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Design and Structural Analysis of Lathe and Milling Machine Bed with Epoxy Granite

Kairamkonda Amar[1],Dr. C. Udaya Kiran[2]
M.Tech (Mechanical CAD/CAM), JB Institute of Engineering and Technology, Moinabad, Ranga Reddy, Telangana

Abstract- Performance of a Machine Tool is highly depends on the Bed. The Bed of the Machine Tool has to be appropriately robust to absorb all vibrations and rigid enough to avoid deflections under different cutting forces transferred over the tool-post and carriage to the Lathe Bed. Cast Iron, Mild Steel are traditional material of bed has some characteristic limitations like low damping, long lead time, long manufacturing and tendency to rusting, etc. The Alternative Materials may include Polymer Concrete, Granite, Epoxy Granite, etc. The outstanding damping and high stiffness has a favourable effect on both tool wear and work piece surface finish. Lathe Machine Bed and Milling Machine Bed are selected for present study. In this work, the 3D model of Lathe and Milling Machine Bed are designed with the help of Solidworks and analysing this machine beds using Ansys. In analysis process, machine beds are analysed using Cast Iron and Epoxy Granite as material and compared both static structural analysis results. Thus the overall objective indulges in comparing the structural characteristic of both Cast Iron and Epoxy Granite bed materials for both Lathe and Milling machines.

Keywords: Lathe Machine Bed, Milling Machine Bed, Structural Analysis, Ansys 17.0, Solidworks 2015

I. INTRODUCTION

In any machine tool, proper design of machine bed majorly contributes in improving the performance of that machine. Properly designed machine bed always absorbs vibrations and deflections generated under various conditions. It must be massive with adequate depth and width to absorb vibration. Traditional Material of Bed like Cast Iron, mild steel have some characteristic disadvantages like long manufacturing lead time, low damping and tendency to rusting, etc.Present work is to overcome these limitations it by substituting Cast Iron with a material made of Granite powder impregnated Epoxy material which has certain favourable properties required for analysing any structural material used for machine tool. Static Analysis of bed is carried out using software. 3D CAD model for Lathe and Milling machine beds are made using Solidworks 2015. Cast Iron and Epoxy Granite materials are compared for their Structural Analysis. NikunjAadeshra [1] has carried out a review on mechanical characterization of Epoxy Granite material and the same is represesnted in Table 2. Table 1 represents mechanical properties of Cast iron as it is mentioned in Ansys.

II. NEED OF EPOXY GRANITE:

Epoxy granite, also recognized as synthetic granite, is combination of epoxy and granite usuallytaken as an alternative material for machine tool base. Epoxy granite may be taken instead of CastIron and steel for better vibration damping, lower assembly cost, and longer tool life [2]. Machine tools and high-precision machines rest on beds made of materials with high rigidity, long term stability and excellent damping characteristics for their static and dynamic performance [3]. Due to the lack of long-term stability and very low damping properties, stainless steel structures are rarely used where high precision is required. A good cast iron that is raised and collected will reduce the dimensional stability of the structure and can be molded into complicated shapes, but requires costly machining methods to produce precision surfaces after casting [4].

Table 1 Properties of Cast Iron

Property	Cast Iron
E(GPa)	80-120
σ F.S. (MPa)	150
σ C.S. (MPa)	600
α (10^{-6}/k)	10
ρ (kg/m^3)	7150
ξ	10^{-3}

Table 2 Properties of Epoxy Granite

Property	Epoxy Granite
E (GPa)	60-80
σ F.S. (MPa)	25-40
σ C.S. (MPa)	65-150
α (10^{-6}/k)	8
ρ (kg/m^3)	2850
ξ	10^{-2}

III. MACHINE TOOL:

A Machine Tool is defined as a stationary, power-driven machine used to create relative motion between tool and work piece to shear the work piece and give it required shape. Lathes, Milling machines, Shapers and tools can be Planers, Power drills or Drill presses, Presses, Grinding Machines and Power saws are seven different types of machine tools [5].

