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Automotive Door Design & Structural Optimization of Front Door for Commercial Vehicle with ULSAB Concept for Cost and Weight Reduction

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Abstract - This research papers describes the drawbacks of existing automotive door structure and suggest design changes to overcome the present drawbacks. This research paper details out the analysis of the existing structure and identifies the drawbacks and explains the process of door system design. Changes required can be found out with correct method as explained in this paper. Validation of the design parameters is of vital importance so the way by which validation of newly designed or modified parts can be done is briefly explained in this paper. Designer from an automobile engineer faces so many different problems during their work. Some of the major problems in automobile door are taken as problem for this research paper and those problems like high weight, high cost, excessive reinforcements, and water leakage. At first theoretically study of the existing system is done. After that deciding the key areas of modification is the flow of this paper. After finding the modification areas we tried some parameters for calculation. On the basis of calculations the design of new parts are finalized.

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AUTOMOTIVEDOORDESIGNSTRUCTURALOPTIMIZATIONOFFRONTDOORFORCOMMERCIALVEHICLEWITHULSABCONCEPTFORCOSTANDWEIGHTREDUCTION

Strictly as per the compliance and regulations of:

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Abstract - This research papers describes the drawbacks of existing automotive door structure and suggest design changes to overcome the present drawbacks. This research paper details out the analysis of the existing structure and identifies the drawbacks and explains the process of door system design. Changes required can be found out with correct method as explained in this paper. Validation of the design parameters is of vital importance so the way by which validation of newly designed or modified parts can be done is briefly explained in this paper. Designer from an automobile engineer faces so many different problems during their work. Some of the major problems in automobile door are taken as problem for this research paper and those problems like high weight, high cost, excessive reinforcements, and water leakage. At first theoretically study of the existing system is done. After that deciding the key areas of modification is the flow of this paper. After finding the modification areas we tried some parameters for calculation. On the basis of calculations the design of new parts are finalized. Then 3D models are prepared in CATIA V5, which are used for analysis purpose. Finally on the basis of analysis results actual metal parts are developed in the proto shop and fitment trials are taken on the vehicle. Once the fitment trial is completed actual testing is done on the vehicle. Comparing those results with the old results the improvement is suggested, during this study some specific parameters are chosen for observation and improvement. On the basis of these results final design is frizzed.

Keywords : ULSAB Concept, Problems in TWB technology, new inner panel for hardpad, water leakage issue.

I. Introduction

Recently, there have been two approaches in reducing automobile weight. One is by using material lighter than steel and the other is by redesigning the steel structure. Although the former seems very effective, it is very expensive so that it may only be used for an expensive automobile. Therefore, the automobile industry is trying to use steel, which is not costly and recyclable. Lightweight steel can be achieved by improving the performance of the structure or adopting new manufacturing techniques. One of the efforts is the ULSAB (ultra light steel autobody) concept. ULSAB suggests three main weight reduction techniques such as hydro-forming and the tailor welded blank (TWB). In this research, the TWB technique is utilized for lightweight door design, and a design process is proposed for optimizing the automobile TWB door. In the automotive door assembly, door inner panel is divided into different thickness without reinforcement components and different thickness sheets, plates are assembled by laser welding. The use of tailored steel solutions eliminates the need for additional reinforcements and overlapping joints in the body, saving material and further reducing total weight. In this way, tailored blanks are a significant enabler to meet specified CO2 targets. Reducing the weight of a car, reduces CO2 emissions. Objective of this paper is Low cost door design for developing countries India, Srilanka, South Africa without compromising any performance and regulatory requirements for example removing molded trim with hard pad, cost saving approximately 1400 Rs/set. Reducing the weight of door assembly by reducing number of components and by using advance technologies like tailor welded blank and high strength material. Existing design has a water leakage problem from the assembly of inner door panel and seal because of different thickness of inner panel. The parts which are newly designed or modified are designed on the basis of space constrained. The main constrained is that avoids as much as modification in the machined parts.

