysis. Design alterations are suggested referring simulation results which result in defect elimination in actual production. A simple, clear, and comprehensive approach described in this article for the design analysis of a cross member panel for eliminating a wrinkling defect.**

***Keywords*— Formability, Simulation, Forming Limit Diagram, Sheet Metal Forming, Crash Forming, Wrinkle Defect.***

## I. INTRODUCTION

Nowadays, sheet metal forming is experiencing a fully automatic mass production in the field of automotive industry, household appliances, cans, etc. The rapid growth of automobile production, intense competition among automakers with overcapacity results in the reduction of the sales price of different car models. Meanwhile, a growing demand for cars with lighter weight, lower power consumption, higher reliability, and higher quality put the forward higher requirement for stamping technology. CAD/CAE/CAM integration technology is playing an increasingly important role in product design, tool design, and manufacturing process. Also, high internal pressure forming parts and air springs are also applied more and more widely, which effectively improves the vehicle's reliability and comfort [1].

A wrinkle phenomenon growth is a result of factors like properties of a sheet metal, various ratios of stresses and the complexity of structural design of the part, tooling conditions and operating parameters. It is very much intricate to analyze wrinkling by considering all the factors at a time as it would result in the complexity of parameters [2]. The simulation analysis provides complete information about the particular material wrinkling behavior under certain operating conditions. From an industrial viewpoint of a tool and die design, wrinkling analysis uses a readily available proved methodologies for predicting wrinkling in most of the similar cases. It also helps to avoid reoccurrences of similar problems. The actual results depend more on the skill of a particular associate working on that task so that the quality of a part produced would match to the predicted desired results [3,4].

*Cross Member Panel:*

Cross member is one of the most vital structural member of any vehicle. It is made of steel having a square shape and is bolted or welded with side members positioned underside of a vehicle. When the vehicle moves on the road various shock loads and vibration taken by its suspension and cross members. As this part related to the rigidity of a vehicle, sturdy and defects free structure is a functional requirement. Rough terrains and rocky trails expose cars cross member to high levels of pressure and harsh forces of nature. Because it is an essential structural component, one should take good care of the cross member for better ground clearance. In most of the designs, cross members are not readily visible as placed on difficult to access places. It made difficult for inspection and scheduled maintenance of it. This point makes sense that cross member must be a durable, designed part.

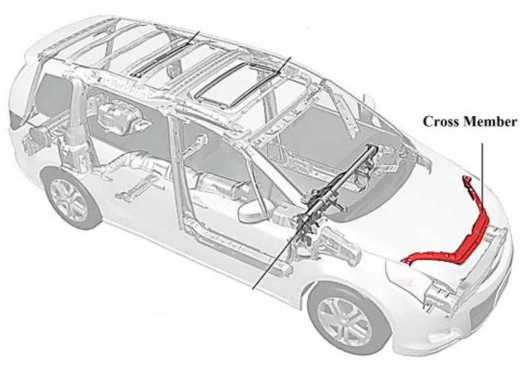


Fig 1: Cross member.

## II. OBJECTIVE

In the present research, the cross-member panel of the vehicle selected as a research object in which wrinkling defect is detected on the allover surface when produced.

The need for wrinkle elimination project identified due to following reasons:

1. Heavy Wrinkles on 100% panel produced.
2. Panel not as per required shape.
3. Spot welding not possible due to wrinkles in mating area.
4. Panel quality not at all acceptable to the user.

Hence, the motive of this research is to eliminate a substantial wrinkling defect of the cross member panel.

Fig 2: Cross member panel with heavy wrinkling defect.

## III. METHODOLOGY

After completing design and manufacturing of dies, dies sent to the vendor for panel production. On the produced panel severe wrinkling defect observed at flange area. As this would affect part fitment, parts rejected. Defects elimination research starts from existing die design and simulation study, to find possible causes, propose remedies and produce panel after remedies implementation. Fig. 3 showing methodology adapted for the study.

