DESIGN & OPTIMIZATION OF AUTOMOTIVE DOOR HINGE

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Abstract : The main goal of automotive industry is lightweight, low cost, reliable and most accurate product design of the vehicle. Finite Element Analysis (FEA) plays a very significant role in product development as it decreases prototyping cost as well as the cycle time for vehicle development. Cars have different types of doors such as side hinged doors, sliding doors and back doors system. This IS14225:1995 standard specifies the requirements for side doors including emergency door locks and side door retention components including latches, hinges and other supporting means, fitted on cars, light and heavy commercial vehicles to minimize the likelihood of occupants being thrown out from the vehicle as a result of any impact. This standard does not apply to those vehicles which are not normally provided with a door. In this study, concept of door hinge is generated in CAD and is evaluated in FEA for static loading as per IS14225:1995.Design optimization is done to meet the regulatory requirement specified in the regulation. FEA Results are compared with physical test results of automotive front door hinge.

IndexTerms–Automotive,Doors,Hinges,Latches,FEA.

I. INTRODUCTION

The major challenge in today's ground vehicle industry is to overcome the increasing demands of higher performance, lower weight, and longer life of components, all this at a reasonable cost and in a short period of time. The precise size of the safety problem posed by inadvertent door openings is difficult to quantify because very few jurisdictions gather the type of crash data needed to evaluate the problem. This task is further compounded by the effect of occupant belt use on injury risk. Notwithstanding the difficulty in quantifying the overall benefit associated with the regulation, the types of changes to door retention components. Additionally, vehicle manufacturers and the ultimate consumers of motor vehicles can expect to achieve further cost savings.

The goal of this exercise is to evaluate the performance of conceptual design of hinge and optimize the performance with Indian Standard 14225-Door Locks and Door Retention Components which is aimed at "minimizing the likelihood of occupants being thrown from the vehicle as a result of impact. Similar kind of regulations such as FMVSS 206 exists in USA whereas in Europe, ECER 11 looks after door locks and door retention components. Therefore, it becomes necessary for Vehicle manufacturers to design the hinge part and validate it with FEA as well as with physical test validation to comply with the requirements which are specified in regulations.

Door hinges are a key product in the automotive industry. The function of door hinge is not only close, open and keeps the open angle of the door but also to reduce the traumas for passengers in the car when a vital accident occurs. Hinges, an automotive part that connects body to automotive door. The main function of door hinge is not only to lock and unlock the door but also to ensure driver and passenger security. Otherwise door-body concept breakdown and severe accident could be occurred.

An automotive door hinge is mainly composed of three parts mobile part, fixed part and hinge pin. Mobile part is mounted on door whereas the fixed part is mounted on body system of the vehicle and hinge pin connects the fixed part and mobile part to retain the door system in to the body system of the vehicle.

Rollover crashes are a major safety problem, resulting in about 4,258 fatalities a year to occupants of passenger cars. A noteworthy aspect of rollovers is that many of the fatal crashes do not involve great amounts of force or destruction to the car. Two thirds of the fatalities in rollovers involve occupants being ejected from the car, often in crashes with low damage.

A number of strategies are available to reduce deaths and injuries in rollovers. The best single measure is to use safety belts. Recent studies have shown that belts are exceptionally effective in rollovers, reducing fatality risk by 70 percent or more. Many occupants do not use manual safety belts, however, especially those who are likely to become involved in severe rollovers.

A first line of defense against rollover fatalities is to prevent a car from rolling over. The next line of defense is to keep the occupant inside the car. As noted above, many of the ejections occur in crashes of low severity. The design of doors and their locks, latches and hinges is crucial here; so is the retention and integrity of windows. Next, the occupants' living space within the passenger compartment must be maintained. The roof has to be strong enough to resist severe compression when the car rolls over. Finally, impacts with the interior surfaces of the passenger compartment should not injure the occupants. Finally, impacts with the interior surfaces of the passenger compartment should not injure the occupants.

