Design and Weight Optimization of CNC Milling Machine Bed

Prudhvi Raju M[1], E V Santhosh Krishna[2], Chaitanya Naga Kumar N[3], Ravindra Babu N[4], Avinash T[5], Jyothi Padmaja K[6]

[1, 2, 3, 4, 5, 6] Dept of Mechanical Engineering

[1, 2, 3, 4, 5, 6] Vasireddy Venkatadri Institute of Technology, Guntur, India

Abstract- *The most conventional structural materials used in precision machine tools are cast iron and steel. To analyze the bed for possible material without changing its geometry that could increase stiffness, reduce weight, improve damping characteristics and isolate natural frequency from the operating range the best idea is weight reduction of the material. To examine the above results the original 3d cnc bed machine is subjected to analysis with various loads which intends to change the weight by optimizing the structure where ever it is possible. In this work, a CNC machine bed is selected for the analysis static and harmonic loads. In the later work the original model is modified 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 modeling software NX7.5. The analysis is to be carried out using ANSYS.*

I. INTRODUCTION

The basic function of machine tool is used to produce a work piece of the required geometry with best surface finish in most economic way and at high rate of production. In fact most of the general purpose machine tools, CNC lathes & machine centers are designed in a way that can cope everything with higher cutting forces with lower cutting forces and vice versa. To accomplish the above function the Machine Tool Structure must possess higher damping, high static and dynamic stiffness. High cutting speeds and feeds and are the essential requirements of the machine tool. So it makes the machine tool structure providing high static stiffness and damping coefficient to improves both static and dynamic performance .The static stiffness of a machine tool can be increased by using either higher modulus material that means, manufacturing the material with less weight to higher stiffness ratio. However, it is difficult to achieve high dynamic stiffness of a machine tool with above methods because the damping of the machine tool structure can't be increased by increasing the static stiffness. However, it has several resonant frequencies because of its continuous structural elements at operating. If the damping is very small to release the vibration energy of the machine tool, the resonant vibration occurs when the frequency of the machining operation approaches one of the natural frequencies of the machine tool structure.

Therefore the material used to manufacture machine tool structure should have high static stiffness and damping in its property to improve both the static and dynamic performance.

II. METHODOLOGY

- Initially the cad model proposed for doing analysis is generated using Unigraphics cad software.
- The generated 3d model is transformed in to generalized format which can easily import in to Ansys software.
- Structural analysis is performed on the original model to examine the results like deflections and stresses.
- Dynamic analysis is performed on the original to examine the results like natural frequencies and operating frequencies.
- Later according the structural results the weight of the component is reduced.
- All the results are tabulated and at last from the results which material and model is used to manufacture.

1. 3D MODELING PART:

The 3d model of cnc milling machine bed, work table and the side guide rolls is considered from the reference 7 of a company broacher of machine Moriseiki mv-45. The reference paper shows the clear drafting part of the above components. Using the reference paper the 3d models are created which can see below. The major dimensions of the machine bed are as follows:

Length = 1000 mm (in X-direction).
Height = 40 mm (in Z-direction) (total height).
Total Bed width = 550 mm (in Y-direction).

2. 3D MODEL OF CNC MILLING BED:

The above geometric dimensions are used to create the 2d sketch of machine bed shown in Figure.1.

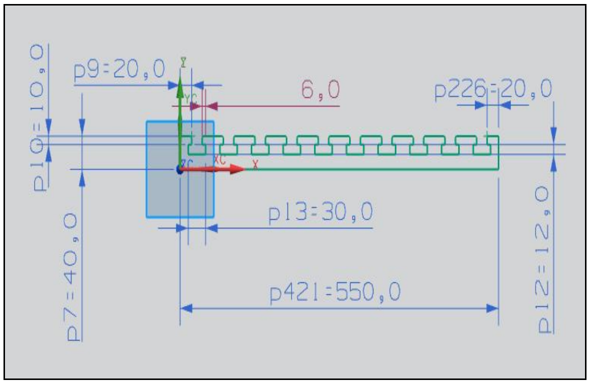


Figure1. 2D sketch of milling machine bed.