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II. Exsisting Inner Door Panel Design

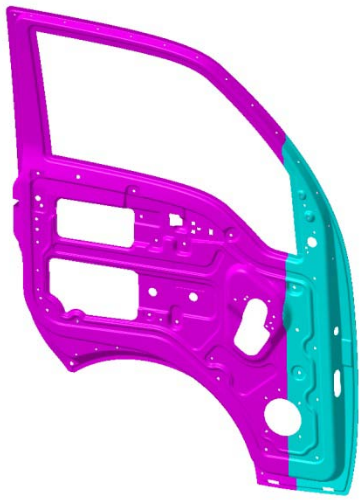


Fig 1 : Front Door Inner Panel, Weight: 6.3 kg

Inner door panel is a component which is use for strengthening the door assembly and it is one of the most important components on witch all accessories are mount like hinges, glass guide channel. Front door sill, window winding regulator, hard pad, molded trim, latch etc. Front door inner panel is use for sealing purpose when the primary sill is mounted on this. The weight of Door inner panel is near about 7to8kg depends upon its material and its thickness. The possible method is the integration method. In the integration method, the part is stamped out of a single blank. This reduces the number of tools needed; the assembly cost, and eliminates any fit ability problem. However, the design engineer is forced to work with same grade, thickness, and corrosion resistance throughout the entire part. Since the most demanding of all these conditions must be satisfied for the entire blank, this would increase the cost and weight of the part

Fig 2 : Assembly of molded trim and with inner panel

a) *Material used for exsisting inner door panel*

0.7mm thick, EDD 513,1.6mm thick, St40e

Table 1 : For material properties

	Grade St 35E	Grade St 40E
% Carbon	30 PPM max	30 PPM max
% Mangnese	0.35-0.45	0.35-0.45
%Sulphur	0.010 max	0.010 max
%Phosphorus	0.06 max	0.06 max
% Silicon	0.015 max	0.015 max
% Alumini	0.02 -0.04	0.02 -0.04
% Titanium	0.015-0.025	0.015-0.025
% Niobium	0.035-0.045	0.035-0.045
% Boron	5-10 PPM	5-10 PPM

	Grade St 35E	Grade St 40E
Yield Strength	180-220 MPa	230-270 MPa
Tensile Strength	345 -386 MPa	390 MPa min
% Elongation	35 min	34% min
R	1.6 -1.9	1.5 -1.9
N	0.21 -0.24	0.20 -0.24

III. Design Of New Door Inner Panel For Reducing Cost And Weight Of Front Door Assy

In this paper we are going to reduce weight of a front door assembly by using tailor welded blank concept for front door inner panel and using less thickness high strength material and reducing cost by replacing molded trim with hard pad in front door assembly and saving 1400 Rs/set.

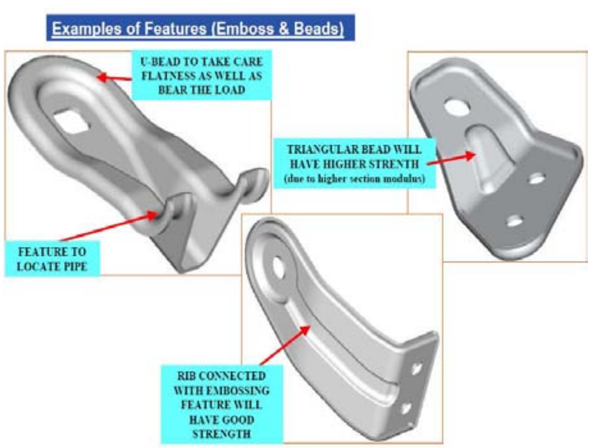
a) *Methods of preparing inner door panel*

1. In current automotive stamping technology, there are two basic paths that can be followed to arrive at the final inner door panel. The first method is part disintegration or part separation. In this technique, each different section of the blank is stamped separately and then spot welded together in the shape of the final part. This method has numerous advantages such as the ability to select the specific properties, i.e. the strength, thickness, corrosion resistance, etc. of each area of the blank. This method also gives a higher yield ratio of materialused.
2. The other possible method is the integration method. In the integration method, the part is stamped out of a single blank. This reduces the

number of tools needed; the assembly cost, and eliminates any fit ability problem. However, the design engineer is forced to work with same grade, thickness, and corrosion resistance throughout the entire part. Since the most demanding of all these conditions must be satisfied for the entire blank, this would increase the cost and weight of the part significantly.

