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Design and Development of Passenger Car Hood Using FEA

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ABSTRACT

The hood system of automotive vehicle is an access panel to the engine compartment to enable maintenance of drive belts, power train and battery. Hood is fundamentally a reinforced skin panel with safety and quality requirements. For every new project computer aided surface (CAS) data is coming from styling department and engineering feasibility data is prepared as per CAS with the provided space. In this study, hood design and development for new project with two durability load cases are considered, 1) Torsion stiffness and 2) Cross member bending. As per initial design consideration created the primary data of hood assembly and development has done as per Computer-aided engineering (CAE) results. Many loop of iteration are done to satisfy the acceptance criteria of durability tests. Computer Aided Design (CAD) tools used for design and development of hood assembly. In the static analysis part, a Finite Element Analysis (FEA) was carried out using software Nastran and Hypermesh. This paper focuses on analysis and techniques used for development of hood assembly with the help of CAD and FEA tools.

Keywords— Computer-aided design, Design & Development, Durability tests, Finite element analysis, Hood Panel.

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I. INTRODUCTION

a Automotive industry is the fastest growing industry today. In the competitive business the automotive companies have to take care of prize of vehicle, its efficiency and service. Research work is in progress in this direction making light weight cars but these cars are less efficient for carrying heavy load and cannot be used in long distance. Same objective may be achieved by making light weight parts of vehicle. Hood is a main component of front portion of a car one which is used for many purposes.

The Hood fulfills extremely important functions during an accident. First and foremost, Hood is made aerodynamic in shape to reduce air effect. Also hood is used to decorate car and add luxurious look. Hood form a sub-segment of vehicle “closures”, which also contains doors and tail gate. Hood must meet extraordinarily high demands in terms of their surface quality, workmanship and stability. Therefore hood must be designed in such a way that, it gives minimum hindrance to aerodynamic flow. The Hood system is an access panel to the engine compartment to enable maintenance of power train, drive belts, battery, fluid levels and lamp units. Hood generally used to cover car engine. Car hood consist of the upper panel and inner stiffener panel and reinforcement members placed there between to increase the strength of said panel in localized area. Loads are transferred to the panel through the metal insert material and dissipated to the panel members through the base structure. The inner stiffener panel provides strength and the outer panel is just a metal cover or skin the underneath of the hood is covered with sound absorbing material. The upper and inner stiffener panels are connected by hemming on outer side. "Hood Scoop" are used to channel air directly to the air filter, which gives improved performance and efficiency. Outer panel and inner stiffener panel of hood are connected by adhesive called "mastic".

The following main parts considered in Hood assembly.

i. Hood Outer.
ii. Hood Inner.
iii. Hood Latch System.
iv. Hood Hinge System.

In the vehicle development, Hood outer is an important part of the front portion of the car which is used to decorate and which gives aesthetic look to the car, the hood outer from style department from achieved the aesthetic look of vehicle, maintain the gap and falseness with surrounding part, as shown in fig. 1.A. Outer hood panel must be follows the aerodynamic criteria, this will change the class as well as type of vehicle. Also to design to pass the standard load cases like, buckling resistance of metal outer panels (Dimpling and Oil Canning), this will change as per manufacture of vehicle. Mainly flushness is considering the aerodynamic consideration of a vehicle. Gap between two components consider on dimensional and shape tolerance of component, which also depend on the manufacturing process. Small gap then required the tight tolerance and high cost.

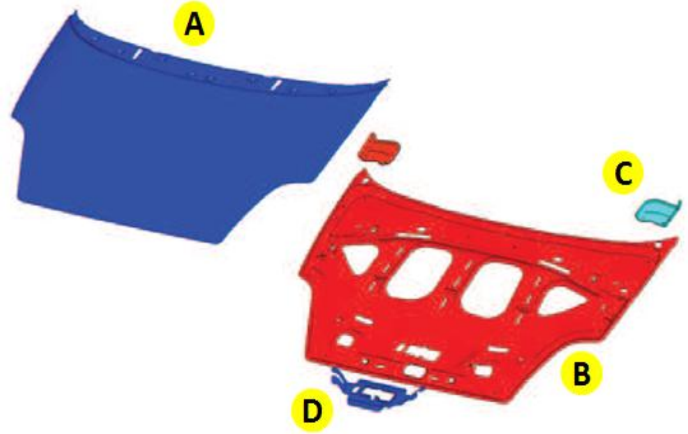

Fig.1 Exploded view of hood assembly.

