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Modeling And Analysis Of A Cnc Milling Machine Bed With Composite Materials

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ABSTRACT

The materials utilized as a part of a machine device have an unequivocal part in deciding the efficiency and exactness of the part made in it. The regular basic materials utilized as a part of exactness machine apparatuses, for example, cast iron and steel at high working velocities create positional mistakes because of the vibrations moved into the structure. Quicker cutting rates can be procured just by structure which has high firmness and great damping attributes. We know that by experiences life of a machine is inversely proportional to the levels of vibration that the machine is subjected. The further procedure is completed to experience the distortion, normal recurrence and removal utilizing Static examination, Modal investigation and Harmonic individually. Since the bed in machine apparatus assumes a basic part in guaranteeing the exactness and precision in segments. Is a standout amongst the most critical apparatus structures which have a tendency to retain the vibrations coming about because of the cutting operation. To break down the bed for conceivable material changes that could build solidness, diminish weight, improve damping characteristics. In this paper constant load is applied on a bed with and without Nanocoating on the material and with composite materials. Graphene is used for coating basing on strength and thermal properties. Modeling of the bed was carried out in CATIA V5 R24 and ANSYS is used for structural analysis. By comparing the stress distribution and deformation in the bed by changing its material with the previous. Finally this thesis summarizes the suitable materials can be used as machine bed material.

Key words: *Machine Tool, Machine Bed, Stiffness, Damping, CATIA V5 R24, ANSYS*

1. INTRODUCTION

Computer Numerical Control (CNC) milling machines play a crucial role in modern manufacturing, providing precision, efficiency, and repeatability in machining operations. The structural integrity of a CNC milling machine bed significantly affects its performance, influencing parameters such as vibration damping, thermal stability, and load-bearing capacity. Traditionally, machine beds are made from cast iron or steel due to their excellent mechanical properties. However, with advancements in materials science, composite materials have emerged as a promising alternative due to their superior strength-to-weight ratio, enhanced damping characteristics, and improved thermal stability. The use of composite materials in machine tool structures aims to reduce weight while maintaining or even improving mechanical properties, leading to increased machining accuracy and energy efficiency. CNC milling machines are used for precision and more productivity. This requires a transfer of high speed as well as the high cutting speed of machine tools. It ensures not only faster cutting rates but also lesser cutting force. Faster cutting speeds can be acquired only by structure which has high stiffness and good damping characteristics. The deformation of machine tool structure under cutting forces and loads which lead to the poor quality of products with less accuracy, both dimensional and also geometrical of the item

This study focuses on the Modeling and analysis of a CNC milling machine bed using composite materials. Finite Element Analysis (FEA) will be employed to evaluate the structural performance of different composite configurations under static and dynamic loading conditions.

2. LITERATURE REVIEW

The selection of materials for CNC milling machine beds significantly influences their structural performance, impacting factors such as stiffness, damping capacity, and overall machining accuracy. Recent studies have explored various composite materials and nanocoatings to enhance these attributes. This literature review examines 20 notable studies from 2011 to 2023 that focus on the modelling and analysis of CNC machine beds utilizing composite materials and nanocoating.

Hybrid Welded Steel and Polymer Concrete Beds: Apotheker et al. (2011) investigated a machine tool bed composed of welded steel and polymer concrete. Their findings indicated a 24.7% increase in natural frequency and a 2.7-fold enhancement in damping ratio compared to traditional cast iron beds. IJRASET+2Science Publications + 2 Academia +2

Carbon Fiber Reinforced Polymer (CFRP) Composites: Selvakumar and Mohanram (2012) analysed the use of CFRP composites in machine tool structures, highlighting significant weight reduction and improved damping characteristics over conventional materials. Springer Link+3IAEME+3IJRASET+3

Graphene Nanocoatings: Yashaswi et.al. (2017) explored the application of graphene nano coatings on CNC milling machine beds, demonstrating enhanced stiffness and vibration damping properties. IAEME

Aluminium Foam Sandwich Structures: Research by Kroll et al. (2011) introduced aluminium foam sandwich structures, offering a balance between lightweight design and structural integrity, suitable for machine tool applications.PMC+1SpringerLink+1

3. MODELING PROCEDURE OF CNC MILLING MACHINE BED

3.1 CNC Milling Machine Bed Model - 1

Firstly we go through the mechanical design to part design and click on ok. Select the XY-Plane and click on sketcher command after that we create a Rectangle by using the rectangle command instantly we given the dimensions height 5mm width 11mm by using the constraints command. By Using Pad command give the pad to that Rectangle with 25mm length. Similarly addition of three more supports under the plate at the bottom of the bed was done using pad and pattern options.