In September 1988, NHTSA granted a petition for rulemaking to establish a standard to protect against unreasonable risk of rollover. The proposed upgrade of the side impact protection standard includes a requirement that the doors remain closed during the impact test; the objective is to reduce the risk of occupant ejection through open doors [1].

Lap/shoulder seat belts, when used, reduced the risk of fatal injury to front-seat passenger car occupants by 45 percent and the risk of moderate-to-critical injury by 50 percent. For light-truck occupants, seat belts reduced the risk of fatal injury by 60 percent and moderate-to-critical injury by 65 percent. Seat belts saved an estimated 14,668 lives of passenger vehicle occupants 5 and older in 2016.

For passenger vehicle occupants involved in fatal crashes in 2016, nearly half of those who were killed were unrestrained in the crash, the occupant survival rate with restraints was higher as 86% as compared to only 14 percent of those that survived without restraints.

The Static Stability Factor (SSF) was introduced to NHTSA in 1973 by vehicle manufacturers as a scientifically potential substitute for dynamic rollover tests, and NCAP began reporting SSF in 2001. NHTSA considers the SSF as a significant factor of rollover resistance, since the SSF represents the vehicle geometric properties that are associated with rollover events, i.e., the center of gravity height and the track width. SSF indicates rollover risk in a single-vehicle crash and the NCAP rollover resistance rating quantifies the risk of a rollover if a single-vehicle crash occurs. The NCAP rollover ratings are produced exclusively for consumer information only, and no regulatory requirements specifically related to rollover mitigation are placed on vehicle. Manufacturers.

The NCAP rating does not predict the likelihood of a rollover crash occurring; only the likelihood of a rollover occurring given that a single vehicle crash occurs. Starting with MY 2004, NHTSA combines a vehicle's SSF measurement with its performance in a dynamic "fishhook" test maneuver and presents a single safety rating for rollover resistance by make-model. In the NCAP rating system, the lowest rated vehicles (1-star) are at least 4 times more likely to rollover than the highest rated vehicles (5-star). NCAP publishes all SSF measurements and the NCAP dynamic rollover test results in Docket No. NHTSA-2001-9663.NCAP star-ratings for rollover resistance of individual vehicles can be viewed by visiting.

The fatality rate for 2017 was 1.17 fatalities per 100 million VMT, down from 1.18 fatalities per 100 million VMT in 2016. The fourth quarter of 2017 represented the third consecutive quarter with year-to-year decrease in fatalities and the fourth consecutive quarter of year-to-year decreases in the fatality rate. Fatalities were projected to have decreased by 2.5 percent during the fourth quarter of 2017. Analysis to generate gross estimates of changes revealed slight decrease in driver, pedestrian, and motorcyclist deaths for the Nation in 2017 as compared to 2016. These estimates may be further refined when the projections for the first quarter of 2018 are released in late spring of 2018.

The SAE recommended the practice of uniform test procedures and minimum static load requirements for vehicle passenger door hinge systems Tests were described than can be conducted on test fixtures and equipment in laboratory test facilities. The test procedures and minimum performance requirements outlined in this recommended practice are based on currently available engineering data.

This IS14225 was adopted by Bureau of Indian Standards (BIS), after the draft finalized by the Automotive Body and Chassis Sectional committee, and had been approved by Transport Engineering Division Council. This Indian Standard regulation was derived from SAE J 934 which is described in above paragraph.

This recommended test procedures was provided by NHTSA. Federal Motor Vehicle Safety Standard (FMVSS) No. 206 established minimum performance requirements for motor vehicle door locks and door retention components. The purpose of Standard 206 is to minimize the likelihood of occupants being thrown from a vehicle as a result of impact [2].

Mustafa Tufekci et al evaluated the door hinge in FEA for Mild steel as well as for in Aluminum alloy material & the aluminum hinge (light weight) re-designed by using topology optimization methods[3].

