Modeling and Analysis of Vibrating Fixtures

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Abstract-Vibration is one of the most common causes of avionic device failure. The aircraft's avionic equipment must be able to resist high vibrations. Because it is not possible to place vibration equipment directly on the shaker table of a vibration machine, a mechanical structure known as a fixture is used to place the equipment and the machine. The proposed work's main goal is to develop the overall performance of the vibrating fixture to study the vibration characteristics of that particular structure at static and dynamic loading conditions, as well as performing random vibration analysis on various types of fixtures made up of Aluminum 2024 andAZ31B magnesium alloy. In this scenario, the natural frequencies, strength, strain and deformation of the structure are calculated at static load and dynamic loading conditions. By determining all of these findings, the proper selection of material for vibrating fixture can be done for mechanical design analysis.

Keywords: Fixtures, vibration, frequency.

I. INTRODUCTION

Avionics are electronic devices used in aero planes and they requires a high level of mechanical design knowledge in order to produce sound and reliable products. Avionics are increasingly being used in strategic or military operations, and these devices are becoming more sophisticated. As a result of these considerations, the failure rates of lea wires, solder joints, cables, castings and the behavior of structures, such as vibrations, shock, dust and temperature are the most common causes of equipment failure in the field.

Only the vibration parameter is used to test the avionic equipment in this study. The frequency levels of the aircraft's working conditions, according to military requirements, range from 20Hz to 2000Hz. Due to the difference in the pitch of the holes on the unit and the vibration machine, the equipment under test cannot be mounted directly on the vibration machine. If the fixture's natural frequency falls within the test range, resonance occurs, causing the input to be amplified, which is undesired. An excellent design of the fixture is necessary to ensure effective trans mission of input to the avionic equipment. Vibration experimentation may requires the use of an external exciter to provide the required vibration. When a certain amount of vibration is applied to the test object and the response is measured; this is applicable in controlled tests such as product testing. Vibration exciters come in a range of configurations, each with its own set of characteristics and operating principles.

A fixture is a structure that is bolted to a shaker or shock testing machine, as well as some devices that are being tested, and is driven by it. A vibration machine's shaker head usually has some sort of hole design that allows machine screws to be installed. Small electronic components can be mounted in these holes for vibration testing. For large electronic boxes, a mechanical adapter is required to allow the shaker head to transmit vibration motion to the electronic box. Vibration test fixture is the common name for this converter. As a result, the vibration test fixture serves as a link between the unit and the machine. The armature's extensions, which take the form of very rigid structures, are what allow the required force to be transferred at the required frequency. Vibration fixtures come in many different sizes and shapes. Making broad statements that can be applied to a specific design is difficult. Serving fixture resonance can be reduced by using a highly damped fixture structure. This can take the form of laminated structures in which energy is dissipated at multiple fixtures. Because resonance amplifies acceleration forces, it's best to keep a fixture's natural frequency at least 50% higher than the highest forcing frequency.

Levine [1] "highlighted the importance of the rigidity of fixture". Nabata & Terasaka[2] "in his paper proposed that large vibration can occur in tools and workpiece during machining". Kang and Peng [3] "concludes with the research trend of computer aided fixture panning". Kaya [4] "in his paper proposed that clamping is very

Figure 1 V875-640 shaker system

important in the fixture design to get rigidity of the fixture". Zheng[5] "establishes the finite element model of fixture unit stiffness and develops the experimental approaches to identify contact stiffness". Akin[6] "proposed that FEA is the most common tool for stress and structural analysis". Anad Raghu, Melkote [7] "proposed that several fixture- related error sources are know to contribute to part location error, which can lead to poor part quality". Camelio and S.Jack[8] "state that fixture imperfections influence dimensional variation on machining processes". Rylance[9] "proposes the FEA is now the basis of multibillion dollar per year industry". Deng[10] "proposed that Fixturing stability is an important concern in machining fixture design and refers to the ability of a fixture to fully restrain a workpiece that is subjected to external forces generated by the machining operation". S. Ratchev, K.Phuah, G.Lammel, W.Huang[11] "proposed that to reduce the overall costs and lead-times of new fixture development and efficient and accurate fixture design verification methodology would have to be developed". Siebenaler, Shreyes [12] "states that knowledge of workpiece deformations induced by loading in a fixture-workpiece system is important to ensure quality part production. As per the literature surveys are concerned, there is some lagging for the vibration analysis of fixtures".

