"Development of Car Door Outer Panel for Improving Dent Resistance & Optimization"

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ABSTRACT

In the present world, the product development of car and its accessories is mainly done by using the virtual simulation software's. But before proceeding to more development based on virtual tools, the capability of the simulation models must be proven or correlated with the physical test measurements and techniques. In the past times for design and development of a car takes years together. And with all the necessary testing done by physically, the product will get the certification for safe product. In present system, the launch of new car is reduced from around 6 years to around 4 years, this is because of the use of virtual simulation tools and techniques adopted by the manufacturing industries. And this will help to get better product at minimum cost as compared to traditional product development process.

As part of the product development cycle improvement process, the main goal of this paper is to improve the strength or stiffness of car front door outer panel by using Dent analysis simulation with primary door assembly. And also the frequency analysis is carried to check the eigen value and mode shapes of door assembly.

The main task includes the dent analysis of outer panel with standard material and then based on the results further analysis is carried to get better and optimized solution. The optimization process includes the change of outer panel thickness and the use of alternative material.

Key words: *Dent resistance, Eigen value, Stiffness, Outer panel thickness*

1. INTRODUCTION

The current study is related to the prediction of the automotive panel dent resistance with Steel and its Alloys. In order to know the motive of this paper and also the introduction of the light weight steel alloys in to the automotive vehicles or development is essential to know the historical background & factors which led to the drive for automotive vehicle weight reduction. Once the motivation for the introduction of lightweight steel alloys into an increasing range of automotive vehicle applications is clear, then the significance of the dent resistance can be evaluated.

One of the main key factor for the innovation for the new design of vehicles in automobile industry in the last 15 years is the cost and supply of the gasoline products (Petrol & Diesel) and the implications of automotive vehicle fuel efficiency that arise in this regard.. To reduce the use of oil by consumers, the Automotive Standards introduced several rules and guidelines which are to be met by the automotive manufactures. In order to meet the new rules and regulations set by the automotive standards, there is need for the new design approaches. The number of research and studies are done to improve the vehicle fuel efficiency.

Basically the main strength to the door will be given by the reinforcements like inner panel reinforcement, outer panel reinforcement, cross beam, latch reinforcement and etc. So in this project we are not going to alter any of the other components other than the outer panel. But also we are not playing with the design of the panel instead we are considering the thickness and the material changes. For this project the main challenge is to obtain outer panel with good strength in terms of dent resistance and stiffness with reduced mass.

2. OBJECTIVE

As part of the product development process of car door outer panel dent resistance improvement the main goal of this thesis is to "*Improve the outer panel dent resistance ability and panel stiffness by using FEA methodology with standard inputs and boundary conditions and mass optimization of door by down gauging and/or material substitution*".In this Project, the door outer panel dent resistance ability and panel stiffness is improved by using the alternative material and also the mass optimization was done by down gauging the outer panel without affecting the dent resistance ability and stiffness of the panel.

3. METHODOLOGY

The main actions of this project are:

- FE model setup with standard quality parameters.
- Simulation of Eigen modes and frequency response of door structure.
- Simulation of Dent analysis on door outer panel.
- Virtual simulation Results comparison with Physical measurements.
- Optimization of door model to achieve best results.

3.1. Door Simulation Process:

The beginning of simulation process starts with extracting the CAD model from the Design department and next importing this CAD model in to FE Pre-processor tool (Hyper mesh). And performing the geometry clean-up and discretization of the model to build the overall FE model of each components of door.

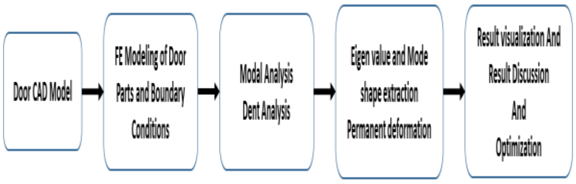

Fig 3.1 Door Simulation Process

Next, step is to apply the necessary inputs, forces and boundary conditions, this will end up with requesting the required outputs from simulation model for results visualization in Post-processing tool.

In this project we are doing first the Modal analysis by using the Abaqus Solver. This modal analysis is generally carried to check the model integration is done properly and getting the eigenvalues and mode shapes.