A. Lathe Machine Bed:

The bed acts as the base for lathe machine where all parts are placed over it. It is rigid and massive and single piece casting made to support further active parts of lathe. In lathe machine, headstock is placed on left end of the bed, while tailstock is situated on right side. On bed the machine carriage rests and slides on it. Outerways and innerways are two sets of guideways on the top of the bed. The tailstock gives sliding surfaces for the innerways and the carriage for the outerways. The guideways of the lathe bed may be inverted V shape and flat [6]. Forces considered on lathe bed are Weight of Headstock-392.4N, Weight of Carriage-294N, Feed force-245.2N, Tangential/ Thrust force-536.62N, Radial force-399.67N.

B. Milling Machine Bed:

It is the foundation part of a milling machine. All other parts are jointed on it. It carries the entire load so it should have high compressive strength so it is made by Cast Iron. It also works as reservoir of cutting fluid. Forces considered on milling bed are Total forces acting on guide ways-272N, forces due to other accessories-717N.These above forces are taken as boundary conditions during analysis process of machine beds.

IV. DESIGN AND ANALYSIS:

A 3D model of the Lathe and Milling Bed is created in Solidworks 2015 design software with the help of tools like sketch toolbar and feature toolbar tools and saved in the step format. Now in Ansys Workbench 17.0, Static Structural analysis is selected and Engineering data is edited for selecting materials (Cast Iron and Epoxy Granite) and with Geometry Tool design file is imported and design is developed at Model Tool which redirects in Mechanical APDL and meshing is applied using Mesh Tool and above forces are applied and Total deformation, Normal stress, Normal strain, Von-Mises stress, and Von-Mises Strain are the solution results selected before solution and at final task is solved using Solve Tool. The analysis is carried out for Cast Iron and Epoxy Granite material.

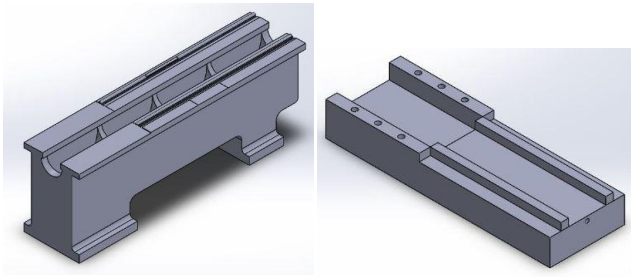

Fig.1 Lathe and Milling Machine Bed Design in Solidworks

A. Boundary Conditions on Beds:

The boundary conditions on Lathe Bed are Weight of Headstock (392.4 N), Weight of Carriage (294 N), Feed force (245.2 N), Thrust force (536.62 N) and fixed support is shown in below Fig.2.

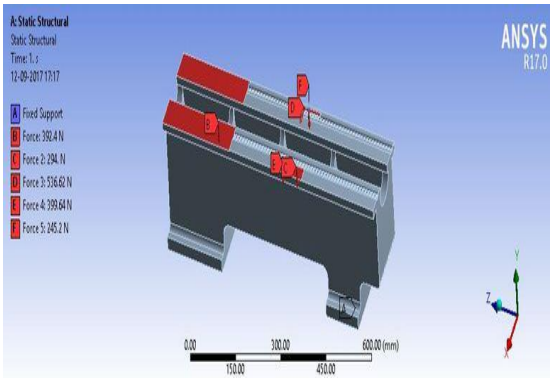

Fig.2 Boundary conditions on Lathe Bed

The boundary conditions on Mill Bed are total forces acting on guide ways, forces due to other accessories and fixed support is shown in below Fig.3.