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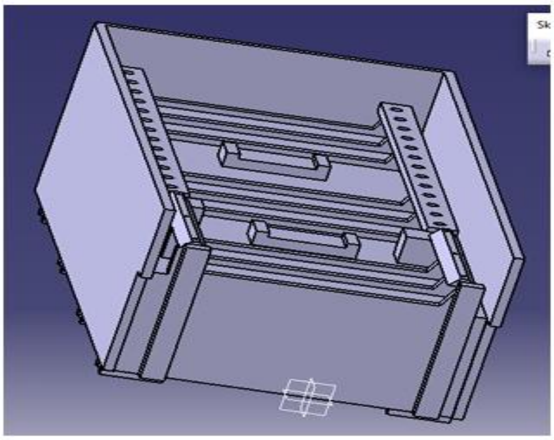

Fig 3.1: CNC Milling Machine Bed Model-1

3.2 CNC Milling Machine Bed Model –2

In model-2 additional supports were added to model -1, to support the distributed load acting on the bed. Some ribs are added at the bottom of the holed plate at the top portion on the bed by using pad and pattern options. Similarly addition of three more supports under the plate at the bottom of the bed was done using pad and pattern options.

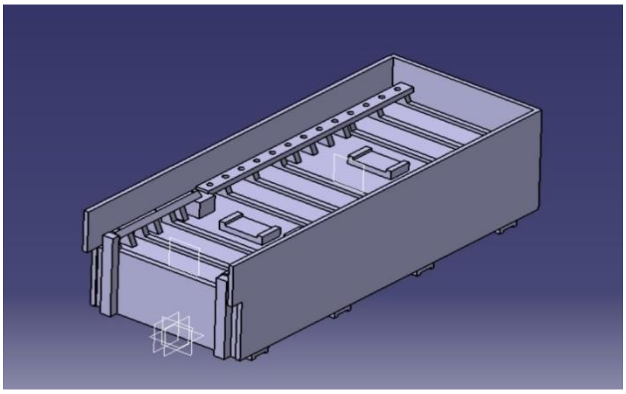

Fig 3.2: CNC Milling Machine Bed Model - 2

4. ANALYSIS OF CNC MILLING MACHINE BED IN ANSYS

4.1Static Structural analysis on CNC Milling Machine Bed Model-1

Engineering geometry Select geometry right click select import geometry open browse select .igs file open model.

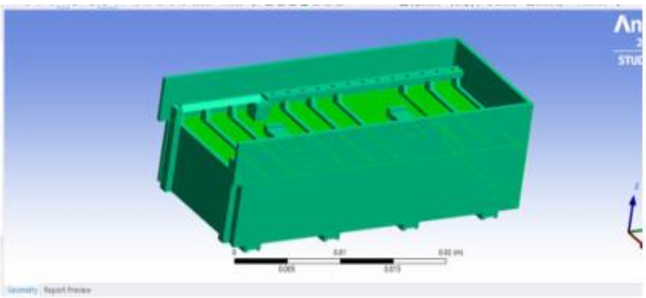

Fig 4.1: Imported model CNC milling machine bed Model 1

4.2 Material properties data

Properties	Value
Density	7200kg m3
Young's Modulus (Pa)	1.1e+11
Poisson's Ratio	0.28
Bulk Modulus (Pa)	8.3333e+10
Shear Modulus (Pa)	4.2969e+10

Table 4.1: Material Properties of Gray Cast Iron

Properties	Value
Density	7850 kg/ m3
Young's Modulus (Pa)	2.e+005
Poisson's Ratio	0.3
Bulk Modulus (Pa)	1.6667e+011
Shear Modulus (Pa)	76923e+0025

Table 4.2: Material Properties of Structural Steel

Properties	Value
Density	2100/ m3
Young's Modulus (Pa)	5.802Gpa
Poisson's Ratio	0.28
Bulk Modulus (Pa)	1.225Gp
Shear Modulus (Pa)	1.898Gpa