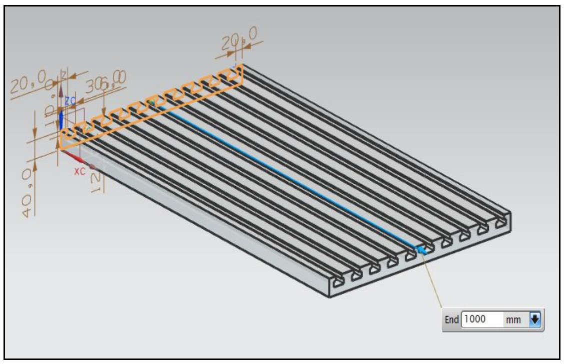


Figure2. Extrusion feature used to create the 3d model of milling machine bed.

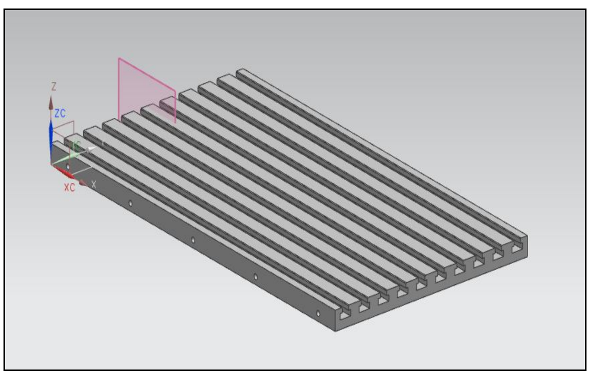


Figure3. Solid model of the port of angle 300

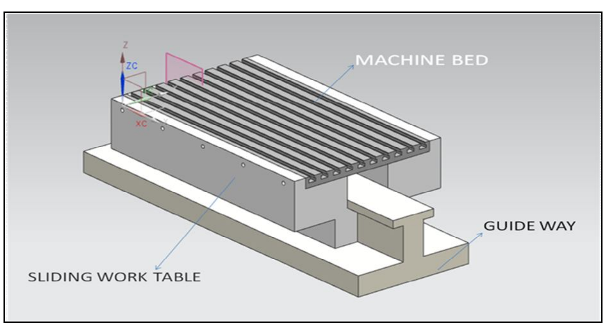


Figure4. Isometric view of machine bed assembly

III. FINITE ELEMENT ANALYSIS OF ORIGINAL CNC MILLING MACHINE

Model of a machine bed was developed and analysis was carried out using ANSYS. To simulate the behavior of the machine bed of FE model summary is given below.

- ✓ Number of elements = 34999
- ✓ Number of nodes = 37522
- ✓ MESH Size = 20
- ✓ No of DOF = 6

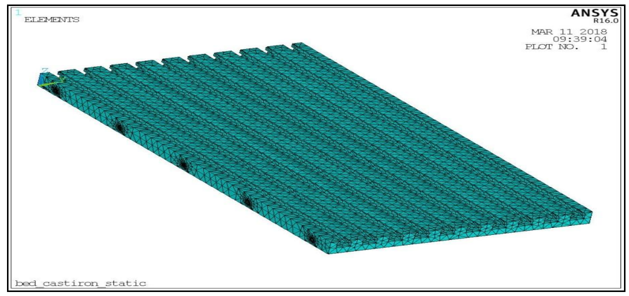


Figure5. Finite elemental model of machine bed of material cast iron

1. BOUNDARY CONDITIONS:

- ➢ The bolting conditions are arrested in all degrees of freedom.
- ➢ An axial force of 717 Newton’s is acted upon the surface of middle four T slots with negative direction.