II.PROBLEM FORMULATION

The main aim of the project is to design a suitable vibration fixture with suitable materials in this process here 3 types of fixtures (L-type, T-type, Cube type fixture) were designing with the help of cad tool solid worksand analyzing with 2 different materials (Al-2024, az31b) by using Ansys workbench, in this process both static and dynamic loading conditions applied on each material/ object, finally thesis can be concluded with optimum model with optimum material, and discussing their advantages and disadvantages and limitations by showing suitable graphs and tables.

Results to be calculated:

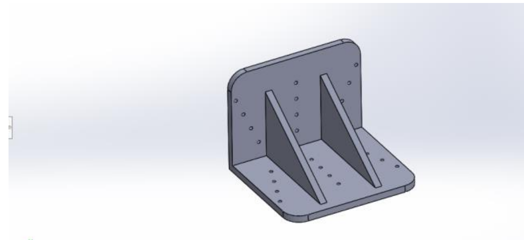
- Deformation, stress, strain, safety factor (static analysis)
- Natural frequency values for 6 modes here each mode consider to be object degrees of freedom (dynamic analysis)

III.MODELLING

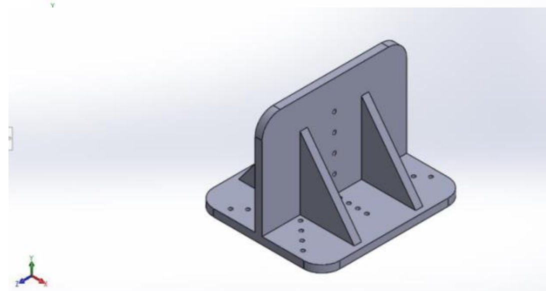
Various fixtures models were modeled using solid works software during the design optimization process. Today, the entire design process, from simulation to analysis, prototyping and manufacturing is entirely dependent on computer-aided engineering solutions. Solid works is a versatile and user friendly software that can perform a wide range of tasks, despite their complexity, with ease.

Various sizes and shapes are considered in this work when designing a vibration fixture. The material properties and geometrical configuration of different vibration fixtures with plate hole patterns are shown in the diagrams below.

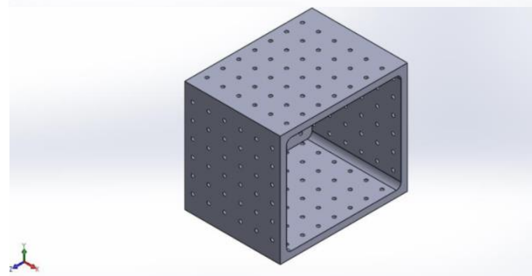
Case 1 :
L - Shape fixture
Dimensions of horizontal plate
400×300×200mm
Dimension of vertical plate
400×350×20mm



Case 2 :
T-shape fixture
Dimensions of horizontal plate
400×350×20mm
Dimensions of vertical plate
400×300×20mm

