Design and Analysis of Chassis and Body in White (BIW) in Automation Using Six-Sigma and Optimization Techniques

Rahul Pratap Yadav

P.G. Student, IMS Engineering College, Ghaziabad, India

Abstract: ***A chassis composed of an internal framework that holds up a man-made object in its production and use. An example of a chassis is the under part of a motor vehicle, consisting of the frame. If the running gear such as wheels and transmission, and sometimes even the driver's seat, are included then the assembly is described as a rolling chassis. On the other hand Body in white or BIW refers to the stage in automotive design or automobile manufacturing in which a car body's sheet metal components have been welded together — but before moving parts (doors, hoods, and deck lids as well as fenders), the motor, chassis sub-assemblies, or trim (glass, seats, upholstery, electronics, etc.) have been added before painting. The project was aimed to design and analysis of chassis and body in white using model and crash test examination by proper utilization of six-sigma, dimension-mass optimization techniques. The modeling and analysis is done by UG NX, SOLIDWORKS and ANSYS. By analyzing the frequency mode defect can easily detect to fix the damages.***

Keywords: Chassis, Body in White (BIW), Optimization, Six-Sigma, Crash test.

1. Introduction

Body on frame is an automobile construction method. That supports a divide body to a rigid frame that works as a foundation for the drivetrain and it was the original method in automobile construction, and extend to this day. Originally frames were made of wood, but steel ladder frames became common in the 1930s. It is technically not equivalent to newer unibody designs method, and almost no recent vehicle uses it. In the case of automobile, the expression rolling chassis means the frame plus the powertrain like engine, driveshaft, transmission, suspension and differential. A body, which is usually not essential for integrity of the structure, is built on the chassis to complete the vehicle.

2. Design of Chassis

A vehicle frame, also known as its *chassis*, is the main sustain structure of an automobile vehicle to which all other elements are attached, similar to the skeleton of a design. Typically the material used to construct vehicle chassis and frames is carbon steel; or aluminum alloys to achieve a more light weight construction. In the case of a separate chassis, the frame is made up of structural elements called the *rails* or *beams*.

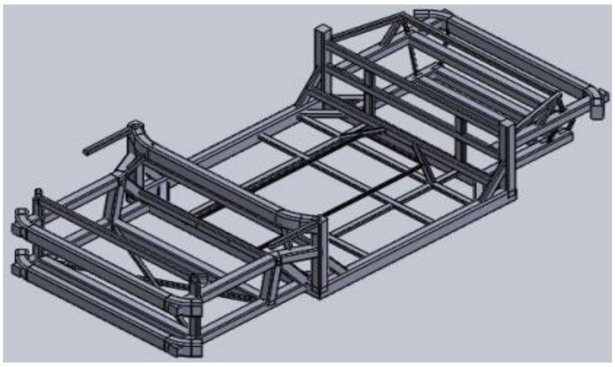


Figure 1: Chassis isometric view

3. Design of Body in White(BIW)

In car design, the Body in White shape belongs to the phase in which the final contours of the car body are worked out, in preparation for ordering of the expensive manufacturing stamping die. Extensive computer simulations of crash worthiness, manufacturability, and automotive aerodynamics are required before a clay model from the design studio can be converted into a Body in White ready for production. Factories may offer BIW cars to racers, who then may replace up to 90% of the car with aftermarket parts. Frequently racers must apply to purchase one of these cars.

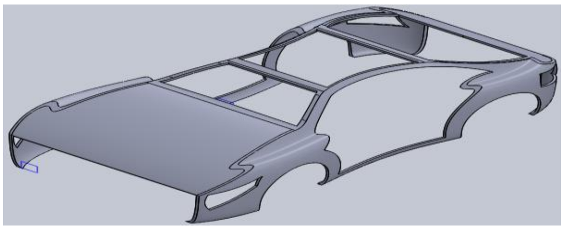


Figure 2: BIW isometric view

4. Design Specification

Chassis with frame Length: 2000mm, Width: 4450mm, Height: 1150mm.

