

Analysis and optimization of vertical machining Centre (VMC) bed by using FEA approach

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ABSTRACT

VMC is most commonly used in an industry for high production rate. The headstock, column and Bed are most important part of VMC; however there are many designing parameters which may influence rigidity and weight of VMC bed component. So to, find the designing parameters the design of part is very important task. Bed is the main structural part of the machine tool and whole structural weight is standing on the Base during static & dynamic condition. It is a force bearing component of machine tool. Also during the typical machining operation, there may be generation of heat due to friction; deformation of base, shearing of mating component this will finally affect accuracy and performance of that machine tool so it is needed for base to having sufficient rigidity to withstand the whole structural weight and also having the optimum weight with good damping characteristic. So that to overcome this type of issue it is must need to at final design decision. For this work, the 3D CAD model for the base line and optimized design has been created by using commercial 3D modeling software CREO and after that we will go for static structural analysis of the component. There are different methods to increase the rigidity of Bed by introducing ribs.

Keyword – VMC bed, analysis, optimization, 3D CREO, Ansys, weight reduction

1. Introduction

“A machine tool is a power driven machine, capable of holding and supporting the work and tool at the same time and directing and guiding the cutting tool or job or both to perform various metal cutting operations for providing different shape and sizes.” A machine tool is devices that utilize mechanical forces for shaping and sizing a product by removing excess material, in the form of chips, with the help of a cutting tool. Machine tools are used for producing components at a rapid rate. Thus they form indispensable part of a modern workshop. Optimum productivity from machine tools calls for a fairly high degree of skill. Properly carried out operations are capable of producing a large number of components at a fairly rapid rate.

1.1. Function Of Machine Tool

The various functions of machine tools are:

- 1) To holding and supporting the work piece to be machined
- 2) To hold and support the cutting tool
- 3) To provide requisite motion to the work piece, tool
- 4) To regulate the cutting speed and feed of the tool and work piece
- 5) To hold various attachments for different operations.

1.2 Classification Of Machine Tool

Machine tools can be classified in different ways.

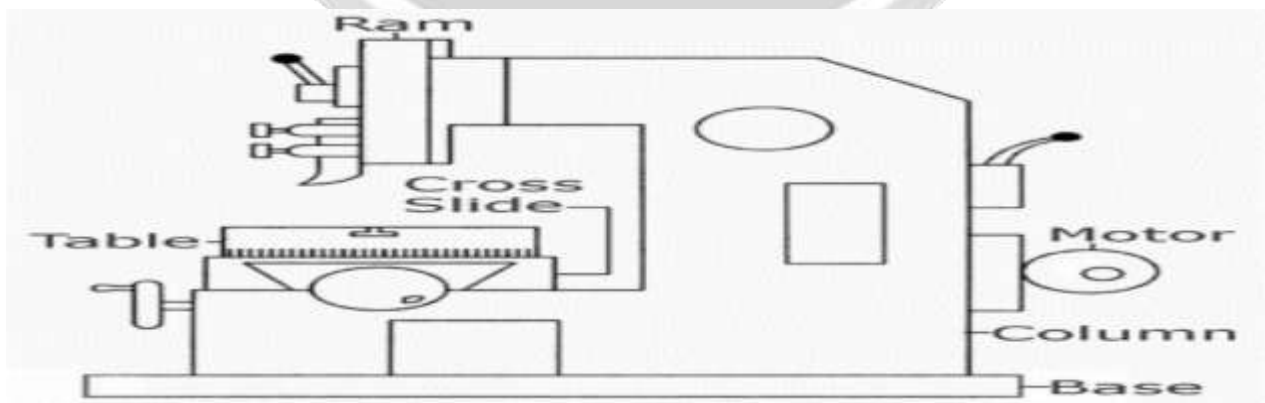
- 1) Classification based on types of the surface generated :

- a) Cylindrical work machine tools – lathe, capstan, turret. Etc.
 - b) Flat surface machine tools –milling machine, shaping machine, planing machine, etc.
- 2) Classification based on the purpose of the machine tool:
- a) Single Purpose
 - b) Multi-Purpose
 - c) Special Purpose
 - d) Transfer Purpose
 - e) Numerically controlled
- 3) Classification based upon the size of chip:
- a) Machine tool using cutting tools lathe, milling, planer, slotter, etc.
 - b) Machine tools using abrasive-honing, lapping, etc.

1.3. Various Elements Of Machine Tools

The various elements of machine tools are:

1. Structure of a machine tool consist of bed, column and frame
2. Table and guide ways
3. Spindles and spindle bearings
4. Base
5. Column
6. Various machine drives
7. Various mechanisms



1.4 Leveling

While installation of machine tool, proper leveling is important to obtain accurate feed motion and surface of components. The bed should be level longitudinal and transverse directions. Installation and leveling standards are provided by the suppliers of machine tool. Before installation of machine tool it is necessary to go through the manual through to ensure efficient working.