Table 4.3: Material Properties of E-Glass

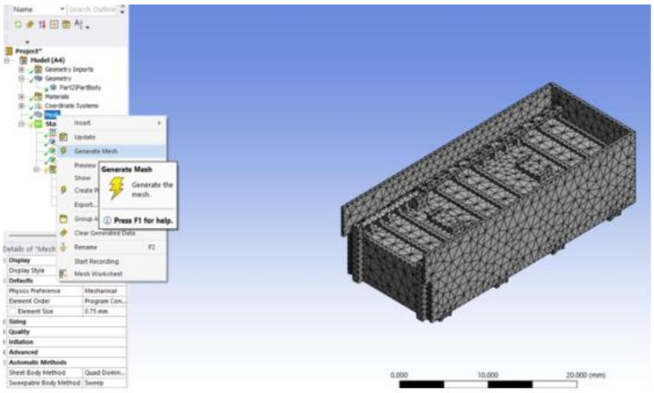

Fig 4.2: Meshed model of CNC milling machine bed model-1

5. RESULTS

5.1 Static Analysis Results of CNC Milling Machine Bed Model - 1

5.1.1 Results of Model –1with Gray Cast Iron

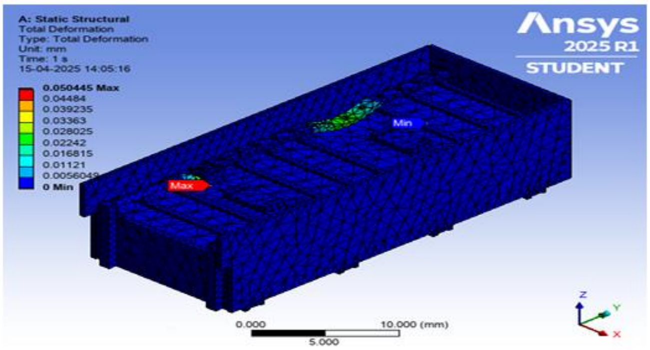

Fig 5.1: Total deformation of CNC milling machine bed model-1with Gray cast iron

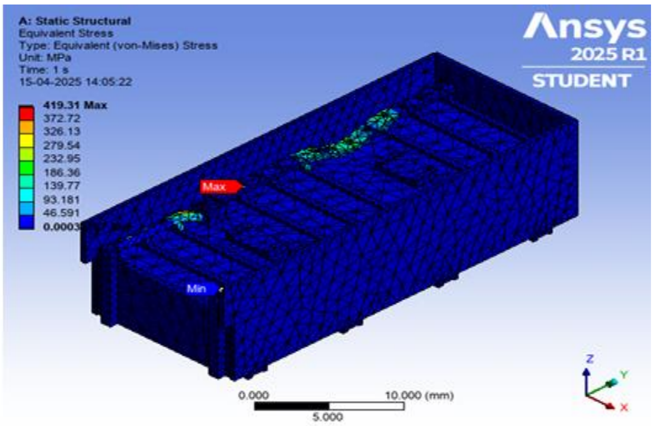

Fig 5.2: Equivalent (von-mises) Stress of CNC milling machine bed model-1with Gray cast iron

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	2.4837e.8	0.0003
Maximum	0.050	0.0042	419.31

Table 5.1: Structural analysis results on Model–1 with Gray cast iron

5.1.2 Results of Model-1with Structural Steel

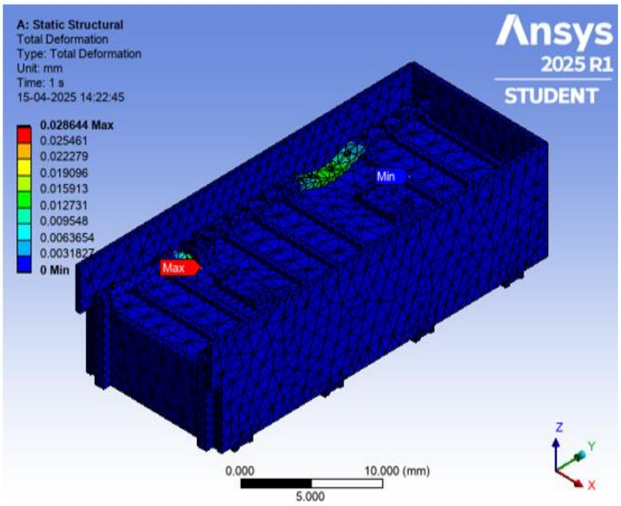

Fig 5.3: Total deformation of CNC milling machine bed model-1with Structural Steel