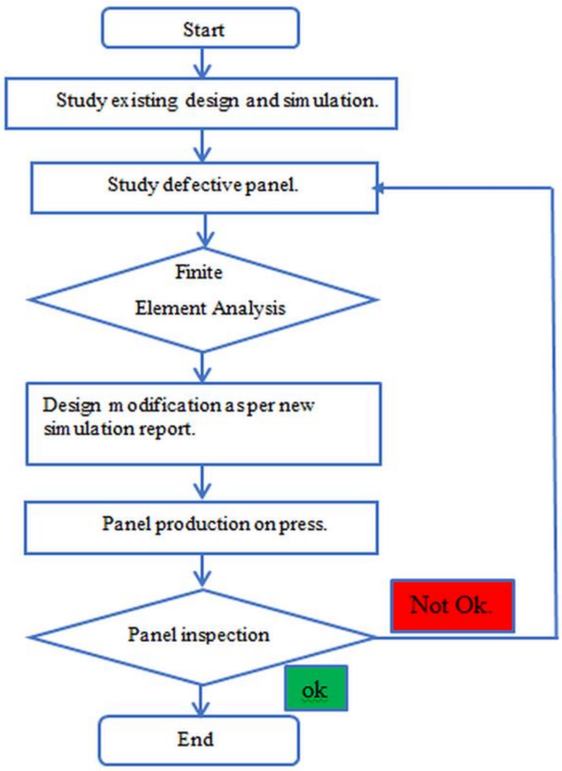


Fig 3: Methodology

## IV. SIMULATION ANALYSIS

In any design process, modeling has utmost importance. As physical modeling is not advisable as it is time consuming and lot of cost is involved in it. For this purpose of a sheet metal simulation, which gives a virtual idea to a designer about its virtual operation. Auto Form software used in this research work. It is one of the most used simulation software by sheet metal manufacturers. If correct process parameters used it gives an exact prediction of defects generation at simulation stage. It is a helpful tool in the hands of designer which helps to minimize process iterations

Material Selection: This is the first step in a simulation. The selected material for a panel is MM21-OA which is an equivalent material grade for commercial quality cold rolled steel (SPCC).

Carbon (C) is 0.15 %,
Manganese (Mn) is 0.60 %,
Phosphorous (P) is 0.050 %, and
Sulphur (S) is 0.05 %
Remaining is iron along with negligible % of impurities.

Mechanical Properties of SPCC Steels:
Following are some of the mechanical properties of SPCC steels:
The tensile strength of the SPCC Steels must be at least 270 N/mm2 (MPa).
The minimum percentage ranges for elongation is from 27 to 31 % starting from 0.25 mm to 2.5 mm and over

Material Specifications:

| | |
|---|---|
| Material Thickness | = 1.2 mm |
| Tensile Strength | = 275.440 MPa |
| Yield Strength | = 170.000 MPA |
| Lankford Coefficient, r | = 1.2 |
| Hardening Exponent, n | = 0.2 |

Formability checking:
This step of formability checking follows material selection and is a first practical simulation step. This step provides checks to validate a choice of particular process and gives an idea of whether or not a design is capable of achieving desired formability with and without various defects and failures. The simulation expert predicts process from its results and makes necessary changes to make it more successful. When designing stamping processes, the quality of the part has been the primary focus, the simulation identify possible cracks, wrinkles or surface defects [2,5]. As shown in fig 4 and 5, light green colour which indicate wrinkling.

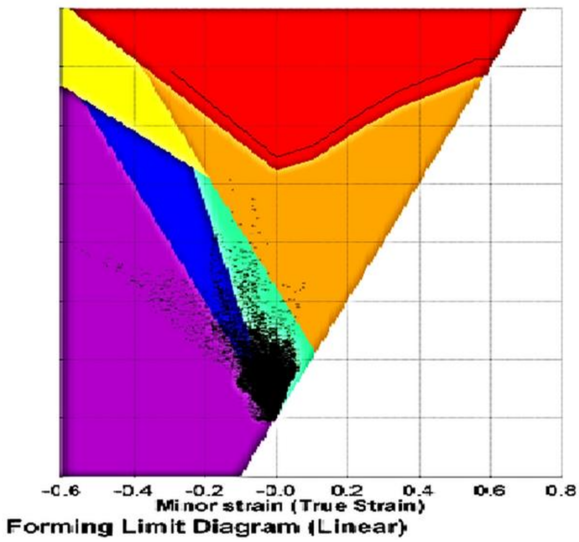


Fig 4: Formability limit diagram

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

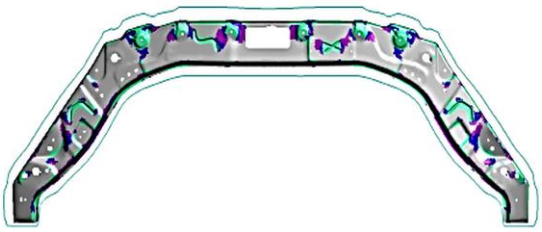

Fig 5: Panel simulation indicating minor defects.