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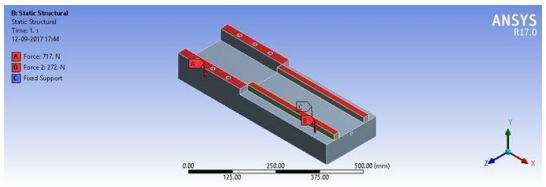

Fig.3: Boundary conditions on Milling Bed

B. Effect of Deformation, Stresses and Strain on Lathe Bed of Grey Cast Iron

In case of Lathe machine Epoxy Granite bed, maximum deformation found is 0.02768 mm at centre of the lathe bed and at ends it is 0 mm. The red and blue colour indicates maximum and minimum deformation respectively. Fig 4 shows the deformation of Lathe Machine Bed.

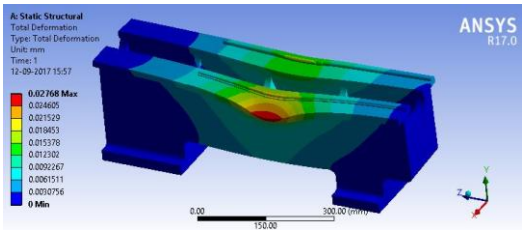

Fig.4 Deformation of Lathe Machine Bed of cast iron

In case of Lathe Machine Cast Iron bed, maximum stress found is 2.7383 MPa at centre of lathe bed and at ends it is 0 MPa. Fig 5 shows the von-Mises stresses of Lathe Machine Bed.

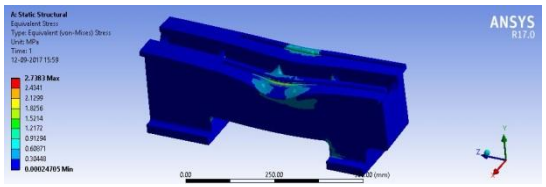

Fig.5 Von-Mises stresses of Lathe Machine Bed of cast iron

In case of Lathe Machine Cast Iron bed, maximum strain found is 1.6836e-5 at centre of the lathe bed and minimum of 2.6781e-9 at ends. Fig.6 shows the von-Mises strain of Lathe Machine Bed.

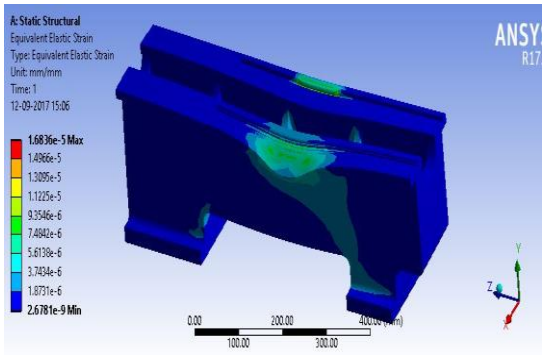

Fig.6 Von-Mises strain of Lathe Machine Bed of cast iron

C. Effect of Deformation, Stresses and Strain on Lathe Machine Bed of Epoxy Granite

In case of Lathe Machine Epoxy Granite bed, maximum deformation found is 0.003166 mm at centre of the lathe bed and at ends it is 0 mm. The red and blue colour indicates maximum and minimum deformation respectively. Fig.7 shows the deformation of Lathe Machine Bed.

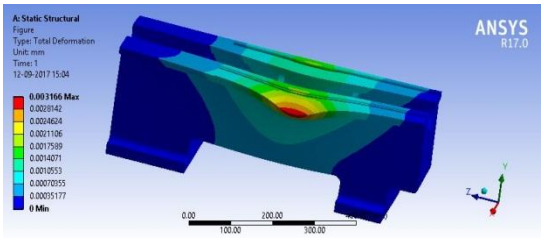

Fig.7 Deformation of Lathe Machine Bed of Epoxy Granite

In case of Lathe Machine Epoxy Granite bed, maximum stress found is 1.6056 MPa at centre of the lathe bed and minimum of 0.00025922 MPa at ends. Fig.8 shows the Von-Mises stresses of Lathe Machine Bed.

