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Design, and Analysis of Aluminium Casing for ECU's used in Electric Bike

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Abstract - *The Government has started giving the subsidy scheme to promote Clean India Green India and increase the use of the electric vehicle in country. By the end of 2022 the country will be well occupied by electric Bikes which will solve all the fuel related issues. Till now the electric bikes have been successful product of many companies. However, the only issue which is seen to be occur in electric bikes is the Heat Generation by its components and its dissipation. So, it become very necessary to design the casing of ECU such that the heat generated by the components of the ECU does not harm the rider and also should not affect the performance and reliability. So, the proper dissipation of heat between ECU casing and surrounding is very important issue to be solved in Electric Bikes. Further these Electronic Control Unit housings are subjected to various harmonic vibration loads generated at various RPM levels. These Project works is focused on design and analysis of Aluminum casing for ECU's used in electric bikes which will all together be more helpful in effective dissipation of heat and efficient against the different vibrational forces and not hamper the performance of electric bikes. Design a casing of electronic control unit (ECU) using SOLIDWORKS17 for solid modelling. Perform FEA Analysis (Modal, Harmonic and Thermal analysis) to investigate mode shape and response of enclosure at specified frequency ranges and also the heat generation in housing and its dissipation. Perform Thermal Analysis for different casing options available and choose one which is best in thermal performances*

1. INTRODUCTION

Electric motorcycles and scooters are plug-in electric vehicles with two or three wheels. The electricity is stored on board in a rechargeable battery, which drives one or more electric motors. Electric scooters (as distinct from motorcycles) have a step-through frame

1.1 WHY E-Bikes:

Global warming is a major concern all around and to save Mother Earth, there are several policies, promises and pledges. With the ever increasing emission of greenhouse gases, there is an increased fear of environment pollution at every step. With modern technology and innovation, transportation and communication have undergone a paradigm shift. Along with this, we are also experiencing the negative effects of industrialization in the form of global warming. Under these circumstances, when there are traffic jams, when you need to run an errand at an odd hour of the day, when you need to go to workplace quickly, you stumble and fumble as there are so many vehicles emitting soot and CO2 polluting the air incessantly. With increased number of fossil-fuel dependent vehicles, they not only add to greater level of pollution but are also leading to depletion of fuel resource. It is here that automobile companies felt the need to innovate motorized vehicle that will get charged through electricity and will not be depending on fossil fuels.

This led to expansion of eco-friendly initiatives and many automobile manufacturing companies invested in research and development to bring forth electric bikes that will help people save a few bucks by reducing consumption of already spiraling fuel price, besides fighting global warming. Most electric bikes are emission-free bikes and this is the USP of the company's manufacturing them in these days of global warming. It will not add to urban pollution. The only thing required is to keep this bike charged with a battery. Electric bike manufacturing is considered as a grass root movement away from fossil fuels.

Definitely, electric bikes are not the only answer to our environment problem, but it definitely will help us to treat environment better. These electric bikes will not make pollution worse and that makes e bikes environmentally safe vehicle. It can be charged with the help of inverter and generator too. In one charge, these electric bikes can go up to 50km and has no tail pipe emissions. It also makes no noise while under operation. The best part of electric vehicles is that they can be run with no registration and license.

In the manufacture and production of electric bikes, the main constraint is the battery in the bumpy roads. Batteries get deteriorated at a fast rate due to excessive current fluctuation. Batteries need frequent replacement and that is the greatest concern for the most Indian companies who manufacture these electric bikes. The replacement cost of the batteries hover around Rs.5000, but otherwise the maintenance cost of electric bikes is almost negligible.

There is a growing market potential of electric bikes in India; however, speed might not be the attractive feature of these e-bikes, they will cater you to run the short

distances maybe home to office or home to college; but these are safer vehicles with benefit of almost no pollution. So instead of kicking a 100 cc motorbike, just press the start button of electric bike and vroom your way friendly on the roads.

It is evident that electric bikes can reduce the air pollution. But there are also some environmental problems caused due to these electric bikes. Disposal of worn out batteries can be a cause of major concern for environmentalists. If this can be addressed, electric bikes can definitely reduce environment pollution.

1.2 Features of Electric Bikes and Scooters:

Electric bikes or scooters, light in weight, trendy, efficient and eco-friendly, are becoming potent alternative to the conventional two-wheelers and the Electric two-wheeler industry in India is developing at rapid.

