Modelling and Analysis of CNC Milling Bed with Carbon Fibre Composite

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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. 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 3D modelling software and analyses were carried out using ANSYS Workbench.**

***Index Terms*— Machine bed, Machine tools, Stiffness, Damping, Ansys.**

I. INTRODUCTION

THE proper design of machine-tool structures requires a thorough knowledge of their forms designs and properties of the material, the dynamics of the particular machining process and nature of the forces involved [1]. Recently, researches have been conducted in the field of improvement of structural design of machine tools by improving stiffness and lightening weight which is especially urgent for the structural parts, such as bed, column, worktable, beam and so on [2]. The arrangement of stiffening - ribs in machine tool structures is a key factor for structural stiffness and material consumption. So the lightening design of stiffening-ribs is significant for machining performance and energy saving. It is generally accepted that the precision of machine tools is determined by their static, dynamic and thermal characteristics. Especially, the dynamic characteristics play an important role in high speed, precision machine tool structures, because vibration during the machining process results in chatter marks on the machined surface and thus creates a noisy environment [3]. High static stiffness against bending and torsion, good dynamic characteristics as reflected by high natural frequency and high damping ratio, ease in production, good long term dimensional stability, reasonably low coefficient of expansion, low cost and low material requirements are the basic properties of machine tool structures that engineers look for designing and fabricating.

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.

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II. LITERATURE REVIEW

A.Selvakumar, P.V. Mohanram, "Analysis of alternative composite material for high speed precision machine tool structures" International journal of Engineering, 2, pp.95-98, 2012[4] 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 work piece depends on the instantaneous relative position of the tool and the work piece 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.

S. Syath Abuthakeer *et al* In the past, the design of CNC machine tools focused on their functional aspects and was hard to acquire any resonance with customers. Nowadays, despite the needs of low price, capabilities withstand at higher cutting speeds and operate at high acceleration and deceleration with high quality machine, many customers request good-looking machine. Regarding this, our study aims to provide various form designs of machine tool structure with the help of structural modifications made in CNC machine tool bed. After the lightening effect was verified by finite element simulation, scale-down models of an original bed and vertical ribs with hollow bed models were fabricated using rapid prototyping method and tested. The dynamic characteristics of those different form designs of the bed were analyzed experimentally. Numerical analysis was done and results were validated with experimental results. Results indicated that the cross and horizontal rib with hollow bed can increase the specific stiffness by 8% with 4% weight reduction and its dynamic performances is also better with increases in the first natural frequencies. The modified design is effective in improving the static and dynamic structural performances of high speed machine tools. [5]

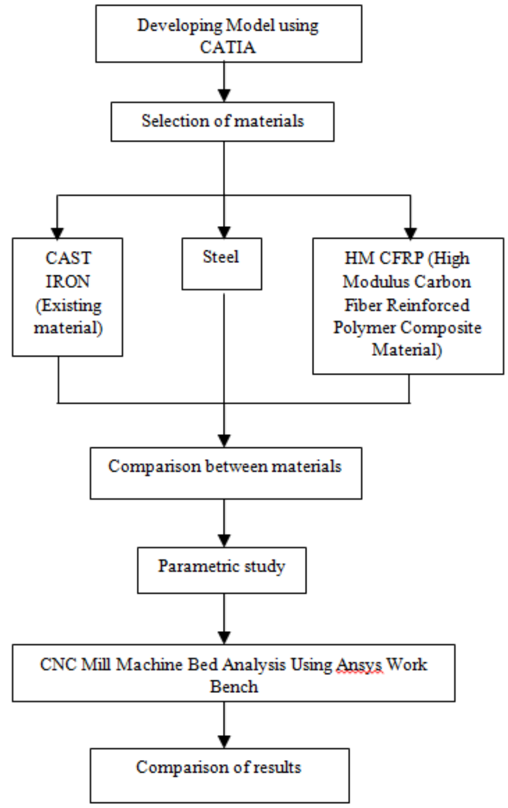
Based on modelling and analysis of IJSRD Vol. 2, Issue 09,2014 ISSN: 2321-0613, Machine Beds are made of grey Cast Iron material, which cause a number of problems in Machine tools. Cast Iron cannot with stand the sudden loads during operation whenever the load reaches Ultimate loads it simply fails without 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. Here we are modelled a different bed which is to industrial standard and verifying with the analysis done by the

III. MATERIAL

A composite is a material that is formed by combining two or more materials to achieve some superior 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 either grown in nature or developed by natural processes.

