VIBRATION ANALYSIS AND OPTIMIZATION OF HOUSING FOR ECU IN AUTOMOBILE USING FEA AND FFT ANALYZER

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Abstract - *Electronic Control Unit housings are subjected to various harmonic vibration loads generated by engine at various RPM levels. Encounter of resonant frequencies of housing in specified frequency range can cause damage to PCB enclosed within housing. Vertical vibration/excitation levels are dominant which cause bending moments in PCB and housing. Basic design of housing will be done using CATIA. Finite Element Analysis shall be used to design and optimum housing which will sustain harmonic loads coming from engine vibrations. Modal & Harmonic analysis will be used to investigate mode shape and response of enclosure at specified frequency ranges. Experimental modal analysis will be performed using accelerometer, impact hammer, & FFT analyzer. Comparative analysis will be done on FEA & Experimental results.*

Key Words: **ECU, CATIA, MODAL & HARMONIC ANALYSIS, IMPACT HAMMER TEST, FFT ANALYZER**

1. INTRODUCTION

The electronic control unit (ECU) used in today's cars and trucks is used to control the engine and other components' functions. An ECU is a computer with internal pre-programmed and programmable computer chips that is not much different from a home computer or laptop. The vehicle's engine computer ECU is used to operate the engine by using input sensors and output components to control all engine functions. The ECU needs inputs from vehicle sensors like the crankshaft sensor and camshaft sensors to compute the information using a program that has been stored in the ECU on a programmable memory chip. The ECU program will use the inputted sensor information to compute the needed output like the amount of fuel injected and when to spark the coil in order to start the engine.

There are different ECUs used for different systems on the vehicle. The different ECUs used can be for the transmission, traction control or ABS, AC, body functions and lighting control, engine, air bags, or any other system a vehicle may have. Some vehicles may incorporate more than one ECU into a single unit called a powertrain control module (PCM). These units can be an advantage by having more modules in one location but may be a disadvantage by adding longer wires to reach the component it operates.

Most never vehicles have started using a communication line between different modules on a vehicle so they can share information and redundant sensors do not have to be used. For instance, a speed sensor at a wheel detects the wheel speed and will be an input to the anti-lock brake module (ABS) ECU. Instead of sending many wires from the one sensor to other ECUs, the ABS ECU will share the information on the network communication lines to all the ECUs that use the information, like a transmission for its shifting of gears, the speedometer to show the speed of the vehicle, or the suspension system to control the suspension as needed.

The use of sharing input sensors throughout the vehicle using only two data lines between ECUs has cut the amount of wiring used in the vehicles. Sharing information between modules also means they need a common language between them so they can operate as a group. When one computer goes down or does not share information due to an error, then it may affect other modules if they need the sensor input from the failed module.
The engine ECU in most vehicles is connected to the onboard diagnostic connector and will relay all diagnostic information on this line to all the other modules or ECUs. This reduces the amount of wire needed and you do not need to go to each ECU when wanting to test them.

2. OBJECTIVES

- The objective is to design a housing of electronic control unit (ECU) using CatiaV5 by reverse engineering

- Carry out the finite element analysis (FEA) on the prepared model using ANSYS
- To verify mode shapes generated at different frequencies in ECU and minimize the vertical vibration by adding cross ribs to the ECU.

3. PROBLEM STATEMENT

In the present work the aim is to find optimize the housing of ECU solution which should be efficient than the existing model of ECU without affecting the PCB. The optimise housing of ECU of FEM results will be compared with the existing on the basis of vibration and weight. The effect of increasing the vibration on the area of housing will be analysed.

4. METHODOLOGY

- The CAD model is prepared in Catia V5 R20. The Analysis is done in ANSYS Workbench.
- Modal and Harmonic will be done to determine resonant frequencies, stress and deformation for all the optimized models prepared.
- The best optimized will be finalised in comparison with the existing model and other samples.
- Impact hammer test will be done to obtain natural frequencies of optimized model.
- Comparative analysis will be made between FEA and experimental results.