Have a look at the unavoidable advantages of Electric Bikes and Scooters:

- License and registration is not required for E Bikes and Scooters.
- Electric two wheelers run on re-chargeable battery and uses electricity as fuel in place of conventional Petrol/Diesel.
- E Bikes and Scooters can beat the rising prices of Petrol/Diesel.
- Simple design, light weight and economical Electric vehicles are very low in running and maintenance cost.
- With the ease of handling, Electric two wheelers saves the commuting time in congested roads especially in urban areas.
- Electric vehicles are more efficient in terms of generating usable energy from their electric engine's battery in comparison to the regular fuel conversion. In this way E Bikes and Scooters are innovative and efficient mode of personal transport.
- Electric bikes or scooters use electricity therefore no emission of harmful gases like Carbon dioxide (CO2) or Nitrogen dioxide (NO2).

1.3 Major Components of an Electric Bike or Scooter:

1. Electric hub motor

Electric hub motor to drive the rear wheel directly and there are two types of Electric Hub Motor i.e. DC Brush Motor and DC Brush less motor having two basic parts namely Permanent Magnet Stator and Wound Rotor.

2. Electronic motor controller

Electronic motor controller is the central controlling unit of any Electric two-wheeler provides electric power to the motor based on inputs from the accelerator.

3. Electronic accelerator

Electronic accelerator sends electronic signals to the Electronic Motor Controller to man oeuvre the bike or scooter.

4. Battery pack

Battery pack is like the fuel tank of E Bike or Scooter. There are different kinds of batteries like Lead Acid, Nickel Metal Hydrate (Ni-MH), Lithium, etc. that are used for supplying energy.

5. Battery charger

Battery charger is used to charge the battery pack of E Bikes or Scooters, just like a mobile phone or a laptop. Some battery chargers are in-built and some are separate that carried always on the move. The charger converts an AC supply to DC to store power in the battery and it can be used with any normal domestic AC plug point. This makes charging of battery pack easy and convenient.

2. LITERATURE SURVEY

In the research paper **"Multi-objective topology optimization of an electric vehicle's traction battery enclosure"** published by **WANG Lu, CHEN Xiao-kai, ZHAO Qing-hai,** the authors have said The traction battery enclosure is one of the most significant parts of an electric vehicle. Better structural performance and lightweight design of battery enclosure are extremely important in current situation. This paper introduces a multi-objective topology optimization design method for the traction battery enclosure, in which both the static stiffness and dynamic frequencies are taken into consideration. The optimization is utilized to achieve a new battery enclosure structure with better static and dynamic performances. The results illustrate that the structural topology optimization approach can be a feasible and efficient design methodology for the traction battery enclosure structural design and can provide the designer with detailed guidance in conceptual design phase.

2. In the study **"Design and Optimization of Sheet Metal Enclosure with the Help of Behaviour Modelling"** by Niteen T. Kakade, Pro. D. G. Gangwani the researchers have said that it is going to be taking this sensor housing which consists of four sheet metal parts and going to take this little assembly and set it up and go through and run

through the analysis and while doing that it going to be pointing out some of the changes that have taken place. So the first of these point out before it even go into analysis and that it taken all the options that used to be in the old analysis file and it is incorporated those into the Pro/Engineer preferences editor. So what this lets it do is go ahead and search for all those difficulties. For instance let's say that it used to know that it used to be able to specify where temporary directories were written during an analysis. So it is going to go ahead and say that it wants to search simulation with the help of software.

3. In the research "**HEAT TRANSFER ANALYSIS IN ELECTRONIC CIRCUIT BOARD"** submitted by **Amol Kharat, Sunil Ingole, Vishal Meshram,** the researchers have presented that in recent years, electrical equipment are drastically developing and miniaturizing. Higher integration of semiconductor devices leads to these developments. On the other hand, higher integration of semiconductor devices on one chip and higher integration of electrical devices in one package means increase of heat generation density. The operation of integrated circuits (IC) at elevated temperature is a major cause of failures in electronic devices and a critical problem in developing more advanced electronic packages. This is because the life expectancy of electronic components reduces exponentially as the operating temperature rises. One such example of an electronic device is the electronic control unit (ECU) in automotive whose function has increased and is expected to further rise in the foreseeable future.

Thermal design of vehicle controller is an important element in the total design process, because of the impact of temperature on performance and reliability. A thermally well designed electrical component applied in a thermally poor designed controller, will still result in a poor total design. And it is important that thermal design on controller should be included as early as possible in the overall design process.