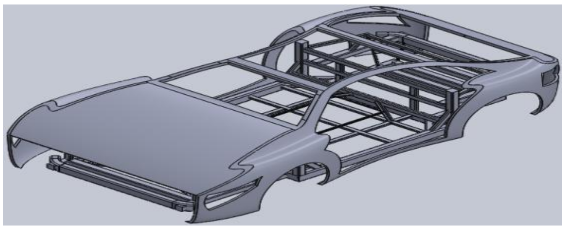


Figure 3: Assembly of chassis and BIW isometric view

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

5. Model Analysis

The purpose of modal analysis in structural mechanics is to resolve the natural mode frequencies and shapes of a design or structure during free vibration. It is general to use the finite element method (FEM) to execute this analysis because, like other computation using the FEM, the object being analyzed can have arbitrary shape and the results of the calculations are satisfactory and acceptable. The physical interpretation of the eigenvalues and Eigen vectors which come from solving the system are that they represent the frequencies and corresponding mode shapes. Sometimes, the only desired modes are the lowest frequencies because they can be the most prominent modes at which the object will vibrate, control all the higher frequency modes.

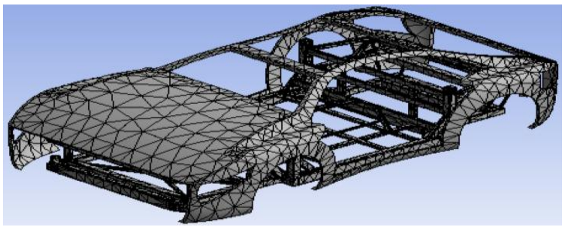
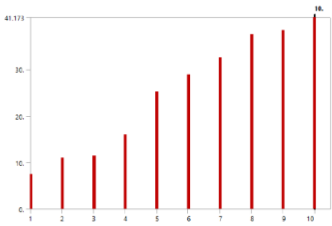


Figure 4: Frame and BIW Mesh isometric view



Mode	Frequency [Hz]
1.	7.4368
2.	10.999
3.	11.505
4.	16.033
5.	25.266
6.	28.906
7.	32.533
8.	37.549
9.	38.334
10.	41.173

