Modelling and Analysis of CNC Milling Machine Bed with Composite Material

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Abstract— Structural materials used in a machine tool have a decisive role in determining the productivity and accuracy of the part manufactured in it. The conventional structural materials used in precision machine tools such as cast iron and steel at high operating speeds develop positional errors due to the vibrations transferred into the structure. Faster cutting speeds can be acquired only by structure which has high stiffness and good damping characteristics. Clearly the life of a machine is inversely proportional to the levels of vibration that the machine is subjected. The further process is carried out to undergo the deformation, natural frequency and displacement using Static analysis, Modal analysis and Harmonic analysis respectively. Since the bed in machine tool plays a critical role in ensuring the precision and accuracy in components. It is one of the most important tool structures which tend to absorb the vibrations resulting from the cutting operation. To analyze the bed for possible material changes that could increase stiffness, reduce weight, improve damping characteristics and isolate natural frequency from the operating range. This was the main motivation behind the idea to go in for a composite model involving High Modulus Carbon Fiber Reinforced Polymer Composite Material (HM CFRP). Though carbon has good strength and stiffness properties but it lacks in damping requirements. On the other hand polymer, though it lacks in strength but it has good damping characteristics and it is used to hold the carbon fibers. This makes it ideal to combine these materials in a proper manner. In this work, a machine bed is selected for the analysis static loads. Then investigation is carried out to reduce the weight of the machine bed without deteriorating its structural rigidity. The 3D CAD model of the bed has been created by using commercial 3D modelling software and analyses were carried out using ANSYS.

Key words: Composite material, hybrid structures, machine bed.

I. INTRODUCTION

The transfer of high speed as well as the high cutting speed of machine tools is very essential important for the improvement of productivity. 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 leads 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 life of a machine is inversely proportional to the levels of vibration that the machine is subjected. The further process is carried out to under goes the deformation, natural frequency and displacement using Static analysis, Modal analysis and Harmonic analysis respectively. To analyse the bed for possible material changes that could increase stiffness, reduce weight, improve damping characteristics and isolate natural frequency from the operating range.

At present the Machine Beds are made of grey Cast Iron material, which cause a number of problems in Machine tools. Cast Iron cannot with stand the sudden loads during operation whenever the load reaches Ultimate loads it Simply fails without any prior indication. Casting is only the Manufacturing process used to produce the beds. This Process leads to various Casting Defects in the component. In order to have high strength and high stiffness the weight of the machine bed should be high.

II. NEED OF COMPOSITE MATERIALS

A. Selvakumar [1] work states that same stiffness, the epoxy granite structure offers a considerable weight reduction, along with high damping characteristics. The epoxy granite structure offers a sharp reduction in mass along with high damping ratio. S. Syath Abuthakeer [2] proposed how to improve static and dynamic characteristics on a CNC machine. Simulation results show that the static and dynamic performances of vertical ribs with hollow bed have been improved. Structural vertical ribs with hollow offers a method to improve the conventional design of machine structure. Based on structural modifications, ribs parameters and distributions can be further optimized. A. Merlo [3] analyzed the combination of hybrid materials (steel, CFRP, Al honeycomb) and an intensive use of gluing technology allows to increase damping and, at the same time, to get a consistent mass reduction (up to 40%) without reducing the overall stiffness. Sivarao [4] Investigation of Tangential Force, Horsepower and Material Removal Rate Associating HAAS CNC Milling, Al6061-T6511 Work Material & TiAlN Coated End Mill Tool. This journal gives about calculation of cutting forces in milling machine process. Thirumaleswara Bhat Anil Antony Sequeira [5] Modified Approach for Cutting Force Measurement in Face Milling Process. This journal gives about calculation of cutting forces in milling machine process.