N.D.More designed and analyzed the door hinge of the automotive car for Regulation IS14225 and was optimized the design to satisfy the specified requirements of door hinges and experimentally validated the final door hinge design [4]

Rahul Aghav proposed a new approach integrated Check Strap for car door system which required less space for mounting and required less time to fix on the door [5]

Daniela Antonescu et al studied and designed solutions to save as much space as possible in narrow parking places. They developed software for kinematic analysis of the 4-bar mechanism used in Canopy sport cars [6].

Mohammad Kurniadi Rasyid analyzed four design concepts of hinges which can be able to withstand loads without formatting or damaged [7]

Dr.A.J.Joshi proposed new design for hinge of the car door which ultimately served the purpose of supporting (holding it to chassis) as well as rapidly disassembled in case of emergency. [8]

Martin Muir demonstrated that with a moderate decrease in stiffness of door hinge, a substantial mass saving can be achieved on even a lightweight failure prone structure. [9]

Caner Guven et al designed an automotive hinge & analyzed by using FEA for the design requirements according to FMVSS206 and other specifications. Design was validated with the physical test results. [10]

Tufan Gurkan Yilmaz et al designed, a lightweight Aluminum door hinge instead of steel hinge for sustainable commercial vehicles where it's mass was reduced to 0.72 kg from 2.3kg (mass reduction - 65%) & prototyped it and successfully tested with physical test [11].

A. Elfasakhany et al proposed a new design of the automotive vertical door opening system (AVDOS) which can be overcame some drawbacks of the available design. The systems were designed to provide a wider door opening by using more swinging configuration, which gave more advantage for smaller vehicles since they had much smaller exit openings than the larger vehicles [12].

II. `ANALYTICAL METHOD

The Hinge design & optimization process is shown schematically. Design process of any part or component is evolved from above mentioned design stages in Product development. Each design stage is elaborated in details as below in Figure 1.

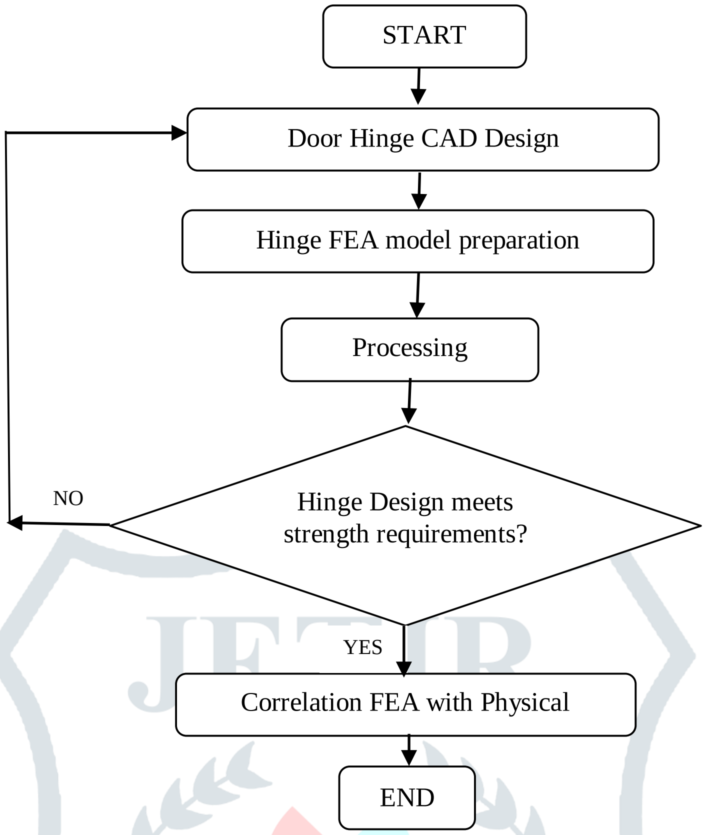

Figure 1: Hinge Design Process Flow Chart

2.1. Hinge Cad Generation

The baseline hinge is generated in CATIA V5 with the help of benchmarking process as shown in below Figure 2.The benchmarking process consists of checking the overall dimensions of any parts or components that are used in various passenger vehicles such as cars and figuring out the general dimensions of that specified parts or components.