Figure 5: Frequency mode graph and plot list

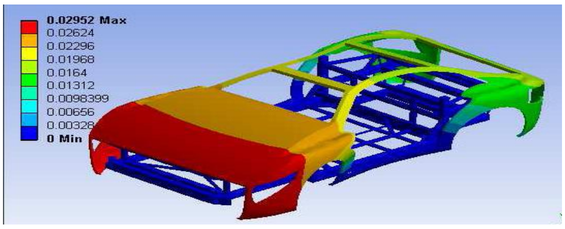


Figure 6: Total deformation frequency mode 1

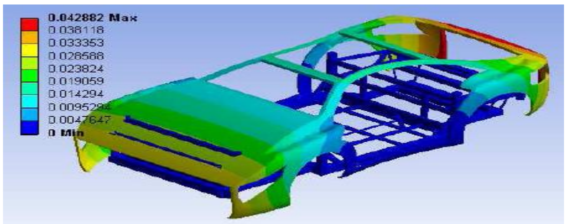


Figure 7: Total deformation frequency mode 2

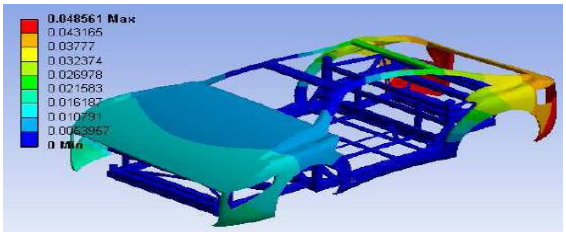


Figure 8: Total deformation frequency mode 3

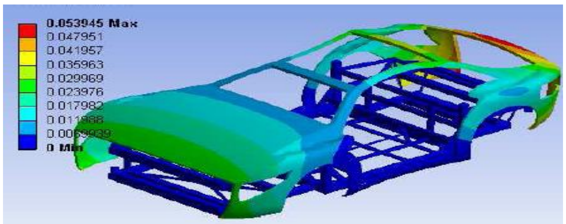


Figure 9: Total deformation frequency mode 4

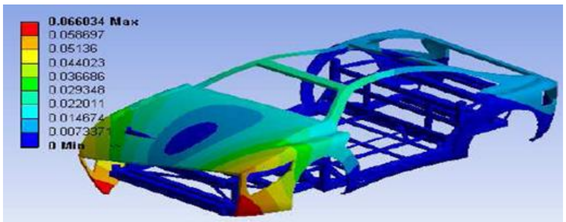


Figure 10: Total deformation frequency mode 5

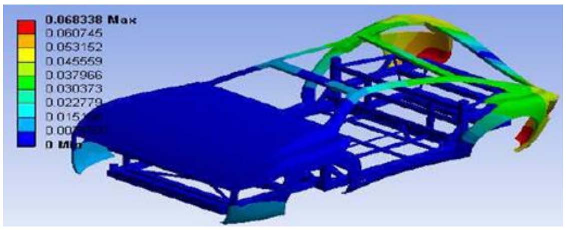


Figure 11: Total deformation frequency mode 6

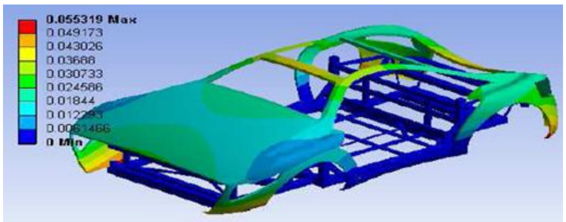


Figure 12: Total deformation frequency mode 7

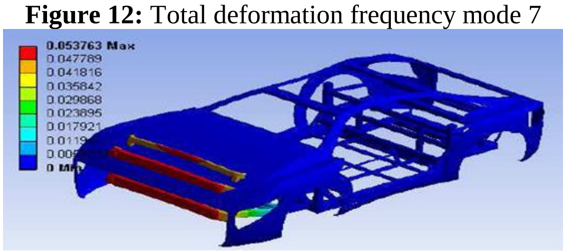


Figure 13 : Total deformation frequency mode 8

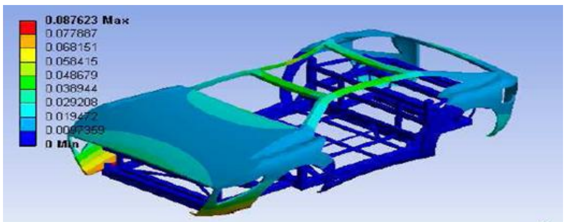


Figure 14: Total deformation frequency mode 9

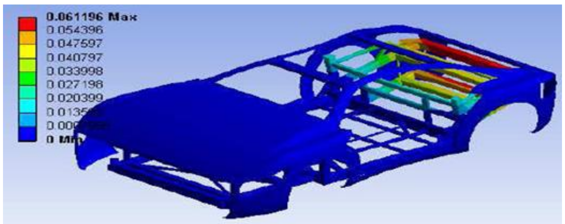


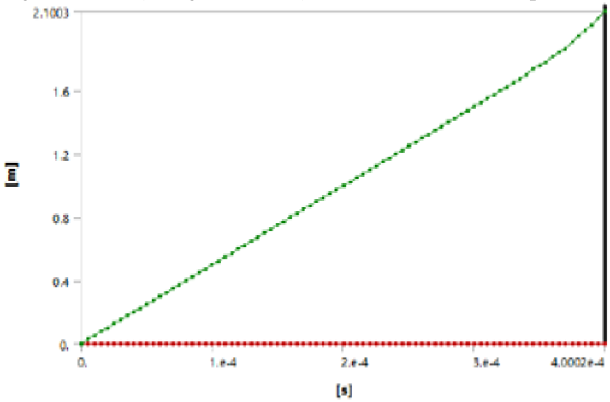
Figure 15: Total deformation frequency mode 10

It is also possible to test a physical object to determine its natural frequencies and mode shapes. This is called an Experimental Modal Analysis. The results of the physical test can be used to calibrate a finite element model to determine if the underlying assumptions made were correct.