4. The study "**Cooling of Automotive Electronic Control Unit and its Analysis with ANSYS Ice Pack"** was conducted by Mr. Akshay Kulkarni, Prof. P. T. Kharat. In this study the authors have put forward their views saying in recent years, electrical equipments are developing with technology. Higher integration of packages on single electronic board causes higher heat generation density. The operational temperature of electronics component is major cause of failure of them. This is due to fact that their life reduces exponentially with operating temperature. One such example of electronic device is Electronic Control Unit which is short termed as ECU of automotives. The function of electronic control unit is increased now days with more functionality. The paper study is concerned with overheating of ECU, its CFD analysis. After analysis temperature reduction parameters are to be studied. A thermally well designed electrical component applied in a thermally poor designed controller, will still result in a poor total design. And it is important that thermal design on controller should be included as early as possible in the overall design process.

5. In the study "**Vibration Analysis and Optimization of Housing for ECU In Automobile Using FEA and FFT Analyzer"** the scholars **Prathamesh Mirajkar, Prof. M.L. Thorat** have put forth that 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.

3. NEED OF RESEARCH

The electric vehicles is slowly making its ground and it is the booming sector in India and also the future of automobile in India. The major problem with the electric vehicles is the cooling of the electronic control unit especially in the bikes. In the bikes, the ECU is placed close to the body of the rider and there are chances of physical contact with the ECU. The temperature of the components inside ECU is near about 90 degrees Celsius. If the box containing the ECU is not cooled properly, then the rider may burn his skin if it comes into contact. So there is a need for designing a casing box for ECU and finding out techniques how it can be cooled effectively. This is also the matter of research going on in the automobile industry now a days.

4. OBJECTIVES

1. Design a casing of electronic control unit (ECU) using SOLIDWORKS 2017 for solid modelling.
2. Perform FEA Analysis and Thermal analysis to investigate the heat generation in housing and its dissipation.
3. Perform Thermal Analysis for different casing options available and choose one which is best in thermal performances.

5. METHODOLOGY

1. To design the casing used for ECU's (Electronic Control Unit) in Electric Bikes.
2. Perform static structural analysis, which will be used to investigate strength of the ECU casing.
3. Performing the thermal Analysis for housing and evaluating the rate of heat dissipation through it.
4. Finding the thermal stress on housing using the Static thermal analysis.
5. To use different techniques for finding the best possible housing optimized in aspect of efficient heat dissipation, resistance against the vibrational force and also checking manufacturing feasibility.
6. Compare the results from the FEA performed.

6. FEA ANALYSIS

6.1 CAD Model:

Prepare CAD model of ECU casing according to size and shape of ECU as shown below,

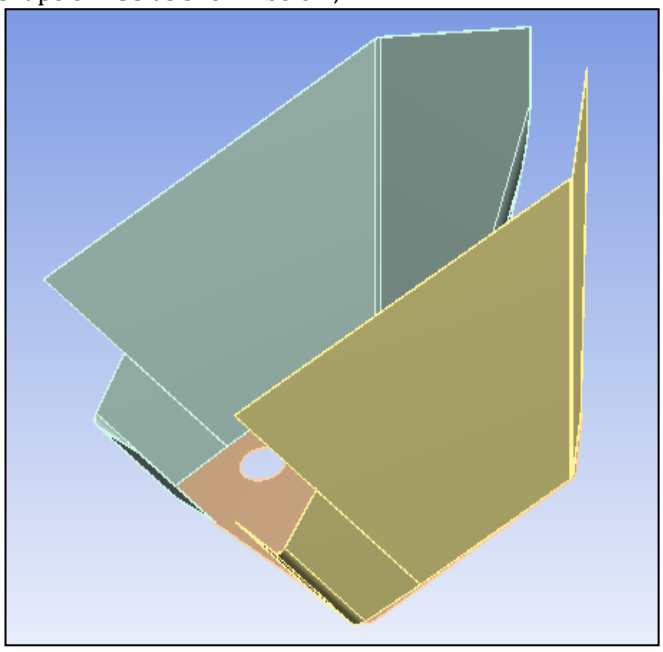

Fig 1: CAD Model of Case

Material of casing is Aluminum Alloy. For analysis considered different cases of thickness. Thickness of casing is varying as 0.5mm, 0.8mm, 1mm, 2mm, 3mm, 4mm, 5mm and 6mm etc.