*A. Critical observations of the first simulation:*

1. Majority of forming (about 80 %) is within the green zone which shows that process is capable of formability.
2. Wrinkling/thickening observed on the top surface, but no major in flange areas. Magenta colour shows it.
3. There are some high compression stress areas, shown by blue colour.
4. There is no chance for splits, which is shown by red colour, not observed

## V. ACTUAL PANEL ANALYSIS

After Successful simulation, die manufactured. However, when panel produced, it has heavy wrinkles all over the flange area, as shown in fig 2. As a 1st action, the process followed observations notes are as below:

1. Die set on a 600 Ton press machine.
2. Die setting parameters checked, found OK as per simulation.
3. Operator skill cross-checked found capable.
4. Sheet metal blank dimensions checked concerning 1:1 scaled drawing of simulation blank, found OK.
5. Sheet metal thickness checked found 1.2 mm, same as die layout specifications.
6. Location of blank checked physically in a die, which is found insufficient.

From this analysis, following probable causes are identified which could have a major impact on the wrinkles formation.

a. Die operation planned in design is incorrect.
b. Part geometry complex.

## VI. NEW SIMULATION ANALYSIS

These causes are checked in simulation to validate and propose corrective actions. Following actions are taken in simulation on above two identified reasons:

Die operation strategy change: Initially, it was planned to form using draw concept. Lower pads will act as a blank holder and panel will get formed on the lower punch. However, it observed that this is not working and results in wrinkling. So, it decided to change the operation type to crash forming. In crash forming, the lower pad removed. Panel forming takes place under upper pads action only.

Wrinkling was observed in old simulation, as shown in below fig 6. However, it was decided to take a decision after actual panel results. Values cannot magnify due to a software limitation. Surface defect height is 3.0 mm as per simulation and which is far better than previous actual panel results.

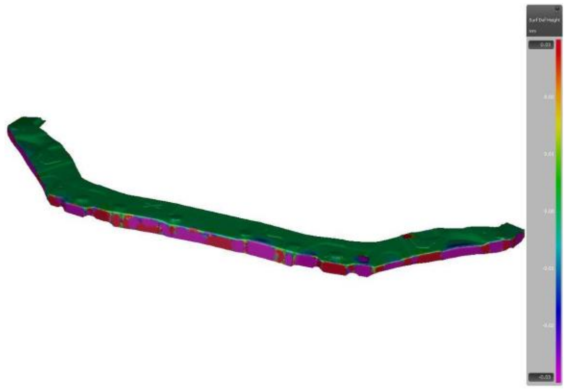

Fig 6: Forming as per earlier strategy in which wrinkles observed.

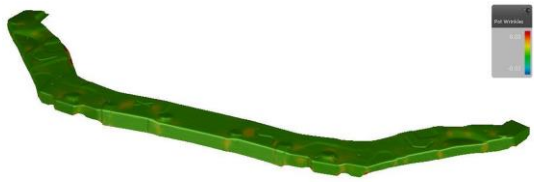

Fig 7: Crash forming shows wrinkle elimination.

*A. Part geometry modified:*

It observed that there is a material thinning above 20% in areas where radius formed with 6.0 mm. When such small radius meets in a corner, it forms sharp areas. It is shown in fig 8 and 9 with the colour yellow and blue.

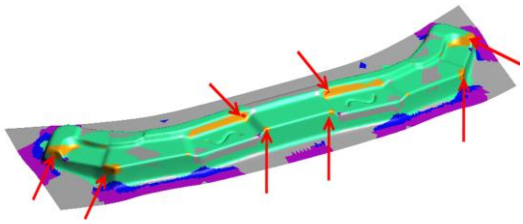

Fig 8**:** Thinning and cracks observed due sharp corners

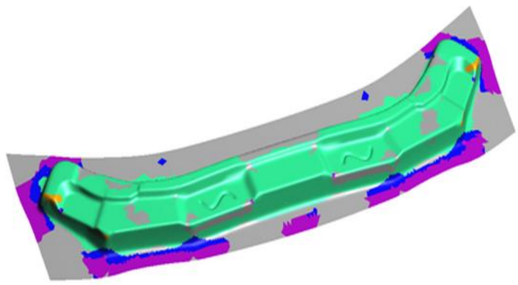

Fig 9**:** Sharp corners removed by balling.