Model characteristic the natural frequencies and the mode shape of the design, investigating the mounting locations of components on the design and observing the response under static loading conditions. The first ten natural frequencies of the chassis are below 50 Hz and vary from 7.4368 to 41.173Hz. Maximum deformation varies from 2.952e-002 m to 6.1196e-002 m. And alternating stress varies from 3.999e+009 to 8.62e+007pa.

6. Crash Analysis

A **crash simulation** is a virtual recreation of a destructive crash test of a car or a highway guard rail system using a simulation in order to examine the level of safety of the car and its occupants. Crash simulations are used by concept designer and automakers during computer-aided engineering (CAE) analysis for crash worthiness in the computer-aided design (CAD) process of modeling new cars. During a crash simulation, the kinetic energy, or energy of motion, that a vehicle has before the impact is transformed into deformation energy, mostly by plastic deformation (plasticity) of the car body material (Body in White), at the end of the impact.



Graph 1: Total deformation

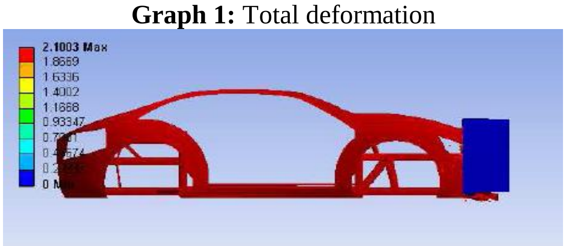
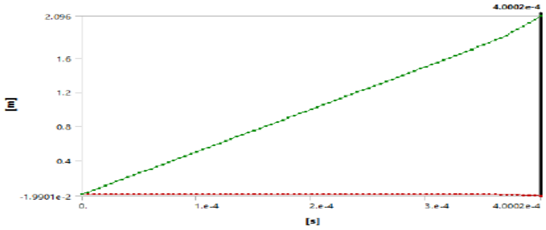


Figure 16: Total deformation



Graph 2: Directional deformation

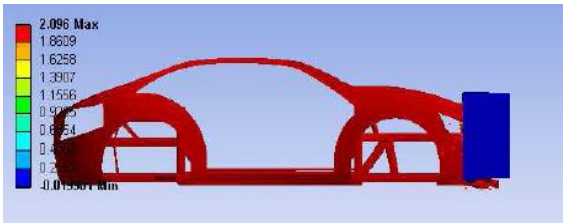
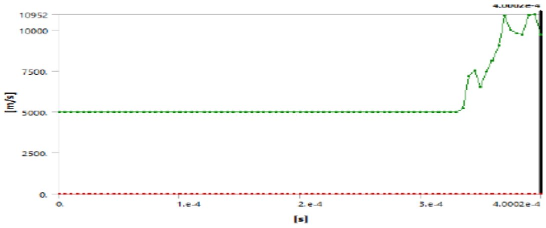


Figure 17: Directional deformation



Graph 3: Total velocity

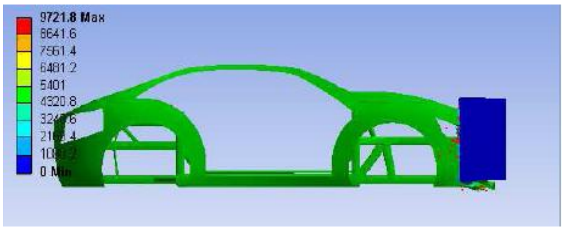
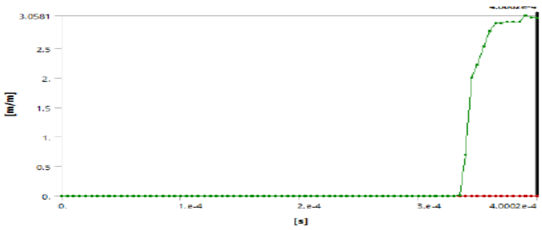


