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Analysis of Failure of Body Control Module Under Various Impact and Vibration Loading

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Abstract

The Body Control Module regulates the operation and coordination between the different parts of the car also by using signals of some sort. The various electronic parts of the vehicle are actually controlled by a Body Control Module – from the car light to the simple door locks; each part has a module that controls it. In today's automotive setups, these modules are operating under a single assembly – they are now controlled by the Body Control Module. It may seem like the module performs a very complex function. Hence this Body Control Module has been protected from the damage during handling and vehicle running condition. This Body Control Module is subjected to various loading conditions such as vibration loading, Impact loading, mechanical shock. One of the case studies is doing to modify the existing Body Control Module. These modifications are carried out by using Computer Aided Engineering approach and verified by the experimental results. The software being used for the simulation is ANSYS and Ls-DYNA/explicit method

Keywords: Body Control Module, Impact, Vibration Loading, Frequency, Engine RPM

1. Introduction

The Body Control Module regulates the operation and coordination between the different parts of the off-highway vehicle also by using signals. The various electronic parts of the vehicle are actually controlled by a Body Control Module. It performs a very complex function. Hence this Body Control Module has been protected from the damage duringworking condition. This Body Control Module is subjected to various loading conditions such as vibration, Impact & creep loading. The Body Control Module design is used for off highway vehicle. In New product development cost and time is very important. Simulations technique is playing important role with testing. When concept of new design BCM considered for off highway vehicle, design should stand under high vibration and structural loading because of the higher engine RPM and working condition. The design should be such that it should withstand these forces in static as well as dynamic conditions and also the design should be feasible for the manufacturing. One particular area that can be applied throughout the whole development process is structural & Material optimization. Based on previous study of the designer this BCM part generally not optimized every times. These modifications are carried out by using Computer Aided Engineering approach and verified by the experimental results. The software being used for the simulation is ANSYS and Ls-DYNA/explicit method.

In case of vibration loading, the vibrations induced on Body Control Module are engine vibration and road vibration. The natural frequency of Body Control Module is above 100 Hz as the engine running at 2600 rpm.

For the impact loading (Drop testing), the Body Control Module is dropped from a height

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of one meter on the concrete ground. The existing Body Control Module is damaged when it is dropped from one meter height during handling. The care is to be taken that the dropped Body Control Module should not break at five locations. These five locations are; 1) Leg drop, 2) Corner drop 3) Side drop 4)Cover drop 5) Base drop.
IEC regulations are used for defining testing parameters and conditions during modification of the Body Control Module. These IEC regulations are as follows;

1. Random Vibration for Vehicle Body Mounted Equipments – IEC 68-2-64;
2. Drop Test (Free Fall) Test – IEC 68-2-32;
3. Mechanical Shock Test – IEC 68-2-27.

2. Literature review

2.1. Vibration Loading

Hong Sustudied “Vibration Test Specification for Automotive Products Based on Measured Vehicle Load Data” Source: SAE 2006-01-0729 [2]. This engineering paper help to justify the vibration test load data for co-relation of automotive products based on the vehicle data. Traditionally in automotive industry, load specifications for design validation tests are directly given by OEMs, which are generated based on an envelop of generic customer usage profiles. The generic test load specifications are, in many cases, over-specified, which may sometimes lead to a different failure mode other than that of the field. In recent years there are many occasions that a proposed load specification for a particular product is requested. For typical vehicle test load specification is generated based on measured data at its particular location, which contains more realistic time domain load levels and frequency contents. The benefits from a defined specification for a particular product, as compared with the generic ones, include avoidance of an unnecessary over-design and different failure modes from the field, and thus cost reduction in product development for both OEMs and suppliers. The measured load information providing the data for body parts and engine mounting parts.

2.2. Effect of Impact loading

Min-Chun Pan, Po-Chun Chen studied “Drop simulation/experimental verification and shock resistance improvement of TFT–LCD monitors” Source: Microelectronics Reliability 47 (2007) 2249–2259 (Science Direct) [3]. This paper gives description about developing a reliable procedure for evaluating the performance of TFT–LCD monitors in drop circumstances. For that International Electro-technical Commission (IEC) regulations are used for drop test conditions. Based on IEC regulations, one meter drop height is used and three modifications are proposed and verified to modify TFT–LCD monitors in drop test. Also, this paper gives an effective drop simulation technique to recover the drawbacks of only using experimental approach. In this study a task of drop simulation, experimental validation and design modifications are perform to improve shock resistance for TFT–LCD monitors.