III. METHODOLOGY

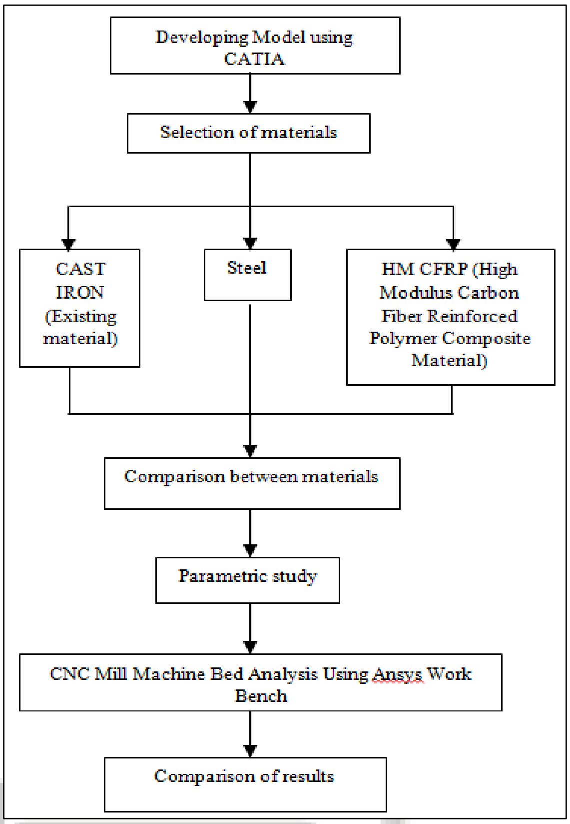


Fig. 1 Flow chart for the process

IV. MACHINE BED

Machine Bed supports the all elements like column, work table and servo motors. Whatever the cutting force induced in the machining process is simply transformed to machine bed, and machine beds absorb the vibrations induced in the machining process. Machine bed contains hole for accommodating lead screw which drives the work table. So that work piece can be moved as per the user programming code. It also supports the column on the rear end of it with the help of lead screws. Machine beds withstand the various forces generated during the cutting. In order to produce the accurate products a machine bed should have high structural stiffness with good damping coefficient, these are the two major design factors considered while the design of machine bed. Whenever machining operation starts machine bed experiences cutting forces. These cutting forces can be divided into three types; they are tangential cutting force, feed force and radial force. The loads applied on the machine bed are calculated as.

Total weight of Machine = 170 Kg.

Load acting on rear end of Machine Bed = 73Kg.

Weight of the Work Table = 18Kg.

Total forces acting on guide ways = cutting force + weight of work table and work piece

= 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. MATERIAL DISCUSSION

Composite materials are engineered materials made from two or more constituent material with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level with in the finished structure. 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 major 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.

Our fiber composites are made of carbon fibers and a matrix, which consists of special resin systems or thermoplastic materials. Both components come together to give the material its specific and unusual characteristics. In doing so, fiber and matrix each have different tasks. The strength and corrosion resistance, as well as the light weight of carbon fiber is only possible as a composite material.

Depending on the application, quantity and finish required, the manufacturing process of carbon fiber can vary. The basic processes include molding, vacuum bagging, compression molding and filament winding. Molding produces graphite-epoxy parts by a layering process whereby sheets of carbon fiber cloth can be placed into molds to achieve a specific product shape. This creates strong and corrosion resistant pieces.

VI. MODELING AND ANALYSIS OF MACHINE BED

A 3D model of the CNC machine bed was created in the CATIA V5 R20 software and saved in the iges format and importing in to Ansys work bench. The analysis was carried out on three materials cast iron, stainless steel and HM CFRP. In this stage Force and displacement boundary condition were applied as follows forces, front end of the machine bed carries cutting force, weight of the work table and weight of the work piece, due to this a total load of 272 N is applied on the Guide ways of Machine bed. Rear end of the Machine bed carries vertical column, and other accessories (ie servo motors, spindles etc..), due to this a total load of 717N will be applied on two flat surfaces of rear end.

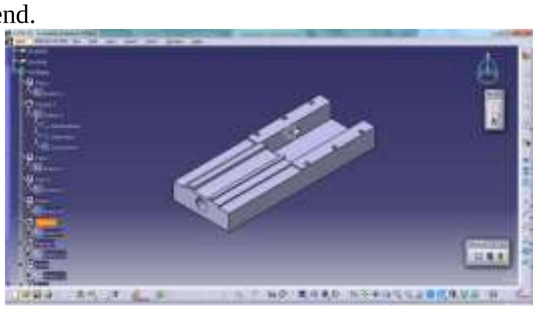


Fig.2. Machine bed model in CATIA

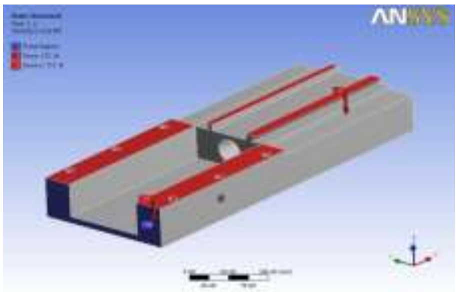
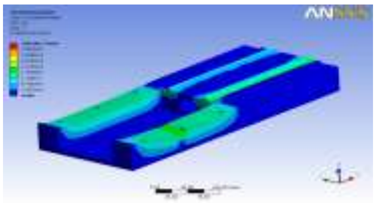


Fig.3. Forces applied on the machine bed

A. *Static Analysis*



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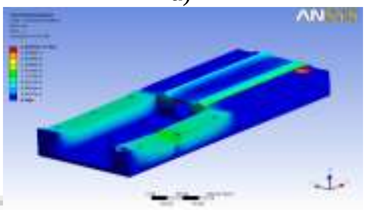