Figure 18: Total velocity



Graph 4: Equivalent elastic strain

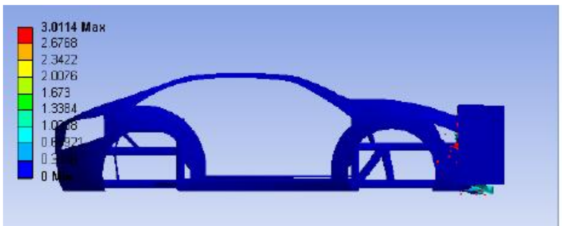
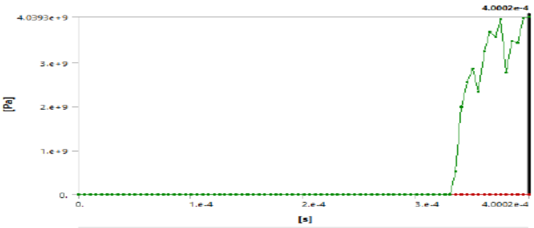


Figure 19: Equivalent elastic strain



Graph 5: Equivalent stress

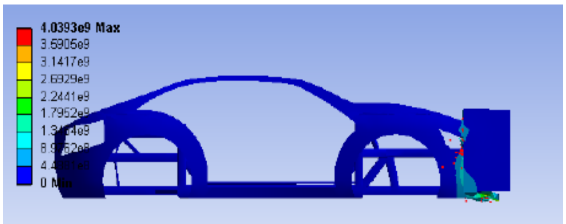
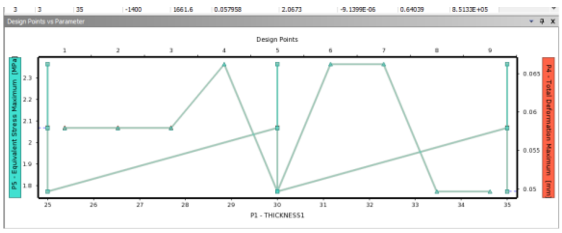


Figure 20: Equivalent stress

Data obtained from a crash simulation indicate the capability of the car body or guard rail structure to protect the vehicle occupants during a collision (and also pedestrians hit by a car) against injury. Important results are the deformations (for example, steering wheel intrusions) of the occupant space (driver, passengers) and the decelerations (for example, head acceleration) felt by them, when 5000m/s velocity is applied than solution is calculated as total deformation is 2.1003m, directional deformation is 2.096m, total velocity is 9721.8m/s, equivalent elastic strain is 3.0114m/m, equivalent stress is 4.0393e+009 Pa.

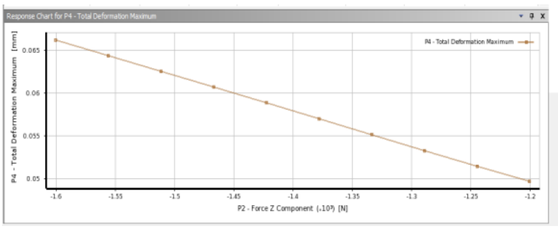
7. Optimization Technique

In the simplest case, an optimization problem consists of minimizing or maximizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding "best available" values of some objective function given a defined domain (or a set of constraints), including a variety of different types of objective functions and different types of domains.

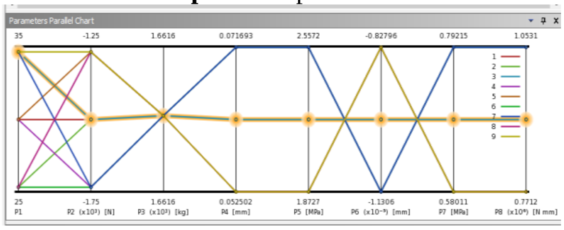


Graph 6: Design point vs. parameters chart

In mathematics, engineering, computer science, economics, or management science, mathematical optimization is the selection of a best element (with regard to some criteria) from some set of available alternatives. And optimization domain is P1 - thickness1 25mm to 35mm and P2 - Force Z Component (N) -1600N to -1200N.