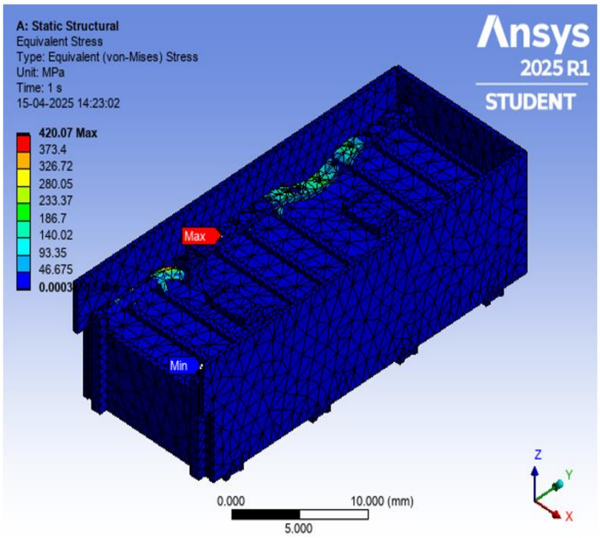

Fig 5.4: Equivalent (von-mises) Stress of CNC milling machine bed model-1with Structural Steel

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	2.5837e.7	0.003
Maximum	0.028	0.002	420.07

Table 5.2: Structural analysis results on Model–1 with Structural Steel

5.1.3 Results of Model -1 with E-Glass

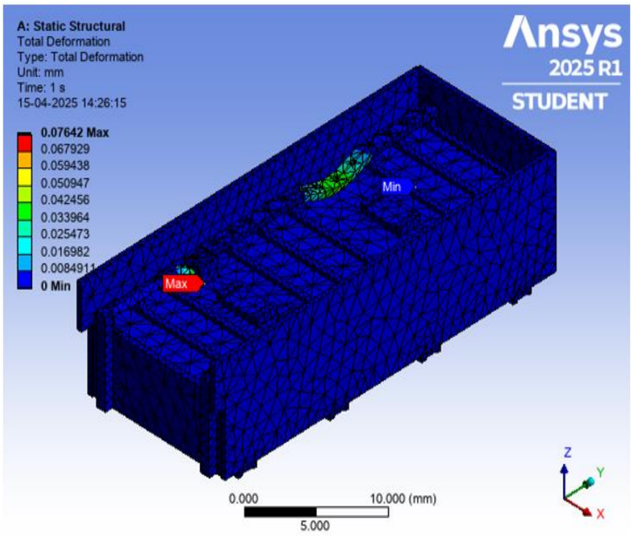

Fig 5.5: Total deformation of CNC milling machine bed model-1with E- Glass

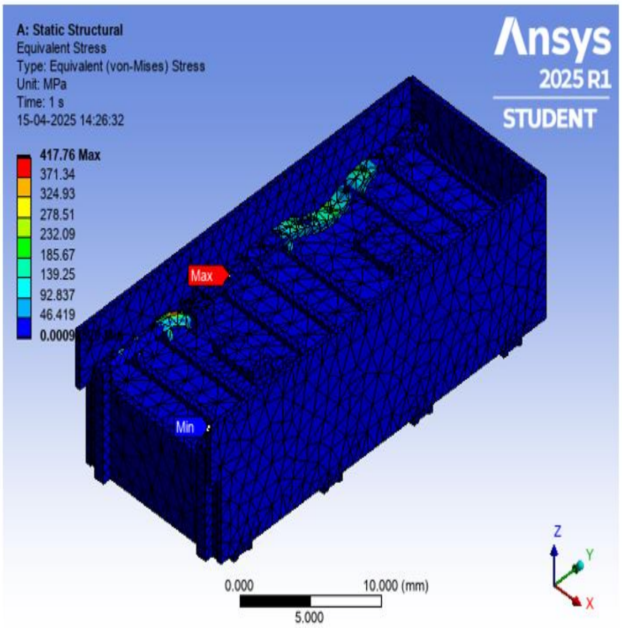

Fig 5.6: Equivalent (von-mises) Stress of CNC milling machine bed model-1with E- Glass

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	3.1678e.4	0009
Maximum	0.0764	0.0064	417.76