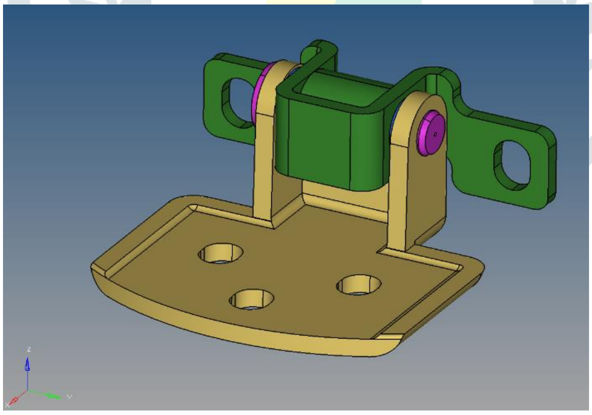

Figure 2: Baseline Hinge Cad Design

2.2 Test Procedure

The physical test set up of hinge static loading is described in the following Figure 3

A door hinge system is mounted on the test fixture as shown in the figure and this fixture is held in Universal Testing Machine (UTM).The load is applied very slowly i.e. 5 mm/min for both the longitudinal and lateral load cases.

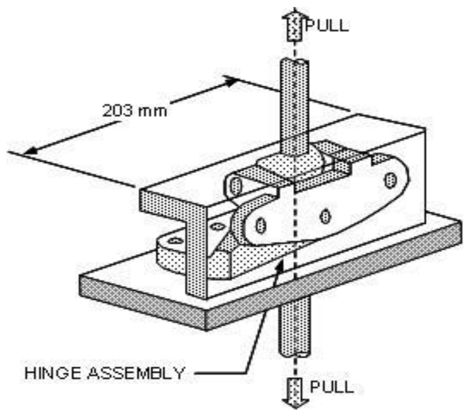

Figure 3: Single Hinge Test Fixture [8]

There are two types of Hinge loading as mentioned below

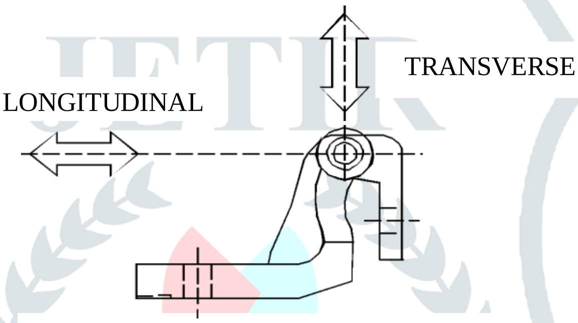

Figure 4: Types of Hinge Loading [8]

2.2.1 Longitudinal Loading: A vehicle passenger door hinge system, when tested under prescribed test procedure must be capable of withstanding an ultimate longitudinal load of 567.5kgf as shown in Figure 4.

2.2.2 Transverse Loading: A vehicle passenger door hinge system, when tested under prescribed test procedure must be capable of withstanding an ultimate transverse load of of 455kgf as shown in Figure 4.

2.3. Finite Element Model Preparation:

Baseline FE model is prepared in Hyper mesh. The parts are modeled with hexahedron and tetrahedron elements to exactly represent the geometry of Door Hinge. Average size of the element is maintained as 4mm and quality of the elements are checked and maintained as per crash standard modeling criteria. The no of solid elements observed in the model are approximately 5000.Loading ram is modeled to impart the load to the hinge system and connected to door side mounting bracket at the two hole locations. The materials and properties are assigned to every individual parts of Door Hinge.

2.4. Material Details:

The material used for Hinge system is S315MC with yield of 253MPa.

