Analysis of a Modelled CNC Milling Machine Bed with different Composite Materials

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Abstract- In Industrial world CNC machines are dominating because of its versatile form of automation. The structural materials used in a machine tool plays a decisive role in productivity, accuracy and surface finish of the parts manufactured in it. The materials which have high stiffness and good damping characteristics are only used as structural materials in machine tool to withstand high operating speeds. The vibrations developed in machining operation gets transferred into machine tool structure. The conventional structural materials such as cast iron and steel develops positional errors due to vibrations transferred into the structure at high operating speeds. We know that by experiences, the proportionality of the life of a machine is inverse to the levels of vibrations that the machine is subjected. In this work, a machine bed is selected for the analysis on static loads. Then work is carried out to overcome the limitations in structural material, conventional materials are replaced with composite materials having high stiffness and good damping characteristics. The main aim of this work is increasing and reducing the structural weight. A 3D CAD model of the machine bed is created by using SOLID WORKS and analysis were carried out on different composite machine bed using ANSYS workbench.

Index Terms: Machine tool, Machine bed, Stiffness, Damping, Solidworks, Ansys.

I. INTRODUCTION

CNC milling machines are mainly used for precision and more productivity. This requires a transfer of high speed as well as the high cutting speed of machine tools. And these operations are invariably accompanied by relative vibrations between work piece and tool. Faster cutting speeds will be acquired only by the 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 as well as geometrical of the product. So, the level of deformation and vibration that determines the components with high precision. Clearly, the lifetime of a machine is inversely proportional to the degree of vibration that the machine is subjected. The further process is carried out to bear the deformation, natural frequency and displacement using Static analysis, modal analysis, and Harmonic analysis respectively. To investigate the bed for possible material changes that would increase stiffness,

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Reduce weight, improve damping characteristics and isolate natural frequency from the operational range. At present most of the machine beds are made of gray cast iron material which has certain drawbacks. Like sudden loads during operation Cast Iron cannot withstand whenever the load reaches ultimate loads.

II. NECESSITY OF COMPOSITE MATERIALS

Bert and Nashif et al. had done the survey on the damping capability of fiber reinforced composites and found out that composite materials generally exhibit higher damping than structural metallic materials. Chandra et al. have done research on damping in fiber-reinforced composite materials. The concept of damping was apparently first introduced by Ungar et.al and was later applied to finite element analysis by Johnson et.al in terms of strain energy. Gibson et.al has developed a technique for measuring material damping in model specimens with the influence of forced flexural vibration. Suarez et al have used Random and Impulse Techniques for Measurement of Damping in Composite Materials. The random and impulse techniques utilize the frequency-domain transfer function of a material specimen with the influence of random and impulsive excitation. Gibson et al used the modal vibration response resultant measurements to characterize, accurately and quickly the mechanical properties of composite materials and structures. Polymeric materials are widely used for sound and vibration damping.

A. Selvakumar, P.V. Mohan ram, "Analysis of alternative composite material for high speed precision machine tool structures" International journal of Engineering, 2, pp.95-98, 2012 shows that Structure material plays a vital role in precision machine tools, which are expected to produce the parts within the specified accuracy of shape and dimensions together with the required surface finish. The shape of the workpiece depends on the instantaneous relative position of the tool and the workpiece and, therefore, of the machine parts which carry them. Hence, a structure which possesses high structural stiffness and high damping is to be selected. Composite materials such as epoxy granite, exhibit good mechanical properties such as high stiffness and damping ratio at a lesser weight, compared to conventional materials. However, for the same stiffness, the basic dimensions of the structures vary.

III. MATERIAL DISCUSSION

A composite is a material that is formed by combining two or more materials to achieve some better properties. Almost all the materials which we see around us are composites. Some of them like woods, bones, stones, etc.