Masaaki TSUTSUBUCHI, Tomoo HIROTA, Yasuhito NIWA, Tai SHIMASAKI studied “Application of Plastics CAE: Focusing on Impact Analysis” Source: Sumitomo Chemical Co., Ltd. Plastics Technical Center [4]. This paper gives information about the plastic parts, which do not have to possess great strength, but high impact absorbing performance in order to prevent the occurrence of injury to a human body at the time of a collision is often demanded for the protection of occupants and pedestrians. Also, a drop-test analysis of mobile devices is conducted with the purpose of evaluating a phenomenon that occurs in an extremely short period of time that cannot be fully understood by a mere experiment. In that the relationship between plastic strain at failure and the strain rate under the conditions of rate and temperature at which the specimen would fracture after yielding and before the occurrence of necking. Such obtained data is often used for prediction of the fracture behavior of specimens during impact analysis.“Impact and plastics”, Source: Zeus, Technical Newsletter. This paper gives information about failure under impact is one of the main failure mechanisms for plastics. Under the impact plastic surface may get fail and the study of fracture surfaces is called Fractography. This Fractography reveals a distinct difference between brittle and ductile fracture surfaces of plastic material.Impact failure of plastics is always brittle failure. In this paper testing for impact performance are given. Impact testing measures the amount of energy used to fracture the material and is relatively easy to perform. The most common methods used are izod impact testing, charpy impact testing, falling dart impact testing and tensile impact testing. From these test methods, amount of impact energy required to fracture the plastic component come to known. To improve the impact performance either changing the material and/or modify the product design. The main methods used to improve impact performance of a material are copolymers, blending polymers, plasticizers, crystalline and reinforcement.

3. Finite Element Analysis

3.1. Geometry

This Body Control Module consists of four mounting locations, cover, base and PCB in between cover and base. This Body Control Module in turn attached inside the dashboard assembly. The cad model of the Body Control Module is as shown in fig.1. This CAD model is created with help of CATIA Tool

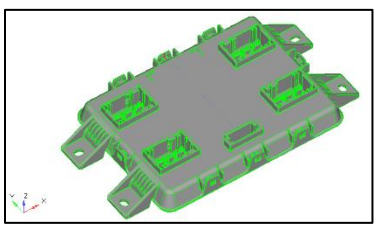

Figure 1:Body Control Module Geometry

3.2. Meshing

The BCM is meshed with two type of meshing as shown in Fig.
1) Tetrahedral Mesh (Modal Analysis ,Tool- Ansys)
2) Shell Mesh (Drop Analysis, Tool LS Dyana)

The step file is imported to the meshing software like Hypermesh, Ansys. For modal analysis we use tetrahedral meshing. This is automated meshing with help of ansys workbench tool. In Impact analysis BCM module is meshed with Shell mesh Proper quality criteria is maintained for shell meshing. As we know the good quality meshing is required for drop analysis. The thickness of the shell element at rib and critical region is properly captured with thickness property. The mesh size of an element is to be taken into consideration because all software’s have some limits for the number of elements. Less the mesh size more will be the number of elements and coarse the mesh size less will be the number of elements. As the number of elements increases the run time increases.

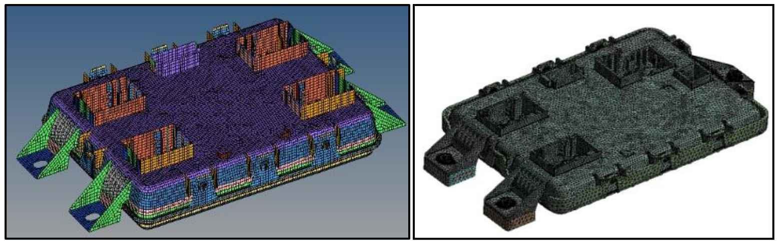

Figure 2: Details of meshing for drop test and modal analysis

In Impact analysis BCM module is meshed with Shell mesh Proper quality criteria is maintained for shell meshing. As we know the good quality meshing is required for drop analysis. The thickness of the shell element at rib and critical region is properly captured with thickness property. The mesh size of an element is to be taken into consideration because all software's have some limits for the number of elements. Less the mesh size more will be the number of elements and coarse the mesh size less will be the number of elements. As the number of elements increases the run time increases.