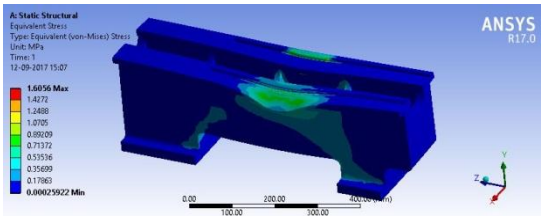

Fig.8 Von-Mises stresses of Lathe Bed of Epoxy Granite

In case of Lathe Machine Epoxy Granite bed, maximum strain found is 0.000022951 at centre of the lathe bed and minimum of 2.53e-6 at its ends. Fig.9 shows the Von-Mises strain of Lathe Machine Bed.

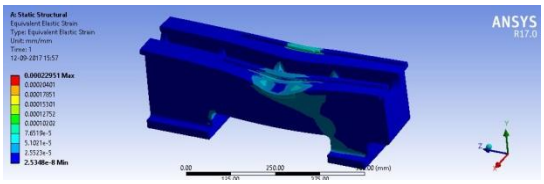

Fig.9 Von-Mises strain of Lathe Machine Bed of Epoxy Granite

D. Effect of Deformation, Stresses And Strain on Milling Bed of Grey Cast Iron

In case of Milling Machine Cast Iron bed, maximum deformation found is 5.6237e-5 mm at one end and minimum of 0 mm at central portion of guide ways. The red and blue colour indicates maximum and minimum deformation respectively. Fig.10 shows the deformation of Milling Machine Bed.

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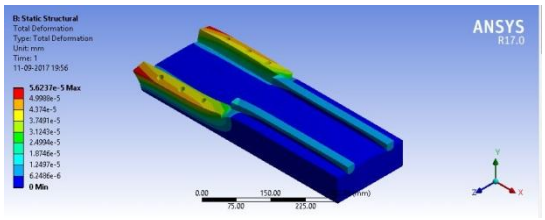

Fig.10 Deformation of Milling Machine Bed of cast iron

In case of Milling Machine Cast Iron bed, maximum stress found is 0.090556 MPa at one end and minimum of 8.43e-5 MPa at central portion of guide ways.. Fig.11 shows the von-Mises stresses of Milling Machine Bed.

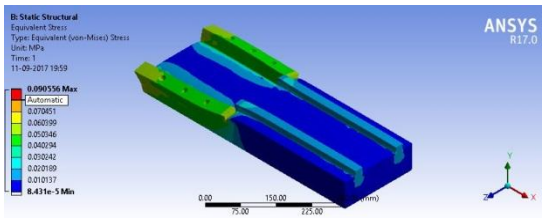

Fig.11 Von-Mises stresses of Milling Machine Bed of cast iron

In case of Milling Machine Cast Iron bed, maximum strain found is 9.1662e-7 one end of the milling bed and minimum of 5.7747e-7 at central portion of guide ways. Fig.12 shows the Von-Mises strain of Milling Machine Bed.

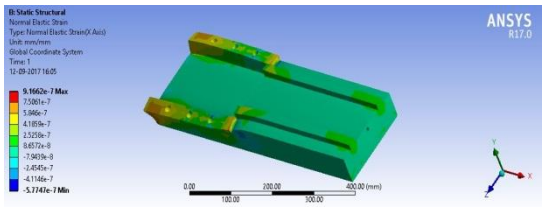

Fig.12 Von-Mises strain of Lathe Machine Bed of cast iron

E. Effect of Deformation, Stresses and Strain on Milling Machine Bed of Epoxy Granite

In case of Milling Machine Epoxy Granite bed, maximum deformation found is 0.00020462 mm at one end and minimum of 0 mm at central portion of guide ways. The red and blue colour indicates maximum and minimum deformation respectively. Fig.13 shows the deformation of Milling Machine Bed.