1.5 Vibration

During cutting operations the various forces acting on the tool produce vibrations. To obtain good surface finish and degree of accuracy, the machine should be free of vibrations. In addition to a strong foundation following design considerations need to be paid attention.

1. The design of machine tool should be such that natural frequency of the machine tool structure does not coincide with that the cutting tool.
2. The natural frequency f_n of machine tool is given by the formula

$$f_n = k \times P / \lambda$$

Where P =straining force λ = Deformation in mm and k is a sign of proportionality

To minimize the vibrations, the stiffness of the structure should be as high as possible which can be achieved by proper selection of partition and rib.

Material should possess good damping properties. Cast iron is a very suitable material for this purpose. Due to this reason, beds, frames of machines are made of cast iron.

1.6 Machine Tool Performance Criteria:

Day by day demand of machine tools is increase not only in quality, but also in sophistication. While designing a machine tool the following factors need consideration:

1. It should be safe and easy to operate
2. It should be accurate
3. It should have good production capacity.
4. Controls should be located at convenient points Blanks should be such that they can be loaded and clamped easily

1.7 Material Used For Machine Tool Structure

Structural materials used in a machine tool have a decisive role in determining the productivity and accuracy of the part manufactured in it. Material selection is a matter of quality and cost. The properties of the material must be adequate to meet design requirements and service conditions. Most commonly used material for machine tool structure is cast iron and steel. While in recent times, granite and epoxy concrete are also developed and used for structures.

- A. **Cast iron** is primarily an alloy of iron, carbon, and silicon. From early times cast iron has been the most commonly used material for machine tool structures. It may be cast into complex and intricate shapes. It is easily machined and may be hand scraped and lapped to a high degree of accuracy. It has fairly good damping properties and also has reasonably good antifricition properties helped by the graphite contained in it. It can be given very good long-term dimensional stability by giving it a special long cycle stress relief annealing treatment. Cast iron should be preferred for complex structures subjected to normal loading, when these structures are to be made large in numbers.
- B. **Structural steel** The main criterion in the selection and inspection of the steel is the tensile strength which is used as the basis of design. Generally load carrying welded structures such as frames, beds, and column.
- C. **Granite** It is used for surface tables and measuring machine structures. Its internal damping is better than that of cast iron. Its wear properties are good. It is reputed to be very stable dimensionally.
- D. **Steel** is very widely used for machine components as it can be manufactured and processed into a number of different specifications each of which has a definite use. Two properties of steel apart from strength are

of special significance in selection of proper grade of steel. First, the maximum hardness that can be achieved and second, the harden ability which determines the depth of hardened zone.

- E. **Epoxy concrete** It is a new material specifically developed over the past two decades for high precision machine tool structure. It is the mixture of binding agent reaction resin and the hardener together with carefully selected and mixed aggregates. It is completely new technology as compared with those of the materials mentioned above. Epoxy concrete does not expand and contract with change in humidity, as does ordinary concrete. It offers great design freedom, similar to cast iron. It costs approximately the same as steel reinforced concrete or even less.

2. Literature Survey

B.V Subrahmanyam,A. Srinivasa Rao,C H Rama Krishna “static and Dynamic Analysis of Machine Tool Structures”, International journal of research in mechanical engineering & technology

Author gives more important to FEA software for analysis of machine tool structure. In this paper authors did static analysis for stress, strain ,deflections and dynamic analysis for prediction of natural frequencies and corresponding mode shapes which will inturn prevent failure of machine tool structure for that they used component of ram and guide of shaping machine, bed of lathe machine and column and knee of milling machine. Result of static analysis gives the maximum vonmises stresses generated in the various component and X-Y-Z direction and deflection of component which shows that milling machine gives higher deflection of 4.189 mm along them. Dynamic analysis shows the deflection for various modes of frequency which conclude that the deflection is increase with an increase in the frequency. The frequency analysis has been taken-up for the first 5 natural frequencies.

S D Kamble,Prof. A S Todkar, “Structural analysis for frame of a machine tool-EDM using CAE took through the evaluation phase of the design”, International Journal of Advanced Engineering Technology

In this paper author gives importance of machine design fundamental used for designing of structure. In this paper existing structural of EDM machine is needed changes for structural strength during subjected to components. For that they made assembly of EDM Machine CATIA software then for analysis done using Ansys software based on this result is needed to enhance the strength of the table support channel so for that author gives modification to the table support channel with different thickness 3mm, 4mm, 5mm & then analyze result shows that the modified design with thickness 3mm gives the less deformation and good acceptance value to reduce the mass of the table within the permissible limit.

