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Wind-induced Stress Analysis of Front Bumper

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ABSTRACT
At high velocities, such as on highways, the relative velocity between the oncoming wind and side winds is very high. The high velocity winds that act on the bumper induce certain stresses on it. These stresses may cause deformation of the bumper; if this deformation exceeds a predesigned value, the functionality of the bumper may be hampered. This may result in safety issues and other design issues. In this paper, the effect and nature of these stresses have been quantified by conducting a wind-induced stress analysis on a model of the bumper. The bumper selected is that of Jeep Wrangler and the modelling is done on Creo 2.2. The CFD simulation and structural analysis is conducted on Ansys Workbench 15. The structural analysis and fluid flow data is summarized alongwith the deformation and induced stress values.

Keywords: *wind-induced stress analysis, Ansys Workbench 15.0, structural analysis, Jeep Wrangler*

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I. Introduction

The speedily increasing fuel prices along with the newly adopted strict regulations to control the emission of greenhouse gases have raised numerous constraints on the automobile manufacturers. SUV's especially are known for the higher drag coefficients due their square shaped body structure. Also, separated vortices in wake region, flow separation and reattachment, skin friction and vortex shedding affect the total aerodynamic performance [1-6]. Hence, the analysis of all the components of the vehicle with advanced tools is essential.

An optimum cross-section shape of front bumper was obtained using a computer program, which was developed using Castigliano's second theorem on beam theory. Impact analysis of the same was then done using aluminum. Aluminium was used as material to reduce the weight of the bumper [7]. Here, structural analysis of the bumper was not done.

A sandwiched structure bumper beam was designed and manufactured to get the same functional requirements as that of the original bumper beam of 2002 Jeep Wrangler. The materials used were aluminum foam core and glass fiber reinforced polypropylene. After performing three-point bending stresses, the results obtained indicated that lightweight materials can be used for the applications where both strength and shock absorbing characteristics is required [8].

Another study was done where different materials were used to test the bumper in frontal collisions different speeds, using finite element method. The materials used were alloy steel, acrylonitrile butadiene styrene(ABS) plastic, polyetheremide (PEI) plastic. It was observed that stress generated due to impact was lesser in ABS plastic [9].

JavadMarzbanrad et al. carried out analysis on automotive bumper in low speed frontal crashes. Out of the three materials used for testing, namely aluminium, glassmac thermo-plastic (GMT) and high strength sheet moulding compound (SMC), the last one showed minimum bumper deflection, highest elastic strain energy, and uniform impact force and stress distribution [10].

A new modelling technique boundary element method (BEM) was used for the stress analysis of front bumper. This new method was simpler and required lesser time than the conventional FEM method. The meshing required in complex shapes was also easier [11].

At high speeds, the wind induced stresses are generated at the bumper surface. In this study structural analysis of bumper due to wind induced stresses is done.

II. Methodology

The following are the important stages through which the work is completed:

- Selection of car model and obtaining the dimensions of the car and bumper for the same.
- Modeling of bumper and external modelling of the car using Creo 2.2 based on the dimension obtained in step 1.

- Assembly of car and bumper to form the bumper assembly.
- CFD flow analysis of bumper assembly using Ansys Workbench 15 (Fluent) at the design velocity.
- Obtaining the overall pressure distribution acting on the front of the vehicle from the flow analysis conducted in step 5.
- Structural analysis of bumper assembly in Ansys Workbench 15 using the pressure distribution obtained in step 5.
- Obtaining induced stress values and total deformation values based on the analysis conducted in step 6.

III. Modeling of Bumper and Car

The CAD modeling of the bumper is done using Creo Parametric 2.2. The bumper selected is the front bumper of Jeep Wrangler. This bumper is selected due to two reasons; for highway driving, SUVs are the most commonly used vehicles and among SUVs, the Jeep Wrangler is selected due to ease of obtaining the dimensions. The dimensions of the bumper of Jeep Wrangler are depicted in Fig. 1 below. Fig. 1 is used as the basis for the CAD model.