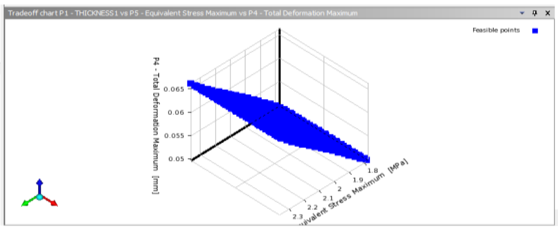


Graph 7: Response chart

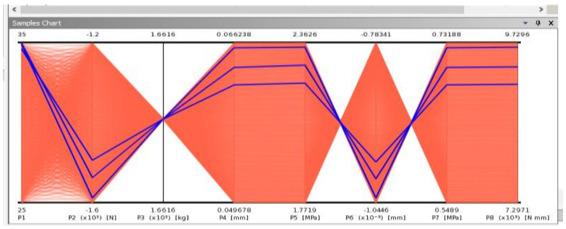


Graph 8: Parameters parallel chart

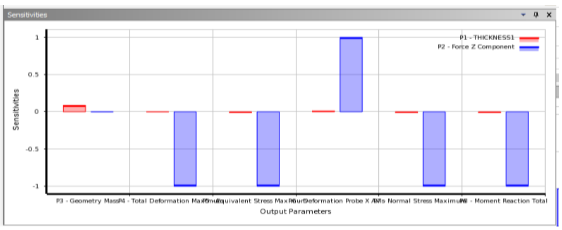
According to optimization design of experiment result is P1 - thickness1 varies from 25 to 35mm, P2 - Force Z Component (N) -1600N to -1200N, P3 - Geometry Mass (kg) is 1661.1, P4 - Total Deformation Maximum (mm) 0.0496 to 0.0662, P5 - Equivalent Stress Maximum (MPa) 1.771 to 2.362, P6 - Deformation Probe X Axis (mm) -9.1398E-06 to -1.0447E-05, P7 - Normal Stress Maximum (MPa) 0.5489 to 0.7318, P8 - Moment Reaction Total (N mm) 851332.10 to 972950.98.



Graph 9: Trade off chart



Graph 10: Sample chart



Graph 11: Sensitivity chart

According to charts and optimization techniques candidate point is

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Table 1: Candidate/Optimization point

	Candidate A	Candidate B	Candidate C
P1 - THICKNESS1(mm)	34.925	34.965	34.625
P2 - Force Z Component (N)	-1587.69	-1537.6	-1493.94
P3 - Geometry Mass (kg)	1661.59	1661.59	1661.59
P4 - Total Deformation Maximum (mm)	0.0657	0.0636	0.061
P5 - Equivalent Stress Maximum (MPa)	2.347	2.280	2.214
P6 - Deformation Probe X Axis (mm)	-1.036E-05	-1.005E-05	-9.775E-06
P7 - Normal Stress Maximum (MPa)	0.7262	0.7035	0.6835
P8 - Moment Reaction Total (N mm)	966023.23	936777.14	910113.66

Topology optimization is, in addition, concerned with the number of connected components/boundaries belonging to the domain. Such methods are needed since typically shape optimization methods work in a subset of allowable shapes which have fixed topological properties, such as having a fixed number of holes in them. Topological optimization techniques can then help work around the limitations of pure shape optimization.

8. Six Sigma:

Six-sigma is a set of tools and techniques for procedure improvement. It was developed by Motorola in 1986. Jack Welch made it central to his business strategy at General Electric in 1995. Today, it is used in many industrial sectors. Six-sigma pursue to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in business and manufacturing processes. It uses a set of quality management methods, mainly empirical, statistical methods, and creates a special infrastructure of people within the organization who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified value targets, for example: reduce process cycle time, reduce pollution, reduce costs, increase customer satisfaction, and increase profits.