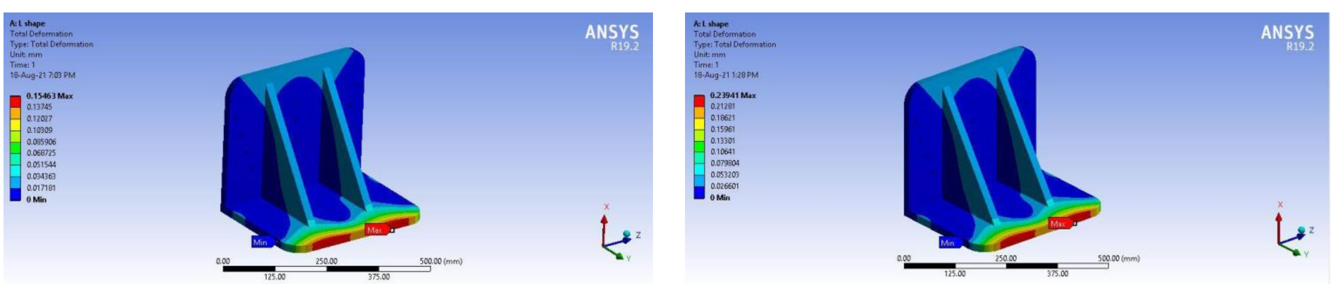


Case 3:
Cube shape fixture
Dimensions
400×350×300mm ,Shell of 20mm



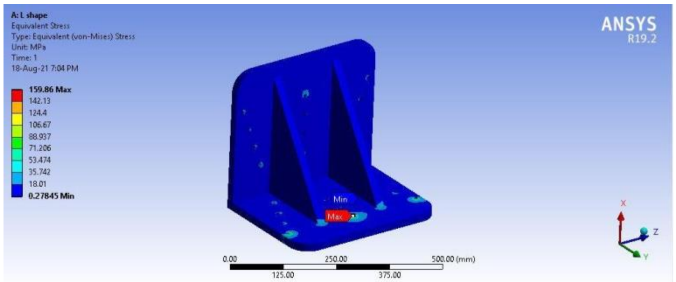
IV. FINITE ELEMENT ANALYSIS OF FIXTURES

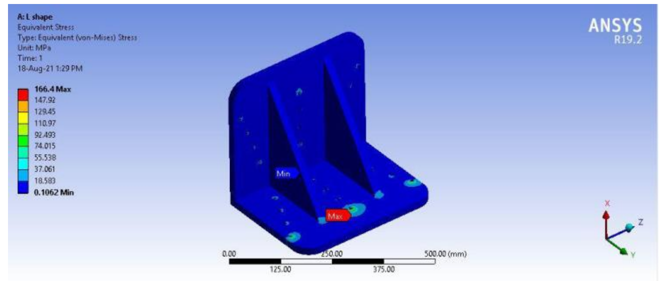
The fixture is analysed using the FEM tool ANSYS. The details of the analysis are summarized in the tables. The boundary conditions- the model is fixed at the mounting hole and Frictionless support is given at the bottom surface of the horizontal base plate. The mesh sensitivity was carried out to refine the mesh to obtain the mesh independent results. Figures illustrate static analysis of various fixtures made of aluminum alloy and magnesium alloy



(a).L- shape fixture (Al alloy) (b) L- shape fixture (Mg alloy)

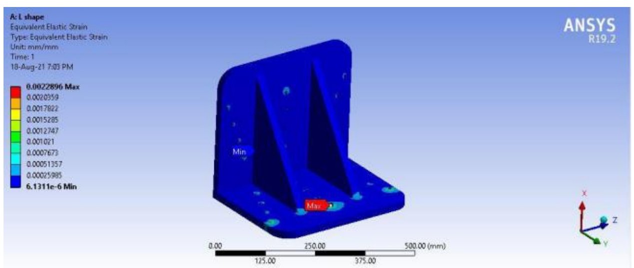
Figure 5.Deformation of L- shaped fixture made of Magnesium Alloy and Aluminum alloy

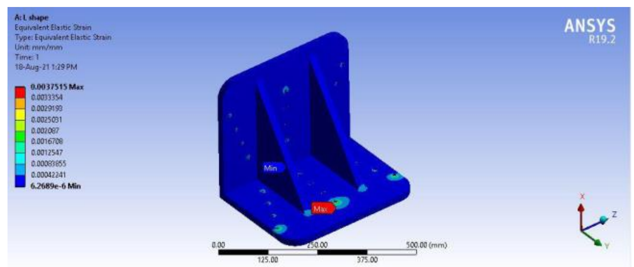




(a).L- shape fixture (Al alloy) (b) L- shape fixture (Mg alloy)

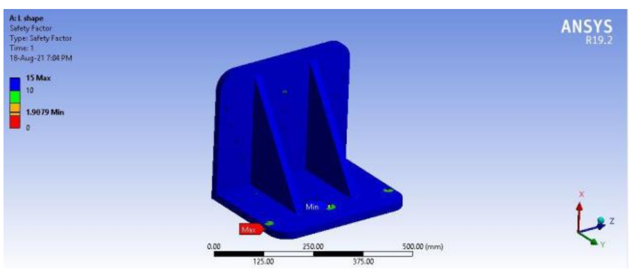
Figure 6.Equivalent Stress of L-shaped fixture made of Magnesium Alloy and Aluminum alloy

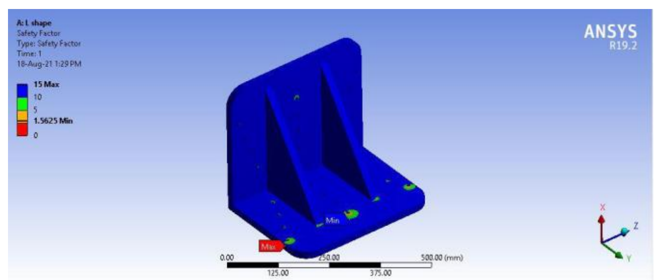




(a).L- shape fixture (Al alloy) (b) L- shape fixture (Mg alloy)

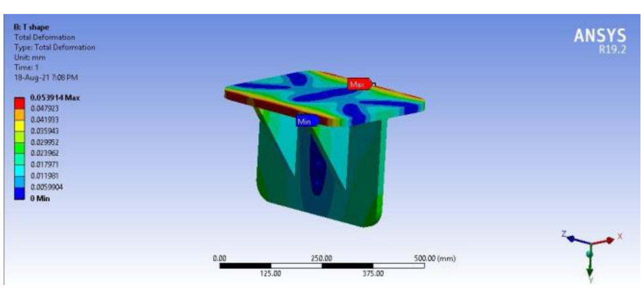
Figure 7.Equivalent Elastic Strain of L-shaped fixture made of Magnesium Alloy and Aluminum alloy