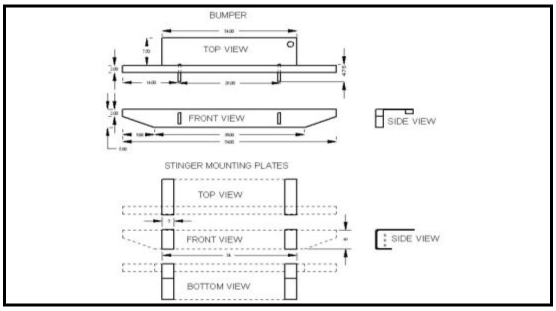

Fig. 1. Dimensions of bumper model

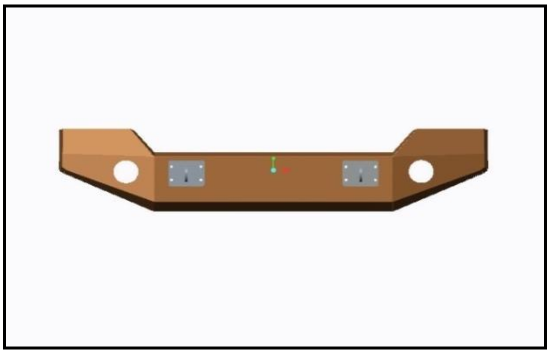

Fig. 2. CAD Model of bumper in Creo 2.2

Fig. 2 shown above depicts the CAD model of the bumper modeled in Creo 2.2. To analyze the flow more accurately and closer to practicality, CAD modeling of the car is done. This car body acts as a bluff body behind the bumper. Fig. 3 shows the assembled diagram of the bumper with car body. To reduce the computation time, the bumper-car assembly is sliced at 1/3rd of the overall length. This modified assembly is imported into Ansys Workbench 15.0 for further analysis.

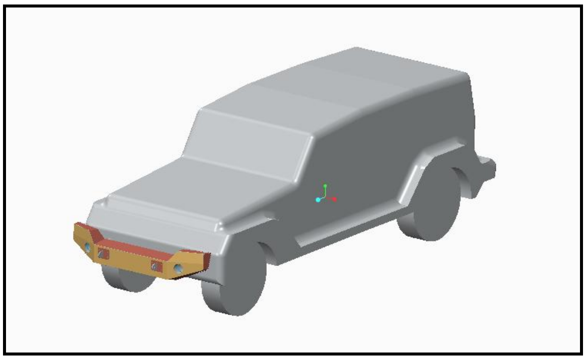

Fig. 3. Assembly of bumper and car model

1. CFD flow analysis

The CAD model of the bumper assembly is analyzed to simulate the flow field around the vehicle at the velocity as specified above. A domain is created to generate the mesh for the flow field around the vehicle. In order to reduce the computation time required and to increase the accuracy of results in the area of the bumper assembly specifically, the domain is divided into three sections; one section of the domain contains the bumper assembly where the results are to be obtained and the main purpose of the other two sections is to simulate the flow accurately. The dimensions of the domain are shown in Table 1 and the image of the domain is shown in Fig. 4 below.

Table 1. Domain Dimensions

Sr. No.	Parameter	Dimension (mm)
1	Length	7000
2	Width	6000
3	Height	4000

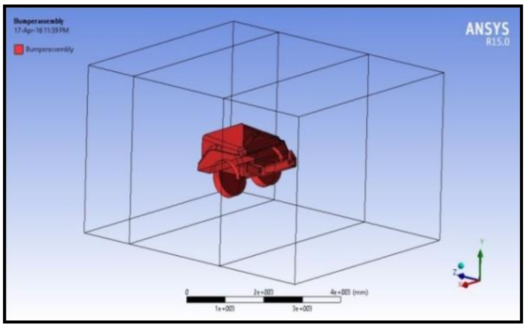

Fig. 4. Flow domain

The mesh is more refined in the region of the bumper assembly as compared to the other two regions so that the accuracy of the pressure data is maintained. The re-ordered mesh inclusive of the sections is shown in Fig. 5 below. The mesh cell size in the two sections without the bumper assembly is 100 mm while the mesh cell size in the bumper assembly is 50 mm. A detailed view of the meshing for the bumper assembly is shown in Fig. 6 below.