3. A solution to the problems listed above is the utilization of tailor-welded blanks. A tailor-welded blank is a blank that is comprised of two separate pieces of sheet metal that has been welded together previous to stamping. Tailor welded blanks allow the welding of the different grades, different thickness or different corrosion coatings together in order give the properties needed in different areas, without increasing the number of tools needed to form the part and eliminating the fit ability concerns. They also allow a high degree of flexibility in designing parts and large blanks can be formed from much smaller sheets .The use of tailor-welded blanks would reduce the weight of the car. Having the ability to selectively place different thickness of material would result in weight reductions. An example of this used in production is the door inner panel. The only strength requirement on a door inner is in the region where the hinges attach to the panel.

b) Design guidelines for designing door inner panel



Beads and ribs increases the cross sectional area of component and load taking capacity increases. By adding beads we are able to reduce spring back effect of component.

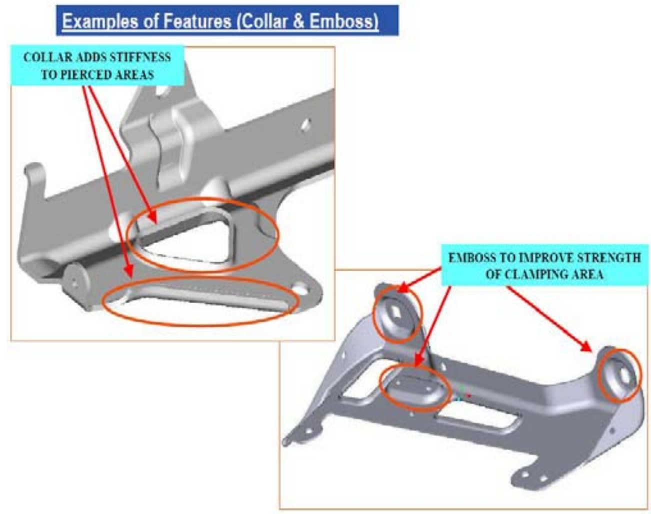


Fig 3 : Significance of ribs and beads

c) Material used for new door inner panel

0.7mm thick, EDD 513, 1.2mm thick, DP590

Table 2 : For material properties

Element	DP 590
% Carbon	0.08-0.12
% Manganese	1.1-1.6
%Sulphur	0.004 max
% P	0.02 max
Yield Strength	350min MPa
Tensile Strength	590min MPa
% Elongation	24 min

d) Design of new door inner panel for solving water leakage issue

Tailor Welded Blanks are made from individual steel sheets of different thickness, strength and coating which are joined together by laser welding. When we design inner door panel with tailor welded blank in witch some portion of a panel having different thickness and other is different. In our case some portion of door inner panel is 0.7mm thick shown below with pink color and another is 1.2mm thick shown below with sky color. There is a 0.5mm gap between these two thicknesses and this is the reason that water is leakage between door inner panel and secondary sill in shower test. Below figures gives the idea of existing and new coditions.

