Design and Structural Analysis of CNC Milling Machine Bed with Composite Material

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Abstract Computer Numerical Control (CNC) is a specialized and versatile form of soft automation. It is one in which the functions and motion of machine tool are controlled by means of prepared program containing code alphanumeric data. The machine tool structure and the structural material used play a vital role in accuracy, surface finish and productivity of parts produced on it. The vibration encountered during machining process gets transferred into machine tool 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 conventional material used for manufacturing as Cast iron, steel possesses some limitation; at high operating speeds they develop positional errors due to the vibrations transferred into the structure. Thus to overcome these limitations it has to be replaced with a structure with high stiffness and damping characteristic, by analysing the structure used. It is difficult to analyse a structure analytically. The further process is carried out to undergo deformation, natural frequency and displacement using Static analysis and Modal analysis. The material changes can increase stiffness, reduce weight and improve damping characteristics. Thus choosing two composite materials, Glass Fibre and Jute Fibre and analysing these two materials and comparing it with cast iron. This makes it ideal to choose these materials in a proper manner. In this work, a machine bed is selected for analysis static loads. Then investigation is carried out to reduce weight of the machine bed without deteriorating its structural rigidity. A commercial 3D CAD model of machine bed is created through CATIA and the machine bed made of two different fibres are analysed through ANSYS. Thus the overall aim indulges in increasing the structural characteristics and reducing the structural weight.

1. INTRODUCTION

The transfer of high speed as well as the high cutting speed of machine tools is very 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 leads to the poor quality of products with less accuracy, both dimensional as well as geometrical of the product. The level of deformation and vibration determines the components high precision. At present the Machine Beds are made of grey Cast Iron material, which cause a number of problems in Machine tools. Cast Iron cannot withstand 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. 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 and Modal 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.

2. NEED OF COMPOSITE MATERIALS

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.

3. METHODOLOGY

4. MACHINE BED

The machine bed plays a crucial role in providing the strength and rigidity to a machine. It accommodates all the accessories and cutting tools and other necessary equipments for the running of the machine. It is subjected to various static and dynamic forces during the machine operation. Its design is vital for the performance and accuracy of the machine tool. A milling machine is a machine tool used to machine solid materials. Milling machines are often classed in two basic forms, horizontal and vertical, which refer to the orientation of the main spindle. Both types range in size from small, bench-mounted devices to room-sized machines.

Unlike a drill press, which holds the work piece stationary as the drill moves axially to penetrate the material, milling machines also move the work piece radially against the rotating milling cutter, which cuts on its sides as well as its tip? Work piece and cutter movement are precisely controlled to less than 0.001 in (0.025 mm), usually by means of precision ground slides and lead screws or analogous technology. Milling machines may be manually operated, mechanically automated, or digitally automated via computer numerical control. Milling machines can perform a vast number of operations, from simple (e.g., slot and keyway cutting, planning, drilling) to complex (e.g., contouring, die-sinking), is often pumped to the cutting site to cool and lubricate the cut and to wash away the resulting swarf.

Machine bed supports all elements like columns, worktable 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 various forces generated during the cutting. In order to produce the accurate products a machine bed should have structural stiffness with good damping coefficient, these two major design factors considered while the design of the machine bed. Whenever the machining operation starts the machine bed experiences cutting forces. These cutting forces are divided into three types; tangential cutting force, feed force and radial force.

5. MODELLING 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, Glass and Jute. 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 (i.e. servo motors, spindles etc...), due to this a total load of 717N will be applied on two flat surfaces of rear end.
A. Static Analysis

![Machine bed model in Catia](image)

**Fig 2 Machine bed model in Catia**

B. Normal Stress and Normal Strain

![Total deformation](image)

**Fig 4 Total deformation a) Cast iron b) Glass Fibre c) Jute**

6. RESULTS AND DISCUSSIONS

Static Analysis for comparison of results obtained from the analysis under static load condition is given below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Total deformation</th>
<th>Normal Stress</th>
<th>Normal Strain</th>
<th>Von Mises Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron</td>
<td>5.172</td>
<td>21.931</td>
<td>0.0039</td>
<td>19.95</td>
</tr>
<tr>
<td>Glass</td>
<td>3.607</td>
<td>21.433</td>
<td>0.0028</td>
<td>19.73</td>
</tr>
</tbody>
</table>
Table 1: Comparison of Static Structural Analysis Results

From the above results following points to be noted;

— Total Deformation of Jute Composite machine bed is less than the deformation of Cast iron and glass due to its high Young’s Modulus than both Cast Iron and Glass Fibre.
— Since stress is independent of Material property, hence stress induced on all the machine beds is approximately same because there is no design modification.
— Normal strain of Jute composite machine bed is less than both Cast Iron and Glass Fibre due to its high Young’s Modulus than Cast Iron and Steel.

Table 2 Comparison of Results from Modal Analysis

Based on the configuration principles, the existing bed material was replaced by Jute and Glass fiber materials shows improvement 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 Jute and Glass Fiber machine bed is less than conventional cast iron machine beds because specific strength

and specific rigidity of Jute and Glass Fibre machine bed is more than cast iron. The work suggests that Jute and Glass Fibre material is best suited for CNC milling machine bed.

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