Hood inner is main functional part in hood design, shown in Fig. 1.B. It's most critical and weight consuming part in hood assembly. In the vehicle development, the hood inner was designed to meet the standard load cases. The exact targets for these load cases are laid down in the vehicle manufacturers technical traditionally; the hood inner panel is designed with a rib structure supporting the hood outer panel. Such a design usually has weak points and stiff points.

The hinges also guide and hold the hood when opened. Their kinematics has to ensure that the hood does not contact other components (Fig. 1. C). For hinges with a single joint, the choice of position is very limited. In many cases, this problem can be overcome by selecting a multi-joint hinge. Different design concepts for hinges have been found. A single-joint hinge used in this project with its rotation point outside the area could provide the required deformation space.

The use of hood latch systems is vital to all cars, trucks or other vehicles. The design of such part needs thorough investigation of professional engineers to make sure that it is safe to use as well as safe for holding the hood to the chase. The hood latch is attachable to the vehicle body member by means of the bracket member. The bracket member is adapted to take up dimensional differences between the hood latch and the vehicle body member in a longitudinal, lateral and/or height direction of the vehicle. The adaptability to different vehicle models is achieved by varying the geometry of the bracket member according to the dimensions of the vehicle model.

The hood lock includes a latch mounted on a body cross member and a striker fitted to the hood. The latch usually features two forks, one for standard locking and the other for safety locking, operated individually, the standard locking typically via a lever below the dashboard and the safety locking by a direct external lever (Fig. 1.D). The lever operation inside passenger compartment causes the first latch fork to rotate and let the hood rise under the action of dampers until retention by the safety fork is reached, this can only be operated by manual voluntary action from outside.

In addition to safety locking, the hood lock design should ensure protection to theft. For that purpose, the hood opening wire hose in the engine compartment must be protected using adequate covers. The latch, positioned close to the longitudinal mid body plane and the two hinges provide the three isostatic dimensional constraints for the hood, but, in order to avoid vibrations and lack of alignment to body, two adjustable rubber dampers, positioned close to the side end, are usually included.

The current design process of hood assembly in Fig. 2, Input of hood project is styling surface and packaging space as constrain. Styling surface means the outer hood panel skin surface. The package space means all surrounding parts of hood assembly, Like Bumper, Head lamp, Fender, Engine and radiator assembly, Short Gun, Latch Mounding Bracket, widescreen, wiper location. Standard fasteners list use in hood assembly is provide. Bump stop use and its location as well as stay rod modal with its location is provided from customer.

Closures Design Team, study the styling surface and packaging space and highlight the problem in styling. Design team create the 3D CAD Model of as per design consideration. 3D model Shear with CAE team and after number of iteration final the Design. 3D model shear with actual manufacturing and after that validation the hood assembly.

II. Literature review

D. Costi et al [1] discussed an optimization procedure for mass optimization through various processes. Four types of optimization processes namely topology, topometry, topography and size. In topometry type of optimization is a mathematical technique that optimizes thickness distribution for 2D elements across the structure. Topography optimization is an advanced form of shape optimization in which a design region for a given part is defined and a pattern of shape variable-based reinforcements within that region is generated using

Optistruct. In size optimization, the properties of structural elements such as shell thickness, beam cross-sectional properties, spring stiffness and mass are modified to solve the optimization problem. The designer has to redesign the frame and the braces following the correct criteria of manufacturability for those objects.

David Salway et al [2] discussed the Multi- disciplinary topology Optimization for vehicle hood design. His highlights a new CAE capability to provide Multi-Disciplinary optimization of hood geometry to achieve the Structural stiffness target at lower weight and cost. The use of topology to determine the material placement and optimization reduce development time and produce a more efficient design.

Masoumi A. et al [3] compared and analyzed steel, aluminium and composite hood for pedestrian protection. Finite element model head impactor was created and impact simulation on three hoods with identical structure made of steel, aluminium and composite material was done on different locations of the hood to study the behavior of the hood.

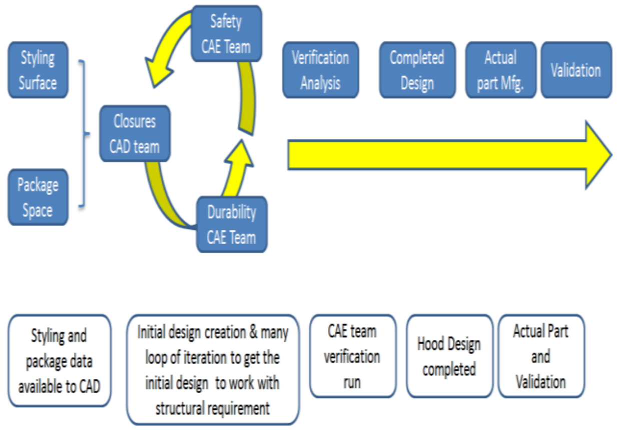

Fig. 2 Current Design process of Hood assembly [2]