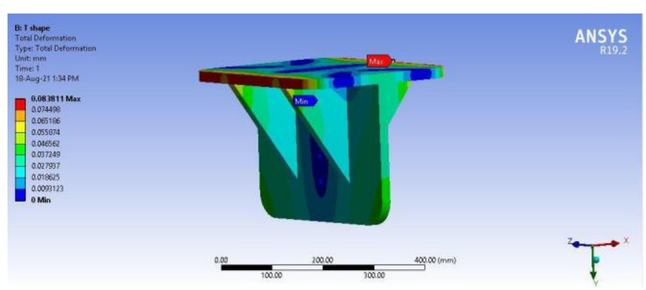




(a).L- shape fixture (Al alloy) (b) L- shape fixture (Mg alloy)

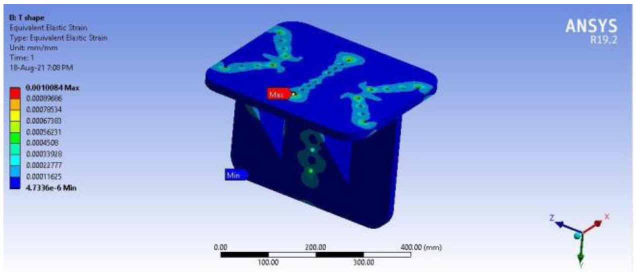
Figure 8.Safety Factor of L-shaped fixture made of Magnesium Alloy and Aluminum alloy



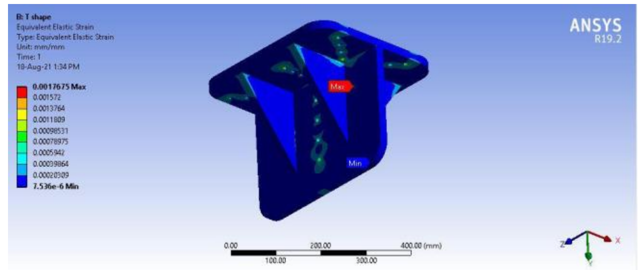


(a).T- shape fixture (Al alloy) (b) T- shape fixture (Mg alloy)

Figure 9.Deformation of T-shaped fixture made of Magnesium Alloy and Aluminum alloy

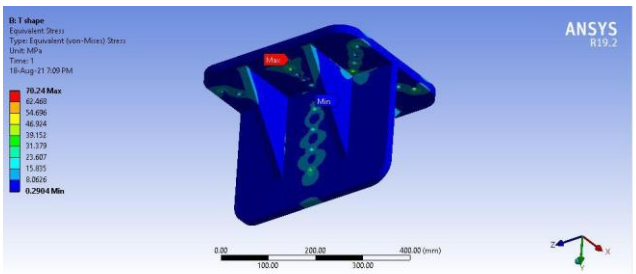


(a).T- shape fixture (Al alloy)

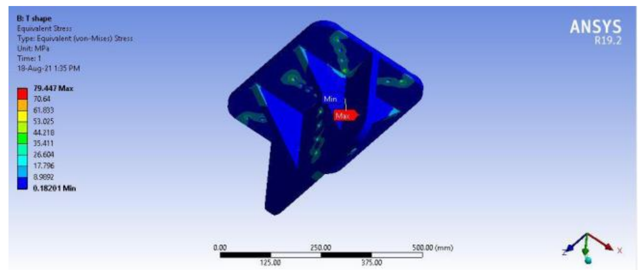


(b) T- shape fixture (Mg alloy)

Figure 10. Equivalent Stress of T-shaped Fixture made of Magnesium Alloy and Aluminum Alloy

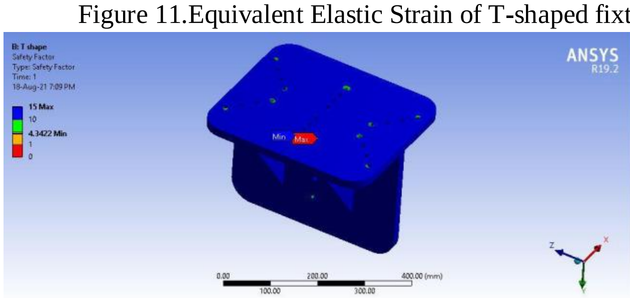


(a).T- shape fixture (Al alloy)

