FEA Analysis of machine tool structures by using filler material

Mr. Virendrasinh N.Chavda[1], Mr. Hitesh R.Raiyani [2]

[1]*Department of Mechanical Engineering (CAD/CAM), LJIET,*

[2]*Department of Mechanical Engineering (CAD/CAM), LJIET, Ahmedabad.*

Abstract — In the new economic year and globalization phase, industries are required to manufacture good quality machine tools with optimized performance at the moderate cost. Moreover, the industries are facing competition internationally due to world-wide globalization of business. Present work deals with the Modeling, FEA analysis and optimization of column structure with composite filler material for Vertical Turret Lathe for 600 mm turning diameter capacity. This includes different structure modeling of column structure, accordance to the relevant standard, specification and use of composite filler material. Modeling the different column structure by consideration of the factor affected to structure strength and rigidity and by applying composite filler material in cast iron column. FEA analysis of the different column-structure for column's strength and rigidity carryout trough the ANSYS – Workbench 14.5 in various fields like stress and displacement. Than validation of computational result (FEA Result) is done. Also for the economy of column-structure, column is optimized using Analysis and modal analysis for natural frequency. Finally 2D details machining drawing of optimized column-structure is generated.

***Keywords** – Structure Material, Filler Material, Structural Bionic Design, Column Stiffeners Arrangement, Parametric Optimization.*

I INTRODUCTION

India is a fast growing country and due to worldwide globalization of business many multinational companies are investing millions of rupees in India. With that it also demands to produce quality product and supplied at the right time. Moreover the quality of the job produced on these machine tools depends straight on the quality and performance of the machine tools produced and some other conditions. To develop good products, design engineers need to study how their design will behave in real-world conditions. To take care of this condition, often analysis and optimization of the proposed design becomes very useful and reliable tool for the design engineer. Due to the large investment in power sector, automobile sector and much more. The demands of very large and heavy components, (pressure vessels, heat exchangers turbine bodies, reactors, large bearing rings, large pipes, electric motor body etc.) and very precise component (linear, piston, pulley etc.) are on peak.

LITERATURE REVIEW

Dail Gil Lee et all : Fiber reinforced composite material reduces the weight of slides up to 34% and increases damping by 1.5-5.7 times without sacrificing the stiffness and positional accuracy[3]

Sung-Kyum Cho : In this paper a small table top machine tool structure was designed and fabricated by using carbon/epoxy composites and resin concrete . Authors have suggested that the redesign structure was 36.8% lighter and structural stiffness was increased by 16% . [4]

Ling Zhao: Machine tool column with stiffening ribs inside using structural bionic method can reduce the maximum static displacement by 45.9% with 6.13% mass reduction and its dynamic performances is also better. **[6]**

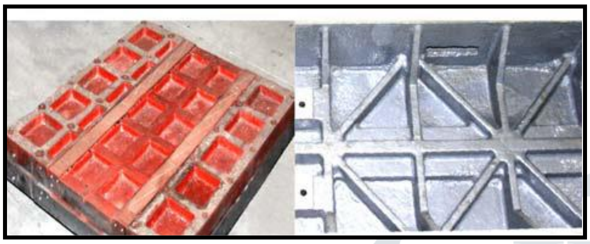


Figure-2. Conventional ribs distribution.

Wedad I. Alazzawy : The effects of changing the c/s area of the column itself and adding stiffeners with different c/s on the deformation was investigated.From result, the best c/s area of column without stiffener is the square shape. And Best stiffener c/s is I sec. and than Rec. [8]

II STRUCTURE MODELING OF COLUMN

FUNCTIONS OF MACHINE TOOL STRUCTURE AND THEIR REQUIREMENTS

Machine tool parts, such as beds, bases, columns, box-type housings, over arms, carriages, tables, etc. are known as structures. Basic functions of machine tool structure are as follows:

a) To provide rigid support on which various subassemblies can be mounted i.e. beds, bases.

b) To provide housings for individual units or their assemblies like speed gear box, spindle head.

c) To support and move the work piece and tool relatively, i.e. table, carriage, tail stock etc.