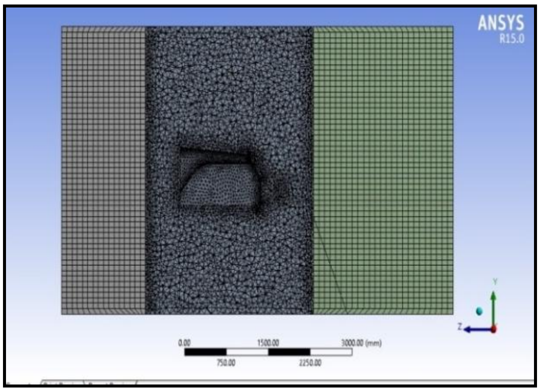

Fig. 5. Meshed domain

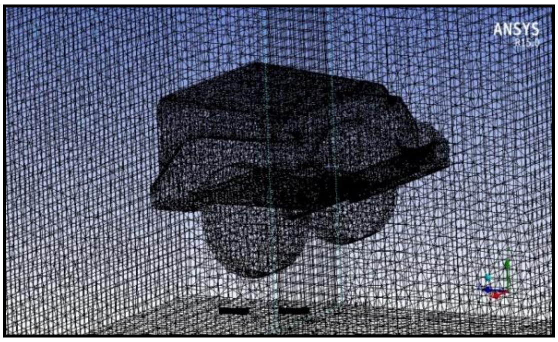

Fig. 6. Detailed view of bumper assembly mesh

The effect of pressure acting on the front and side surfaces of the bumper is simulated and the pressure contours are obtained as shown in Fig. below. As can be observed from the Fig. 7, two stagnation pressure zones are created in the front of the bumper assembly. One region is the stagnation caused by the bumper and the other one is the stagnation caused due to the front end of the vehicle. The stagnation gives rise to a high pressure area in front of the bumper, where the maximum pressure that acts on the bumper is obtained.

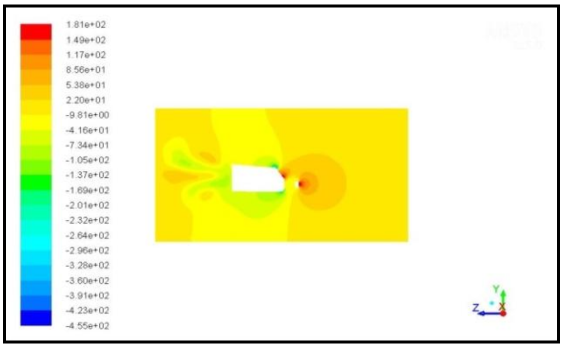

Fig. 7. Pressure contours on longitudinal cut-planes

As can be seen from the Fig. 8 below, the value of pressure at the stagnation region is approximately 180.95 Pa as compared to the low pressure region around the bumper, where the pressure is approximately 8.56 Pa. The pressure acting on the side faces of the bumper is much lower as compared to the front face of the bumper. This is due to the wake region formed when the flow is deflected around the side of the bumper. The pressure value on the side faces of the bumper is approximately 53.77 Pa.

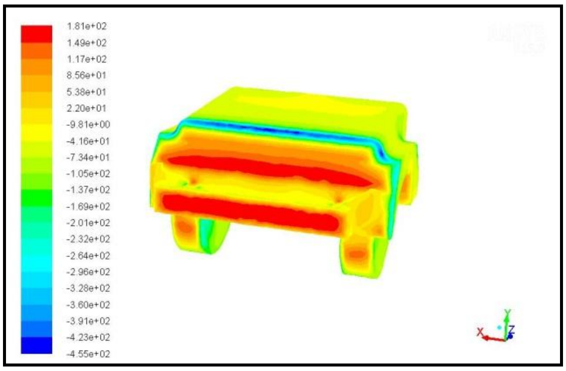

Fig. 8. Pressure contours on the bumper assembly

The variation of the pressure acting on the bumper with respect to the time or the flow field is required to be monitored since the pressure fluctuations caused due to fluctuating flow field may result in inaccuracy of the obtained values. In order to avoid this, monitors are placed on the front and side face as a uniform pressure distribution. These monitors obtain the differing pressure values as the flow progresses and plot the results of the same in the form of Pressure versus Iterations of the simulation. The pressure versus iterations graph for the front face is shown in Fig. 9 and the same for the side faces is shown in Fig. 10.