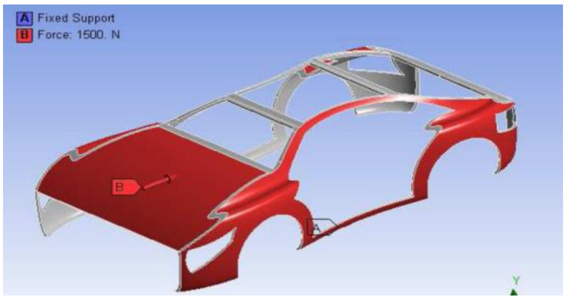


Figure 21: Static structure

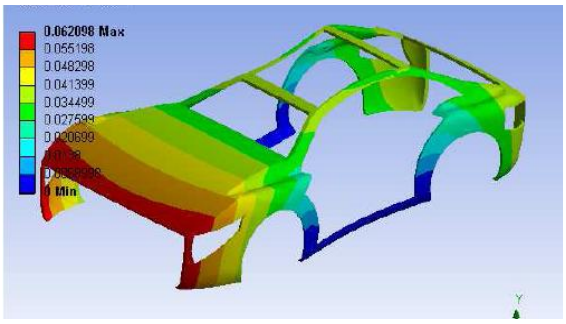


Figure 22: Total deformation

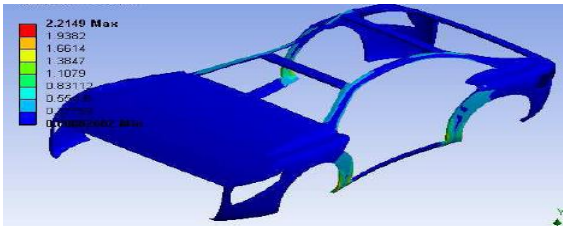


Figure 23: Equivalent stress

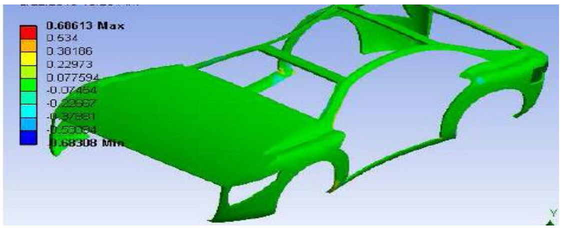
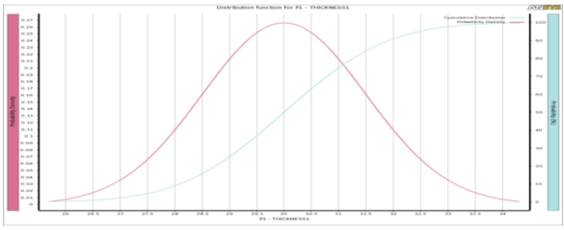
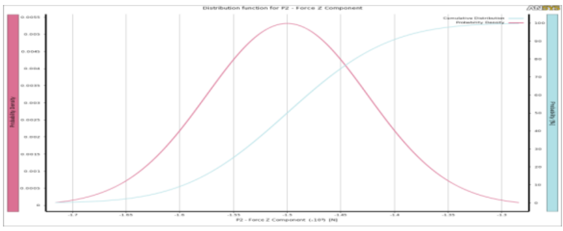


Figure 24: Normal stress

Applied force is -1500N (-Z direction). So that result is calculated as maximum total deformation is 6.2098e-002 mm, equivalent stress is 2.2149 MPa, normal stress is 0.68613 MPa.

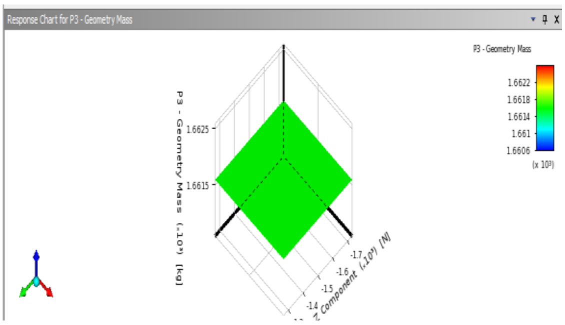


Graph 12: Distributed function for thickness

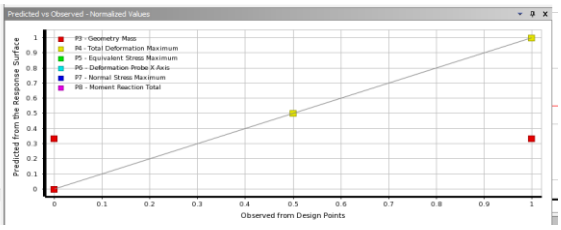


Graph 13: Distributed function for thickness

According to distributed function graph P1 – thickness1 probability- Density Function varies from 0.0042 to 0.2659 and Cumulative Distribution Function varies from 0.0020 to 0.998 and P2 - Force Z Component- Probability Density Function varies from 0.0053 to 8.4535E-05 and Cumulative Distribution Function varies from 0.0020 to 0.998.