Are natural composites, as they are advanced by natural processes. There are several reasons for the re-emergence of interest in metal- matrix composites, the most important one being their engineering properties. MMCs are of light weight and exhibit good stiffness and low specific weight. It is generally considered that these materials offer savings in weight, at the same time maintaining their properties. MMCs also have other advantages as well, like strength, fracture toughness, thermal stability, and ductility and enhanced elevated temperature performances. However, cost remains a principal point of interest for commercial applications of MMCs in future. Rapid development in MMCs has been recorded in the past few years, but these have not been cost- conscious efforts. More recently, reduction in processing costs; costs of raw material and the desirability of special properties have generated a great amount of interest.

Composites used in this work are Kevlar epoxy, Carbon epoxy, and E-glass epoxy. Epoxy is a thermosetting polymer formed from the reaction of an epoxide "resin" with polyamine "hardener". Epoxy has a broad scope of applications, including fiber-reinforced plastic materials and general purpose adhesives and fiber-reinforced plastic materials. The applications for epoxy-based materials are boundless and include adhesives, coatings and composite materials such as those using carbon fiber and fiberglass reinforcements (although polyester, vinyl ester, and other thermosetting resins are also used for glass-reinforced plastic). The chemistry of epoxies and the range of commercially available variations allows polymers to be produced with a very broad range of properties. Generally, epoxies are known for their excellent chemical, heat resistance and adhesion, good-to-excellent mechanical properties and very good electrical insulating properties. Many properties of epoxies can be modified. And epoxies are the future in industrial world.

IV. MACHINE BED

The machine bed has an influential role in providing rigidity and the strength of a machine. Its design is crucial for accuracy and the performance of the machine tool where it boards all the accessories and cutting tools and other necessary equipment for the running of the machine. It is the one happened to subjected to various dynamic and static forces during the machine operation. A milling machine is a machine tool, exceptionally used to machine solid materials. The basic categorization of milling machine forms is horizontal and vertical, which refer to the orientation of the main spindle. The two types have the size range from small, bench-mounted devices to room-sized machines.

Machine Bed brace all the elements like a column, worktable and servo motors. The cutting force which is induced in the machining process is simply transformed to machine bed, and machine beds absorb the vibrations induced in the machining process. The machine bed contains a hole for bracing lead screw which drives the worktable. Therefore that workpiece can be moved as per the user programming code. And also supports the column on the machine bed rear end with the help of lead screws. Machine beds withstand the various forces generated during the cutting. Accurate products will be produced only when the machine bed has high structural stiffness and good damping coefficient. So that the two major design factors structural stiffness and damping coefficient considered while designing the machine bed. Whenever machining operation starts machine bed experiences cutting forces. Those forces can be divided into three types, they are the tangential cutting force, feed force and radial force. The loads applied to the machine bed are calculated as.

Total weight of Machine = 170 Kg.
The load acting on the rear end of Machine Bed = 73Kg.
The weight of the Work Table = 18Kg.
Total forces acting on guideways = cutting force +
Weight of work table and workpiece
= 95 + (18*9.81)
= 272N
Force due to other accessories = 73 * 9.81= 717N
All the above-calculated loads are applied on the
Machine bed during the analysis of the machine bed.

V. MOFELLING AND ANALYSIS OF MACHINE BED

A 3D model of the CNC machine bed was created in the SOLID WORKS software and saved in the Iges format and imported into Ansys workbench. The analysis was carried out on four materials Cast iron, Kevlar epoxy, e-glass epoxy and carbon epoxy. In this stage, Force and displacement boundary condition were applied as follows forces, the front end of the machine bed carries cutting force, the weight of the work table and weight of the workpiece, due to this a total load of 272 N is applied to the Guideways of Machine bed. The rear end of the Machine bed carries vertical column, and other accessories like servo motors, spindles and so on. Therefore a total load of about 717N will be applied on two flat surfaces of the rear end.