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. This was the main motivation behind the idea to go in for a composite model involving High Modulus Carbon Fibre 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 fibres. This makes it ideal to combine these materials in a proper manner.

IV. METHODOLOGY



V. MODELLING OF MACHINE BED AND ITS COMPONENTS

A 3D model of the CNC machine bed, its supporting rib and a workpiece for real time analysis was created in CATIAV5 of the dimensions:

TABLE I
Dimensions

Model	Dimension (mm) Length x Breadth x Depth
Bed	900 x 562.5 x 30
Workpiece	300 x 300 x 20
Supports	620 x 30 x 25

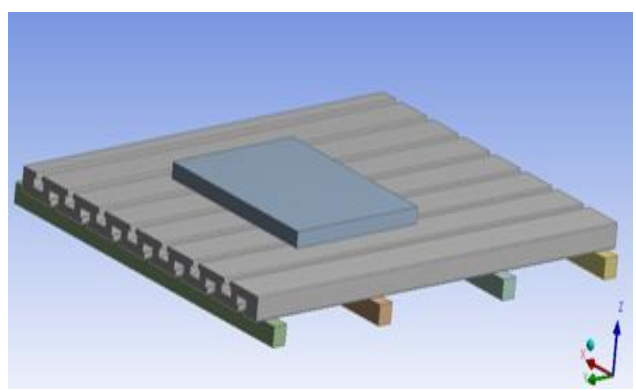


Fig. 1 Machine bed, workpiece and support model in CATIA

VI. FINITE ELEMENT ANALYSIS

The saved CATIA model was imported to ANSYS in iges format and static analysis was performed on different combination of machine bed material and workpiece material.

The contacts were defined between the workpiece & machine bed and machine bed and support. The support were fixed in all d.o.f and load was applied of magnitude 450 Newton’s pressure on line of contact with tool to work piece.

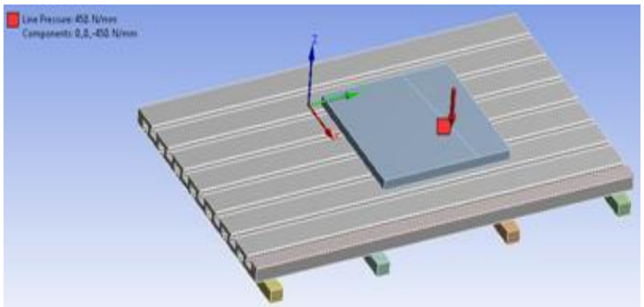


Fig 2 Force applied on the workpiece

A. Static analysis of different cases.

Static analysis was performed for the load applied and results were compared. The different cases are listed below

Case 1: Both component made with grey cast iron : In this case the workpiece and the machine bed were assigned with the material properties of grey cast iron and results are shown in figure 3 & 4.

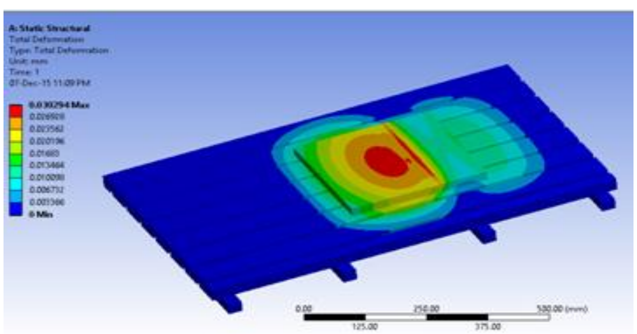
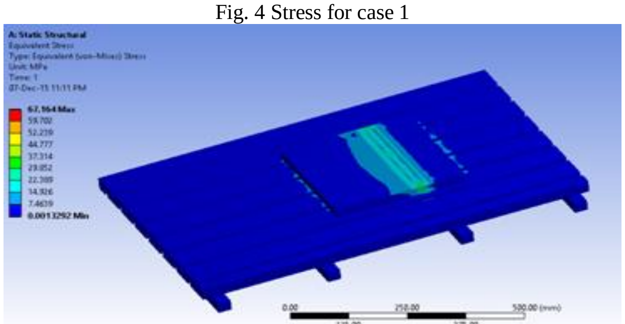