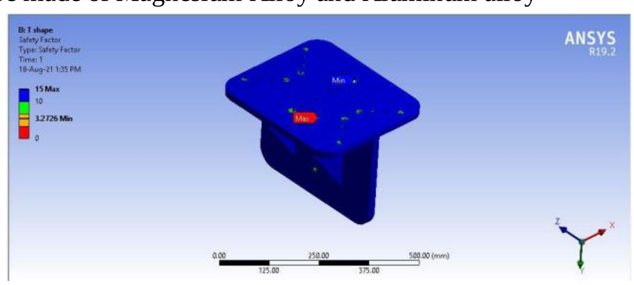


(b) T- shape fixture (Mg alloy)

Figure 11.Equivalent Elastic Strain of T-shaped fixture made of Magnesium Alloy and Aluminum alloy

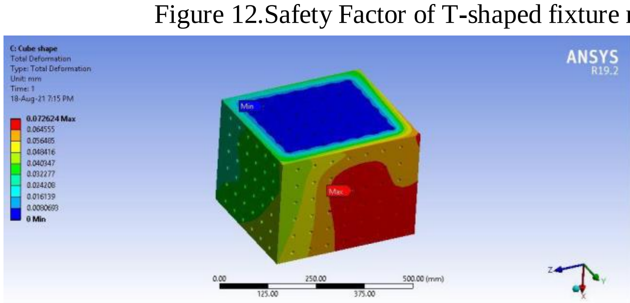


(a).T- shape fixture (Al alloy)

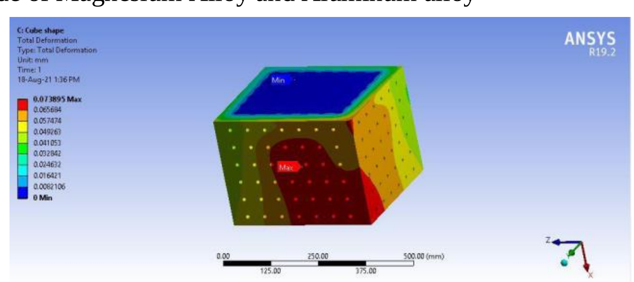


(b) T- shape fixture (Mg alloy)

Figure 12.Safety Factor of T-shaped fixture made of Magnesium Alloy and Aluminum alloy

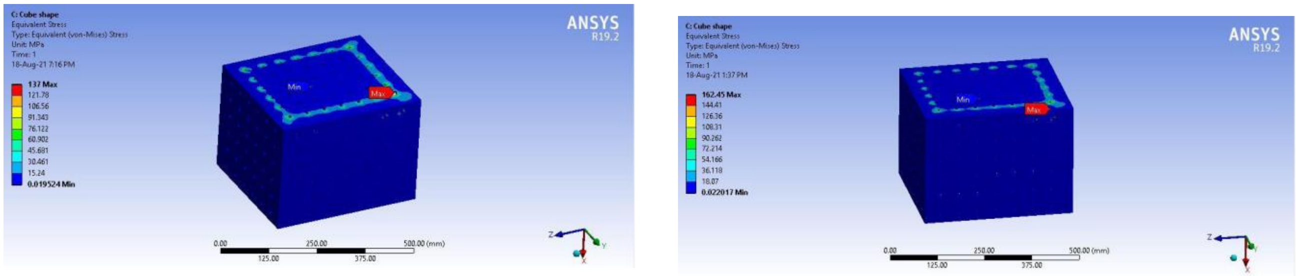


a).Cube- shape fixture (Al alloy)



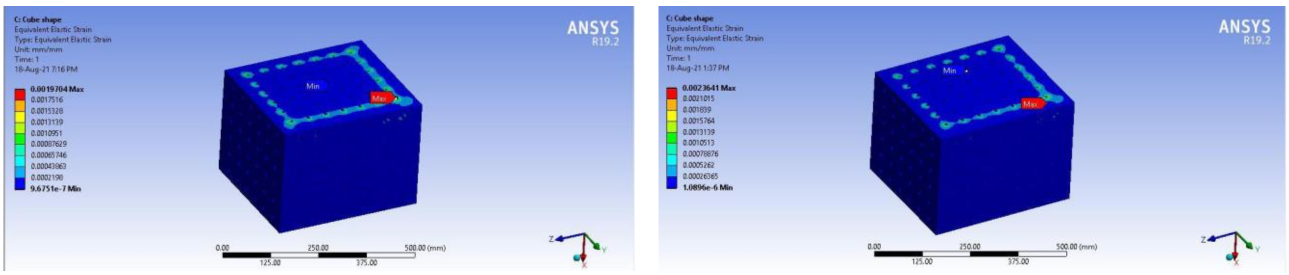
(b) Cube- shape fixture (Mg alloy)

