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DESIGN AND WEIGHT OPTIMIZATION OF THE LATHE BED BY REPLACEMENT OF EXISTING MATERIAL WITH ADHESIVE MATERIAL BY ANSYS APPROACH

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ABSTRACT

Lathe bed acts as the base on which the different fixed and movable parts of the Lathe are mounted. Lathe beds are usually manufactured with Cast iron or Mild steel. In case of extremely large machines, the bed may be in two or more pieces, bolted together to from the desired length. Lathe Bed is heavy rigid structure which is having high damping capacity for the vibrations generated by machines during machining.

In this paper, static structural and modal analyses are carried out on lathe bed at maximum load conditions. These simulation results are used to reduce the weight of the lathe bed without deteriorating its structural strength and damping capacity by adding ribs and removing mass where less deformation and stresses are induced. FEA analysis of modified lathe bed is carried out with Gray cast iron and Epoxy-granite which is a mixture of granite and epoxy resin-hardener as an alternative material. Effectiveness of both materials are compared in terms of induced stresses, deformation and weight reduction. Lathe bed CAD models have been generated with Creo modeling software. The FE model has been generated by ANSYS APDL. The analyses are carried out using ANSYS APDL. The results are shown in the form of contour plots and also tabulated, to analyse the effect of weight reduction on the structural integrity of the machine bed before and after the weight reduction and conclusions are drawn about the optimized design

Keywords: *Weight optimization, Lathe bed, FE Analysis, Epoxy-granite.*

I. INTRODUCTION

The bed of Lathe acts as the base on which the different fixed and operations parts of the Lathe are mounted. Lathe beds are usually made as single piece casting of semi-steel (i.e., toughened cast iron), with the addition of small quantity of steel scrap to the cast iron during melting; the material „cast iron" facilitating an easy sliding action. In case of extremely large machines, the bed may be in two or more pieces, bolted together to from the desired length. Lathe Bed are heavy rigid structure which is having high damping capacity for the vibrations generated by machines during machining. The rigid structure will helps to avoid deflections. The guides and ways which are present on the top of the bed will act as rails and supports other parts like tail stock. The bed will be designed in such a way that easily bolted to the floor of the machine shop.

II. PROBLEM STATEMENT

Fig 1. shows the extra duty lathe machine manufactured by M/s Honest lathe, this lathe bed is selected for the complete analysis for both static and natural frequencies. Then investigation is carried out to reduce the weight of the machine bed without deteriorating its structural rigidity and the accuracy of the machine tool by reducing the material where lathe bed under goes less stress and deformation region also FE analysis will be carried out with Epoxy-granite by applying on modified lathe bed. In this work, the 3D CAD model for the base model and the optimized design has been created by using commercial 3D modeling software Creo. The 3D FE model has been generated using ANSYS APDL. The analyses were carried out using ANSYS APDL. The results were shown in tabular form to analyze the effect of weight reduction on the structural integrity of the machine bed before and after the weight reduction and conclusions were drawn about the optimized design.

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Fig 1: Heavy duty lathe machine

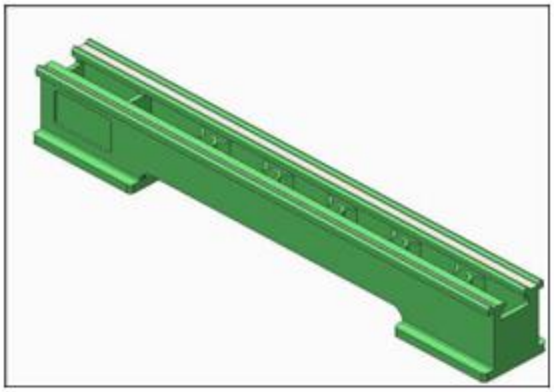

Fig 2: Solid model of lathe bed

Length	1420 mm
Width	174.5 mm
Height	215.7 mm

III. MATERIAL PROPERTIES

A. Gray Cast Iron

Cast iron is one of the oldest ferrous metals used in construction and outdoor ornament. It is primarily composed of iron (Fe) carbon (C) and silicon (Si), but may also contain traces of sulphur (S), manganese (Mn) and phosphorus (P). It has a relatively high carbon content of 2% to 5%. It is hard, brittle, nonmalleable (i.e. it cannot be bent, stretched or hammered into shape) and more fusible than steel. Its structure is crystalline and relatively brittle and weak

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in tension. Cast-iron members fracture under excessive tensile loading with little prior distortion. Cast iron is, however, very good in compression. The composition of cast iron and the method of manufacture are critical in determining its characteristics.

Property	Value
Young"s Modulus	140e9 N/m^2
Poisson"s Ratio	0.3
Density	7200 kg/m^3

B. Epoxy Granite

Epoxy granite, also known as synthetic granite, is a mixture of epoxy and granite commonly used as an alternative material for machine tools bases. Epoxy granite is used instead of cast iron and steel for better vibration damping, longer tool life, and lower assembly cost.

Precision granite castings are produced by mixing granite aggregates (which are crushed, washed, and dried) with an epoxy resin system at ambient temperature (i.e., cold curing process). Quartz aggregate filler can also be used in the composition. Vibratory compaction during the moulding process tightly packs the aggregate together

Property	Value
Young"s Modulus	70e9 N/m^2
Poisson"s Ratio	0.25
Density	2900 kg/m^3

IV. MESHING

Meshing of solid model is done by the Element chosen, element edge length have been adjusted to 0.02 m in order to obtain a regular uniform mesh. Automatic sizing creates elements of wide range of dimensions. Therefore manual sizing is done.