A. Material for machine tool structure:

Values of some properties of above discussed material are listed in table, below:

Table .1 Some properties of some structural material – app. Average value [6]

Material	Modulus of Elasticity N/mm^2	Specific Gravity	Specific Stiffness N/mm^2	Coefficient Of thermal Expansion $^0C^{-1}$	Thermal conductivity $Wm^{-1}k^{-1}$	Tensile strength N/mm^2
Cast Iron	117000	7.21	16000	12×10^{-6}	75	230
Mild steel	207000	7.93	26000	12×10^{-6}	80	460
ranite	39000	2.66	15000	8×10^{-6}	0.8	14.7
Epoxy Concrete	33000	2.5	14000	12×10^{-6}	0.5	25

Table .2 Comparison of structure materials [6]

Material	Merits	Demerits
Cast iron	-Possible to cast it in complex and intricate shapes. -Easily machined, hand-scraped and lapped to high degree of accuracy. -Fairly good damping properties -Good anti-friction properties	-Comparatively lower strength -Time and cost taken to produce a finished casting -Technological constraints to produce cast structures i.e. minimum wall thickness -High shrinkage rates during curing -Need anti-corrosion treatment
Epoxy Concrete	-Used for precision machine tool structures -It offers great design freedom same as cast iron -Outstanding damping properties, long term stability	

B. **Grey Factor Affecting Strength and Stiffness of Machine Tool Structure:**

Machine tool structure is design for higher strength and stiffness, various parameter of machine tool structure profile affect on strength and stiffness are:

- Shape of cross-section.
- Effect of aperture.
- Stiffeners arrangement in structure.
- Effect of bolt arrangement and external vertical stiffeners column

Figure-3. Structure Modeling Of VTL Column

III FEA ANALYSIS OF COLUMN STRUCTURE

A. Cutting Force Calculations: Drilling [6]

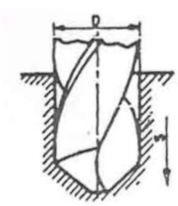


Figure 4. Cutting force during drilling operation [6]

Specification:

- Diameter of drill (D) : 32.5 mm
- Material to be cut : cast iron (200 BHN)
- Cutting speed (v) : 34.66 m/min
- Feed per revolution (s) : 0.3 mm/rev
- Efficiency of transmission : 85%

Cutting speed

$n = v \times 1000 / \pi .D$

$= 34.66 \times 1000 / \pi \times 32.5$

$n = 339.5$ rpm

Power at spindle

$N = 1.25 \times D^2 \times K \times n \times (0.056 + 1.5 \times S) \times 10^{-5}$

$= 1.25 \times (32.5)^2 \times 1.5 \times 339.5 \times (0.056 + 1.5 \times 0.3) \times 10^{-5}$

$N = 3.4$ KW

Where, K = material factor

$Th = 1.16 \times K \times D \times (100 \times S) \times 0.85$

$= 1.16 \times 1.5 \times 32.5 \times (100 \times 0.3) \times 0.85$

= 1018.6 kgf

$Th = 10.186$ KN

Torque at spindle

$Ts = 975 \times N / n$

$= 975 \times 3.4 / 339.5$

$Ts = 2.269$ kgf-m

B. Load Calculations and Constrains:

The cutting forces are not acting directly on the column but get transmitted through turret, X -slide and Z-slide. To calculate its effect moment from a point on column is taken.

Actual load on column:

Net load acting on column

$w = w_1 + w_2 + w_3 + w_4$

$w = 10186 - 1600 - 3018.75 - 3871.19$

$w = 1696.06$ N

C. Analysis Report:

Table .3 Analysis report for column: Drilling Operation

Particulars	Details
Model description	Column
Software used	ANSYS – Workbench 14.5
Assumptions	Only static loading is required. Self weight of structure is ignored.

Material to be used	FE 30, Material properties are as follows: E = 1.048 X10^5 MPa μ = Poisson's ratio = 0.25 ρ = Density = 7.19 X 10^{-9} tonne/mm3
	Elastomer , Material properties are as follows: E = 1X10^8 Pa μ = Poisson's ratio = 0.47 ρ = Density = 930 Kg/m3
	Cementious , Material properties are as follows: E = 24099 MPa μ = Poisson's ratio = 0.2 ρ = Density = 2200 Kg/m3
Type of element used	Tetrahedral
Loads	Dead weight of Turret, X-slide, Z-slide. Thrust force during drilling.
Constraints	Column is fixed on base, so face from where column is assembled to base is taken fixed.
Constraints Parameter	Stress: 7.84532 -11.76798 M Pa and Deflection: 1 - 3 micron