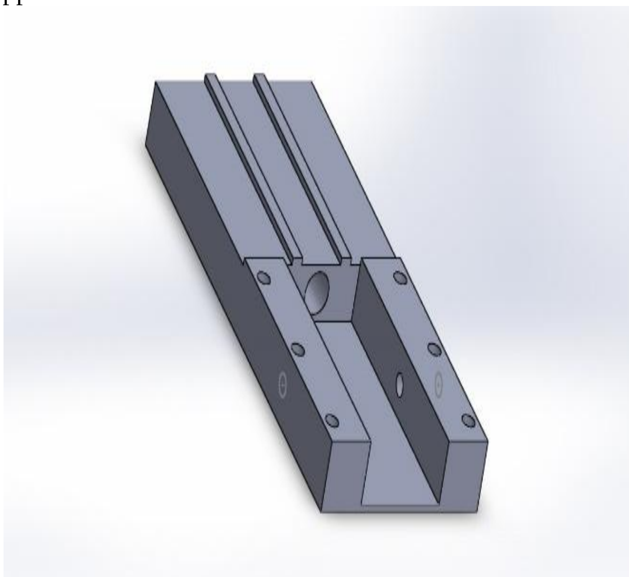
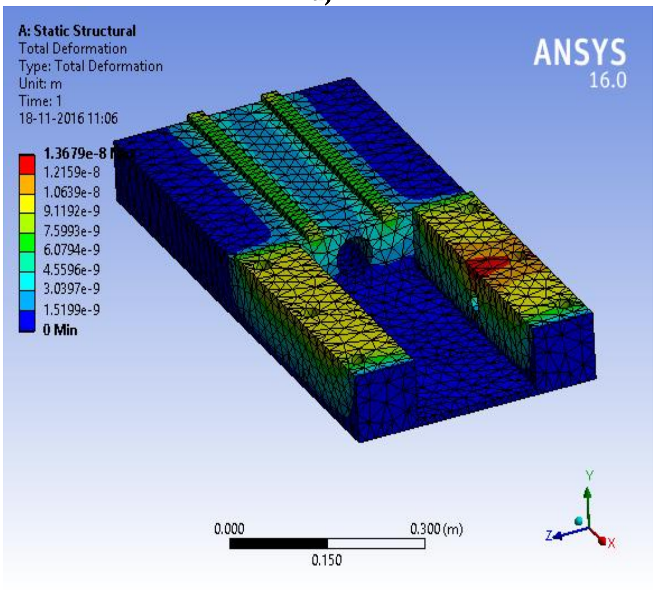


Fig 1 Machine bed Model in Solidworks

A. Static Analysis

a)



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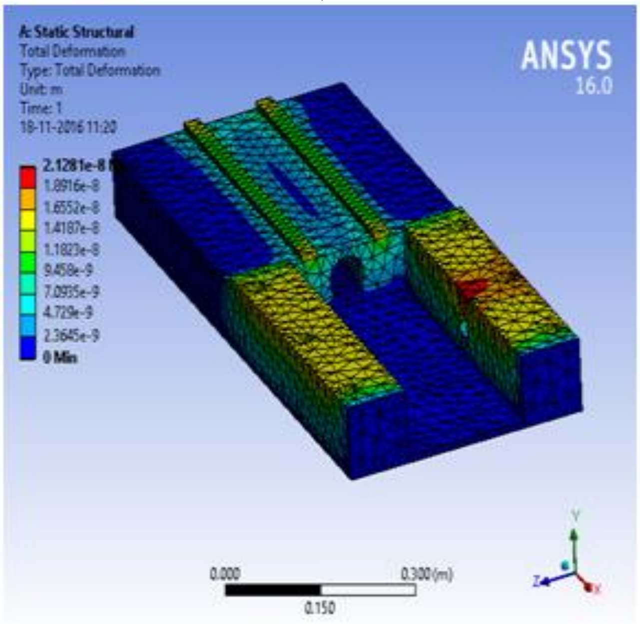

