Modeling and Analysis of CNC Milling Machine Bed with advanced 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.

Chapter 1

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 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. 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 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.

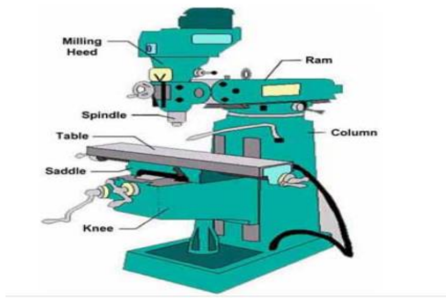


Fig 1.1: milling machine

1.2 Milling Introduction

Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling, and straddle milling etc. can be carried out on a milling machine. This training module is intended to give you a good appreciation on the type of milling machines and the various types of milling processes. Emphasis is placed on its industrial applications, operations, and the selection of appropriate cutting tools. On completion of this module, you will acquire some of these techniques from the training exercises as illustrated in figure 1. However, to gain maximum benefit, you are strongly advised to make yourself familiar with the following notes before undertaking the training activities, and to have a good interaction between yourself and the staff in charge of your training. Assessment of your training will be based on a combination of your skill and attitude in getting the work done.

1.3 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 reemergence 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 costconscious efforts. More recently, reduction in processing costs; costs of raw material and the desirability of special properties have generated a great amount of interest.

Flow chart for the process

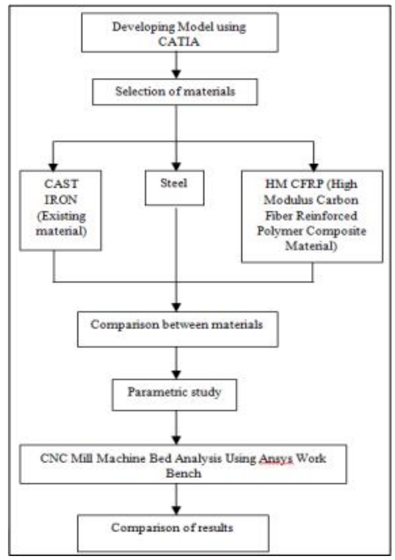


Fig. 1.2: Flow chart for the process

1.4 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 roomsized 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 swarfMachine 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.

CHAPTER 2

2. 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[1] 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 aimsto 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. [2] 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 paper.

- Sruthi Srinivasan*1 Mr.B. Subramanyam*2 Design and Structural Analysis of CNC Milling Machine Bed with Composite Material, 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.

Chapter-3

3.1 DESIGN:

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.

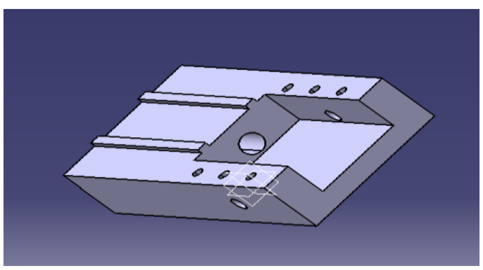


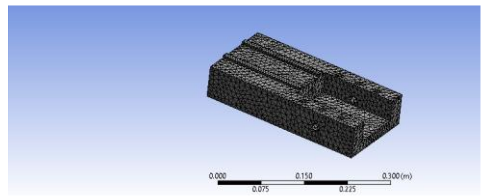
Fig 3.1: 3D modeling milling bed

4 Ansys:

ANSYS is general-purpose finite element analysis software, which enables engineers to perform the following tasks:

1. Build computer models or transfer CAD model of structures, products, components or systems
2. Apply operating loads or other design performance conditions.
3. Study the physical responses such as stress levels, temperatures distributions or the impact of electromagnetic fields.
4. Optimize a design early in the development process to reduce production costs.
5. A typical ANSYS analysis has three distinct steps.
6. Pre Processor (Build the Model).

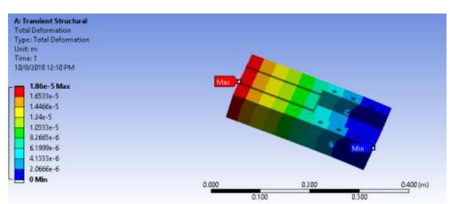
Mesh



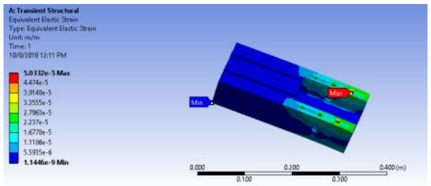
In this stage Force and displacement boundary condition were applied as follows forces, front end of the machine bed carries cutting force, weight of the work table and weight of the work piece, due to this a total load of 272 N is applied on the Guide ways of Machine bed. Rear end of the Machine bed 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.