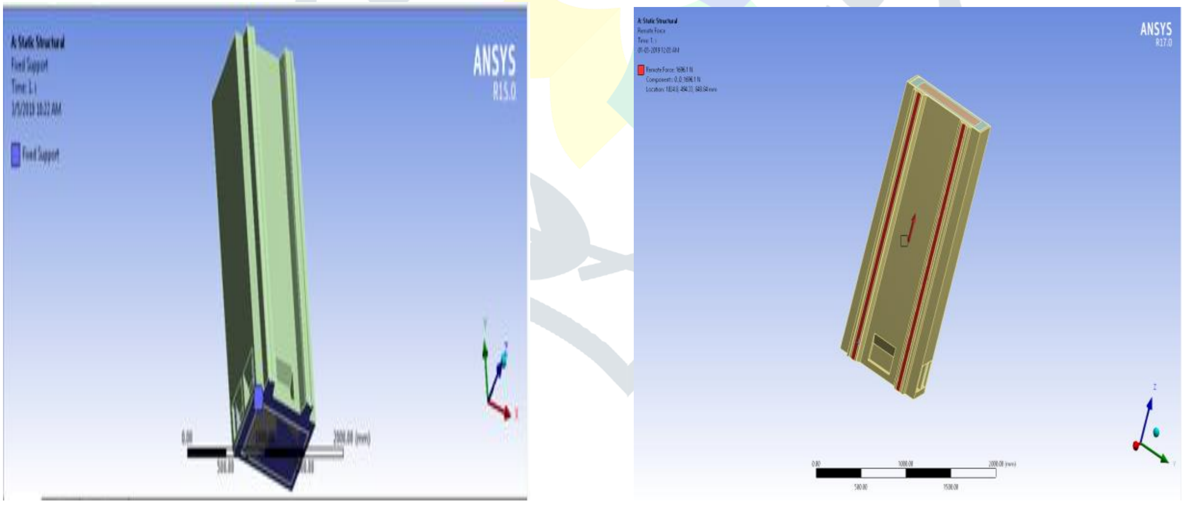
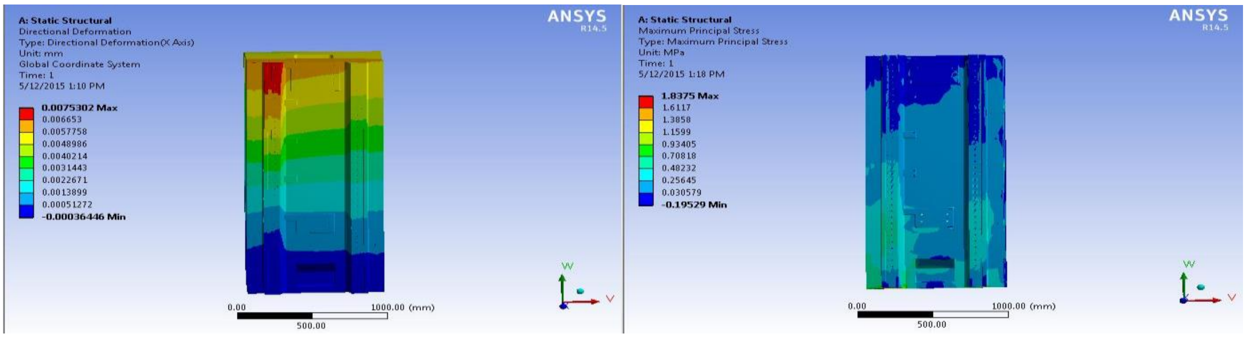


Figure 5. Constrain And Load on VTL Column

Table .4 FEA meshing details of column

Meshing Details	
Nodes	150400
Elements	89083
Element size	Default
Element type	Tetrahedral