S. SyathAbuthakeer, P.V. Mohanram, G. Mohan Kumar, “Structural redesigning of CNC lathe bed to improve its static and dynamic characteristics”,International Journal Of Engineering

In this paper the design of CNC machine tools is focused on their functional aspects. author aim is to provide various form designs of machine tool structure with the help of structural modifications made in CNC machine tool bed..The improvement of structural design of machine tools is done by improving the stiffness and lightening the weight of the parts, such as head, bed, column, and worktable. In this paper the author investigated that the arrangement of stiffening ribs in machine tool structure is a key factor for structural stiffness and material consumption. To improve both the static and dynamic performances, the machine tool structure should have high static stiffness and damping. This lead to using either higher modulus material or more material in the structure, the static stiffness of the machine tool may be increased. The objective of the work carried out in this paper is to increase the structural stiffness, reduce the weight and deformation of machine tool bed by designing and fabricating suitable forms. FEM simulation is carried out using ANSYS software. The three dimensional models are established in CAD system, Pro/E and imported in to ANSYS. The models are then simplified to meet the FEM requirements. The material used is gray cast iron. All degrees of freedom of bottom surface are restricted and external loads are applied to corresponding positions of bed. After analyses author conclude that structural vertical ribs with hollow offers a method to improve the conventional design of machine structure. Finite element simulation revealed that the modified type bed possesses better static and dynamic properties.

B. Malleswara, K.SunilRatna Kumar, “Design and structural analysis of CNC vertical milling machine bed”,International Journal of Advanced Engineering Technology

In this paper author did complete analyze the machine tool bed for reduction of weight without deteriorating its structural rigidity & accuracy. For that they take 3D modeling software CATIA. They created 3D FE model using HYPERMESH software and for the complete analysis of that model they took Ansys software and for material they took different material like cast iron G15, cast iron G40, cast iron G70 after applying various loading and boundary condition analysis was carried out for effect of weight reduction on structural integrity of machine bed before and after the weight reduction. Then after this analysis for the optimized structure optistruct FE software is used which shows location/area where mass can be reduced and or removed. Then this optimized model is imported into hypermesh for meshing and result of static structural analysis for Different material is observed with the help of grapes and comparison between different material. This shows that cast iron having moderate ductility & moderate displacement. so from the result author conclude that weight optimized by approximately 1.5% and structural rib with hollow improve conventional design of machine design structure.

A.Selvakumar, P.V.Mohanram, “Analysis of alternative composite material for high speed precision machine tool structure”, International Journal Of Engineering

This paper presents the importance of the structural material used in the machine tool. The conventional structural materials form heavy structure which is not desirable in precision machine tool. Development of alternative material for the structure which exhibit good damping and stiffness characteristics with minimum weight is prime requirement for the machine tool manufacturers. The concepts of composite material for the machine tool structure given in this paper provide high damping and moderate stiffness which is very beneficial.

3. Conclusions

From the literature review ,we can conclude that analysis of the machine tool structure for the various purpose by the analytical method is the more time consuming and very complex method also it doesn't gives the precise way for the analysis because of its complexity but by using the FEA software we can get batter result with the more precision and more accurately than analytic method and also in this FEA , Static and Dynamic analysis of machine tool structures plays an important role on the efficiency and job accuracy of the machine tool. Static analysis is useful for estimating stresses strains and deflections, and also improving structural stiffness where as dynamic analysis deals with the prediction of natural frequencies and corresponding mode shapes, which will in turn, prevent the catastrophic failure of the machine tool structures.

4. References

1. B.V Subrahmanyam, A. Srinivasa Rao, C H Rama Krishna “static and Dynamic Analysis of Machine Tool Structures”, International journal of research in mechanical engineering & technology ,Volume 4, Issue SPL 1(2013-14) 14-18
2. S D kamble, Prof. A S Todkar, “Structural Analysis for frame of machine tool-EDM using CAE tools through the evaluation phase of the design”, International journal of advanced engineering technology, Volume 4, Issue 4 (2013) 07-10
3. S. SyathAbuthakeer, P.V. Mohanram, G. Mohan Kumar. “Structural redesigning of a cnc lathe bed to improve its static and dynamic characteristics”, International journals of engineering 78 (2011) 389-394
4. B. Malleswara Swami, K.SunilRatna Kumar, CH.Ramakrishna, “Design structural analysis of cnc Vertical milling machine bed”, International Journal of Advanced Engineering Technology volume 3, Issue 4(2012) 97-100
5. A.Selvakumar, P.V.Mohanram, “Analysis of alternative composite material for high speed precision machine tool structure”, International journals of engineering,(2012) 95-98
6. YANG Xu-dong, SUN Dong, “The Beam Structure Analysis And Research of Beam-fixed CNC Gantry Boring And Milling Machine.” Journal of Convergence Information Technology (JCIT) Volume 8, Number 17(2013) 84-90
7. Naeem S. Mian, S. Fletcher, A.P. Longstaff, A. Myers, “ Efficient estimation by FEA of machine tool distortion due to environmental temperature perturbations”, Journals of Precision Engineering 37 (2013) 372– 379