2.5 Loading and Boundary conditions:

All degrees of freedom of Body side mounting bracket are constrained & load is applied through loading ram as shown in Figure 5.

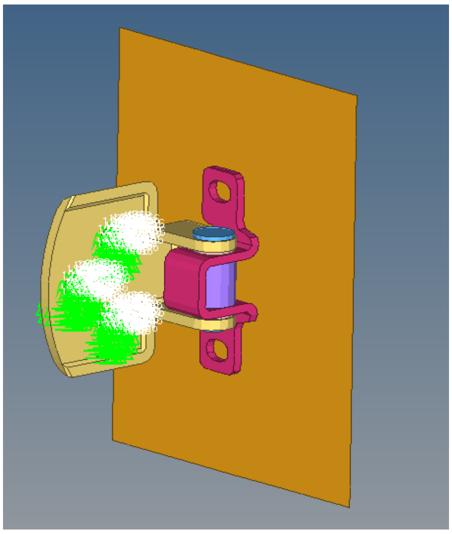

Figure 5: FEA Loading and Boundary conditions

3.0 Baseline Result Details

3.1. Longitudinal loading-Baseline

The von-Mises stress observed in baseline design is 317.2MPa in Longitudinal loading as shown in below Figure.6.

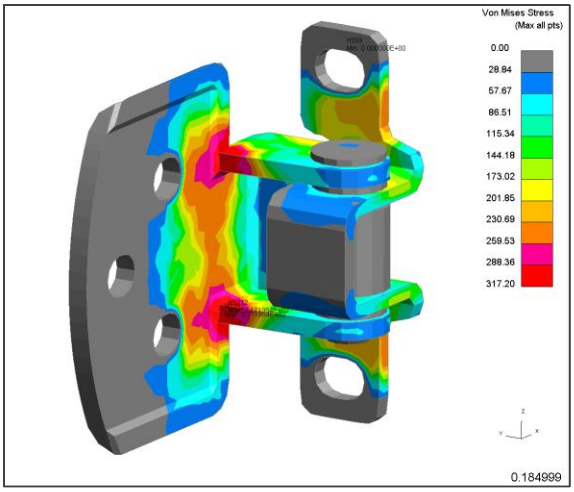

Figure 6: von-Mises stress plot of Hinge system

3.2. Lateral loading-Baseline

The von-Mises stress observed in baseline design is 316.6MPa in Lateral loading as shown in below Figure 7.

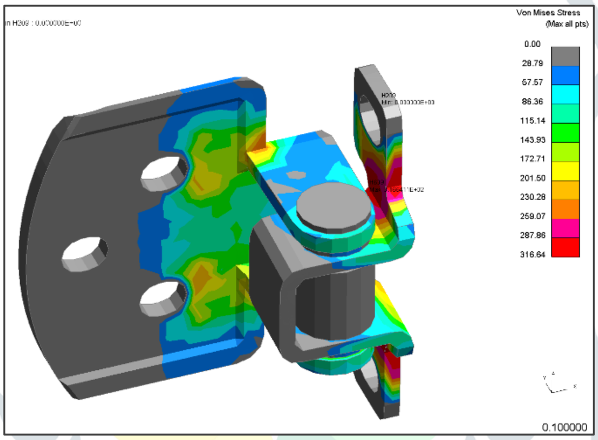

Figure 7: von-Mises stress plot of Hinge system

4.0 Design Modification

The Bodyside hinge mounting bracket is modified as shown in Figure 8.The bead is added along with the collar.