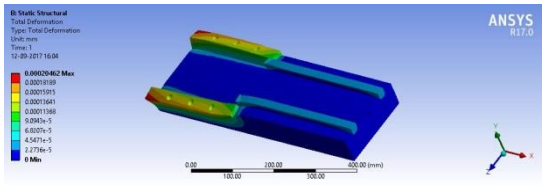

Fig.13 Deformation of Milling Machine Bed of Epoxy Granite

In case of Milling Machine Epoxy Granite bed, maximum stress found is 0.088353 MPa at one end of milling bed and minimum of 5.2368e-5 MPa at central portion of guide ways. Fig.14 shows the Von-Mises stresses of Milling Machine Bed.

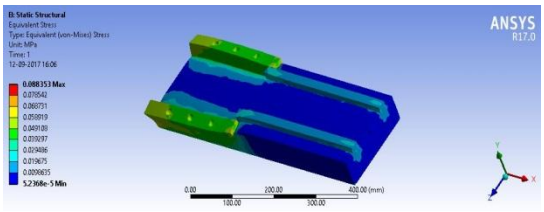

Fig.14 Von-Mises stresses of Milling Bed of Epoxy Granite

In case of Milling Machine Epoxy Granite bed, maximum strain found is 8.2324e-7 at one end of milling bed and minimum of 7.6646e-10 at central portion of guide ways. Fig.15 shows the Von-Mises strain of Milling Machine Bed.

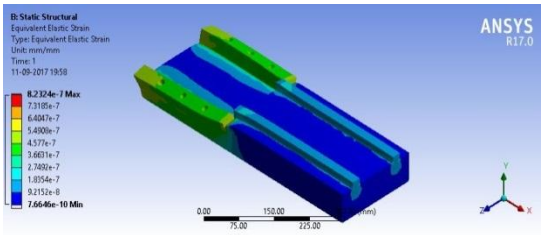

Fig.15 Von-Mises strain of Lathe Machine Bed of Epoxy Granite

V. SUMMARY OF ANALYSIS

The following tabular column compares the Lathe Machine bed made of Cast Iron and Epoxy Granite of their analysis results such as deformation, von-Mises stress and von-Mises strain.

Table 3 Comparison of Cast Iron Lathe Bed and Epoxy Granite Lathe Bed

S. No	Material	Deformation (mm)	Von-Mises Stress (MPa)	Von-Mises Strain
1	Cast Iron Lathe Bed	0.02768	2.738	$2.295*10^{-5}$
2	Epoxy Granite Lathe Bed	0.003166	1.605	$1.683*10^{-5}$

The following tabular column compares the Milling Machine bed made of Cast Iron and Epoxy Granite of their analysis results such as deformation, von-Mises stress and von-Mises strain.

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Table 4 Comparison of Cast Iron Milling Bed and Epoxy Granite Milling Bed

S. No	Material	Deformation (mm)	Von-Mises Stress (MPa)	Von-Mises Strain
1	Cast Iron Mill Bed	5.6237 $*10^{-5}$	0.090556	9.1662e-7
2	Epoxy Granite Mill Bed	2.0462*10 $^{-5}$	0.088353	8.2324e-7

By taking into the above results, the induced deformation, stress, and strain in Epoxy Granite machine bed is less than conventional Cast Iron machine beds.

VI. Conclusions:

For Lathe Machine Bed, when Cast Iron is replaced by Epoxy Granite, the total deformation has been reduced to 0.496mm, von-Mises stress to 1.1327MPa and von-Mises strain by 1.268 and similarly for Milling Machine Bed, the total deformation reduced to 3.5775*10-5mm, von-Mises stress to 0.00170266MPa and von-Mises strain to 0.93296.By taking into the above results, the induced deformation and strain in Epoxy Granite machine bed is less than conventional Cast Iron machine beds because specific strength and specific rigidity of Epoxy Granite machine bed is more than Cast Iron. The work suggests that Epoxy Granite material is most suitable for Lathe and Milling machine bed.

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