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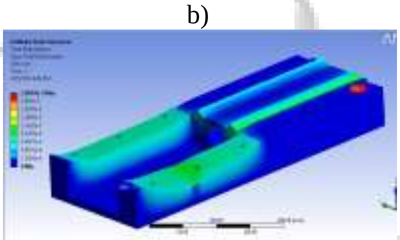
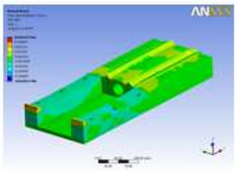
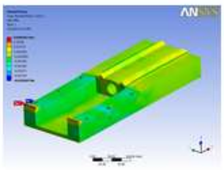


c)

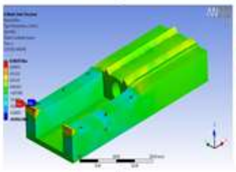
Fig.3. Total Deformation a) cast iron b) stainless steel c) HM CFRP

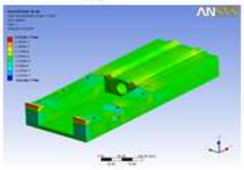
B. *Normal Stress and Normal Strain*



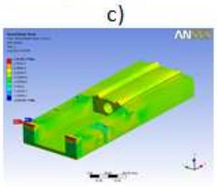


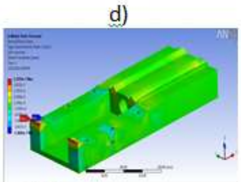
a) b)





c) d)

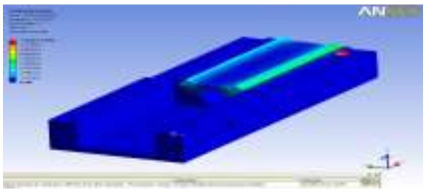




e) f)

Fig.4. Normal stress induced a) cast iron b) stainless steel c) HM CFRP ; Normal Strain induced d) cast iron e) stainless steel f) HM CFRP

C. *Harmonic Analysis*



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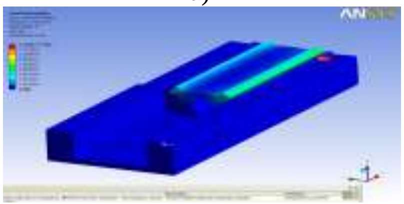

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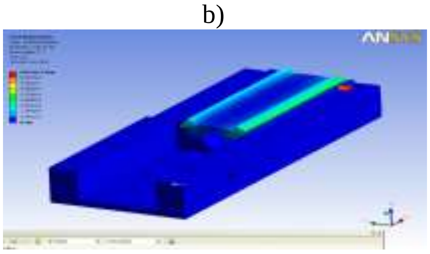

c)

Fig.5. Total Deformation due to harmonically varying loads a) cast iron b) stainless steel c) HM CFRP

VII. RESULTS AND DISCUSSIONS

Static analysis for comparison of the results obtained from the analysis under static load condition is given below tabular column.

	Cast iron	Steel	HM CFRP
Total Deformation (mm)	3.9449×10^{-5}	2.652×10^{-5}	2.0543×10^{-5}
Normal Stress (mpa)	0.040435	0.036949	0.040435
Normal Strain (mpa)	2.5335×10^{-7}	1.4113×10^{-7}	1.3193×10^{-7}

Table 1 Comparison of Static Structural Analysis Results

From the above results following points to be noted

- Total deformation of HM CFRP composite machine bed is less than the deformation due to both Steel and Cast Iron due to its high Young's Modulus than both Steel and Cast Iron.
- Since stress is independent of Material Property, hence stress induced all the machine beds is approximately same because there is no design modification.
- Normal Strain of HM CFRP composite machine bed is less than the both Steel and Cast Iron due to its high Young's Modulus than both Steel and Cast Iron.

Modes	Cast iron		Steel		HM CFRP	
	Frequency (Hz)	Deformation (mm)	Frequency (Hz)	Deformation (mm)	Frequency (Hz)	Deformation (mm)
1	703.07	18.12	821.02	17.72	1165.6	20.104
2	955.47	15.507	1120	15.322	1585.2	17.493

3	1360.9	26.283	1580	25.745	2253.9	29.605
4	1956.8	15.414	2269.7	14.626	3240.8	17.274
5	2183.3	22.879	2541.8	22.315	3617.7	25.759
6	2537	21.179	2974.1	20.929	4209.1	23.9

Table 7.2 Comparison of Results from Modal Analysis

VIII. CONCLUSIONS

Based on the configuration principles, the existing bed material was replaced by HM CFRP material shows improve in the static characteristics. Simulations results show that the static characteristics of the machine bed have been improved. Generally Composite materials also offer high specific strength and high specific modulus with less weight in machine tool industries. This composite materials offers 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 HM CFRP machine bed is less than conventional cast iron machine beds because specific strength and specific rigidity of HMCFRP machine bed is more than cast iron. The work suggests that HM CFRP material is best suited for CNC milling machine bed.

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