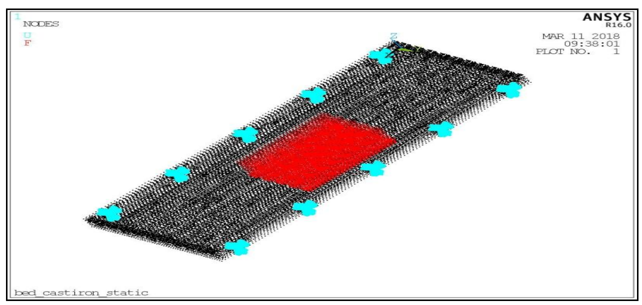


Figure6. Boundary conditions showing applied on the Machine bed

2. RESULTS:

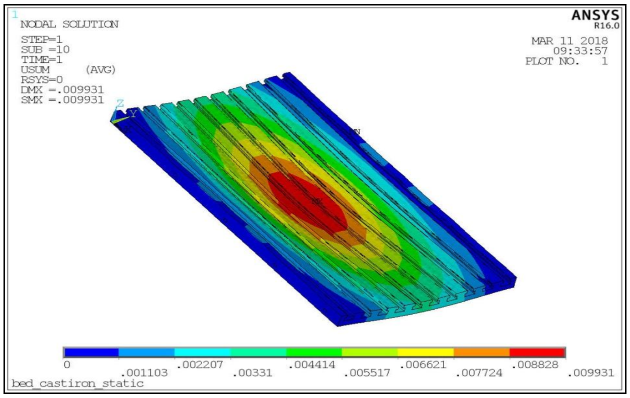


Figure7. Total deflection of machine bed

3. VONMISES STRESS:

It gives the result of max stress generated due to load which is used to calculate factor of safety for material cast iron. Below Figureure shows the max stress obtained of 23 MPa. The factor of safety is 275/23=11.95 (Yield strength/VonMises stress).

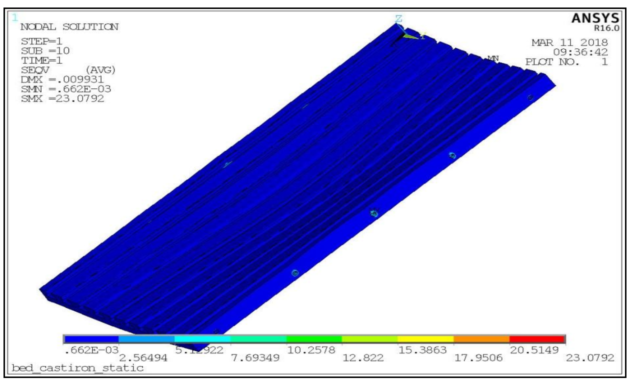


Figure8. VonMises stress of machine bed of material cast iron

The summary of results for structural static analysis for material cast iron is shown in Table.1.

Table1. Results for static analysis

Results for static analysis		
Item	Value	Units
Total deflection (Usum)	0.009	mm
Deflection in X-Dir	3.8	mm
Deflection in Y-Dir	0.001	mm
Deflection in Z-Dir	3.2	mm
VonMises Stress	23	MPa
FOS	275/23=11.09	no units
Weight	120	Kg

IV. MODEL ANALYSIS OF ORIGINAL MACHINE BED

Model analysis is carried out on machine bed to know the natural frequencies and mode shapes acting upon on the machine bed. The first 10 natural frequencies obtained are shown in Table.2.

Table2. Shows first 10 natural frequencies for machine bed

Mode. No	Frequency (Hz)
1	203.37
2	246.23
3	403.38
4	599.56
5	658.02
6	729.8
7	822.29
8	1121.38
9	1212.99
10	1236.55