Fig. 3 Deformation for case 1

Fig. 4 Stress for case 1



Case 2: Bed grey CI and SS workpiece: In this case the workpiece is assumed as made up of stainless steel and the machine bed is made up of grey cast iron and results are shown in figure 5 & 6.

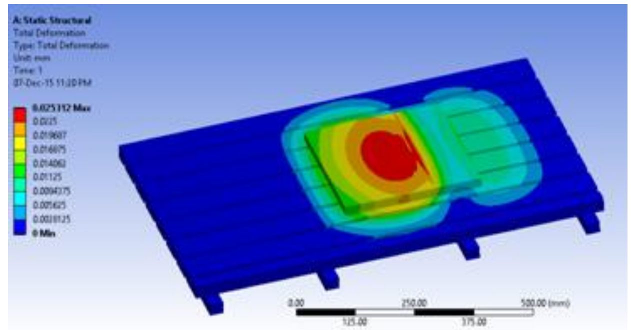


Fig. 4 Deformation for case 2

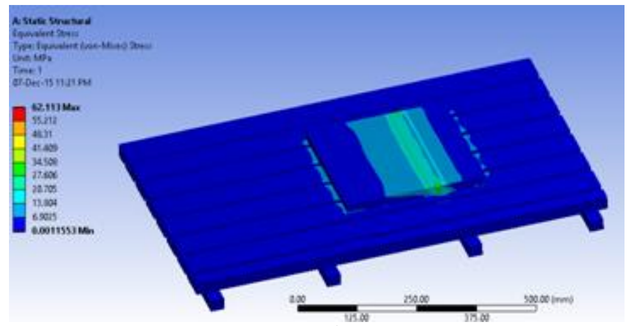


Fig. 5 Stress for case 2

Case 2: Bed grey carbon fibre composite and Grey CI workpiece: In this case the workpiece is assumed as made up of grey cast iron and the machine bed is made up of carbon fibre composite and results are shown in figure 7 & 8.

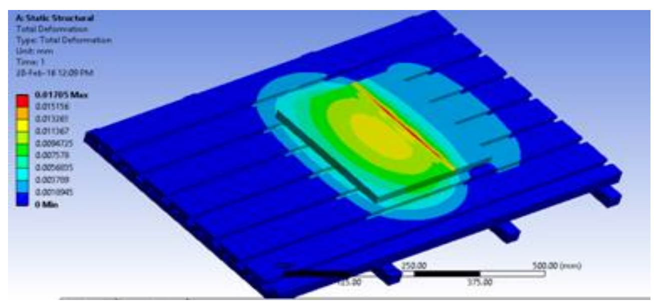


Fig. 6 Deformation for case 3

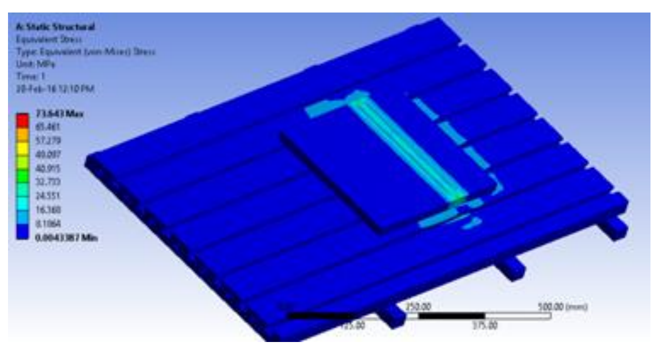


Fig. 7 Stress for case 3

VII. MODAL ANALYSIS

Modal analysis is performed on the component to find the natural frequency. The first two modes of natural frequency is shown below.