5. DESIGN

Computer-aided design (**CAD**) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

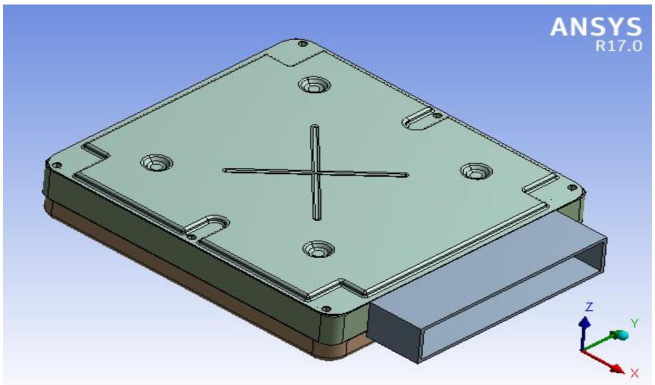

Fig. 1 CATIA model

6. ANALYSIS

It is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). FEM subdivides a large problem into smaller, simpler, parts, called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Modal Analysis

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a seismic analysis.

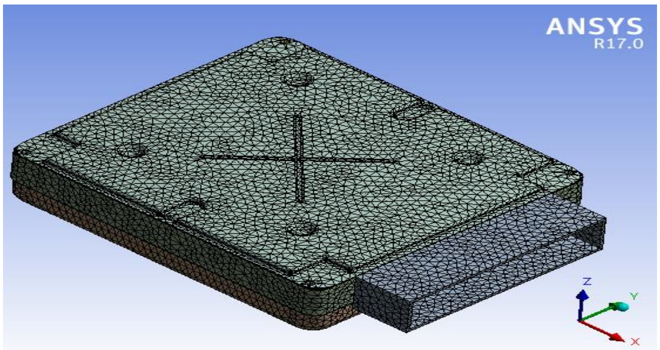

Fig. 2 Meshing of model

Element Details:

- Element Type: Hexahedron, Tetrahedron
- Element Order: First Order
- Mesh Method: Solid
- Node Population count: 148047
- Element Population count : 75972

Boundary Condition

After carrying out meshing of lower control arms the boundary conditions are applied to it. The same boundary condition is applied as that is experienced by the physical lower arm. The force that is calculated in chapter 3 is applied on the part which is connected to spring. In actual structure the ball joint is connected to the steering knuckle. The steering knuckle is connected to wheel/tire envelop. The handling bushing and ride bushing is the connected to sub frame of the chassis.

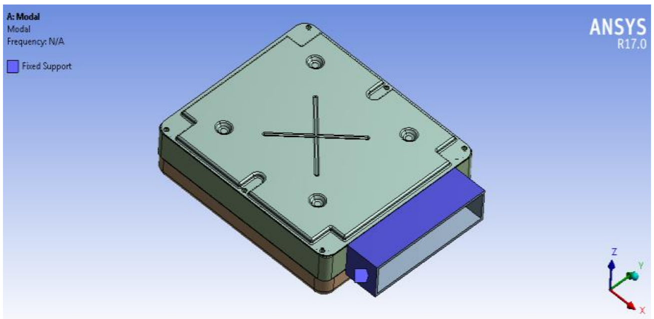

Fig. 3 Boundary Condition

Deformation at different mode:

Deformation is shown in figure below with max deformation 0.380mm at frequency 248.72Hz.

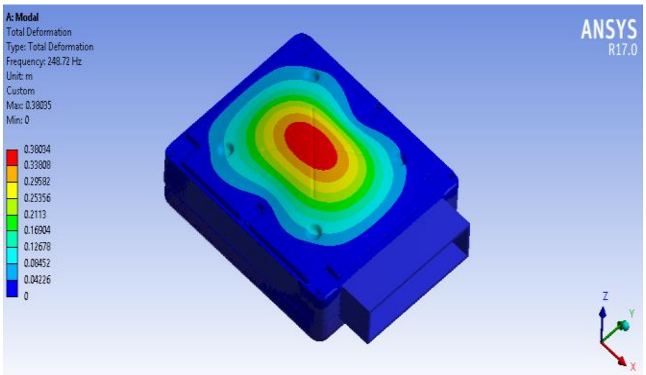

Fig. 4 Deformation of model

Results of original ECU showing frequency at different modes are as follows:

Sr.no.	Mode	Frequency
1	1	248.72
2	2	291.52
3	3	403.65
4	4	568.13
5	5	586.2
6	6	661.87
7	7	717.61
8	8	891.65
9	9	1005.1
10	10	1031.6

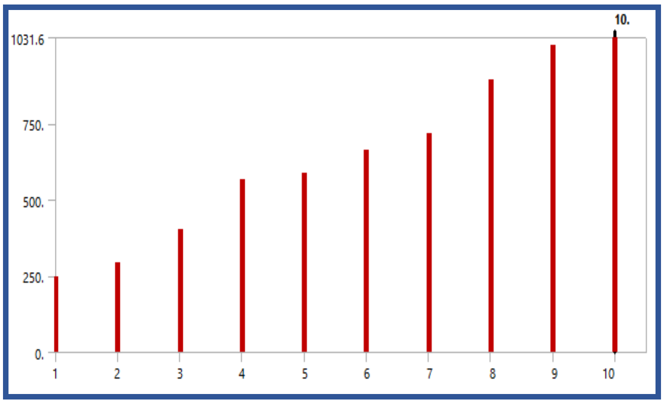

Fig. 5 Frequency (Hz)/Mode

Harmonic Analysis:

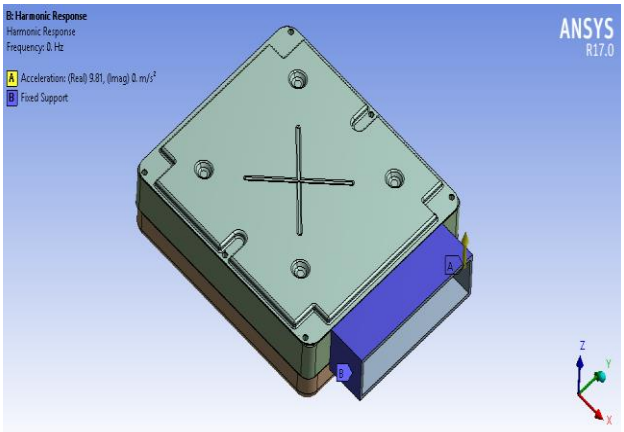

Fig. 6 Boundary Condition for Harmonic Response

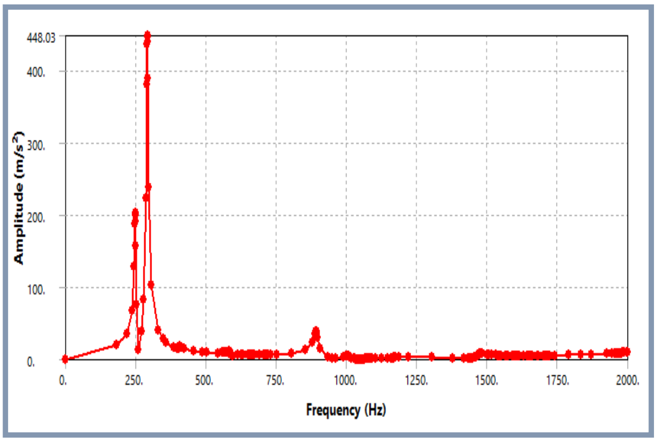

Fig. 7 Amplitude/Frequency

From the above modal and harmonic analysis, it is observed that it is necessary to modify the original ECU to operate in harsh or vibrating environment and following design change is made such as insertion of cross rib in the ECU housing so as to limit the vertical excitation and to increase the stiffness.

Modified ECU Plate:

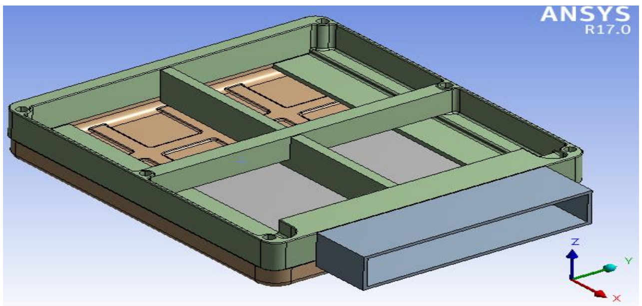

Fig. 8 Modified model of ECU

Modal Analysis of modified ECU

Boundary condition of modified ECU is shown below showing the fixed support

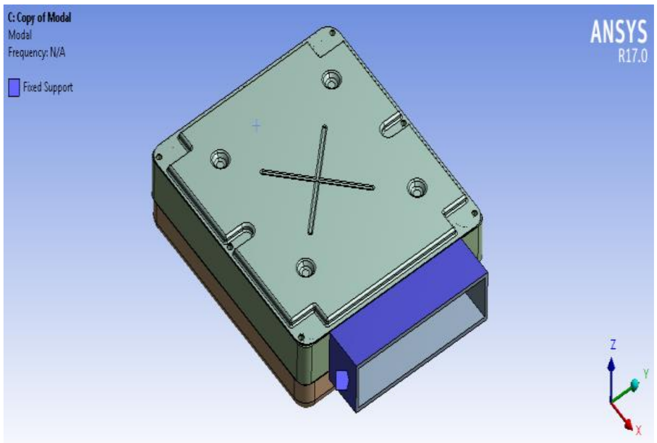

Fig. 9 Boundary Condition

Deformation of Modified ECU

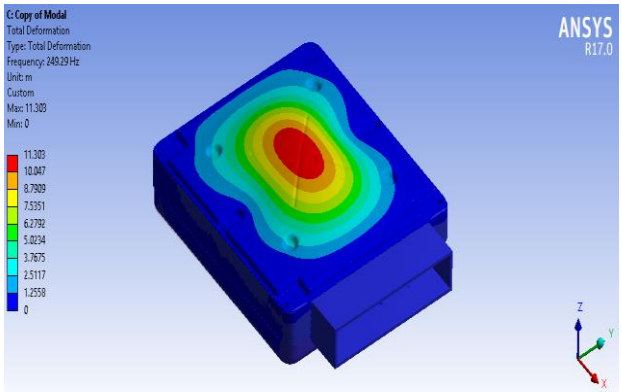

Fig. 10 Deformation of model

Results of Modified ECU:

Results of modified ECU showing frequency at different modes are as follows:

Sr.no	Mode	Frequency (Hz)
1	1	249.29
2	2	286.15
3	3	404.75
4	4	569.32

5	5	591.88
6	6	662.08
7	7	722.03
8	8	900.78
9	9	994.07
10	10	1016.05

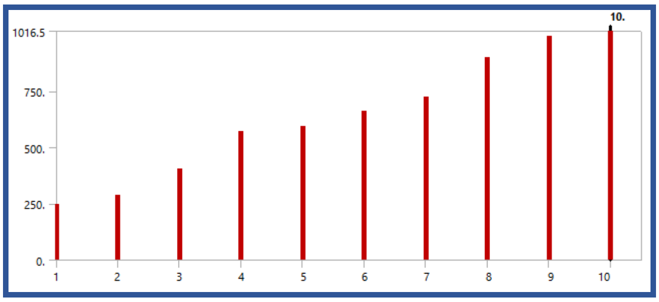

Fig. 11 Frequency (Hz)/Mode

Harmonic Analysis:

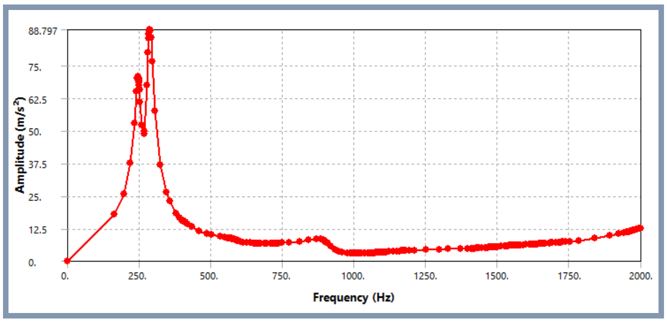

Fig. 12 Amplitude/Frequency

From the above modal and harmonic analysis, we can summarize the results in the following manner,

- In case of modal analysis, the natural frequency was increased in modified model
- In case of harmonic analysis, Acceleration amplitude in Z-axis decreased from $448.03 m/sec^2$ to $88.797 m/sec^2$
- Stiffness of modified ECU is increased by 6.3% so as to limit the excitation.

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