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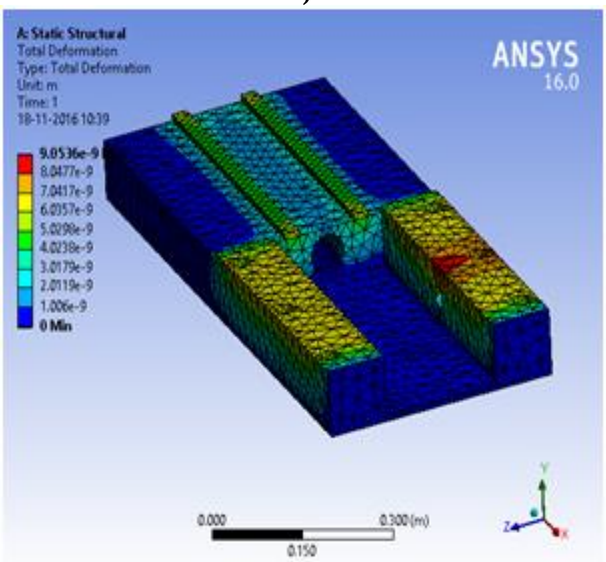
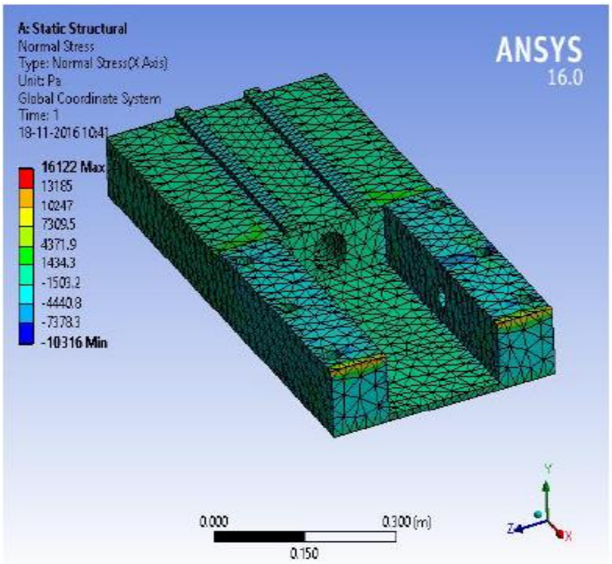


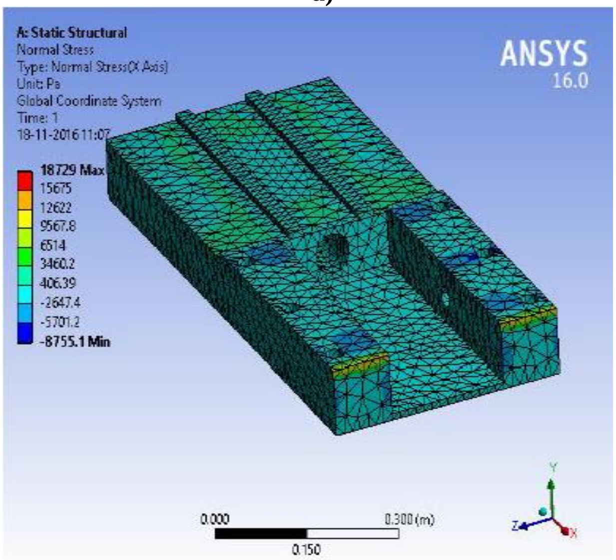
(d)

Fig 2 Total deformation a) cast iron b) Kevlar epoxy c) e-glass epoxy d) carbon epoxy