PRESENT COLUMN DEFLECTION &STRESS



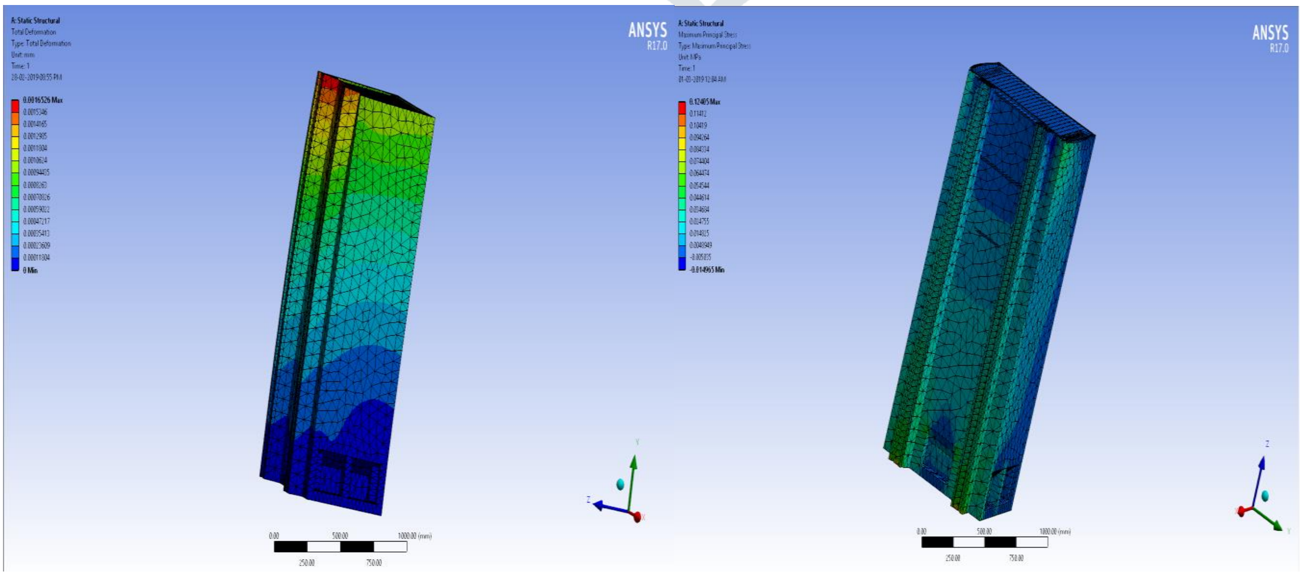
Part Name	Parameter	Analyzed Result Obtained	Permissible Deflection/Stress
COLUMN	DEFLECTION	0.00753 MM	0.01 MM
	STRESS	1.8375 MPa	7.8453 MPa

D. DESING OF EXPERIMANTAL

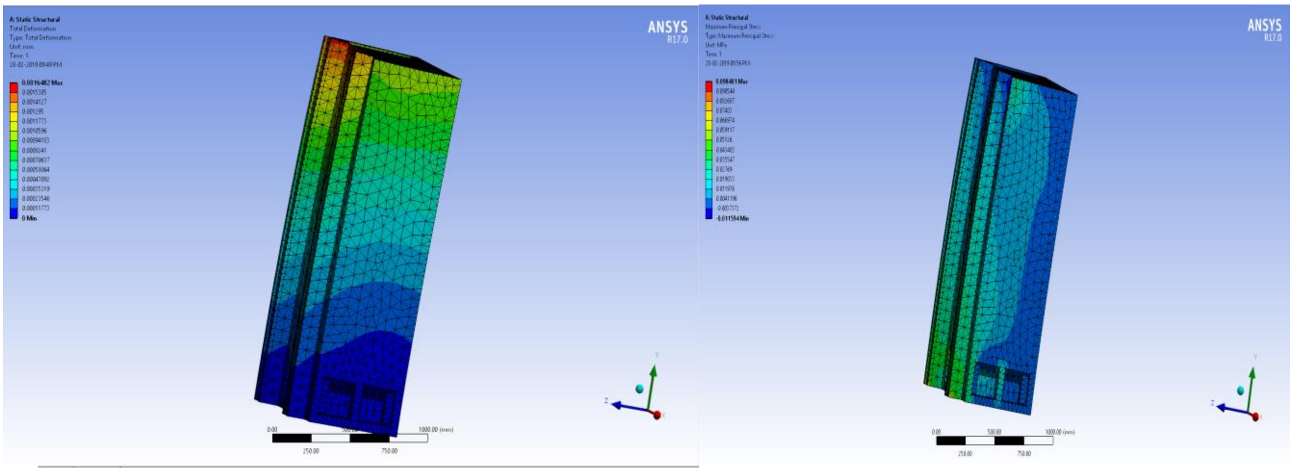
Sr No	Elastomer Thickness (mm)	Cemetitious Materialdensity(Kg/M^3)	Column Thikckness(mm)
1	12	2200	21
2	12	2300	23
3	12	2400	25
4	16	2200	23
5	16	2300	25
6	16	2400	21
7	20	2200	25
8	20	2300	21
9	20	2400	23