V. BOUNDARY CONDITIONS

The base of the lathe machine bed is fixed to the floor. Therefore base of lathe bed is constrained in all directions (U_X=U_Y=U_Z=0).

Gravitational force is applied, to add stress distribution and deformation due to self weight. Below figure shows the boundary conditions applied on the FE model

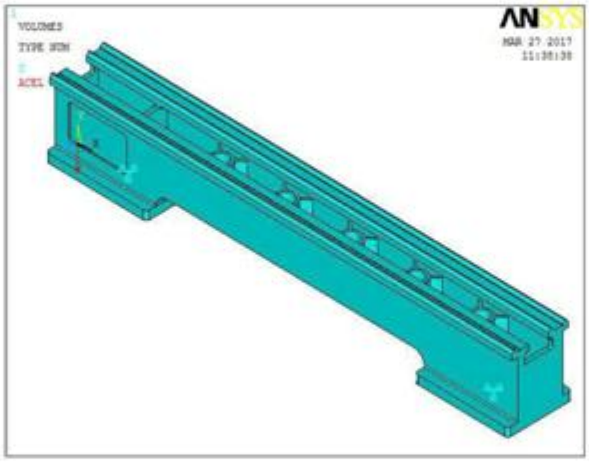

Fig 3: Fixed boundary conditions and gravitational acceleration applied on lathe bed

VI. FORCE APPLIED ON LATHE BED

To design a lathe bed, initially we have to analyse, the stresses and deformations inducing in lathe bed due to cutting forces generated by cutting tool and work piece interaction. The design of lathe bed is preceded by analysis of forces that are acting on the system due to tool work piece interaction. In current analysis we considered the maximum torque which is supplied by electric motor of lathe machine.

Cutting forces will be transferred to lathe bed at carriage region. So we applied force at carriage region (while in machining process, carriage slides over lathe bed. We simplified analysis by fixing its location. we considered its location near to the head stock because in most manufacturing cases we don't slide carriage beyond middle portion lathe bed) as shown in fig :4. The following forces are applied on lathe bed.

1. Maximum torque which can be generated by prime mover is converted into force and applied on carriage region. as shown in calculation.
2. Weight Of Head Stock - 246 – 105.8 = 140.2 kg / 1375 N (Carriage and tailstock weights are not subtracted due to unavailability of individual weights. It does not affect FEA results because we are not reducing loads and as compared to lathe bed weight these weight are very less in magnitude)
3. Self weight of the lathe bed due to gravitational force
4. Maximum Weight Between Centres - 36.2 kg / N. This force is divided into 2 equal parts (i.e., 177.5 N). This force is applied on headstock and tailstock. All forces applied on lathe bed are shown in fig. 4.

Spindle bore (Diameter)	34.5 mm (r =17.25 mm)
Spindle speed range	55 - 2200 rpm (N)
Electric motor	2 Hp or 1.5 kW (P)

Technical specifications of lathe machine

$$P = \frac{2 X \pi X N X T}{60}$$

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1500 = (2 X π X 55 XT) / 60

T = 260.33 N-m

T = F X r

260.33 = F X 0.01725

F = 15092 N

This force applied at region of carriage for simulating actual locations from where cutting forces transferred to lathe bed. since number of nodes are 700 at this region, hence force is divided into 700 parts (21.6 N). The forces applied as shown in below figure: 4.

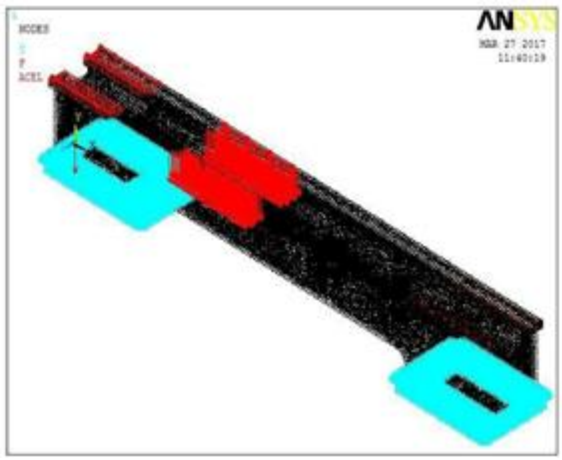

Fig 4: Force applied on lathe bed

VII. STATIC AND MODAL ANALYSIS RESULTS BEFORE WEIGHT OPTIMIZATION

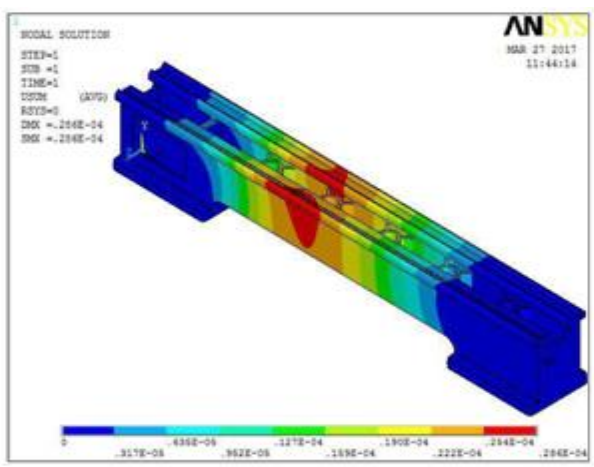

Fig 5: Deformation of lathe bed before weight Optimization

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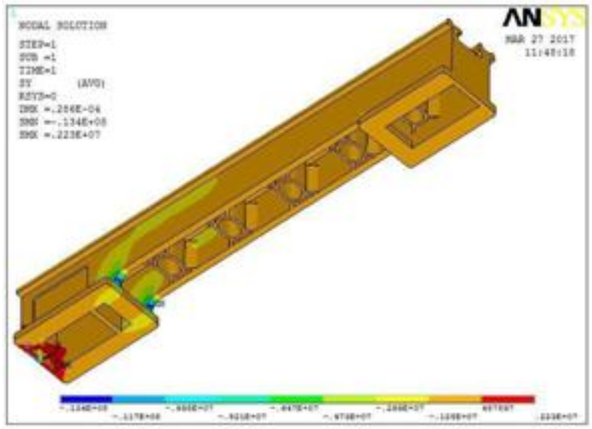