Next, the Dent analysis setup is done in Hypermesh and exported an input file for Abaqus solver. In this project the main requirement is to check the permanent deformation occurring in outer panel of door in standard points. And based on the dent resistance results further updating to the simulation model is done if required.

The bulk data section includes the data's which specify the model geometry, elements, connectivity, element properties and material properties, boundary conditions and loads. Only the entry fields which are used in door model are briefly described below.

- Node
- Rigid Elements
- S3 and S4 – Shell Element
- C3D8 Elements
- Section Shell
- Section Solid
- Material

3.2. Boundary Condition for Modal Analysis:

The Base line Door model hinge location and the Latch point are constrained in all 6 DOF. And requested 20 Mode numbers. Below figure shows the constrained area of Baseline door model.

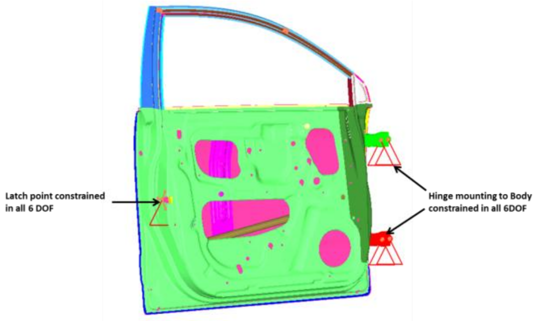

Fig 3.2 Boundary conditions for Baseline door model

3.3. Modal Analysis Result

For the Base line door model, the 20 number of modes are extracted. And the first mode frequency is 25.18Hz, which shows that our model setup and connections are done properly. If there are any parts missing connection will lead to the reduced frequency close to 0Hz. As this analysis is carried with constrained condition so we are not getting any rigid body modes in the analysis. If the Modal analysis is done with free-free boundary condition then will get total 6 rigid body modes from the door model. In which three are translational and three are rotational rigid body modes in X, Y and Z directions respectively.

The results from the door Eigen values (Hz) shows that there is very slight difference between each of the three door models. It indicates that with change in material grade has no much effect on the first two models because the both materials are Steel with different grades. And in third model there is difference in 2nd, 3rd and 6th modes, this is because of the material change from steel to Aluminium. And also the thickness of the panel is increased from 0.75mm to 1.00mm.

Mode	Eigen Value (Hz)		
	Base line model	Second model	Third model
1	25.18	25.18	25.08
2	29.34	29.34	31.21
3	31.27	31.27	34.99
4	43.91	43.91	43.58
5	50.15	50.15	48.91
6	56.64	56.64	60.92

Table 3.1 Structural modes summary

3.4. Dent Test Analysis

There are generally 9 possible locations for dent testing on outer panel of door model. And out of 9 locations we selected 4 locations for dent resistance analysis by FEA. The locations selected are Location 1, 5, 6 and 7.

Abaqus was used for the dent resistance analysis on outer panel of door model, the analysis performed on three different materials Steel-180P and Steel CR4 with 0.75 thickness and third material is AL -T4 with 1mm thickness.

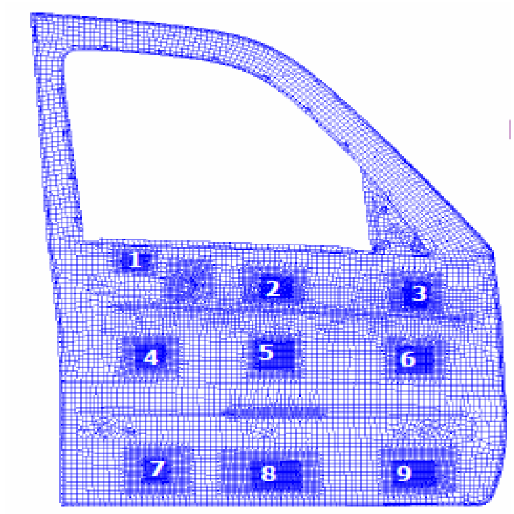

Fig 3.3 General locations for Dent resistance analysis

3.5. Dent test locations and Door Model constraints:

The Base line Model Outer panel dent resistance is evaluated in this project. The below mentioned are the assumptions made for the Door model,

Diameter of rigid ball = 50mm

Load applied = 210N

Constrained all 6 DOF in Hinge and Latch points.