Figure 13.Deformation of Cube-shaped fixture made of Magnesium Alloy and Aluminum alloy



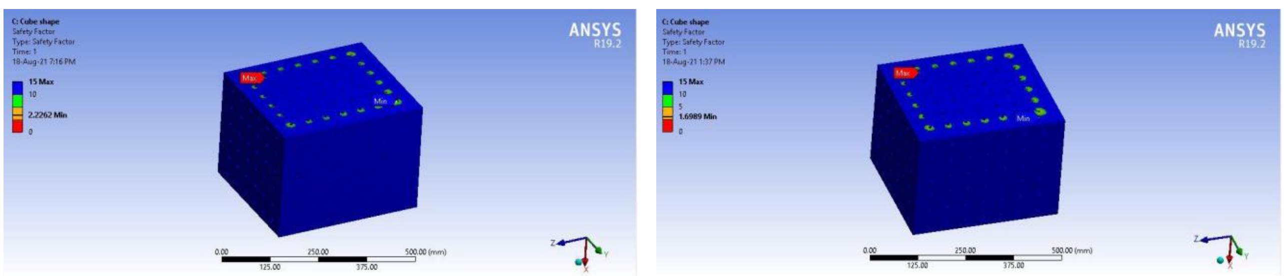
a).Cube- shape fixture (Al alloy) (b) Cube- shape fixture (Mg alloy)

Figure 14. Equivalent Stress of Cube-shaped fixture made of Magnesium Alloy and Aluminum alloy



a).Cube- shape fixture (Al alloy) (b) Cube- shape fixture (Mg alloy)

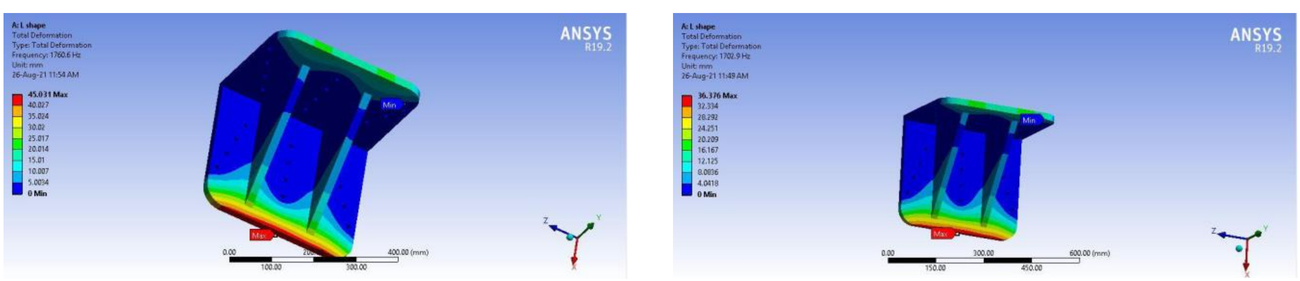
Figure 15. Equivalent Elastic Strain of Cube-shaped fixture made of Magnesium Alloy and Aluminum alloy



a).Cube- shape fixture (Al alloy) (b) Cube- shape fixture (Mg alloy)

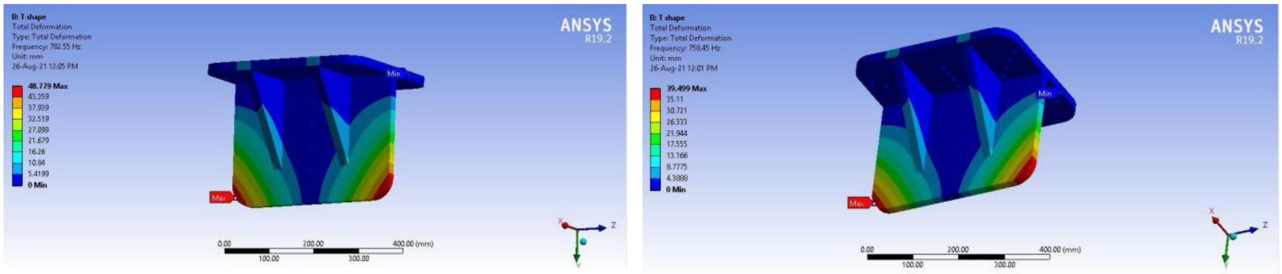
Figure 16. Safety Factor of Cube-shaped fixture made of Magnesium Alloy and Aluminum Alloy

Figures shows modal analysis for various fixtures made of aluminum alloy and magnesium alloy.