Fig 6: Stress Distribution of lathe bed in Y direction before modification

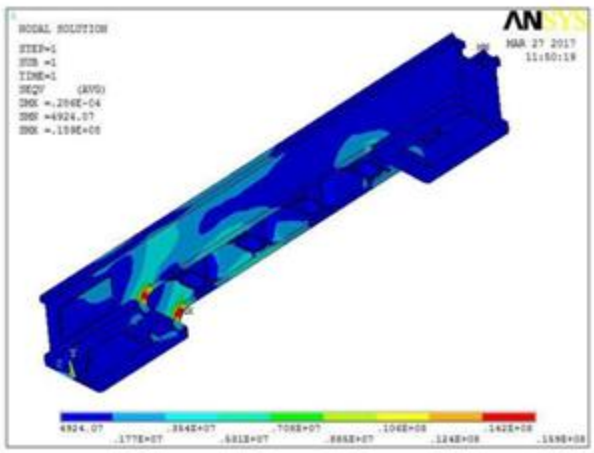

Fig 7: Von-mises stress Distribution of lathe bed before modification

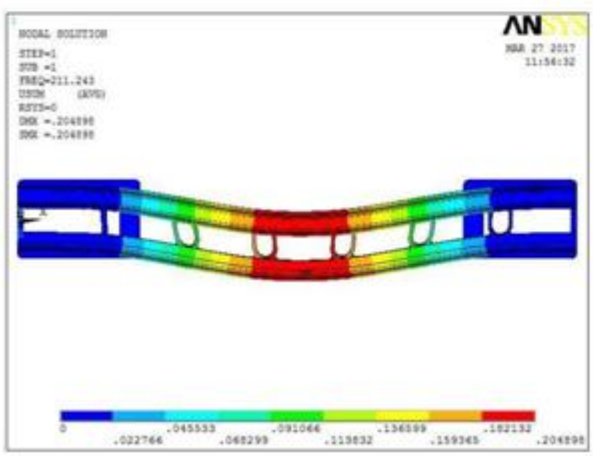

Fig 8: Natural Frequency mode – 1 Deformation

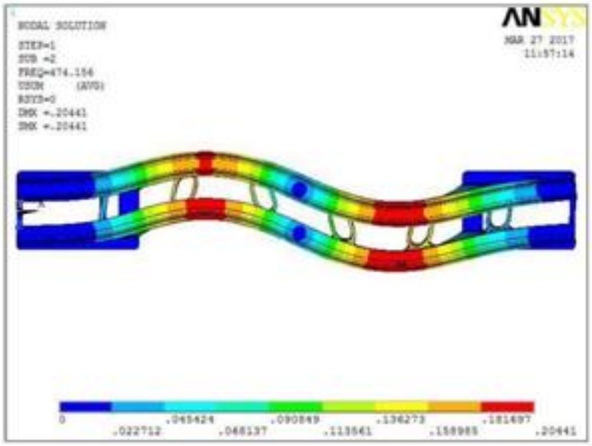

Fig 9: Natural Frequency mode – 2 Deformation

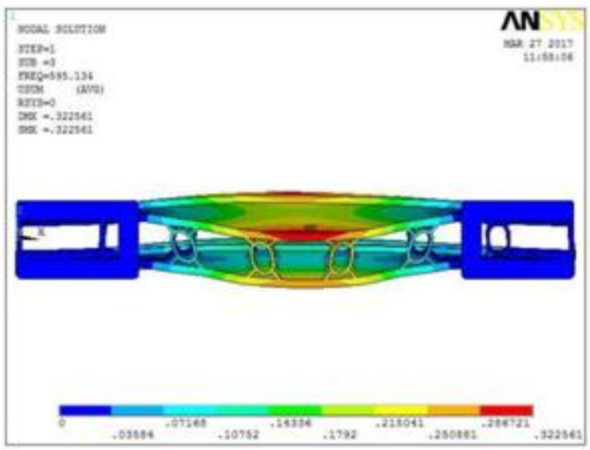

Fig 10: Natural Frequency mode – 3 Deformation

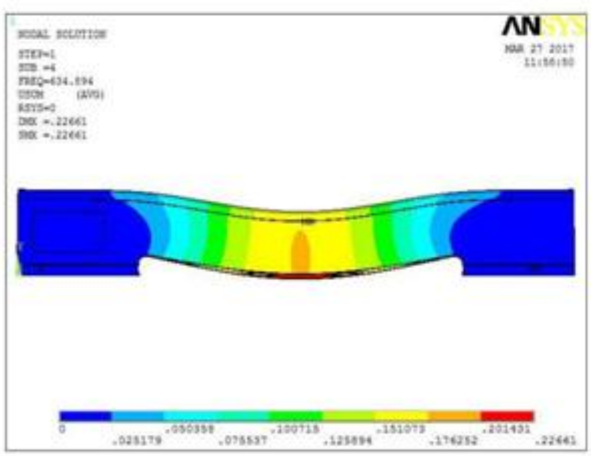

Fig 11: Natural Frequency mode – 4 Deformation

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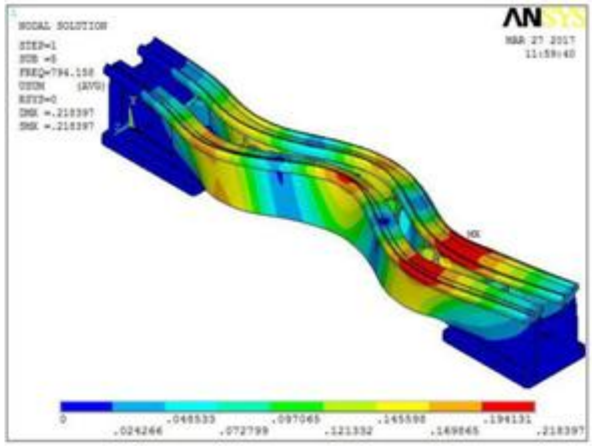


Fig 12: Natural Frequency mode – 5 Deformation

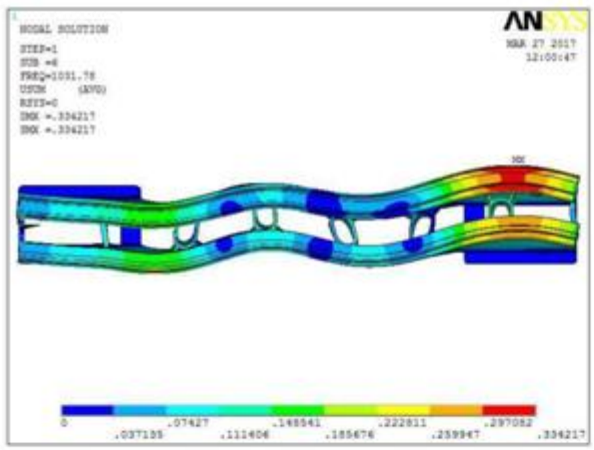
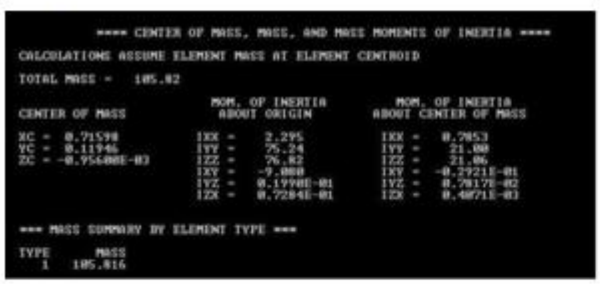


Fig 13: Natural Frequency mode – 6 Deformation



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**** CENTER OF MASS, MASS, AND MASS MOMENTS OF INERTIA ****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS =    105.82

                          MOM. OF INERTIA          MOM. OF INERTIA
CENTER OF MASS             ABOUT ORIGIN         ABOUT CENTER OF MASS

XC =  0.71598           IXX =    2.295           IXX =   0.7853
YC =  0.11946           IYY =    75.24           IYY =    21.00
ZC = -0.95600E-03       IZZ =    76.82           IZZ =    21.06
                        IXY =   -9.000           IXY =  -0.2921E-01
                        IYZ =  0.1990E-01        IYZ =   0.7017E-02
                        IZX =  0.7204E-01        IZX =   0.4071E-03

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE      MASS
   1   105.816
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Fig 14: Mass of lathe bed before modification