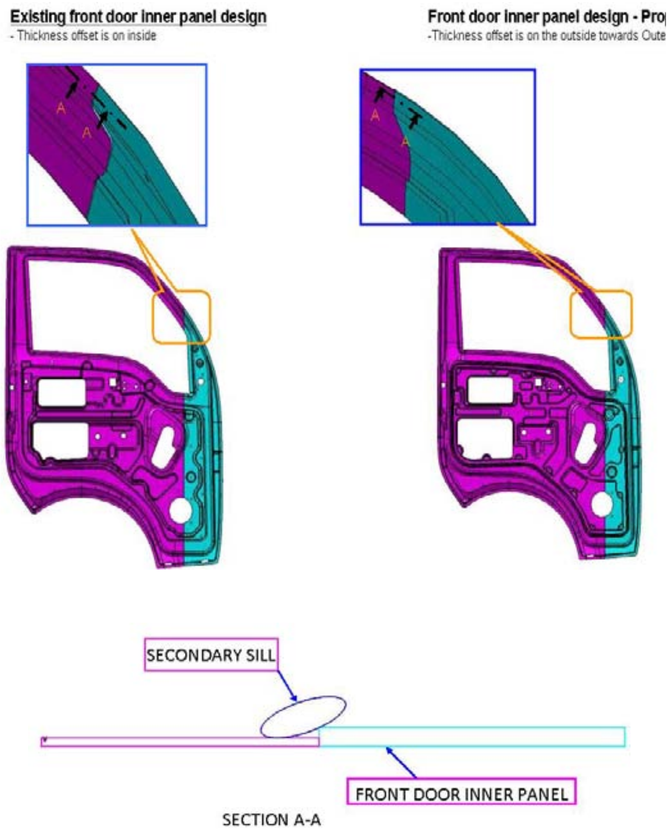


Fig 4 : Existing inner door panel condition with inside thickness

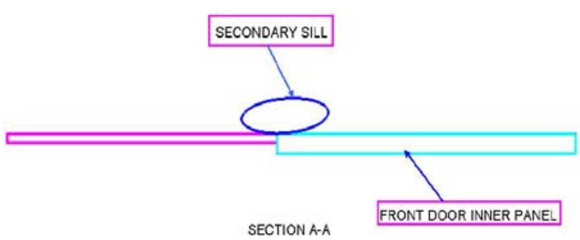


Fig 5 : New inner door panel condition with outside thickness

New front door inner panel for hardpad & no water leakage issue,weight-5.9kg

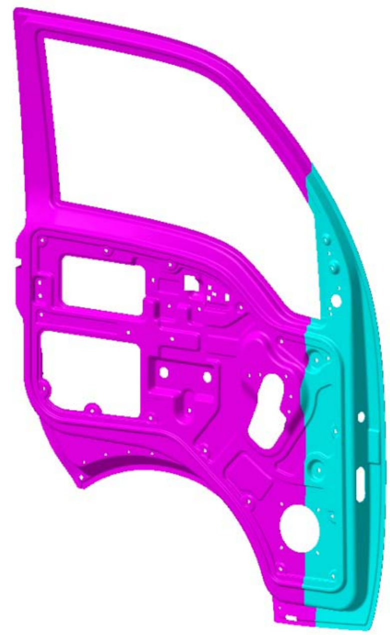


Fig 6 : New front door inner panel

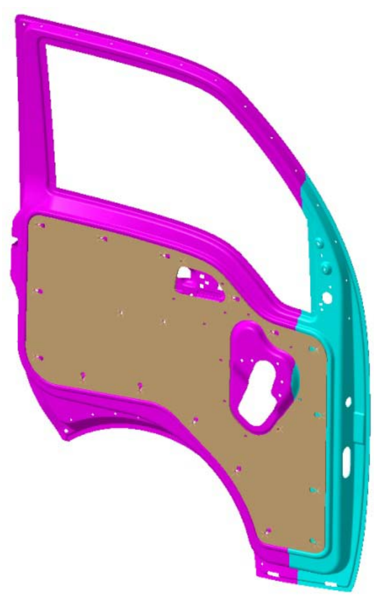
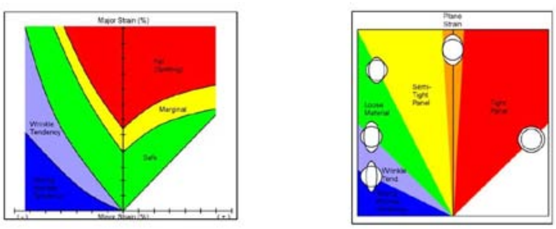


Fig 7 : Assembly of new door inner panel & hard pad

IV. Forming Analysis

The technique of sheet metal forming analysis requires non-contact optical 3D deformation measuring system. The system analyzes, calculates and documents deformations of sheet metal parts, for example. It provides the 3D coordinates of the component's surface as well as the distribution of major and minor strain on the surface and the material thickness reduction. In the Forming Limit Diagram, the measured deformations are compared to the material characteristics. The system supports optimization processes in sheet metal forming by means of; Fast detection of critical deformation areas, Solving complex forming problems. The optical forming analysis with forming analysis system provides for precise and fast measurement of small and large components using a high scanning density. Forming analysis system operates independently of the material. It can analyze components made from flat blanks, tubes or other components manufactured by an internal high pressure forming process (Hydro forming). The Forming limit curve is used in sheet metal forming for predicting forming behavior of sheet metal. The diagram attempts to provide a graphical description of material failure tests, In order to determine whether a given region has failed, a mechanical test is performed. The mechanical test is performed by placing a circular mark on the work piece prior to deformation, and then measuring the post-deformation ellipse that is generated from the action on this circle.