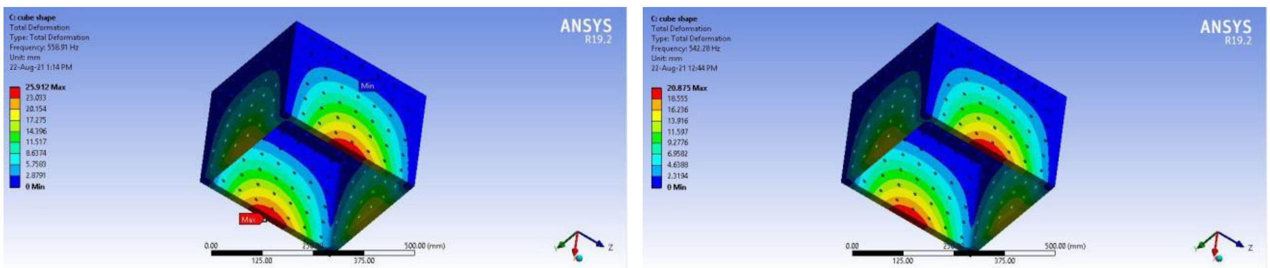
(a).L- shape fixture (Al alloy) (b) L- shape fixture (Mg alloy)

Figure 17. Modal analysis of L-shaped fixture made of Magnesium alloy and Aluminum alloy



(a).T- shape fixture (Al alloy) (b) T- shape fixture (Mg alloy)

Figure 18. Modal analysis of T-shaped fixture made of Magnesium Alloy and Aluminum alloy



(a) Cube- shape fixture (Al alloy) (b) Cube- shape fixture (Mg alloy)

Figure 19. Modal analysis of Cube-shaped fixture made of Magnesium alloy and Aluminum alloys

V. RESULTS AND DISCUSION

Table 1: Comparison of Static analysis values of Fixtures made of Aluminum Alloy

Aluminum Alloy	Deformation	Stress	Strain	Safety Factor
L- Shape	0.15463	159.86	0.0022896	1.9079
T-Shape	0.053914	70.24	0.0010084	4.3422
Cube Shape	0.072624	137	0.0019704	2.2262

Table 2: Comparison of Static Analysis values of Fixtures made of Magnesium Alloy

Magnesium Alloy	Deformation	Stress	Strain	Safety Factor
L-Shape	0.2394	166.4	0.0037515	1.5265
T-Shape	0.083811	79.447	0.0017675	3.2726
Cube Shape	0.073895	162.45	0.0023641	1.6989

Table 3: Natural frequencies of fixtures made of Aluminum alloys are compared

Aluminum Alloy	L-Shape	T-Shape	Cube Shape
Mode 1(Hz)	1760.6	782.55	558.91
Mode 2(Hz)	1872.9	810.12	695.95
Mode 3(Hz)	1907.2	1115.9	819.08
Mode 4(Hz)	1961.1	1538.2	1089
Mode 5(Hz)	1973.7	1879.5	1479.3
Mode 6(Hz)	2125.3	1880.5	1675.1

Table 4: Natural frequencies of fixtures made of magnesium alloys are compared

Magnesium Alloy	L-Shape	T-Shape	Cube Shape
Mode 1(Hz)	1702.9	758.48	542.28
Mode 2(Hz)	1815.9	782.43	674.17
Mode 3(Hz)	1843.2	1084.7	793.42
Mode 4(Hz)	1897.1	1495.1	1052.8
Mode 5(Hz)	1909	1817.8	1435
Mode 6(Hz)	2062.2	1828.3	1625