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VIII. STATIC AND MODAL ANALYSIS RESULTS AFTER WEIGHT OPTIMIZATION

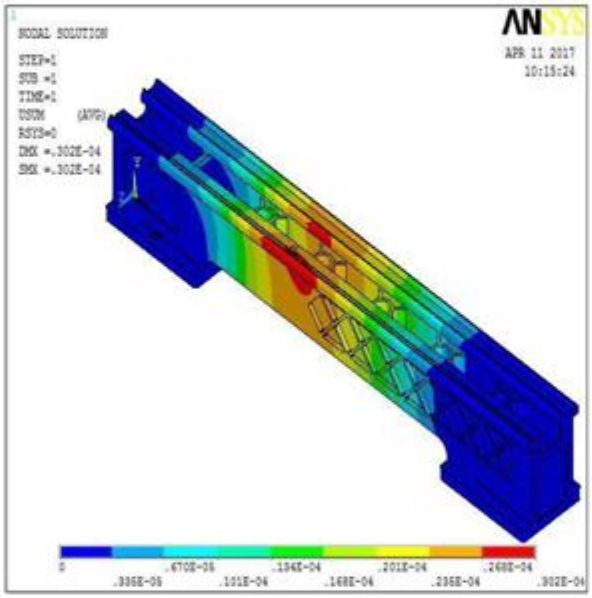

Fig 15: Deformation of lathe bed before weight optimization

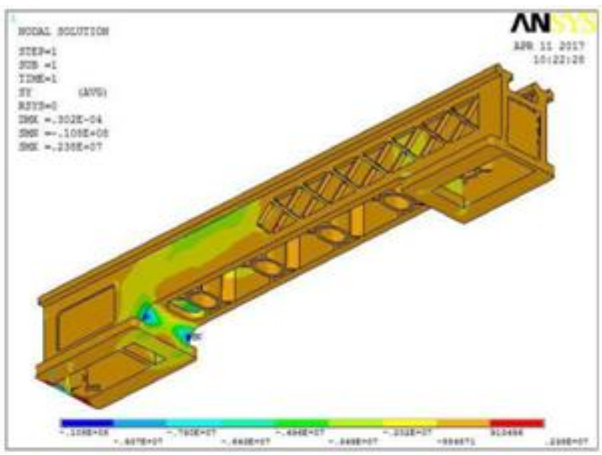

Fig 16: Stress Distribution of lathe bed in Y direction before modification

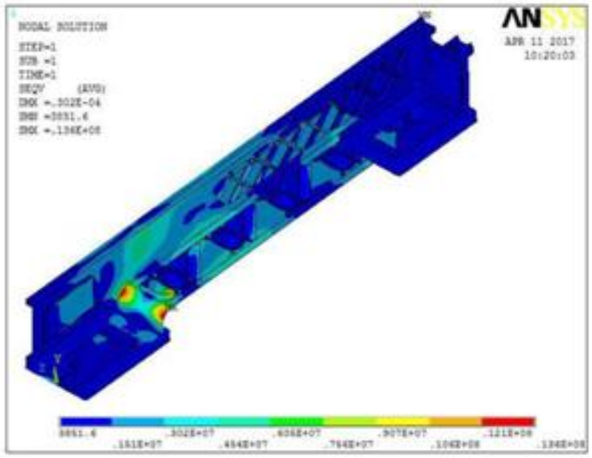

Fig 17: Von-mises stress Distribution of lathe bed before modification

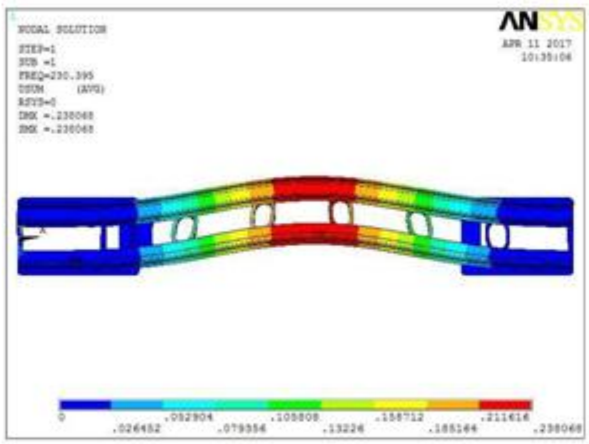

Fig 18: Natural Frequency mode – 1 Deformation

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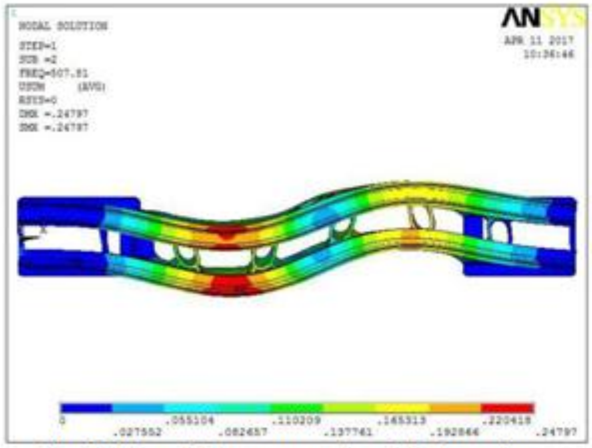

Fig 19: Natural Frequency mode – 2 Deformation

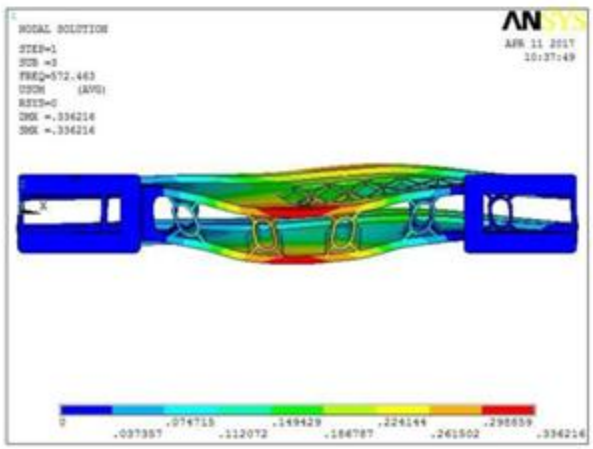

Fig 20: Natural Frequency mode – 3 Deformation

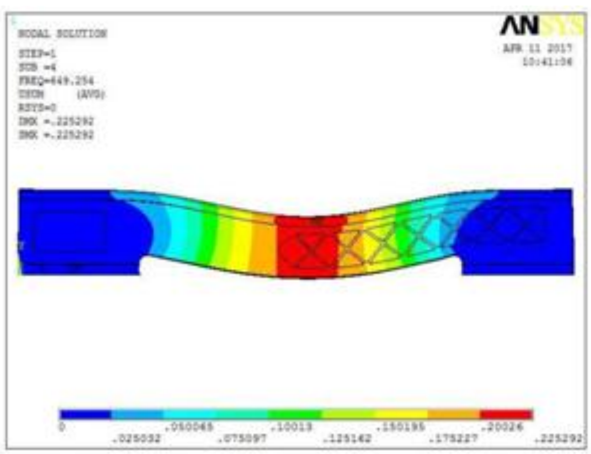

Fig 21: Natural Frequency mode – 4 Deformation

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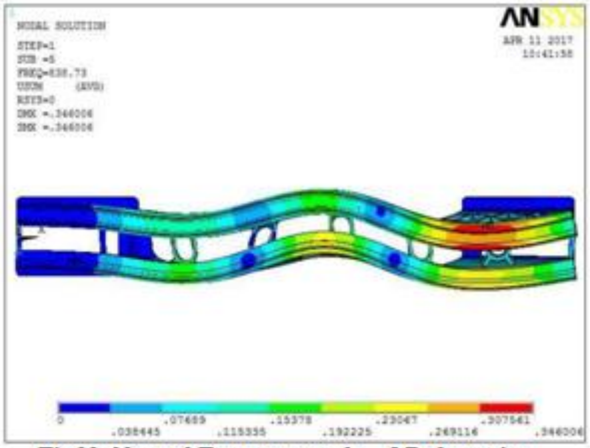