6.2 Meshing:

Meshing of casing is shown below

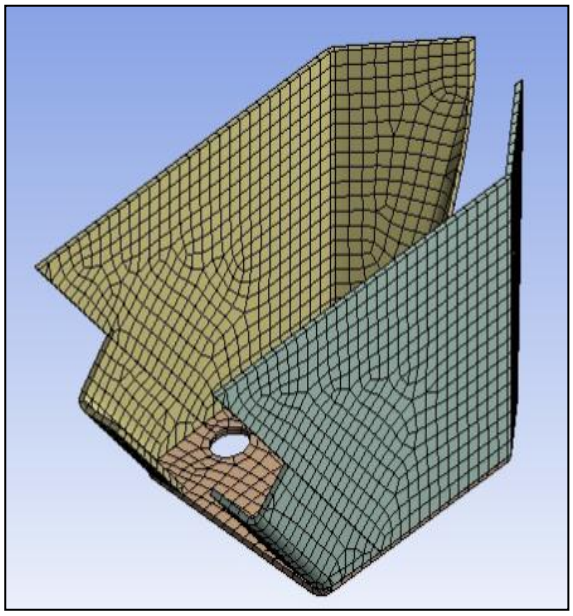

Fig 2: Meshing of case

Mesh count for different thicknesses is shown below,

Table no.1: Thickness and Mesh Count

THICKNESS	MESH COUNT
0.5mm	84174
0.8mm	82213
1mm	27814
2mm	23123
3mm	23069
4mm	18452
5mm	17604
6mm	17728

6.3 Boundary Conditions of Static Structural Analysis:

Following boundary conditions are apply for analysis

6.3.1 Fixed Support

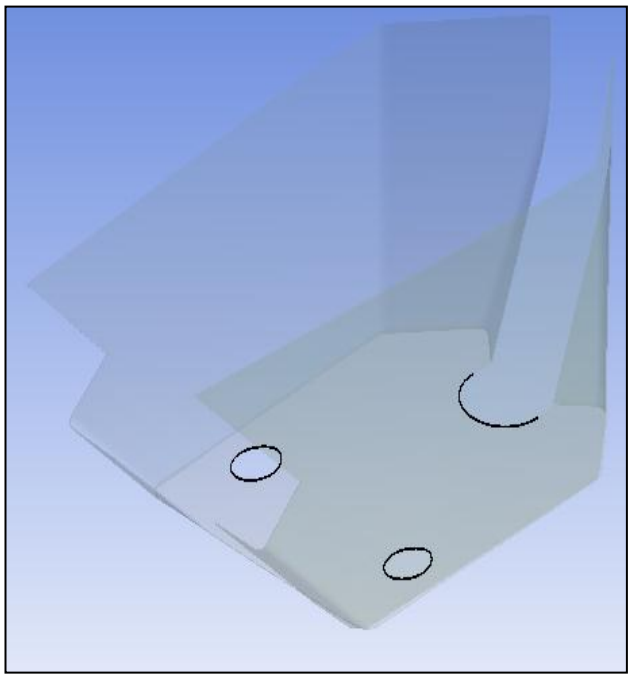

Fig 3: Fixed Support

Casing fixed at location shown in above image.

6.4 Force:

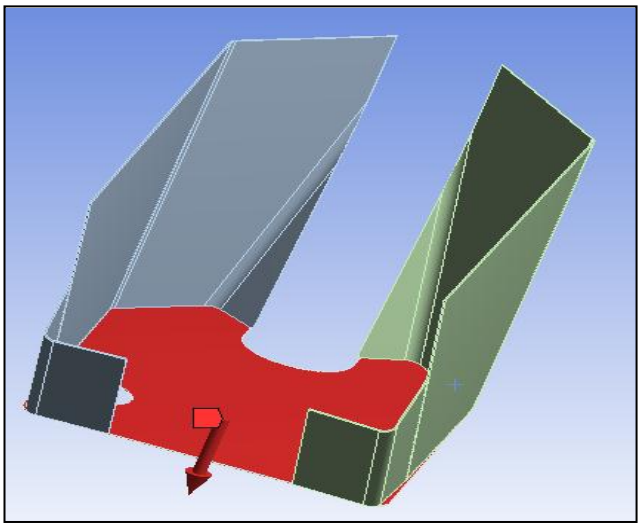

Fig 4: Force applied on down direction

By considering mass of ECU applied force in downward direction as shown in above image,