3.3. Material Properties for Body Control Module

Table 1

Sr.No	Material	Density (T/mm3)	Modulus (MPa)	Poisson's Ratio	Max Stress (MPa)	Strain at break (%)
1	**PP 20% TF Homo polymer**	**1.05 e-9**	**3000**	**0.3**	**36**	**14**
2	**PP 20% TF Copolymer**	**1.05 e-9**	**800**	**0.3**	**23**	**>40**

3.4. Drop Test

3.4.1. Calculation for The Drop Velocity

The drop velocity is calculated by using the energy method. In this the Potential energy will be converted into equivalent Kinetic energy,

Potential Energy = Kinetic Energy

$$\frac{1}{2}mV^2 = mgH$$

$V = \sqrt{2gH}$, [mm/s]

$$V = \sqrt{2*9810*1000}$$

$V = 4429.45$, [mm/s]

This drop velocity is input for the FEA analysis.

3.5. BCM Corner Drop

3.5.1. Material - PP 20% TF Homopolymer

The simulation is performed for the corner drop using the material Polypropylene with 20% Talc

Filled. From the simulation result it is observed that Effective Plastic Strain value is 0.336 which is greater than the percentage breaking stain, So, the Body Control Module fails. The damage occurred on the corner location and on the side clip which is located in between two mounting legs. This damage occurs due to the load distribution

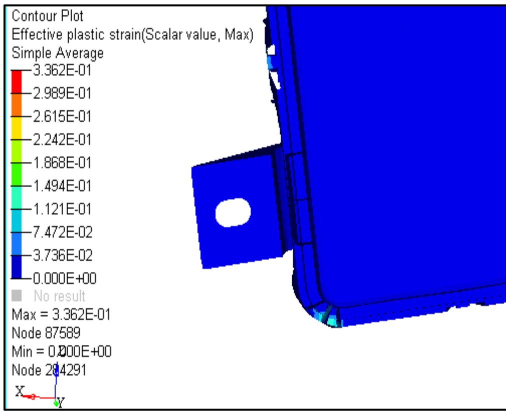

Figure 3: BCM Corner Drop (PP20% TF Homo polymer)

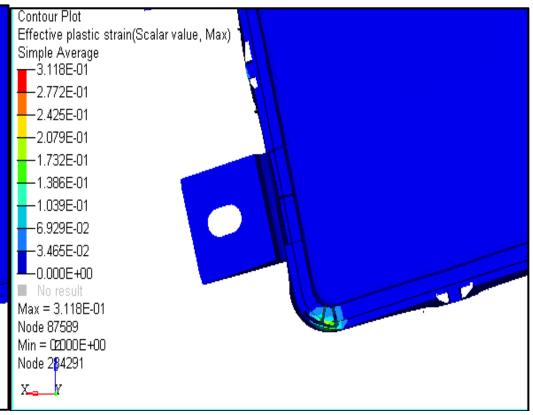

Figure 4: Modified BCM –Corner Drop (PP 20% TF Copolymer)

From the simulation result it is observed that the value of the Effective Plastic Strain is 0.311 which is less than the percentage breaking strain of the material. Hence the design is safe for the material polypropylene with 20% Talc Filled. As the modified design is safe for the material polypropylene with 20% Talc Filled copolymer, hence the remaining drop test simulations are performed.

3.5.1.1.Drop on the mounting leg

In the leg mounting drop simulation, the value of Effective Plastic Strain is 0.167 which is less than the percentage breaking strain. Hence there is no failure occurs in the mounting leg

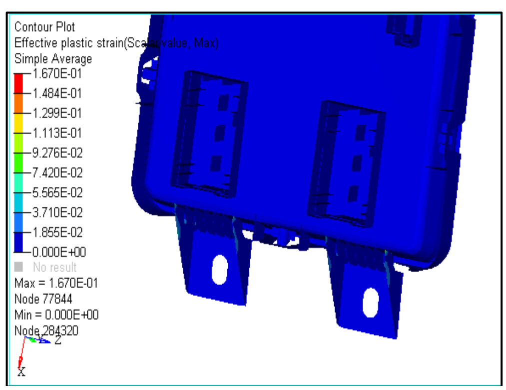

Figure 5: Mounting leg drop

3.5.1.2. Drop on side clip

In the side drop simulation, the value of effective plastic strain is 0.417 which is greater than the percentage breaking strain. But this value shows higher compressive strains on the point of impact. Hence there is no failure occurs in the side clip

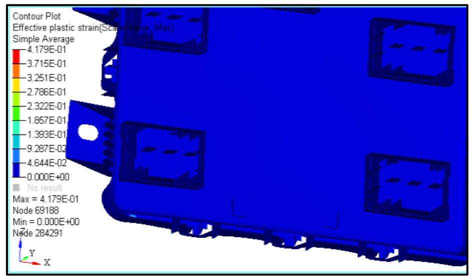

Figure 6: Side Clip Drop

3.5.1.3. Drop on cover

In the cover drop simulation, the value of Effective Plastic Strain is 0.326 which is less than the percentage breaking strain. Hence there is no failure occurs in the cover drop