Fig 22: Natural Frequency mode – 5 Deformation

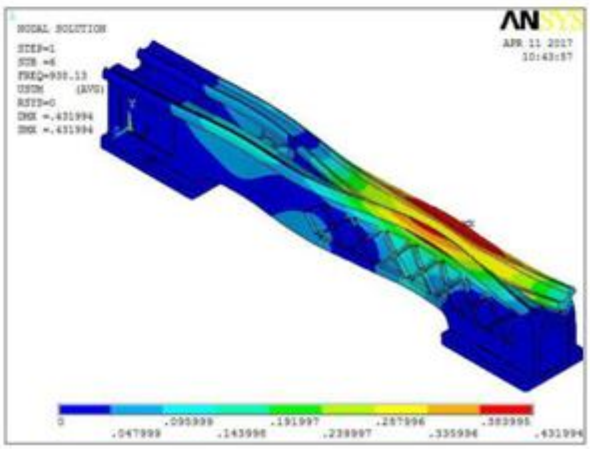

Fig 23: Natural Frequency mode – 6 Deformation

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**** CENTER OF MASS, MASS, AND MASS MOMENTS OF INERTIA ****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS =   97.992

                          MOM. OF INERTIA        MOM. OF INERTIA
CENTER OF MASS            ABOUT ORIGIN           ABOUT CENTER OF MASS

XC =  0.68270            IXX =   2.120          IXX =  0.7496
YC =  0.11824            IYY =   65.42          IYY =   19.75
ZC = -0.10261E-02        IZZ =   66.88          IZZ =   19.84
                         IXY =  -7.956          IXY = -0.4538E-01
                         IYZ =  0.1984E-01      IYZ =  0.7952E-02
                         IZX =  0.7245E-01      IZX =  0.3807E-02