. Hamacher et al [4] discussed the Simulation of a Vehicle Hood in Aluminum and Steel. They study the hood of the VW Golf V is taken as an example to analyze the potential of a hybrid construction of aluminum and steel. Structural stiffness, oil canning and dent resistance behavior are analyzed using Abacus. With the objective of reducing the total hood weight, the performance of the hood is compared to reference values of the series production steel hood. The generated finite element model contains all components of the Golf hood, but most important are the outer and the inner panel, which are designed both in steel and aluminum. Three static load cases are defined to analyze the structural stiffness of the different hood versions. Due to that contact definitions are required. The simulated variations show different lightweight potentials. Taking the material costs into account, a first attempt for an improved hood is made.

This paper focuses on analysis and techniques used for development of hood assembly with the help of CAD and FEA tools. The hood design and development for new project with two durability load cases are considered, 1) Torsion stiffness and 2) Cross member bending. As per initial design consideration created the primary data of hood assembly and development has done as per Computer-aided engineering (CAE) results. Numbers of iterations are done to satisfy the acceptance criteria of durability tests. Computer-aided design (CAD) tools used for design and development of hood assembly. In the static analysis part, a finite element analysis (FEA) was carried out using software Nastran and Hypermesh. The major learning from the project is design and developing an efficient and robust Hood design approach, which enables savings in time and effort to develop the new product design.

III. Durability Tests

Any automotive components must be check on three tests, 1) Durability tests, 2) NVH tests and 3) Crash tests. In durability tests, stress and strain point of view checking of all parameters of the component. NVH tests conducting for check the natural frequency of component. So it is not match with the engine frequency zone. Crash tests are on the vehicle level tests are on the basis of vehicles safety regulation. In this paper, two durability tests are considered.

A. Torsional stiffness Test

This simulation determines torsional rigidity of hood system. Requested results after the test is without damage of the bonding or joining points, without visible permanent deformations, elastically deformation under maximum load is allowed in linear area only.

Such kind of simulation is carried generally in two ways on vehicle in fully open condition and on bench condition where in hood is mounted in horizontal position and is held fixed at pivot hinges. One of bump stop location is constrained in z direction and at other bump stop point vertically downward load is applied.

In this project, used the four bump stops, two is inner side and two is outer side. So force is applied on two bump stop on one side simultaneously and other bump stop is fixed. Two readings are taken for torsional test i.e. inner bump stop and outer bump stop location, shown in Fig. 3 and Fig. 4 for inner and outer bumpstop location.

Following formula for calculating the stiffness.

$$C_T = \frac{F \times b}{\varphi_{IST} \times 1000} \frac{Nm}{^\circ}$$

Where, F is load force applied in N, b is distance between bumpstop in m, s is elastically deformation and φ is torque angle in degree.

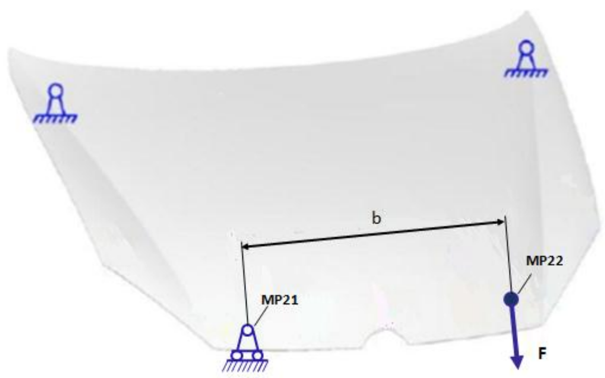

Fig.3 Torsional stiffness boundary condition for inner bumpstop (Case 1).

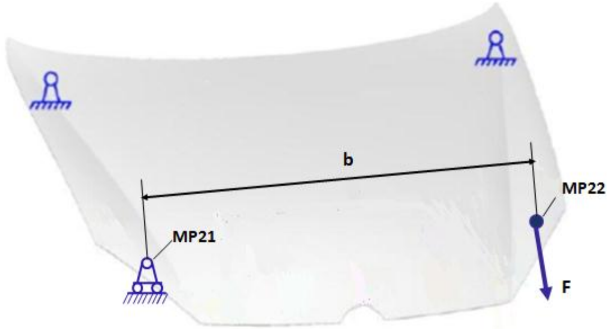

Fig.4. Torsional stiffness boundary condition for outer bumpstop (Case 2).