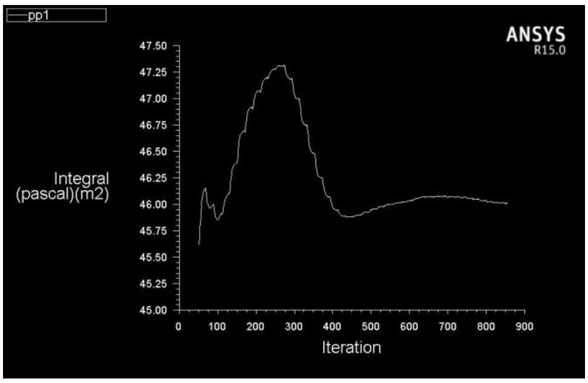

Fig. 9. Pressure versus iterations graph for front face

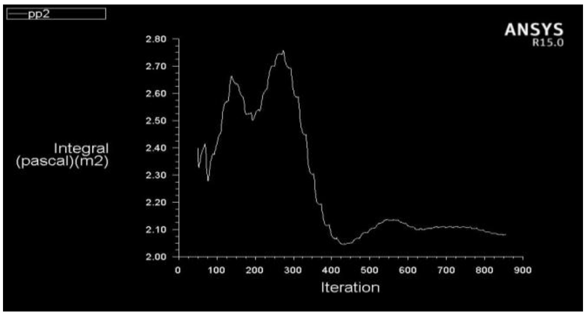

Fig. 10. Pressure versus iterations graph for side face

IV. Structural Analysis Results

The structural analysis was carried out after obtaining the pressure distribution from CFD analysis. The pressures applied on the bumper for structural analysis were the maximum values obtained from pressure distribution. The pressure applied on front bumper was 180.95 Pa and on side faces was 59.77 Pa. The attachment of the bumper to the front hood of the vehicle was given fixed support. The deformation on the bumper after structural analysis is shown in Fig. 11. It can be seen that the front experiences 0.0002247 mm as maximum deformation. The side faces almost has no effect of wind. The equivalent stress generated in the bumper is shown in Fig. 12. The Equivalent Von-Mises stress generated in the bumper is 0.21477 MPa. Maximum stress is created at faces where almost no deformation is present because deformation absorbs the stress. Average stress is created at the center of the bumper. The wind induced stresses created will have very little effect on the functioning of the bumper.

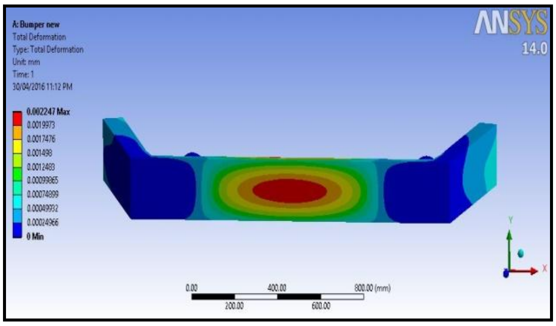

Fig. 11. Deformation on bumper

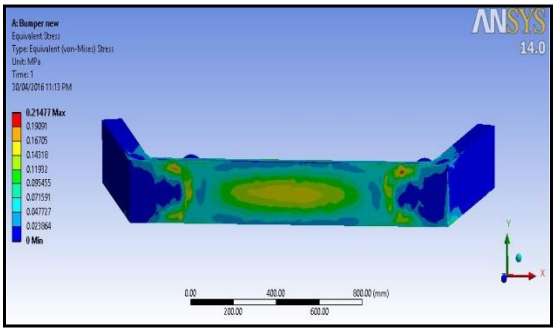

Fig. 12. Equivalent stress on bumper

V. Conclusion

- The selected bumper was modelled according to the obtained dimensions and analyzed for both the flow field (CFD analysis) and for stresses and deformations (Structural analysis).
- The pressure distribution on the front and side faces was obtained from the CFD analysis conducted at a vehicle speed of 60 km/hr.
- Pressure values obtained were 180.95 Pa on the front face and 59.77 Pa on the side faces.
- The obtained pressure values were used in Static structural analysis to calculate the Equivalent Von-Mises stresses and maximum deformation.
- The maximum deformation obtained was 0.0002247 mm and the Equivalent stress generated in the bumper was 0.21477 MPa.

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