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE      MASS
   1   97.9920
```

Fig 24: Mass of lathe bed after modification

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IX. STATIC AND MODAL ANALYSIS RESULTS AFTER WEIGHT OPTIMIZATION WITH EPOXY-GRANITE

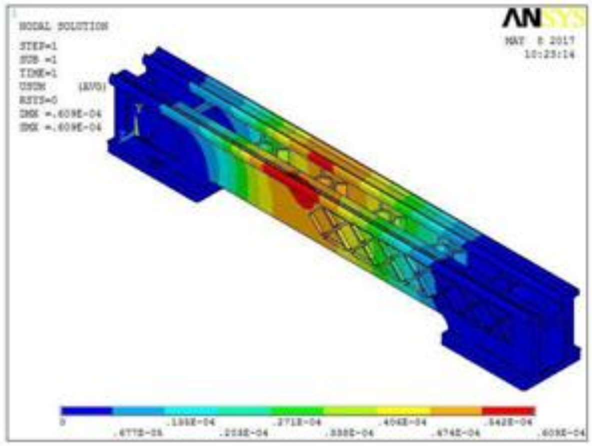

Fig 25: Deformation of lathe bed before weight optimization

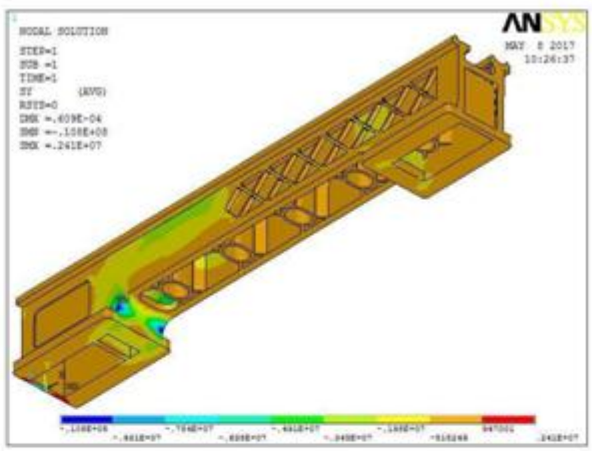

Fig 26: Stress Distribution of lathe bed in Y direction before modification

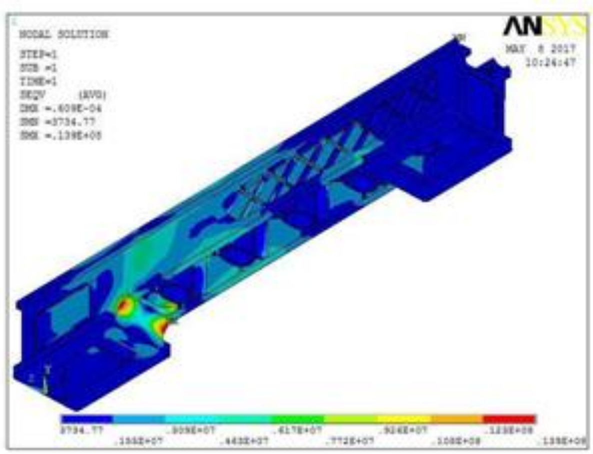

Fig 27: Von-mises stress Distribution of lathe bed before modification

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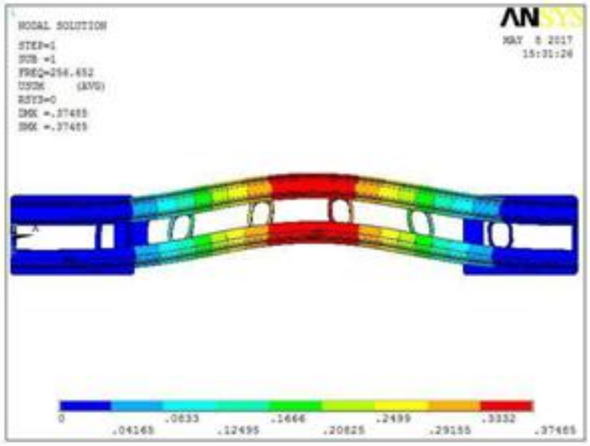

Fig 28: Natural Frequency mode – 1 Deformation

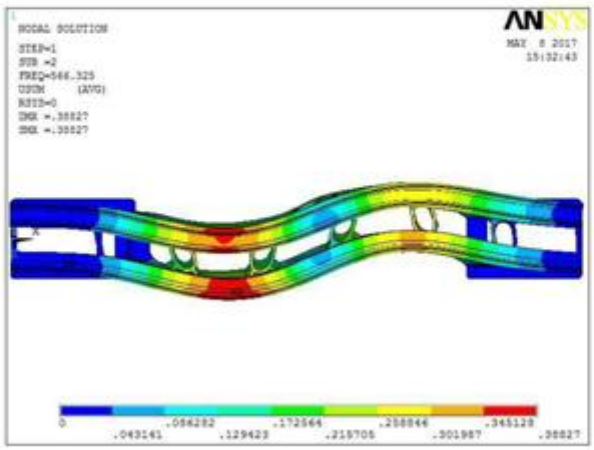

Fig 29: Natural Frequency mode – 2 Deformation

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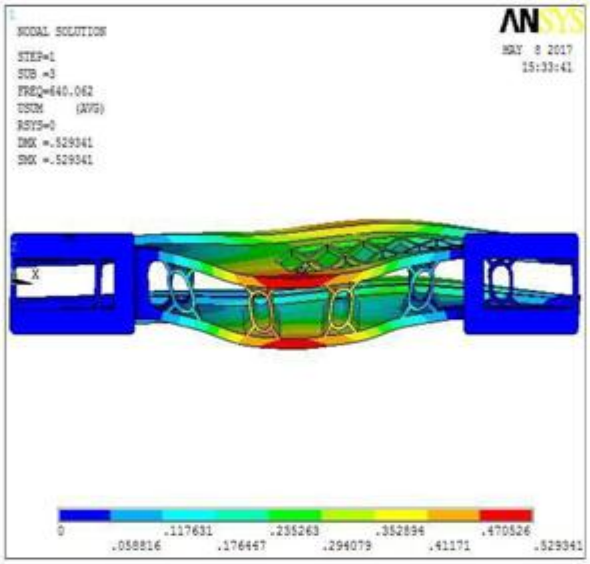


Fig 30: Natural Frequency mode – 3 Deformation

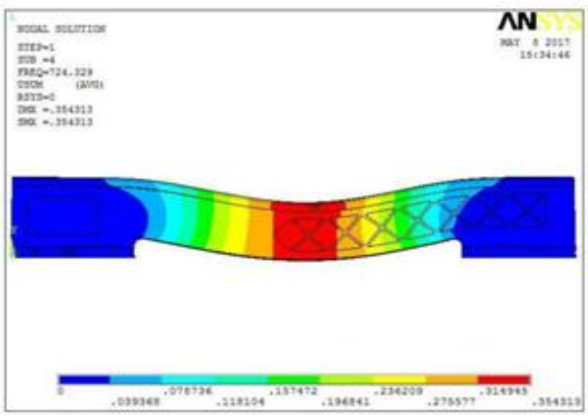