In torsional stiffness load cases, 80 N load applied on the bumpstop position. Acceptance criteria of torsional stiffness as differ from company to company, as best the practises, stiffness must be

- cH ≥ 100 Nm/mm for inner rubber bumpstop (Case1)
- cH ≥ 180 Nm/mm for outer rubber bumpstop (Case2)

B. Cross member bending

This simulation determines bending rigidity of bonnet subsystem. It ensures robustness of bonnet under its own weight. It prevents bonnet from sagging or bending when in the open position& when customer pulls/ pushes bonnet edge down to close. Bonnet is mounted in horizontal position and is held fixed hinges. Lift cylinder attachment points on both the side RH and LH are constrained in Z direction. One of bump stop location is constrained in z direction and at other end point load is applied.

This bending simulation, the position of the bonnet as per design with original hinges, slide bearing on the ramp of the bonnet lock, forces in Z direction could be recorded. Two readings are taken for front cross member bending i.e. inner bump stop and outer bump stop location, shown in Fig. 5 and Fig 6.

The formula for calculation the bending rigidity,

$$C_H = \frac{F \times 0.5\ b}{S_{12} \times S_{12}} \frac{Nm}{mm}$$

Where the (is bending stiffness.

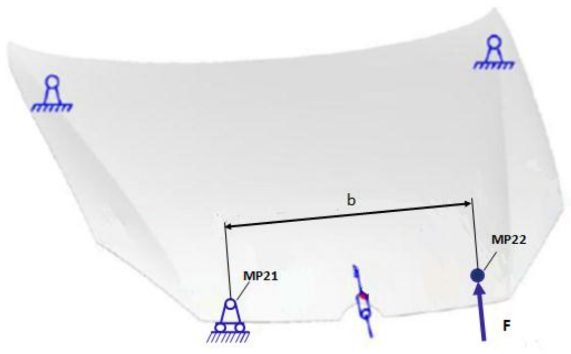

Fig.5 Bending tests boundary condition for inner bumpstop (Case 1).

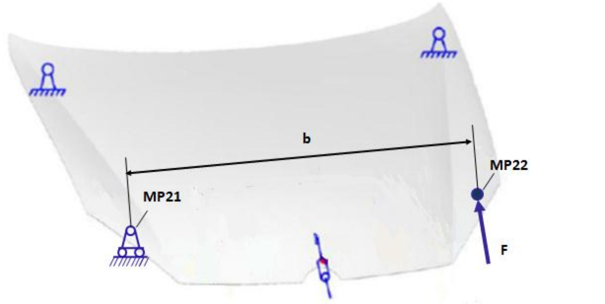

Fig.6 Bending tests boundary condition for outer bumpstop (Case 2)

In bending load cases, 120 N load applied on the inner and outer bumpstop position. Acceptance criteria of bending stiffness as best the practises, stiffness must be

- cH ≥ 25 Nm/mm for inner rubber bumpstop (Case1)
- cH ≥ 25 Nm/mm for outer rubber bumpstop (Case2)

IV. Design and development

The design and development of any automotive product is follows the following flow chart of design process.

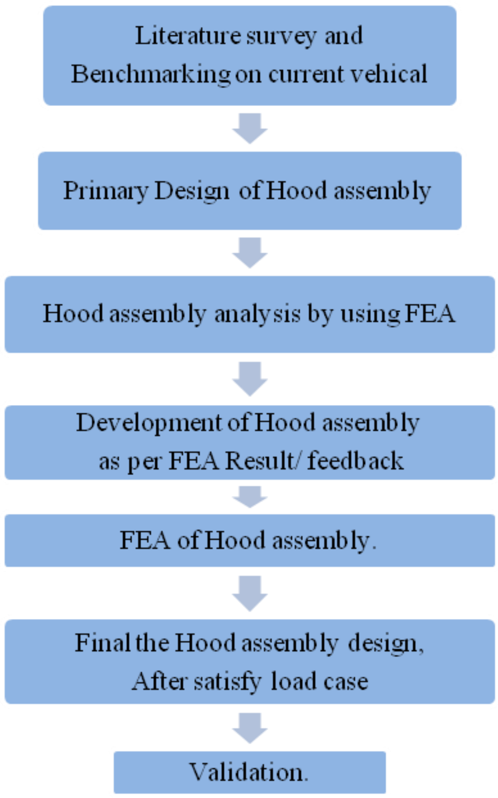

Fig. 7 Flow chart of hood assembly design design

For Primary design of hood assembly created on basis of following design consideration. The benchmarking data are available on reference for creating the initial design.