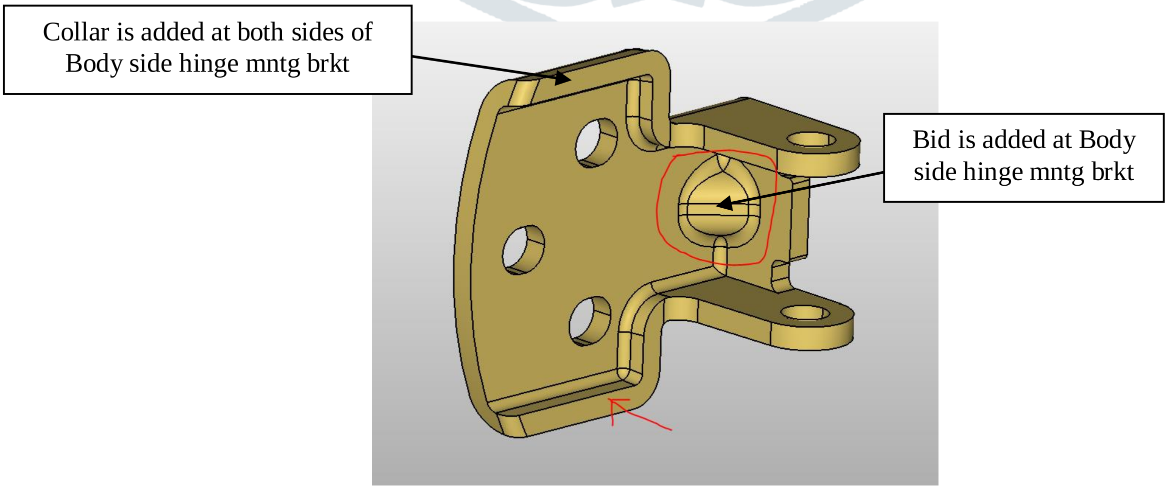

Figure 8: Modified design of Hinge system

5.0 Final Result Discussion

5.1. Longitudinal loading-Modified Design

The von-Mises stress observed in baseline design is 2302MPa in Longitudinal loading as shown in below Figure.6 which is less than yield strength of 253MPa.

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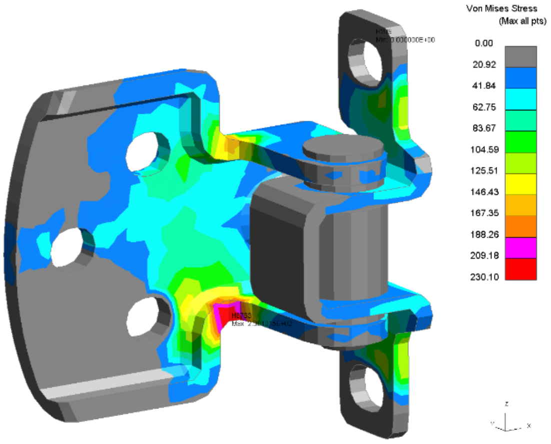

Figure 9: von-Mises stress plot of Hinge system

5.2. Lateral loading-Modified Design

The von-Mises stress observed in baseline design is 205.5MPa in Lateral loading as shown in below Figure 7 which is less than yield strength of 253MPa.

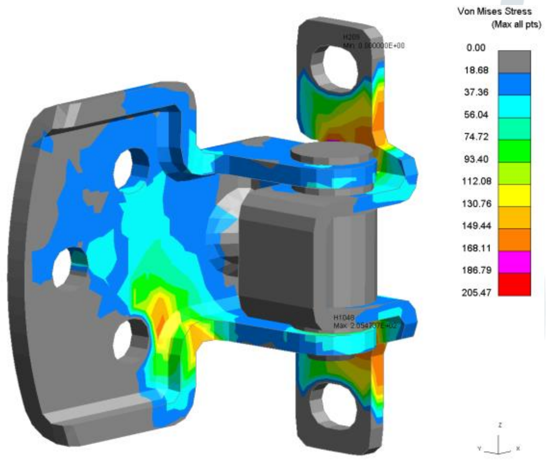

Figure 10: von-Mises stress plot of Hinge system

6.0. Conclusion:

Optimized design of automotive door hinge meets safety requirements of IS14225 test.

Future Scope:

Design optimization can be further done without affecting the performance of Hinge system.

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