Fig 31: Natural Frequency mode – 4 Deformation

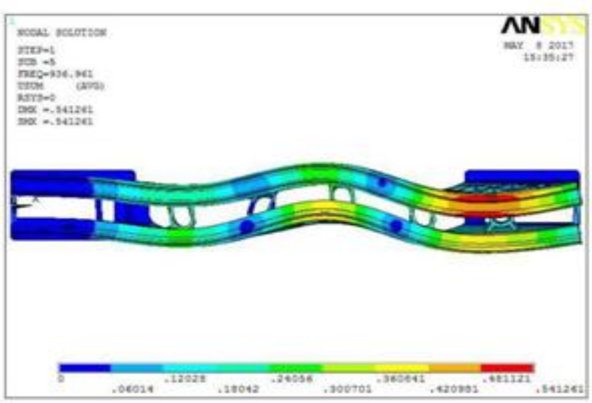


Fig 32: Natural Frequency mode – 5 Deformation

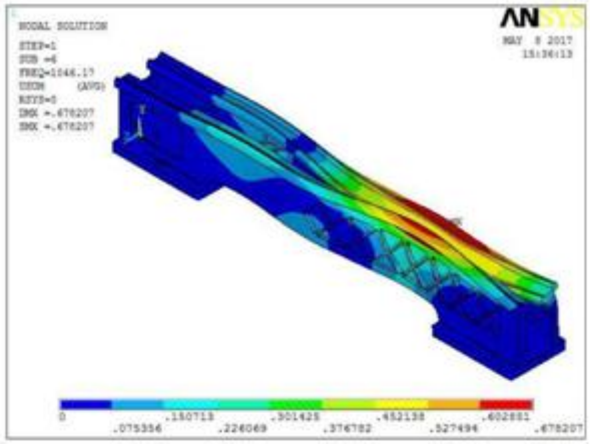
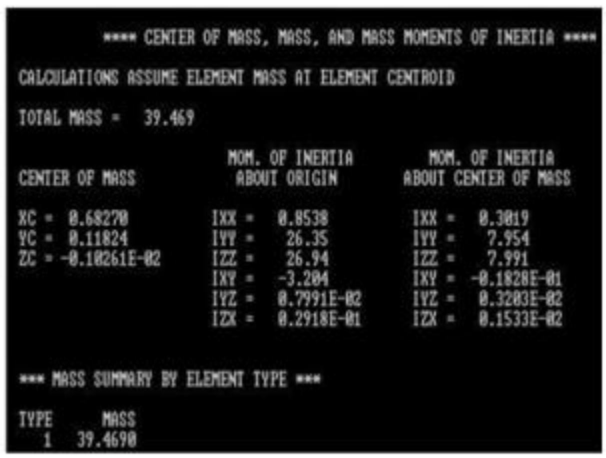


Fig 33: Natural Frequency mode – 6 Deformation



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**** CENTER OF MASS, MASS, AND MASS MOMENTS OF INERTIA ****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS =   39.469

                          MOM. OF INERTIA         MOM. OF INERTIA
CENTER OF MASS             ABOUT ORIGIN         ABOUT CENTER OF MASS

XC =  0.68270          IXX =  0.8538         IXX =  0.3019
YC =  0.11824          IYY =   26.35         IYY =   7.954
ZC = -0.10261E-02      IZZ =   26.94         IZZ =   7.991
                       IXY =  -3.204         IXY = -0.1828E-01
                       IYZ =  0.7991E-02     IYZ =  0.3203E-02
                       IZX =  0.2918E-01     IZX =  0.1533E-02

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE      MASS
   1   39.4690
```