Case 1: Carbon fibre bed with grey cast iron component

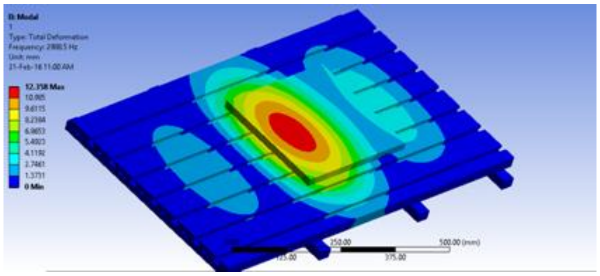


Fig 8 Deformation at Mode 1

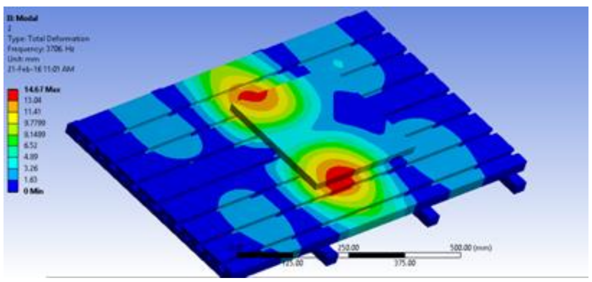


Fig 9 Deformation at Mode 2

TABLE II
Natural Frequency for case 1

Mode	Frequency
1	2988.543920007
2	3705.985027413

Case 2: Carbon fibre bed with Structural Steel iron component

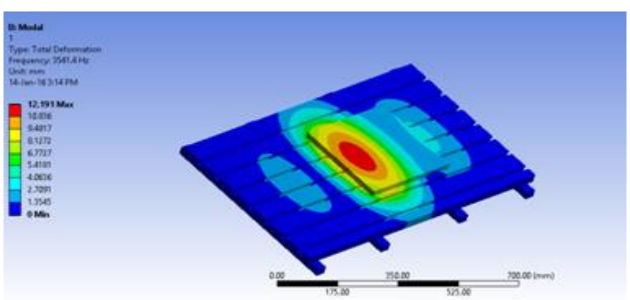


Fig 10 Deformation at Mode 1

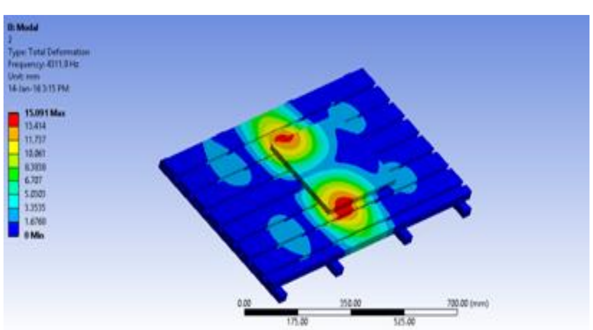


Fig 11 Deformation at Mode 2

TABLE III
Natural Frequency for case 2

Mode	Frequency
1	3541.406190864
2	4311.925719392

VII. RESULT AND DISCUSSION

Behaviour of machine bed for different combination of material is shown below in tabular form.

TABLE IV
Comparison of Static Structural Results

Case	Stress (MPa)	Deformation (mm)
Case 1	67.614	0.030294 mm
Case 2	62.113	0.025312 mm
Case 3	73.643	0.01705 mm

From the above result we can conclude following points

- Even if we observe all cases, case 3 has minimum deformation and stress is bigger as both the materials are good enough to resist max load.
- The total deformation of the composite is less as compare to other two materials due to its high modulus of elasticity.
- Finally we can say using carbon fibre composite is very useful to industry which tends to longer life as deformation and stress is within the limits.
- Natural frequency of different cases of composite material is found out successfully.

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