A. Styling Surface Study

The styling surface received from computer aided surface (CAS) deportment. One of the basic tasks in the process of automobile design is styling, the design of smoothly curved forms using free-form curves and surfaces, the curve or surface to be "visually pleasing", in some functional or aesthetic aspect. Check this surface is feasible for the reflection mapping, aerodynamic, radii and curvature for homologation rules, gaps on other parts as well as manufacturing parameters. The outer panel of hood assembly is design on the basis of styling surface. Hence the design as well as manufacturing aspect of hood assembly is considered.

B. Gap and flushness

Flush refers to the deviation in height in the split-lines between two components that are assembled. This mainly originates from variation in production, and is more sensitive for double-curved surfaces. Over flush and under flush consider as per aerodynamic aspect of exterior of vehicle. Always Front part of car is over flash with back part of car. Gap is the distance between the surfaces, Fig. 8. The width of the gap is determined of the space needed in order to assure that the opening and closing function is not compromised. Due to variation that can occur, in production and assembly and required over-slam, the gap size for moving components often need to be wider than for split-lines between nonmoving components. Variation can cause uneven or very large gaps that lower the perceived quality of a car. [5]

C. Split-lines

Split-lines refer to the space between components that are assembled. The components are not allowed to have contact with each other in order to fulfill certain functions. An example of this are the doors or engine hood on a car, these must have split-lines wide enough between the different components in order to avoid clash when closing and opening them.

Fig.8 Split-line between the hood and the fender.

D. Joining process

In primary design, joining process also consider. Mainly three joining process used on hood assembly, Spot welding for inner to reinforcement, mastic as well as hemming use for outer panel to inner panel and bolts for hood assembly to other assembly, i.e Latch and Hinges assembly.

E. Manufacturing process

During the product design manufacturing process is important aspect. In hood assembly, we use the steel sheet metal manufacturing process, like drawing, flanging, trimming, piercing, and forming.

V. Finite Element analysis

A finite element analysis (FEA) was carried out on primary data of hood assembly. The finite element model has been prepared by using pre-processor Hypermesh and the post processor has done on Nestran Software. The first run of FEA analysis has done on primary data. As per the CAE feedback, the hood assembly has modified. Number of CAE iteration has done and as per that development of hood assembly are done. Modifications are described as per parts, as shown in below.

A. Hinge Reinforcement

Hinge reinforcement has modified on following points as shown below.

- Thickness of hinge reinforcement reduced from 1.6 to 1.4 for Weight reduction.
- Form shape changed (i.e. Flanges & beads added) for increasing the stiffness to meet CAE target.
- Shape of reinforcement changed to increase the contact area of latest Bonnet outer and inner face.
- Spot weld points between inner and hinge reinforcement reduce from 10 spot weld points to 6 spot weld points.
- Hinge mounting holes diameter changed for better bearing surface.
- Hinge reinforcement locating holes position change to maintain 10 mm clearance from grommet.

B. Lock Reinforcement

Lock reinforcement has modified on following points as shown below.

- Rear flange angle changed to meet CAE criteria and for better stiffness.
- Side flanges removed for weight optimization.
- Shape changed to match latest bonnet inner.
- Modified to maintain 5 mm clearance from bonnet inner to reduce risk of Corrosion.
- Welding Spots between inner and lock reinforcement reduced form 6 spots to 4 spots.
- Slot dimension change for weight reduction.

C. Hood Inner assembly

Hood inner assembly has modified on following points as shown below.

- Weld spot reduction from 26 to 16.
- This assembly and Drawing modified to change in part form.
- Flange modify for mastic area.
- As per new Style, Modification in boundary flange on inner assembly.

The focus of all the modification are enhancing the components strength, reduced weight of assembly, easy for manufacturability and joining, proper assembly loading and reloading of component, reduced the process time and cost like weld spot and mastic area as reduces.

VI. Conclusions

In this paper, the design and development of hood assembly, is discussed with the help of two durability cases. The tortional stiffness and cross member bending tests are consider for this project work, on two different bumpstop location i.e case 1 and case 2. The primary design created on given benchmarking data and basic design consideration. The surface study, reflection mapping, aerodynamic, radii and curvature for homologation rules, gaps, flushness, joining process, manufacturing parameters as well as assembly sequences aspects are consider on primary design .

Primary design gives the first CAE run and as per the CAE feedback, hood assembly has modified. CAE gives the feedback in term of stiffness and deflection. The design has modified for the increased strength, weight reduction as well as reduced the process time and cost. Number of CAE iteration has done and as per that development has done on hood assembly.

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