Table 5.3: Structural analysis results on Model–1 with E-Glass

5.2 Static Analysis Results of CNC Milling Machine Bed Model – 2

5.2.1 Results of Model–2with Gray cast iron

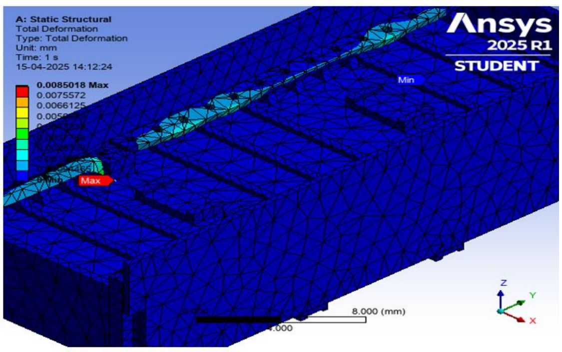

Fig 5.7: Total deformation of CNC milling machine bed model-1with Gray cast iron

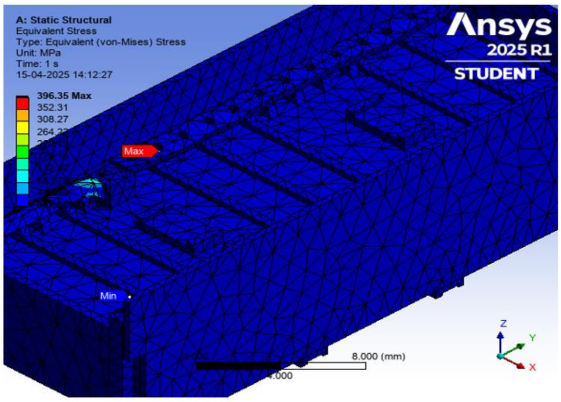

Fig 5.8: Equivalent (Von-Mises) Stress of CNC milling machine bed model-2with Gray cast iron

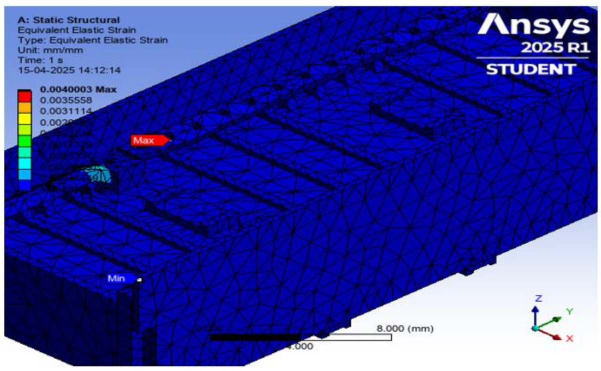

Fig 5.9: Equivalent Elastic Strain CNC milling machine bed model-2 with Gray cast iron

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	1.1468e.7	0.006
Maximum	0.008	0.00400	396.35

Table 5.4: Structural analysis results on Model–2 with Gray cast iron

5.2.2 Results of Model-2 with Structural Steel

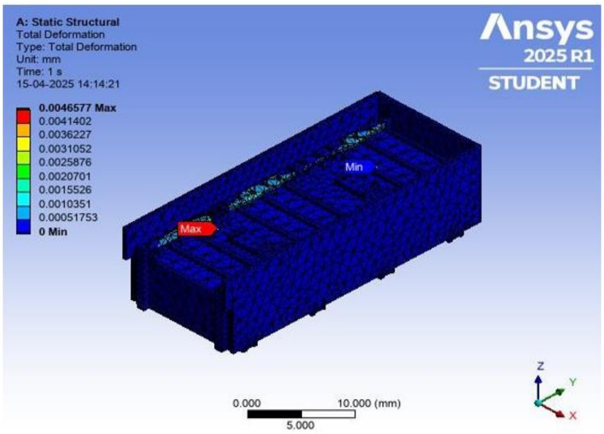

Fig 5.10: Total deformation of CNC milling machine bed model-2 with Structural Steel