FEA Result of column

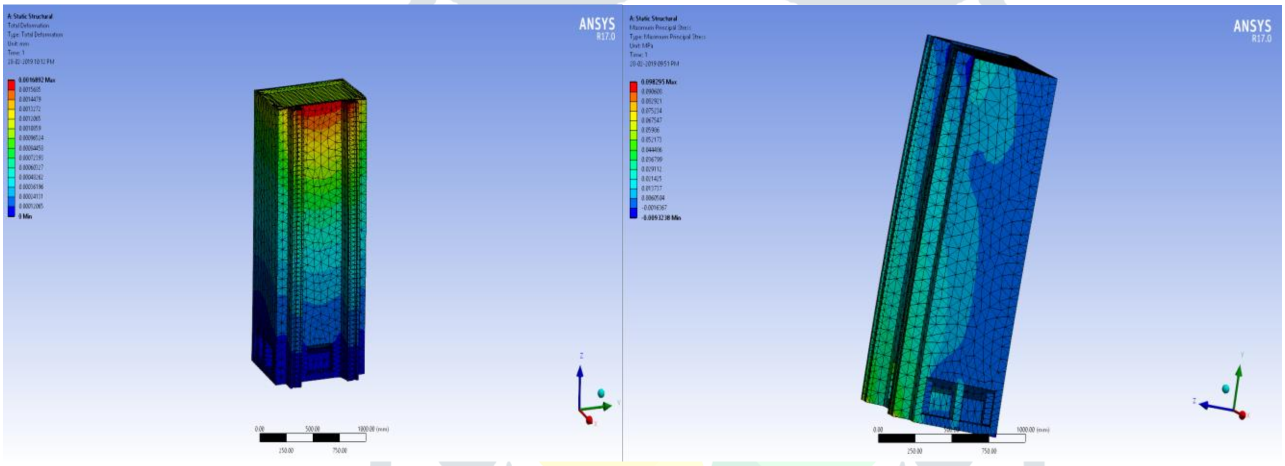
Case-1



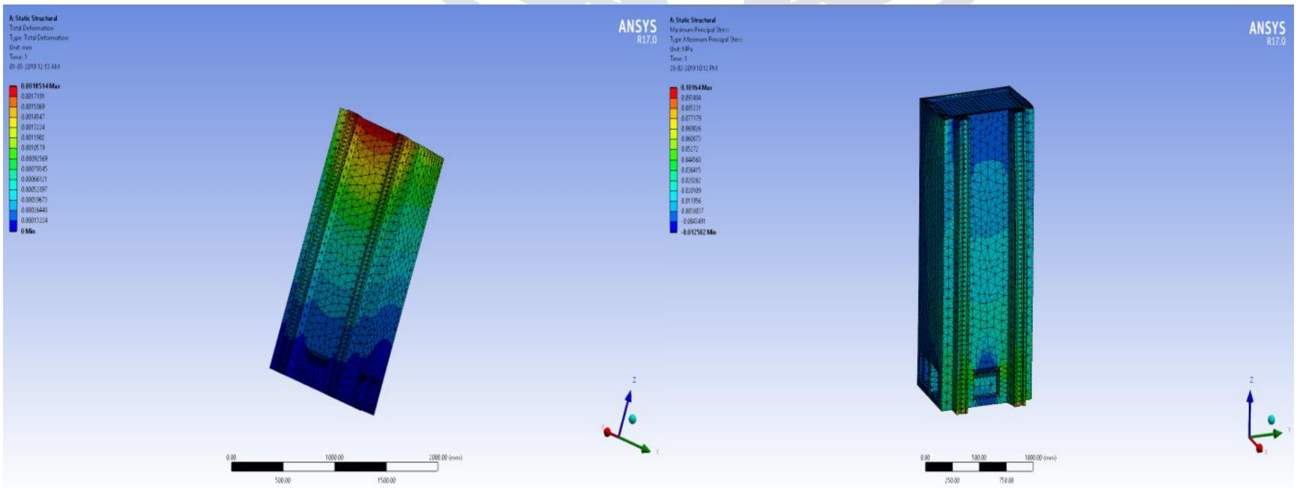
Case-2



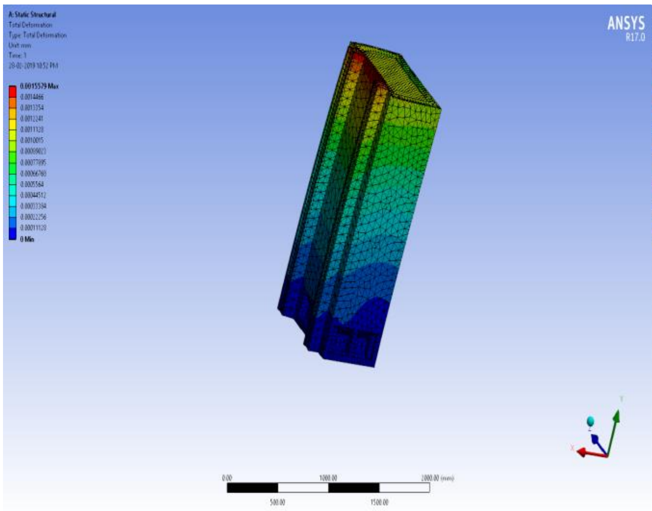
Case-3

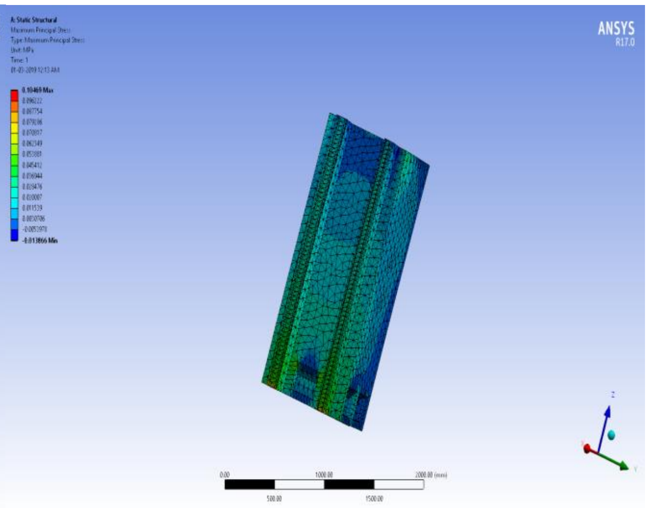


Case-4

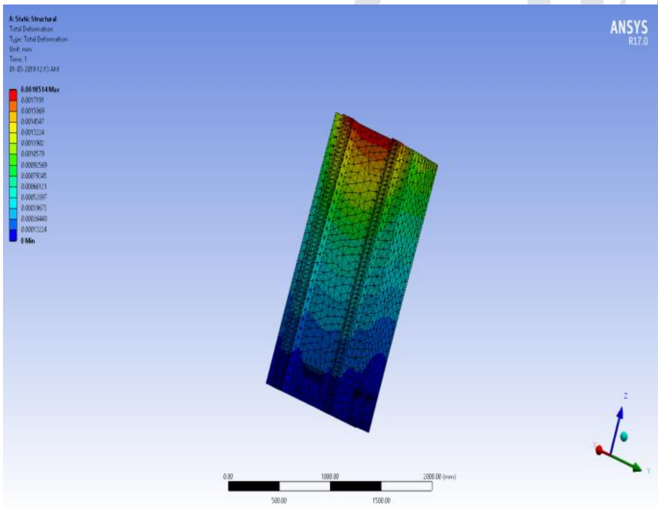


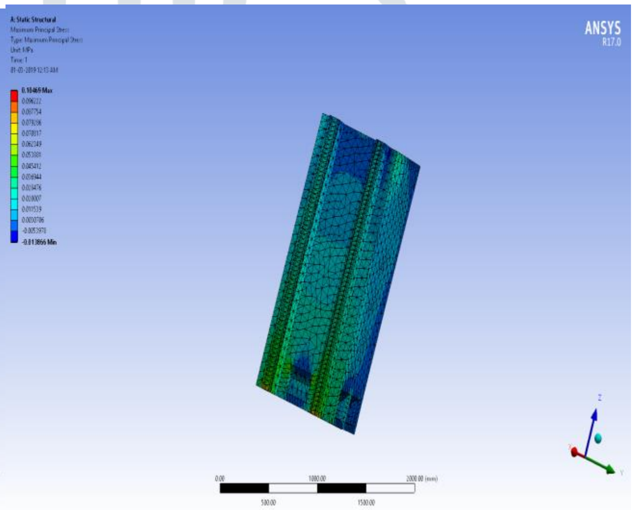
Case-5



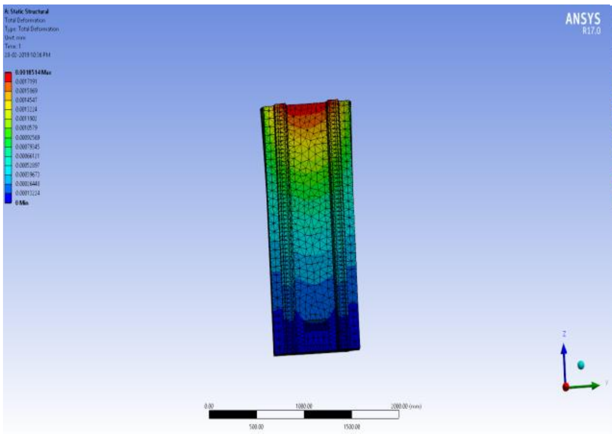


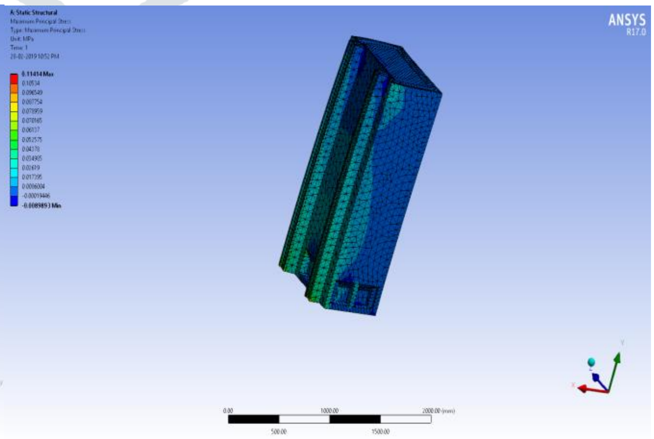
Case-6



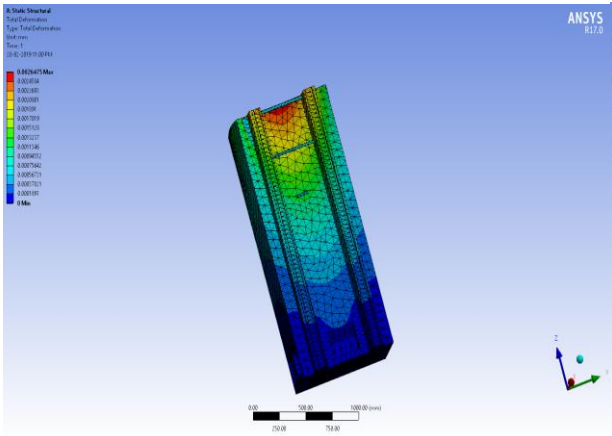


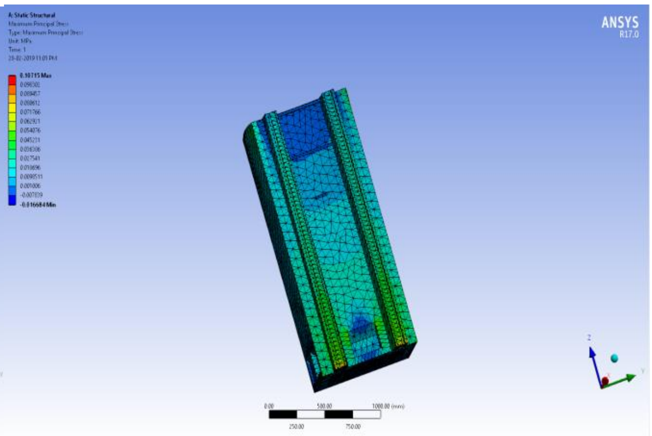