Average Weight of ECU is 300 gram hence calculated force as F = 2.943 N

6.5 Boundary Condition of Steady State Thermal Analysis:

6.5.1 Convection at Internal Surfaces

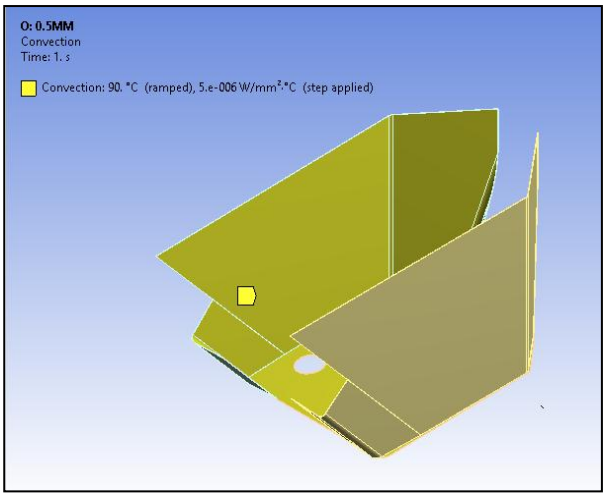

Fig 5: Convection at Internal Surfaces

As ECU is placed at inside of casing so, internal temperature is more as compare to external,

Temperature: 90°C

Film Coefficient: $5e^{-6}\ \frac{W}{mm^2 °C}$

6.5.2 Convection at External Surfaces:

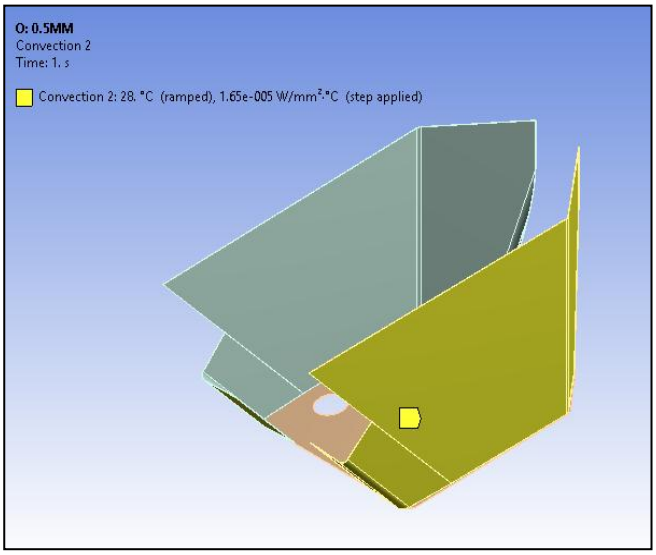

Fig 6: Convection at External Surfaces

Considered external temperature as atmospheric temperature,

Temperature:28°C

Film Coefficient: $1.65e^{-5}\ \frac{W}{mm^2 °C}$

6.6 Results of Static Structural and Steady State Analysis:

For 0.5 mm:

1. Temperature:

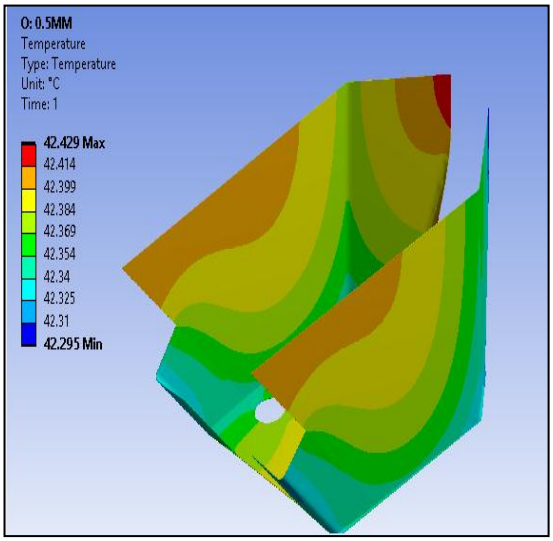

Fig 7: Temperature for 0.5mm

2. Deformation

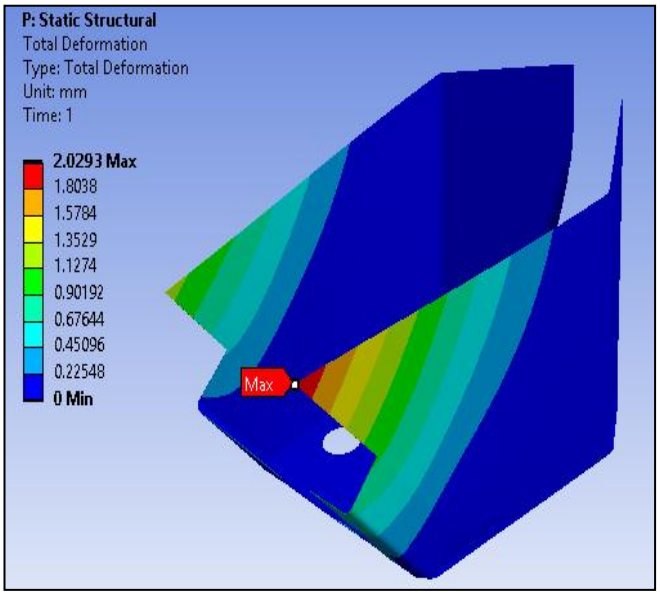

Fig 8: Deformation for 0.5mm

3. Equivalent Stress:

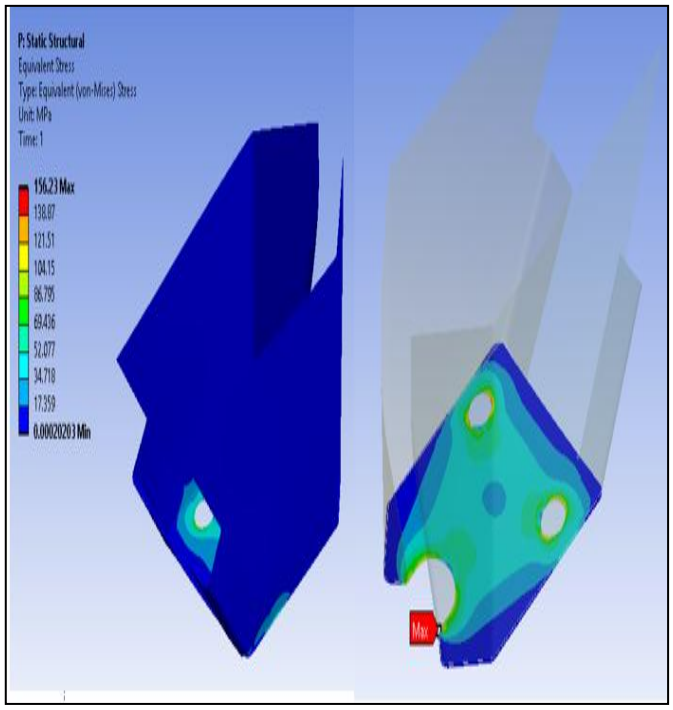

Fig 9: Equivalent Stress for 0.5 mm

Similar FEA analysis was performed on various thickness viz. 0.8mm, 1mm, 2mm, 3mm, 4mm, 5mm, and 6mm. The summary of the results obtained from the FEA analysis is as shown in the table below.

Table no. 2 FEA Result Summary

Thickness (mm)	Weight (Kg)	Temperature (°C)	Stress (MPa)	Deformation (mm)
0.5	0.226	42.49	156.3	2.029
0.8	0.362	42.39	113.0	1.176
1	0.452	42.38	115.0	0.5237
2	0.9	41.24	152	0.1377
3	1.344	42.29	148.2	0.117
4	1.784	42.15	130.4	0.1206
5	2.219	42.07	127.5	0.1256
6	2.65	42.00	123.5	0.1209

7. RESULT & DISCUSSION

1. For 1 mm thick ECU casing best result are shown.
2. For 1mm thick optimum weight is produce that is 0.452 kg.
3. Acceptable stress for steel is 125Mpa and stress produce in this casing is 115Mpa which is in limit.
4. Deformation is acceptable as we go for 0.1377mm or 0.117mm deformation, stresses increases beyond the limit so we select 0.52mm deformation.
5. Temperature is also within limits that is 42.38 ◦c below 45 ◦c.

8. CONCLUSION

We have done FEA for 8 different thicknesses for ECU casing. After studying this we have conclude that for 1mm thickness of ECU casing all the value are within limit so we consider 1mm thickness ECU Casing has best result.

9. FUTURE SCOPE

We can add fins to the box for better thermal conductivity and ribs to design for reducing more weight.

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