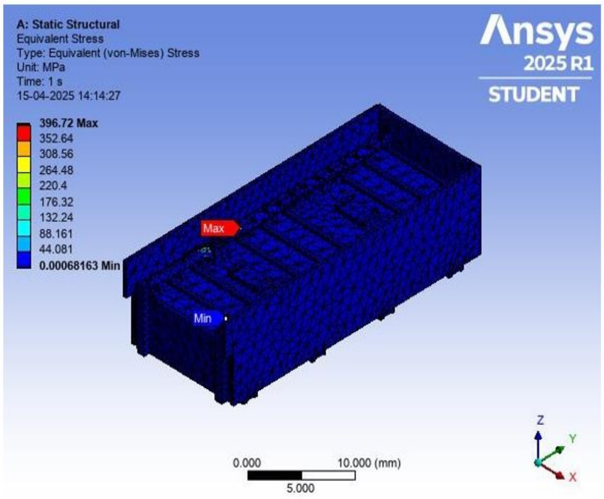

Fig 5.11: Equivalent (Von-Mises) Stress of CNC milling machine bed model-2 with Structural Steel

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	0.0006	8.3481e-9
Maximum	0.0046	0.00219	396.72

Table 5.5: Structural analysis results on Model–2 with Structural Steel

5.2.3 Results of Model -2 with E– Glass

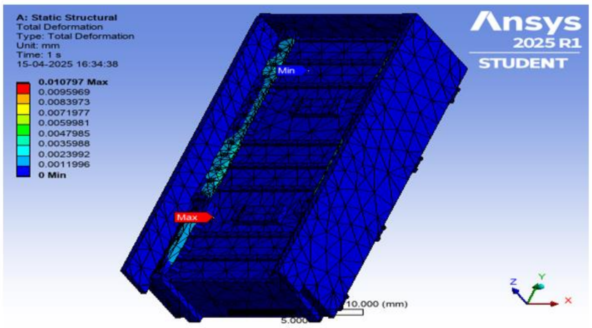

Fig 5.12**:** Total deformation of CNC milling machine bed model-2 with E- Glass

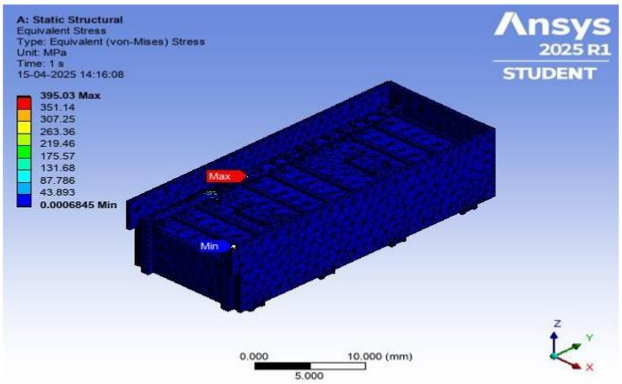

Fig 5.13**:** Equivalent (Von-Mises) Stress of CNC milling machine bed model-2with E - Glass

Type	Total Deformation (mm)	Equivalent Elastic Strain	Equivalent (Von-Mises) Stress (MPa)
Minimum	0	1.4934e-8	0.0006
Maximum	0.0107	0.0060	395.03

Table 5.6: Structural analysis results on Model–2 with E– Glass

5.3 Comparative Results of Static Analysis with Three Materials

Material	Total deformation (mm)		Equivalent(Von-Mises) stress (MPa)	
	Model -1	Model -2	Model -1	Model -2
Gray Cast Iron	0.050	0.008	419.31	396.35
Structural Steel	0.028	0.004	420.07	396.72
E-Glass	0.0764	0.010	417.76	395.03

Table 5.7: Comparison of Structural analysis results of Model-1 & Model-2

6. CONCLUSIONS

The CNC milling machine bed is a foundational component that directly impacts the performance, precision, and efficiency of CNC milling machines. Its primary functions of providing stability, absorbing vibrations, supporting heavy loads, and maintaining thermal stability make it essential in a wide range of industries, from aerospace and automotive to medical and energy sectors. The present work mainly focused on design and structural analysis on CNC milling machine bed. Initially Model-1 is created in CATIA software and static analysis was performed on Model-1 with three materials properties. By observing the results of model -1, a modified one namely Model-2 was prepared and analysed with same material properties.

Form the analysis results it was observed that, the equivalent stress and deformation values are less in Model-2 compared with Model-1. In Model -2, the equivalent stress value 395.03MPa is minimum with E-Glass material compared with other material values and maximum deformation is also within the considerable range. Finally it was concluded that CNC milling machine bed with Model-2 design and E- Glass material will give better results.

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