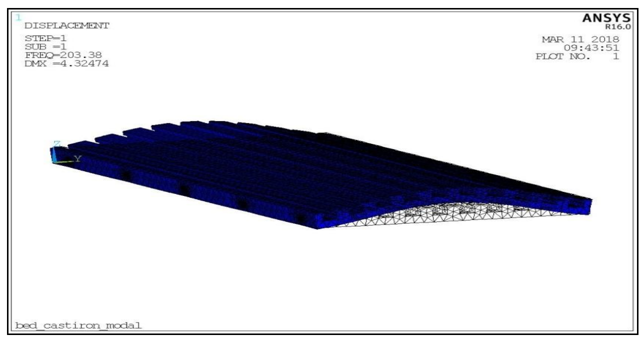


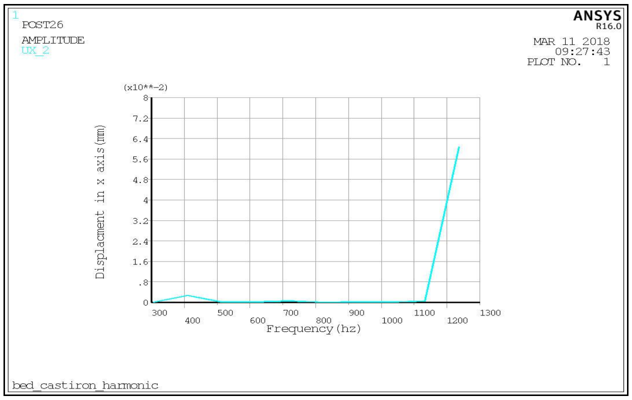
Figure9. Mode shape1 @ frequency 203 Hz

V. HARMONIC ANALYSIS OF ORIGINAL MACHINE BED

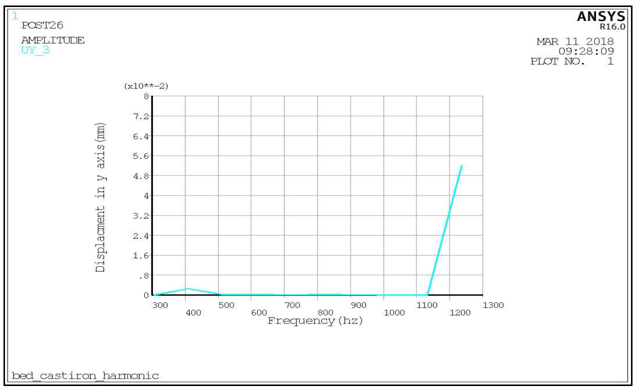
Any sustained cyclic load will produce a sustained cyclic response (a harmonic response) in a structural system. Harmonic analysis gives the ability to predict the sustained dynamic behavior of the structures, thus enabling to verify whether or not the designs will successfully overcome resonance.

VI. RESULTS OF HARMONIC ANALYSIS FOR ORIGINAL CNC BED

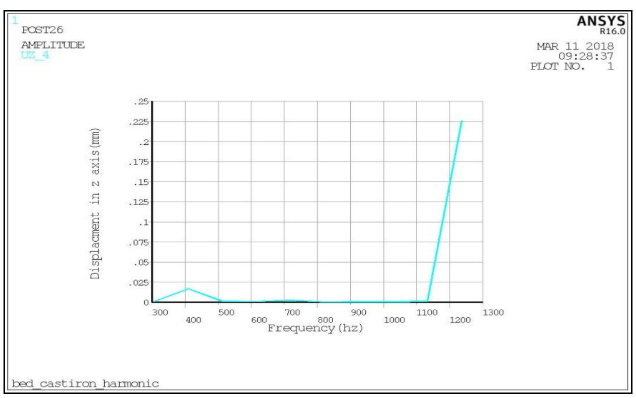
From the analysis the response of the CNC bed over the specified frequency range in X, Y and Z directions are shown in the graphs: 1, 2, and 3.



Graph1. Frequency Vs displacement in X-dir for original machine bed



Graph2. Frequency Vs displacement in Y-dir for original machine bed



Graph3. Frequency Vs displacement in Z-dir for original machine bed

From the above three figures it is observed that the maximum deflection in X, Y and Z direction is 5.6 mm, 5 mm and .225 mm respectively. From the above figures it is also observed that the maximum deflections are occurring at 1250Hz, 1250 Hz and 1250 Hz in X, Y and Z directions respectively.

From the above results it is observed that the VonMises stress is very less and the factor of safety is very high. So weight reduction can be made by removing the material at low stress regions. Two modified model were done as shown in the below figures and the above analysis are repeated to check the deflections and stresses.

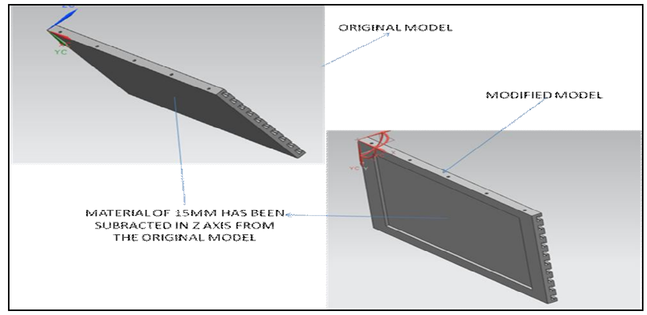


Figure10. Modified Model 1 of machine bed

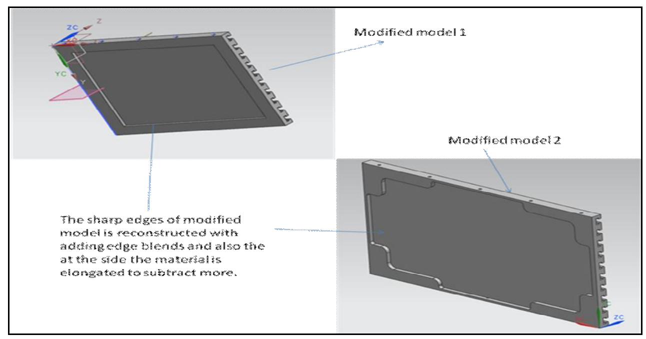
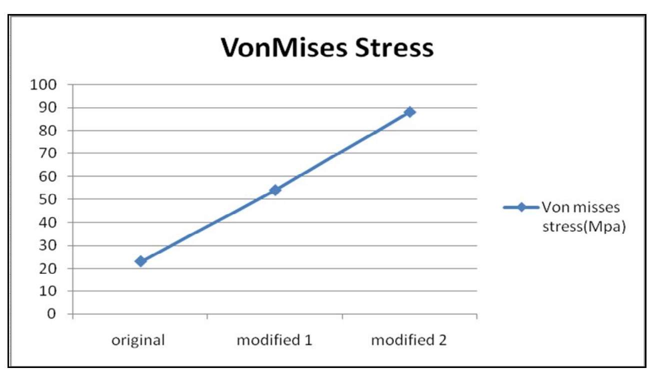