Below figures shows the Base line door model constrained locations, locations of 4 dent points, Rigid ball, applied loads.

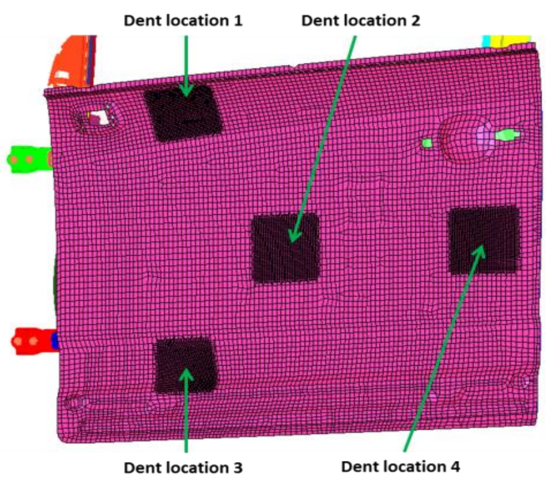

Fig 3.4 Selected Dent resistance test Locations

For Dent resistance analysis, the Abaqus solver is used for the Non-linear analysis. And first the load is applied on to the rigid ball and in second step the load released. And the permanent deformation on the door outer panel checked.

4. Results

A comparison of all three test models with 0.75mm thickness Steel 180P and Steel CR4 and 0.72mm thickness Steel CR4 materials are summarized in below tables. And the permanent deformation less than 0.1mm for Steel material is accepted. And these are accepted when a load of 210N is loaded and unloaded from 4 locations for each model analysis.

Material	Thickness - mm	Location 1		Location 5	
		Displacement in mm	Permanent Deformation in mm	Displacement in mm	Permanent Deformation in mm
Steel 180P	0.75	3.1	0.031	15.35	0.005
Steel CR4	0.75	2.87	0.031	15.14	0.016
Steel CR4	0.72	3.52	0.033	15.71	0.003

Material	Thickness - mm	Location 6		Location 7	
		Displacement in mm	Permanent Deformation in mm	Displacement in mm	Permanent Deformation in mm
Steel 180P	0.75	2.39	0.03	0.854	0.018
Steel CR4	0.75	2.35	0.029	0.825	0.0178
Steel CR4	0.72	2.46	0.032	0.91	0.019

Table 4.1 Dent Resistance Analysis Results

Material Name	Yield Strength N/mm^2	Youngs Modulus N/mm^2	Density T/mm^3	Poissons ratio
Steel 180P	190	200000	7.83E-09	0.3
Steel CR4	180	204000	7.80E-09	0.33

Table 4.2 Material data of Outer panel

Outer Panel Material	Thickness in mm	Outer Panel Mass in Kg	Overall door mass in Kg	Mass Reduction in %
Steel 180P	0.75	5.150	20.10	--
Steel CR4	0.75	5.050	20.00	0.49
Steel CR4	0.72	4.923	19.77	1.64

Table 4.3 Mass details

Sl No.	Model	Applied Load (N)	Displacement (mm)	Panel Stiffeness
1	Base line Door Model	210	15.350	13.681
2	Second Door Model	210	15.145	13.866
3	Third Door Model	210	15.716	13.362

Table 4.4 Panel Stiffness

CONCLUSION

In this Study, the mass of the door second model is reduced by 0.1Kg as compared with the door base line model by the utilisation of alternate material for the outer panel without modifying the base design and thickness. We achieved a mass reduction of 0.1Kg in one door of the car for the second model. By applying the second model material in a four door car we can approximately reduce 0.4Kg.

And in third model, the mass is reduced by 0.33Kg as compared with door base line model by using the alternate steel material with change in the thickness, and the results are within the target range for the third door model. By applying the third model criteria in four door car we can approximately reduce 1.32Kg.

In present paper it is concluded that, the door second model is as efficient as of door base model with mass reduction of 0.1Kg. And third model is also efficient as the second model, but needs to test further analysis to check the overall performance with other loading conditions.

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