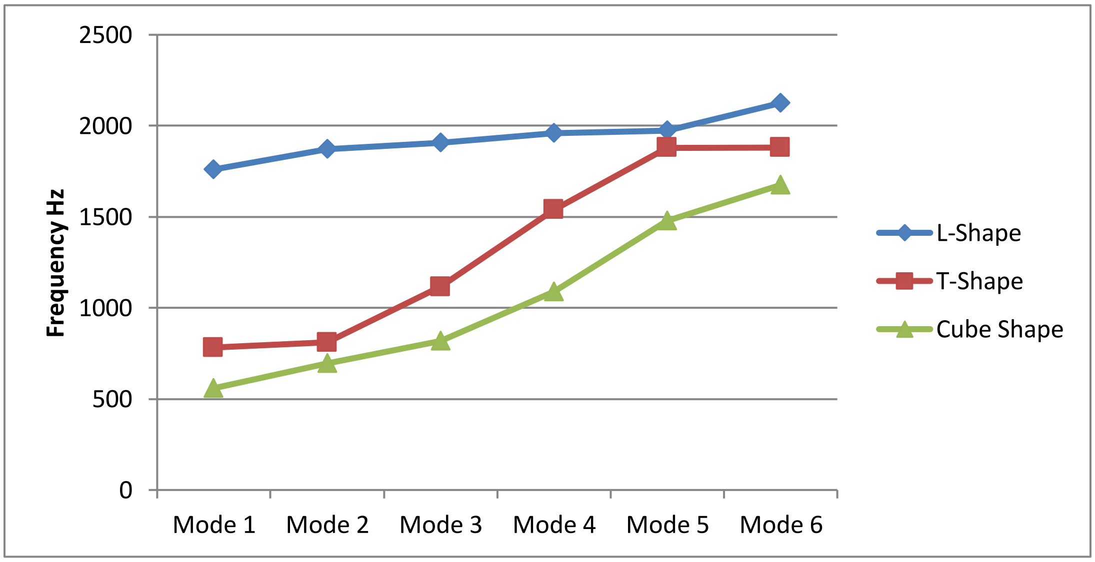


Figure 20. Graph of Frequencies and Mode Shapes for Different Aluminum Alloy Fixtures

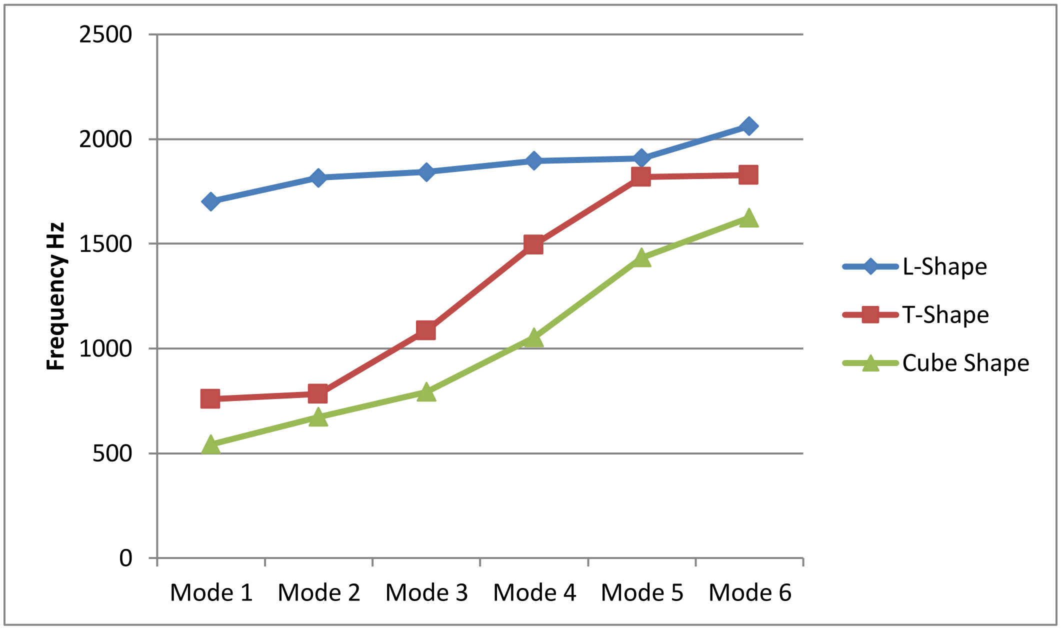


Figure 21. Graph of Frequencies and Mode shapes for Different Magnesium Alloy Fixtures

V. Conclusion

The main aim of the project is to design a suitable vibration fixture with suitable material, in this process here 3 types of fixtures (Cube, "T" type, "L" type fixtures) were designing with the help of cad tool solid works and analyzing with 2 different materials (Al-2024, az31b) by using Ansys workbench, in this process both static and dynamic loading conditions applied on each material/ object,

From static analysis results it is state that all 3 objects having their individual strength values for each material, in this process T-shaped fixture is having higher strength values compare to other 2 models, and then cube shape vibration fixture has taken 2nd position and then after L shaped has 3rd rank, in terms of their strength values,

But it is not possible to decide a material or object by knowing only static analysis results, to get more clear knowledge about each object and each material here dynamic analysis is also performed and calculated results like natural frequency values, from dynamic analysis results L-shape object has better results than other 2 models, and then T-shape has 2nd best frequency values, and cube shape has least frequency values in each mode, and there is almost nearly 50% difference is there, so that this cube shape vibration fixture is not suitable for real time applications, and even though it has good static analysis values but poor dynamic analysis values,

Finally thesis can conclude with L-shape vibration fixture with al-2024 material, even though T-shape has good static results than any other model/material, but it has 2nd best dynamic analysis results, so that here L-shape is chosen due to its high range natural frequency range values. And al-2024 is having good strength to weight ratio.

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