Color	Zone	Description
	Low Strain	Minimal Major and Minor strain, located at the intersection of the two axes
	Strong Wrinkling Tendency	High compressive forces producing a strong tendency to wrinkle, most evident in thin materials
	Wrinkling Tendency	Compressive forces sufficient to cause thickening of the part and minor wrinkling
	Safe	Is the area between the shear margin on the left and the thinning limit on the right, and below the FLC safety offset. This area will not likely experience failure during forming
	Marginal	The area between the safe and fail zones. This area provides a buffer for process and material variability. The safety offset is usually 10% for steels and 6-8% for aluminums
	Fail	Any area to the left of the shear limit, above the FLC and to the right of the thinning limit. This area may experience localized thinning or necking, failure

Fig 8 : Color bands in forming limit dig

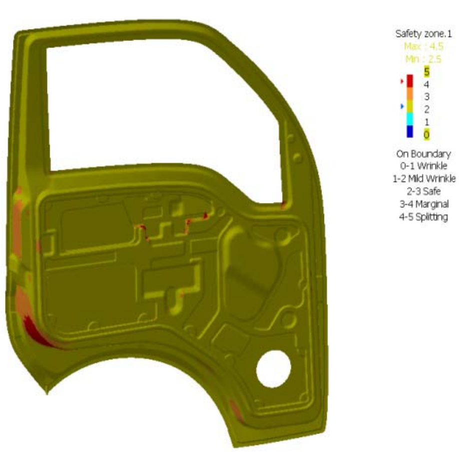


Fig 9 : Inner panel in safety zone

V. CAE Analysis

To evaluate the stiffness and sag performance of the front door for both existing and hard pad. Different stiffness's considered for front door assemblies are. The objective of this analysis is to predict the vertical sag behavior of the front door assembly of CUB (Goods Carrier). As per the procedure, there should not be a permanent set exceeding 1 mm and maximum latch point deflection (elastic) should not be more than 10 mm. At the latch point under two conditions

Table 3 : Boundary and Load conditions

Location No	Load Cases	Force
2	Torsional rigidity top	An inboard force 1000N is applied to the door inner corner(top)
3	Torsional rigidity bottom	An inboard force 1000N is applied to the door inner corner(bottom)
4	Beltline inner	A horizontal force of 600N is applied to the beltline reinforcement at the midpoint of the window opening (inner)
5	Beltline outer	A horizontal force of 600N is applied to the beltline reinforcement at the midpoint of the window opening (outer)

a) Results

Stiffness Analysis :

1) Predicted vertical stiffness of door with hard pad interiors is lower than existing front door design
2) Predicted beltline inner stiffness of door with hard pad interiors is lower than existing front door design
3) Predicted beltline outer stiffness of door with hard pad interiors (CAE Proposed design) is equivalent to existing front door design

Door Sag Analysis :

Predicted maximum elastic deflection and permanent set in door under worst door sag load case are as follows.

1) Existing design: Maximum elastic deflection is 7.75mm and permanent set is 0.23
2) Hard pad design: Maximum elastic deflection is 9.27mm and permanent set is 0.34

VI. Conclusion

In this paper we design new front door assembly components with tailor welded blank technology for reducing weight and cost of door assembly. Tailor-welded blanks allow combining different strengths of steel in one part without adding complications at the joints. Weight of a door assembly is reducing by 0.4 kg, by reducing weight of a door inner panel by using less thickness high strength material, reduce cost by replacing molded trim with hard pad. We are successfully solved water leakage problem by modeling front door inner panel correctly.

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