Case-7



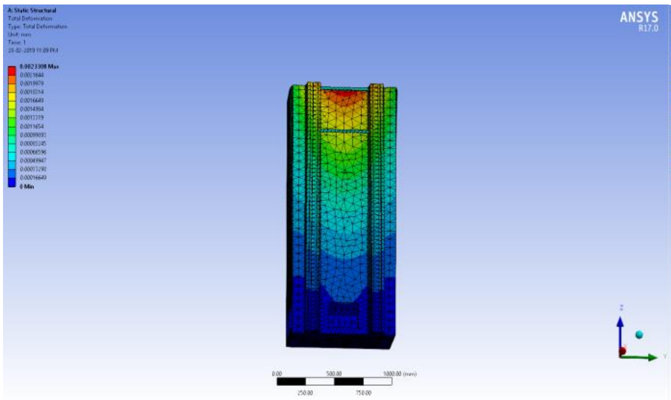


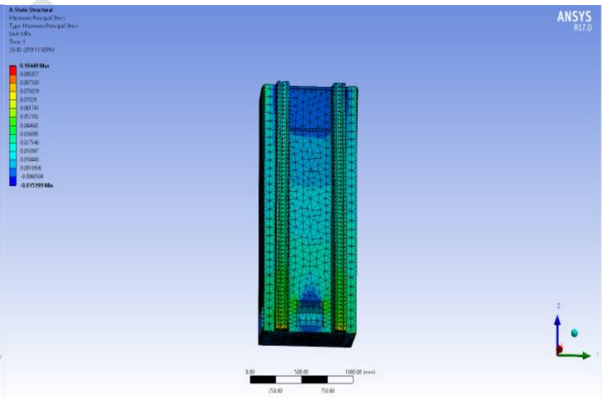
Case-8





Case-9

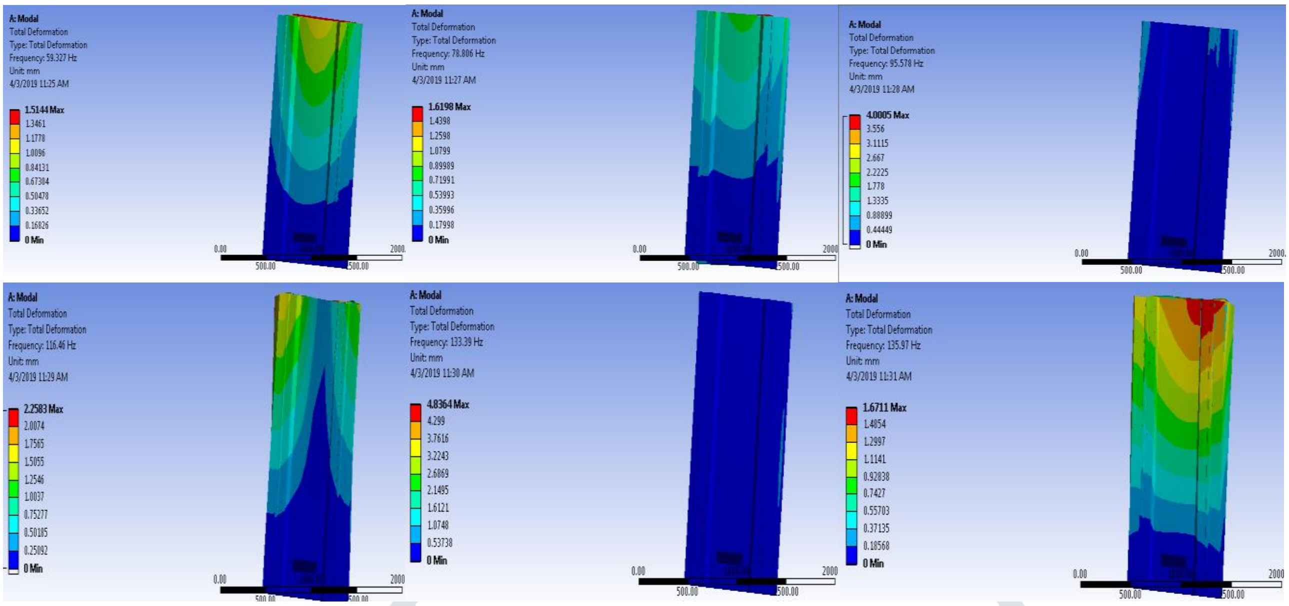




RESULT

Sr NO	ELASTOMER THICKNESS (MM)	CEMETITIOUS MATERIAL DENSITY (KG/M^3)	COLUMN THICKNESS (MM)	DEFLECTION (MM)	STRESS (N/MM^2)
1	12	2200	21	0.0026657	0.12405
2	12	2300	23	0.0016526	0.09840
3	12	2400	25	0.0016482	0.098295
4	16	2200	23	0.00168.92	0.10164
5	16	2300	25	0.0018514	0.10469
6	16	2400	21	0.0018514	0.10469
7	20	2200	25	0.0015579	0.11414
8	20	2300	21	0.0026475	0.10715
9	20	2400	23	0.0023308	0.10449

Modal analysis of optimized column



Result

Part name	Mode no.	Natural frequency of vibration
SCOLUMN	Mode 1	59.327 HZ
	Mode 2	78.806 HZ
	Mode 3	95.578 HZ
	Mode 4	116.46 HZ
	Mode 5	133.39 HZ
	Mode 6	135.97 HZ

CONCLUSION

In the new economic year and globalization phase, industries are required to manufacture good quality machine tools with optimized performance at the moderate cost. From this work the following conclusions are made.

The use of stiffeners & filler materials can produce a great reduction in deformation of structure under the static loading.

For cost reduction, mass can be reducing by use of stiffeners and apertures.

The high transfer speed as well as the high cutting speed of machine tools is achieved by the structure design with less materials consumption and by using filler materials.

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