Fig 34: Mass of lathe bed after modification with Epoxy-granite

TABLE 1

PARAMETER	LATHE BED (BEFORE WEIGHT OPTIMIZATION)	LATHE BED (AFTER WEIGHT OPTIMIZATION)	MODIFIED LATHE BED WITH EPOXY GRANITE
STRESS IN Y DIRECTION (MPa)	13.4 (Compressive) 2.23 (Tensile)	10.8 (Compressive) 2.38 (Tensile)	10.8 (Compressive) 2.41 (Tensile)
VON-MISES STRESS (MPa)	15.9	13.6	13.9
DISPLACEMENT	0.0286	0.0302	0.0609

(mm)			
MASS (kg)	105.816	97.992	39.469

Structural analysis results comparison

Table 2

PARAMETER		**LATHE BED (BEFORE WEIGHT OPTIMIZATION)**	**LATHE BED (AFTER WEIGHT OPTIMIZATION)**	**WEIGHT OPTIMIZED LATHE BED (EPOXY GRANITE)**
Mode 1	**Frequency (Hz)**	211.24	230.40	256.652
	Displacement (mm)	204.898	238.068	374.85
Mode 2	**Frequency (Hz)**	474.16	507.81	566.325
	Displacement (mm)	204.41	247.97	388.27
Mode 3	**Frequency (Hz)**	595.13	572.46	640.062
	Displacement (mm)	322.561	336.216	529.341
Mode 4	**Frequency (Hz)**	634.89	649.25	724.329
	Displacement (mm)	226.61	225.292	354.313
Mode 5	**Frequency (Hz)**	794.16	838.73	936.961
	Displacement (mm)	218.397	346.006	541.261
Mode 6	**Frequency (Hz)**	1031.8	938.13	1046.17
	Displacement (mm)	334.217	431.994	678.207

Modal analysis results comparison

X. CONCLUSION

In this project, we have prepared Lathe bed CAD model of M/s South Bend Lathe Co.

The weight of the lathe bed before modification is 105.816 Kg, after modifying the design weight of the bed has reduced to 97.992 kg. This weight reduction is equal to 7.4% base model weight. Also Structural and modal analyses are carried out for modified lathe bed with Epoxy-granite material. By changing lathe bed material bed weight has reduced to 39.469 kg. This weight reduction is equal to 62.7% base model weight.

We conformed that modified Lathe bed CAD model is not deviating with base Lathe bed CAD model in terms of vibrational damping capacity by conducting modal analysis for 6 modes (Natural Frequencies). We get higher natural frequencies in case of modified model with Epoxy granite material.

Through these structural and modal analysis results, we can conclude that modified model with Epoxy granite material is best in terms of weight, stresses and damping capacity.

XI. FUTURE SCOPE

1. Accuracy of structural analysis result of lathe bed can be increased by applying forces which are measured by machine tool dynamometer and strain gauges during maximum load conditions of lathe machine.
2. We can extend this study to dynamic analysis and thermo-structural analysis. FE analysis can also be done with composite materials like High Modulus Carbon Fiber Reinforced Polymer.
3. Number of nodes and elements decides simulation time and size of analysis (size of global stiffness matrix). By reducing problem dimensionality from 3D to 2D, we can reduce number of elements and very fine mesh can be attain which leads greater approximation and interpolation of FEA results. But it needs lot of surface modeling skills.

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