Gray Cast Iron:

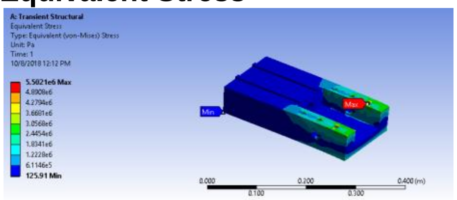
Total Deformation



Equivalent Elastic Strain

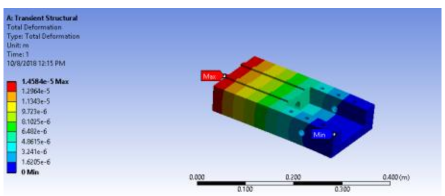


Equivalent Stress

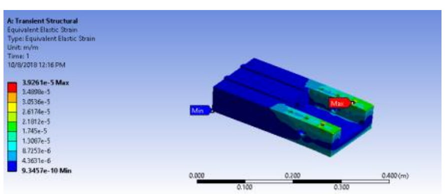


AISI 1065 carbon steel:

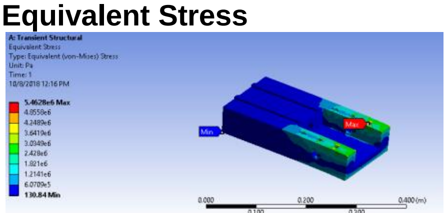
Total Deformation



Equivalent Elastic Strain

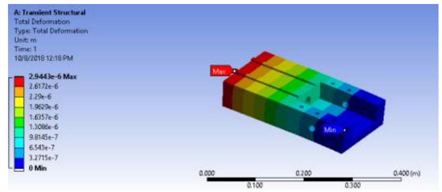


Equivalent Stress

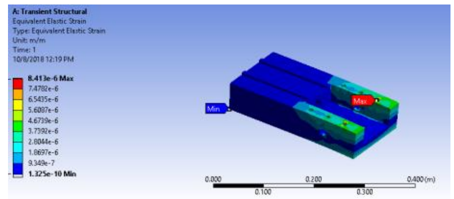


Carbon Fiber

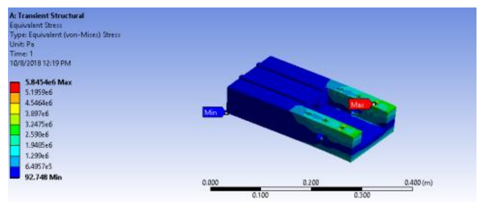
Total Deformation



Equivalent Elastic Strain

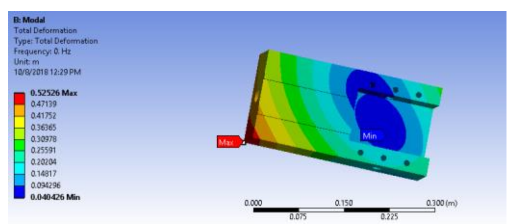


Equivalent Stress

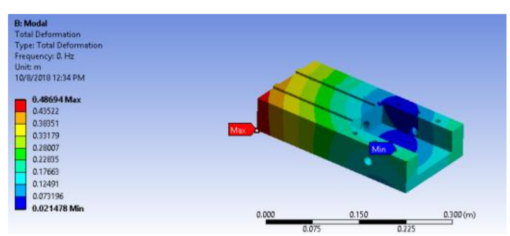


Vibration analysis:

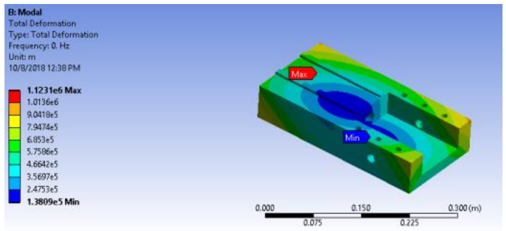
Gray Cast Iron



AISI 1065 carbon steel



Carbon Fibre



CONCLUSIONS:

Based on the data related to the component, the existing bed was replaced by composite material for better strength and stiffness. FEA analysis shows that there is improvement in the design life of the machine bed. By considering all the result data it can be seen that deformation is least in composite because of its high rigidity. The study suggests that Carbon Fibre Composite is best suited for CNC machine bed

Based on the configuration principles, the existing bed material was replaced by carbon fiber AISI 1065 carbon steel 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 Carbon Fibre, AISI 1065 carbon steel machine bed is less than conventional gray cast iron machine beds because specific strength and specific rigidity of Carbon Fibre, AISI 1065 carbon steel machine bed is more than gray cast iron. The work suggests that Carbon Fibre, AISI 1065 carbon steel material is best suited for CNC milling machine bed.

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