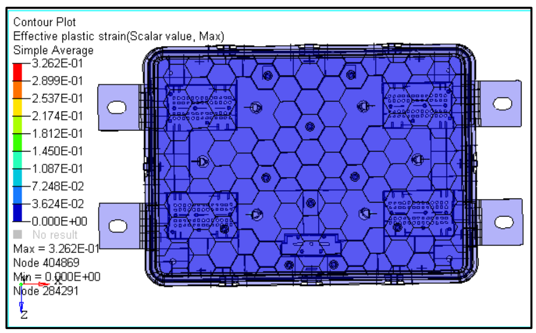

Figure 7: Cover Drop

3.5.1.4. Drop on base

In the base drop simulation, the value of Effective Plastic Strain is 0.276 which is less than the percentage breaking strain. Hence there is no failure occurs in the base drop.

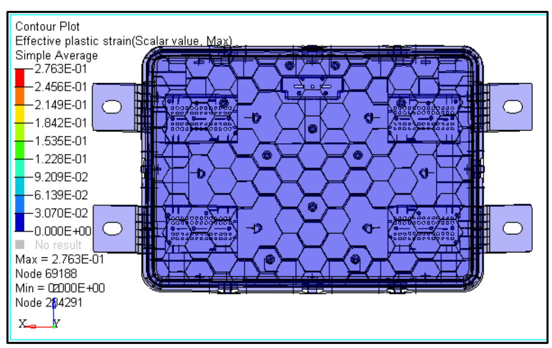

Figure 8: Base Drop

From the above drop test simulation for the modified design and for the material polypropylene with 20% Talc Filled copolymer, the modified Body Control Module is safe in all drop tests. Hence the modified Body Control Module is tested for the modal analysis to find out the natural frequency.

3.6. Modal Analysis

Modal Analysis on BCM has been carried out using Ansys to measure first mode natural frequency, total deformation of geometry, high and low stress regions. Engine frequency depends on the Engine rated RPM, Number of cylinders and Factor of safety.

3.7. Boundary Condition

Bottom face of the steel block is fixed in all direction. All bolt contacts molded with 1.5 times of bolt diameter.

MPC bonded contacts are molded in between mating parts. The linear material properties used in modal analysis for BCM module. Density is adjusted to match the weight of the assembly and total weight of the assembly is distributed on the Cover and base part.

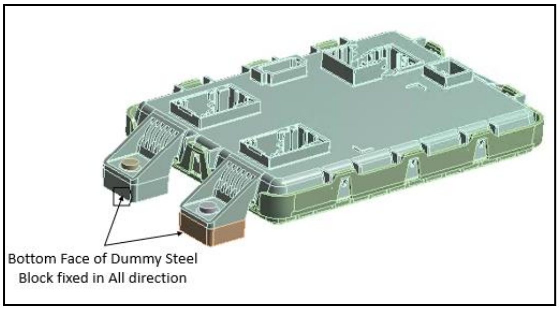

Figure 9: Boundary Condition

3.8. Engine Frequency calculation

Engine frequency depends on the Engine rated RPM, Number of cylinders and Factor of safety.
Total Number of cylinders are - 6nos.Rated speed of Engine is – 2000RPM

Hence,Frequency = [(Engine speed in RPM/60) X (No. of Cylinders/2)] + Factor of safety.

Here, Frequency = [(2000/60) X (6/2)] + 30
= (33.33X3) + 30
= 100 + 30
Frequency = 130 Hz.

Factor of safety is 30…value is derived from Historical data, So we need to target frequency of every component on engine and which supports the engine must have at least 130Hz frequency.

3.9. Modal Analysis Results

The modal analysis of BCM with material 20%GF copolymer is carried out by using ANSYS. The amplitude of vibrations is measured. The first modal frequency is at 124 Hz which meeting the target goal 100Hz with 24Hz margin.