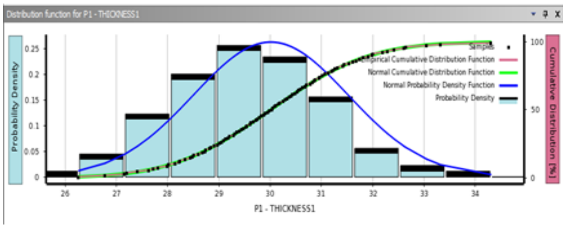


Graph 14: Response point chart

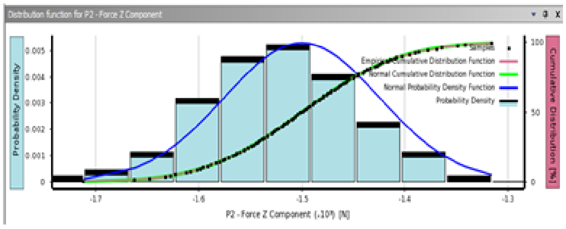


Graph 15: Goodness of fit matrices chart

According to six sigma approach output parameters are P4 - Total Deformation Maximum (mm) 0.0525 to 0.0726, P5 - Equivalent Stress Maximum (MPa) 1.8727 to 2.57, P6 - Deformation Probe X Axis (mm) -1.1305E-05 to -8.2796E-06, P7 - Normal Stress Maximum (MPa) 0.58012 to 0.79215, P8 - Moment Reaction Total (N mm) 771205.082 to 1053078.008.



Graph 16: Distribution function for thickness



Graph 17: Distribution function for force z component

According to six sigma analysis design data can be define in term of probability which is varies from 0.0069 to 0.9930 and sigma level varies from -2.4620 to 2.4620, P1 - Thickness1 26.258mm to 34.311mm, P2 - Force Z Component -1711.43N to -1315.66N, P3 - Geometry Mass 1661.59Kg, P4 - Total Deformation Maximum 0.0539mm to 0.0724mm, P5 - Equivalent Stress Maximum 1.92MPa to 2.56MPa, P6 - Deformation Probe X Axis -1.117E-05mm to -8.5893E-06mm, P7 - Normal Stress Maximum 0.595MPa to 0.7837MPa, P8 - Moment Reaction Total 798460.63mm to 1042318.29mm

The term Six Sigma originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a *sigma* rating indicating its yield or the percentage of defect-free products it creates. A six sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects.

9. Conclusion

With high force and speed using Shape optimization and six sigma approaches, here is the complete design of chassis and BIW. And we have effective result of design using different techniques and approaches. And it provides a unique design solution; require less space with compact dimension by effective utilization of optimal control theory. The typical problem is to find the shape which is optimal in that. It minimizes a certain cost functional while satisfying given constraints. Six-sigma seeks to improve the quality of process outputs. SOLIDWORKD, UG NX and ANSYS software is used for this purpose. And the graph and plots of velocity magnitude with time define the variety of conditions and results.

10. Further Possible Work

There is many more method that can formulate to know about whether design and mechanism will work properly/effectively or not such as structure analysis, vibration, linear and nonlinear buckling and fatigue analysis etc. So these methods can be used to improve other factors of car body frame and BIW.

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References

[1] http://en.wikipedia.org/wiki/Chassis
[2] http://en.wikipedia.org/wiki/Body_in_white
[3] http://en.wikipedia.org/wiki/Body-on-frame
[4] http://en.wikipedia.org/wiki/Monocoque
[5] http://en.wikipedia.org/wiki/Vehicle_frame
[6] http://en.wikipedia.org/wiki/Vehicle_frame
[7] http://en.wikipedia.org/wiki/Six_Sigma
[8] http://en.wikipedia.org/wiki/Crash_simulation
[9] http://en.wikipedia.org/wiki/Modal_analysis_using_FE M
[10] http://en.wikipedia.org/wiki/Mathematical_optimization
[11] http://en.wikipedia.org/wiki/Shape_optimization12
[12] Automobile Engineering Vol.1-Vol.2, Dr. Kripal Singh, Standard publication distributors.