Figure11. Modified Model 2 of machine bed

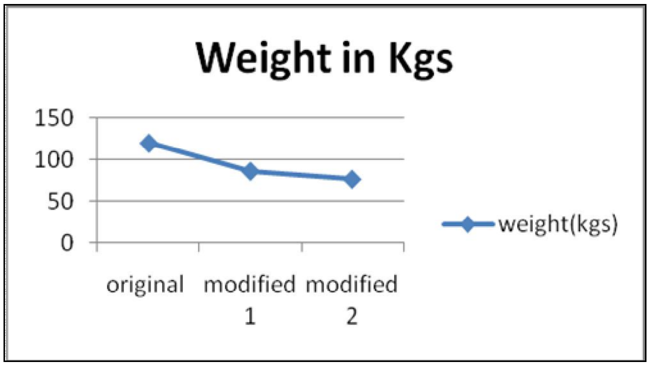
The deflections, Von Mises stresses obtained for original, modified 1 and modified 2 models are tabulated and compared.

Table3. Comparison of deflections for all the models

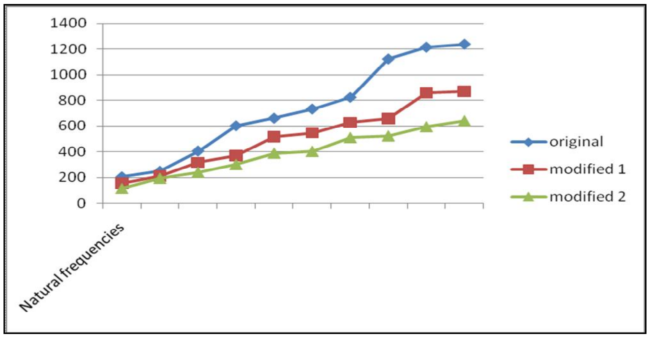
	original	modified 1	modified 2
Total deformation(mm)	0.009	0.03	0.09
Deformation in x direction	3.8	0.001	0.003
Deformation in y direction	0.001	0.005	0.013
Deformation in z direction	3.2	6.5	0.0012



Graph 4.VonMises stress for different models



Graph 5. Weight in Kgs for different models



Graph 6. Comparison of Natural frequences different models

VII. CONCLUSION

In this project, a CNC machine bed was selected for the analysis for static loads. In the later work the investigation is carried out to reduce the weight of the machine bed without deteriorating its structural rigidity. From the analysis results the following conclusions are made.

1. From the results, it can be concluded that the rigidity of the column structure is better for modified model.
2. The optimize weight for the machine bed is decreased from 120kg to 88 kg,(approximately 36.6%) and it will make the manufacturing cost less for bed.
3. The Von miss stress for modified model 2 after the decrease in weight is 88 MPa and is in permissible safe limit.

REFERENCES

[1] Sruthi Srinivasan, “Design and Structural Analysis of CNC Milling Machine Bed with Composite Material”, Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-12, 2016.

[2] S. Syath ABUTHAKEER, P.V. MOHANRAM, G. Mohan KUMAR, “structural redesigning of a cnc lathe bed to improve its static and dynamic characteristics”, International journal of engineering, 2011.

[3] Shana WANG, “Static Analysis and Size Optimization for the Bed of Gantry Milling Machine based on ANSYS Workbench”, School of Art & Design Guilin University of Technology, Guangxi.

[4] Ersan Gonul, Muhsin Kılıc, and Fatih Karpat, “A Study on Design and Manufacturing for the Side Wall of Large CNC Portal Milling Machine”, 2nd International Conference on Research in Science, Engineering and Technology (ICRSET’2014), March 21-22, 2014 Dubai (UAE).