*B. Major Strain checking after Crash Forming:*

Study of major strains is utmost important. It gives an idea about formability of a material under specific parameters.

Fig 10: Major strain checked

As per rules of formability, the major strain of any material must be any value which is more than zero. As shown in fig 10, we found it is all values taken at various sections are above zero. So, we can conclude that, as per new strategy of crash forming, a panel showing good formability with minimum defects.

Fig 10**:** Defect-free panel produced

## VII. VALIDATION

The new simulation gave proper corrections which implemented in a die. These changes are same as discussed in simulation analysis and physical repetition avoided here. In crash forming, as explained earlier, lower pad in a die is removed. Forming operation is carried out by an action of the upper pad against a lower punch. Implementing crash forming requires special operating skills. For crash forming initial trials taken on the hydraulic press which operates to avoid impact forces. After successful trials on a hydraulic press, we moved to take trails on the mechanical press. It is advisable to perform crash forming by an experts only, to get desired quality results. An actual panel production validates FEM analysis on the press, and a defect-free panel produced. Above fig. 10 shows the panel produced on the press after simulation correction implementation in dies.

We have observed a new panel defect free, and heavy wrinkling defect eliminated.

## VIII. RESULT DISCUSSION

The results obtained from new simulation analysis are similar to the actual panel produced. Following table shows the comparison of the results. The significant impact observed by changing the forming strategy to a crash forming which helped to eliminate heavy wrinkling defect which was present on all over the part wall.

Table 1, wrinkling height found up to 3.0 mm max as per FEA simulation results, whereas in the actual panel, the wrinkles not observed at all. Considering thinning, FEA results shown as 20 % thinning [6], which is acceptable. The actual panel showed only 10% thinning, which is far better. As per formability rule, minor and major strains values must be positive. Negative not at all acceptable, for successful formability of any material. Both these values observed positive and same reflected in actual results.

Table 1: FEA and actual results comparison

| Sr. No | Result Description | FEA Results | Actual Results | Corrective action |
|---|---|---|---|---|
| 1 | Wrinkling Height | 3 mm max. | 0 mm | No action needed. |
| 2 | Material thinning | 20% of panel thickness | 10% of panel thickness | No action needed |
| 3 | Wrinkling Forming. | Minor strain Positive values | Wrinkling not observed | No action needed |
| 4 | Formability | Major strain 0.04 to 1.3 | Formed ok. | No action needed |

## IX. CONCLUSION

This paper presents the research work with an objective of elimination of heavy wrinkling defect of a cross member panel using FEA simulation and experimentally. It found that crush forming has better results than draw concept forming in sheet metal. Though simulation software is capable of virtual trials, its effectiveness depends on the experience of a person who drives it. All possible causes for defect generation are studied, and four probable causes found. From this, following conclusions can be drawn:

1. Simulation results shows that crash forming can be used for cross member panel forming.
2. Crash forming can be used for wrinkle elimination after design change is incorporated and actual panel is produced.
3. Experimental and numerical results were found to agree closely.

Appropriate actions are taken on top two causes and validated experimentally. The panel found free of defects. Experimental and numerical results were found to agree jointly.

## REFERENCES

[1] T.Y. Badgujar, V.P. Wani, Optimization of Stamping Process Parameters for Material Thinning with Design of Experiment Approach, In: Iv Int. Conf. Prod. Ind. Eng. CPIE-2016, 2016.
[2] S. Prakash, D. Kumar, Investigation and Analysis for the Wrinkling Behaviour of Deep Drawn Die Sheet Metal Component By Using Fast Form, Proc. Natl. Conf. Trends Adv. Mech. Eng. m (2012) 536–543.
[3] T.Y. Badgujar, V.P. Wani, Stamping Process Parameter Optimization with Multiple Regression Analysis Approach, Mater. Today (2017).
[4] S.S.Bobade, T.Y. Badgujar, A State of Art In A Sheet Metal Stamping Forming Technology - An Overview, Int. J. Adv. Res. Innov. Ideas Educ. (2017) 3760–3770.
[5] G. Brabie, B. Chirita, A. Albut, Minimization of sheet thickness variation and other defects of mini drawn parts using a blank holder plate made from concentric rings, Precis. Eng. 42 (2015) 311–320.
[6] L. Marretta, G. Ingarao, R. Di Lorenzo, Design of sheet stamping operations to control springback and thinning: A multi-objective stochastic optimization approach, Int. J. Mech. Sci. 52 (2010) 914–927.