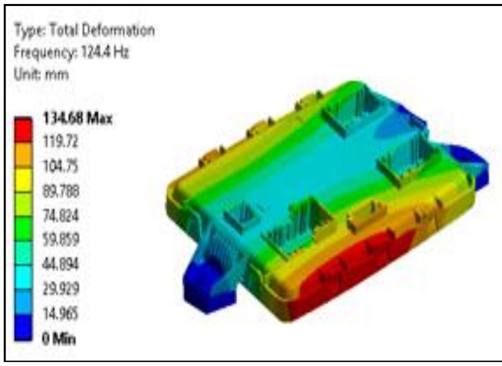

Figure 10: Mode Shape No:-1

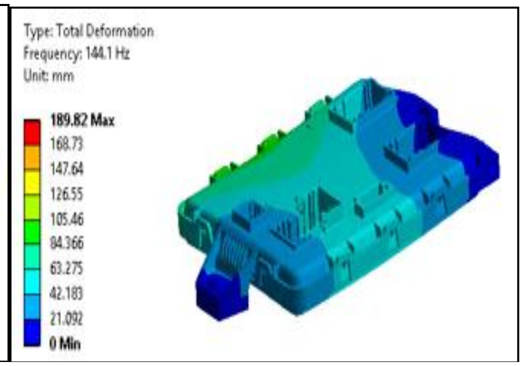

Figure 11: Mode Shape No:-2

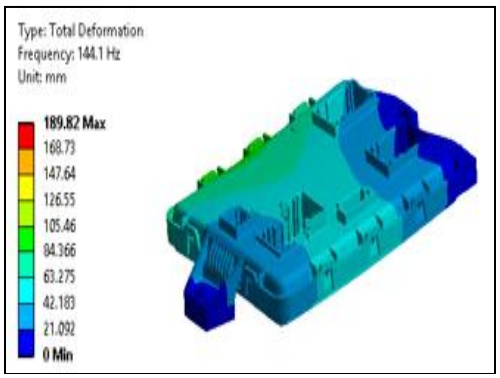

Figure 13: Mode Shape:-3

3.10. Modal Analysis Result Summary

Table 2: Body Control Module Modal Analysis Frequency (Hz)

Mode Shape Number	**BCM Material Loxim 20% GF Co-polymer**	**BCM Material Loxim 20% GF Homo polymer**
Mode -1	**124 Hz**	**239 Hz**
Mode-2	**144 Hz**	**278 Hz**
Mode-3	**209 Hz**	**405 Hz**

3.11. Experimental Analysis

In actual practice measurements of natural frequency is based on acoustic resonance analysis. There are basically two methods used by industry pulse like and continuous. Pulse like method uses electro-dynamic hammer to strike the object and measure the amplitudes. Continuous method uses a shaker table in which the piezo sensor detects the vibrations. The experimental setup shown in Fig includes the hammer, FFT analyzer, wired connections, table and laptop. The BCM is fitted on the table with the help of cap screws and Steel block. BCM is hit at top locations. The pulse of hit is sensed and converted to digital signal. The value of frequency is s displayed on of FFT analyzer screen.

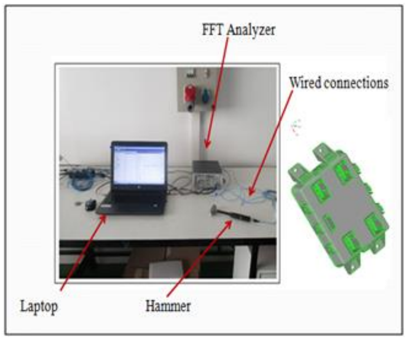

Figure 14

3.12. FFT Analyzer

The BCM has been fixed on dummy steel block. so that it can vibrate freely. The mechanical pulse from a small electromagnetically operated hammer ensures that the BCM commences to vibrate in its natural modes. A microphone which is mounted nearby the surface of BCM detected theses vibrations and converts them to electrical signals. The electrical signals then transferred by Fast Fourier Analysis into natural frequencies and displayed on screen as shown in Fig. It shows the value of natural frequency for that component The frequency values displayed on screen are noted.

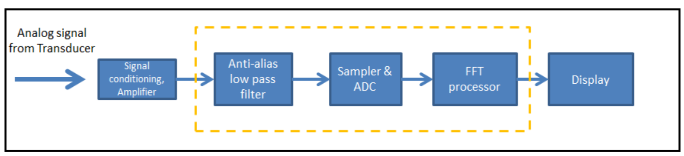

Figure 15: Schematic Diagram of FFT Analyzer

3.13. Experimental Analysis Results

Table 3

Body Control Module Design	**Modified Design Virtual Analysis Results**	**Modified Design Experimental Analysis Results**	**% Difference**
Mode Shape No 1	**124**	**145**	**11**
Mode Shape No 2	**144**	**165**	**12**
Mode Shape No 3	**209**	**230**	**12**

4. Conclusion

From Above vibration and impact analysis study it is observed that the material for BCM module 20% GF copolymer is recommended.BCM module meets the engine target goal frequency 100Hz with 24Hz margin. Vibration analysis study showed good correlation with experimental analysis.

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