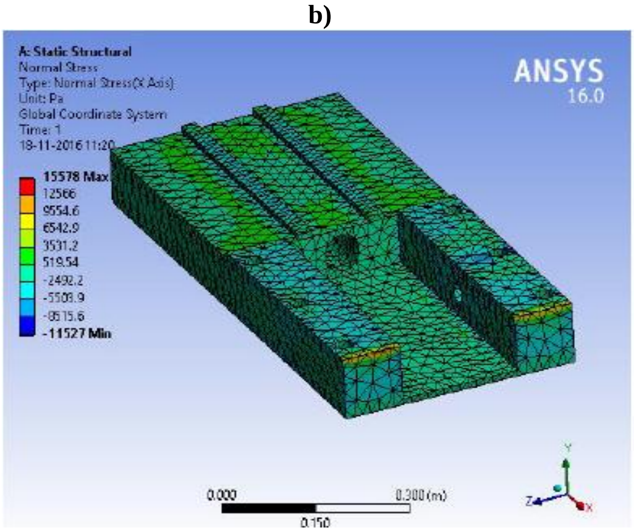
B. Normal Stress



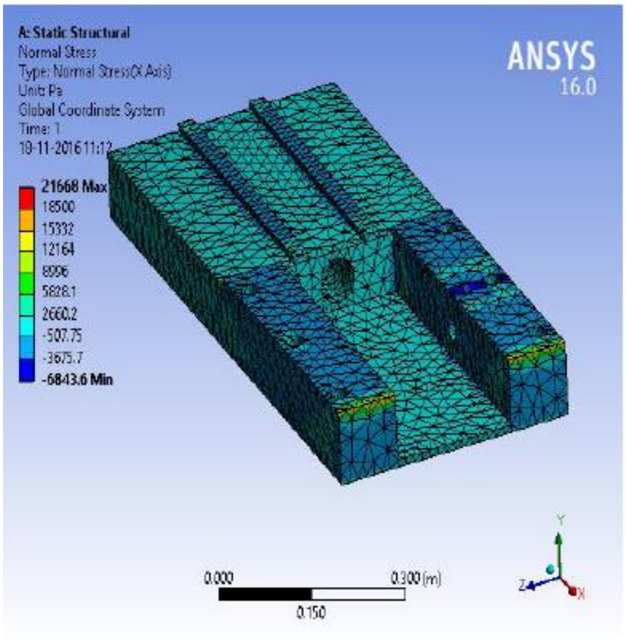
a)



b)



c)



d)

Fig 3 Normal stress developed a) Cast iron b) Kevlar epoxy c) e-glass epoxy d) carbon epoxy

VI. RESULTS AND DISUSSION

Comparison of the results obtained from analysis under static load condition is given below in tabular column

Table 1 Comparison of Static Structural Analysis Results

parameter		Cast iron	Kevlar epoxy	e-glass epoxy	Carbon epoxy
Vonmises stress(pa)	Min	4.41e-11	1.52e-11	9.27e-11	2.30e-11
	Max	22620	25711	20376	29427
Total Deformation (m)	Min	0	0	0	0
	Max	9.05e-9	1.36e-8	2.12e-8	1.53e-8

Total deformation of Kevlar epoxy and carbon epoxy composite bed is very less than the deformation due to Cast iron. Since the stress is independent of Material Property, hence stress induced in all the material machine beds is approximately same because of there is no design modification.

Table 2 Comparison of Modal Analysis Results.

modes		1	2	3	4	5
Cast iron	F	4593.9	4658.6	5367.9	5433.6	5911
	D	0.4762	0.4532	0.3932	0.3985	0.2067
Kevlar epoxy	F	8738	8854	10307	10443	11354
	D	1.089	1.0371	0.9177	0.9230	0.4796
e-glass epoxy	F	5482.8	5564.8	6355.1	6428.6	6988.7
	D	0.8862	0.8429	0.7181	0.7328	0.3817
Carbon epoxy	F	7941	8042.2	9460.7	9598.7	10414
	D	1.022	0.97158	0.8762	0.8739	0.4588

The above tabular column shows the comparison of modal analysis of four materials.

In table where

F = Frequency (Hz)

D= Deformation (m)

VII. CONCLUSION

Based on the configuration principles, the existing bed material was replaced by Kevlar epoxy and Carbon epoxy composite material shows improve in the static characteristics. Simulations results show that the static characteristics of the machine bed are improved. Generally, Composite materials provide high specific modulus and high specific strength with less weight in machine tool industries. These composite materials provide high accuracy and precession of the component manufactured in such machine tools made of composite materials. By considering all the results, the induced deformation and strain in Kevlar epoxy and carbon epoxy machine bed is less than conventional cast iron machine beds because specific strength and specific rigidity of composite machine bed are more than cast iron. The work suggests that Kevlar epoxy and carbon epoxy composite material is best suited for CNC milling machine bed.

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