DESIGN AND DEVELOPMENT OF EPOXY GRANITE FOUR GUIDEWAY MICRO MILLING MACHINE

KNOWLEDGE AND SERVICE
1951

STUDENT DETAILS

K. Aditya Anirudh (22M501)

Guided by : Dr. Mahendrakumar N , Assistant professor

OVERVIEW OF THE PRESENTATION

- Problem definition
- Objectives
- Methodology
- Literature review
- Analytical calculation for micro-milling design process
- Design of CI and EG micro-milling machine
- Finite element analysis
- Design for manufacture and assembly
- Conclusion

PROBLEM DEFINITION

- It is desirable that the challenges due to vibration in machine tools be brought to a minimum level.
- The conventional machine tool materials have either high stiffness or high damping capacity but suffer from a major disadvantage of low strength to weight ratio.
- Steel reinforcements and reference plates that are used in milling machine tends to improve the structural stiffness and to meet required GD&T but it results in poor damping and also bi-metallic effect causes thermal issues
- A machine tool usually operates in a thermally unsteady state due to heat generation from various internal and external sources. Nearly 40-60% of errors in machined components arise due to thermal issues.

OBJECTIVE

To design and develop a micro-milling machine tool using epoxy granite material as an alternative for existing conventional cast iron structures, without steel reinforcements for better thermal stability and which needs to be operatable at high speeds with improved damping characteristics.

METHODOLOGY

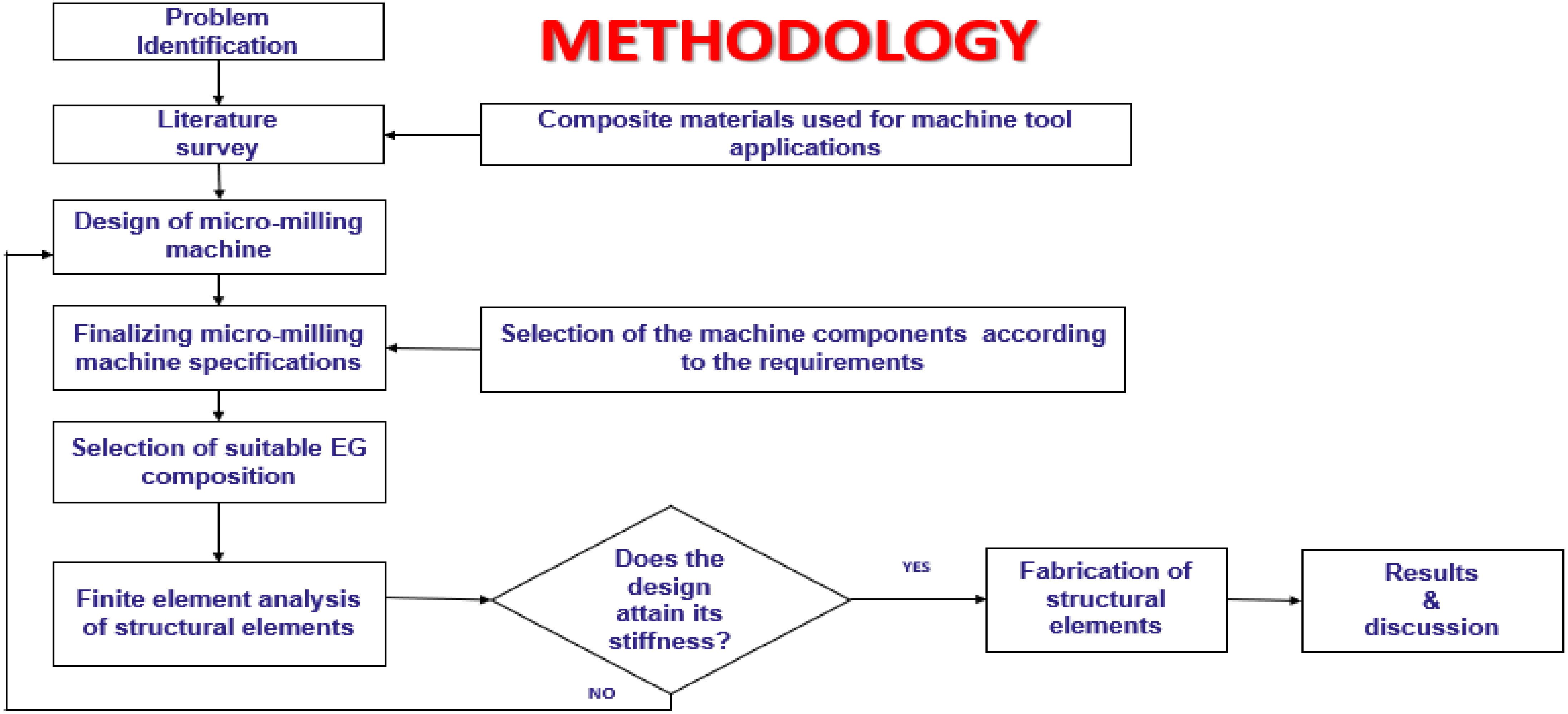


Fig. 1 Methodology

LITERATURE REVIEW

Rivin et al., 2000 studied that machining at higher speeds leads to vibration at the joints and interfaces of machine tool elements which may influence the surface finish and geometrical dimensions and tolerances (GD&T) of work piece

Emmanuil Kushnir et al., 2001 made a study that materials like cast iron and steel are the widely used conventional materials in machine tools, because they possess higher stiffness respectively

LITERATURE REVIEW

Rao et al., 1997 reported that inherent disadvantages such as high initial cost for pattern, complex production process, final machining, heat treatment, need for corrosion resistant coating and poor environment of operating foundries have led researchers to look for alternative materials

Rahman et al., 2000 studied that the alternative materials for cast iron are Ferrocement, Natural stone (Granite), Polymer concrete, Hybrid composites, PC filled in steel weldments

LITERATURE REVIEW

Dai Gil Lee et al. 2016 reported that the static stiffness of the machine tool reformed with granite material(natural stone) shows superior dynamic stiffness, about 0.5–1.3 times of the conventional casting machine.

- It was pointed out that the long-term stability of granite is limited. There is a significant sensitivity with respect to the influence of moisture and also it is difficult to cut and use bulk stones

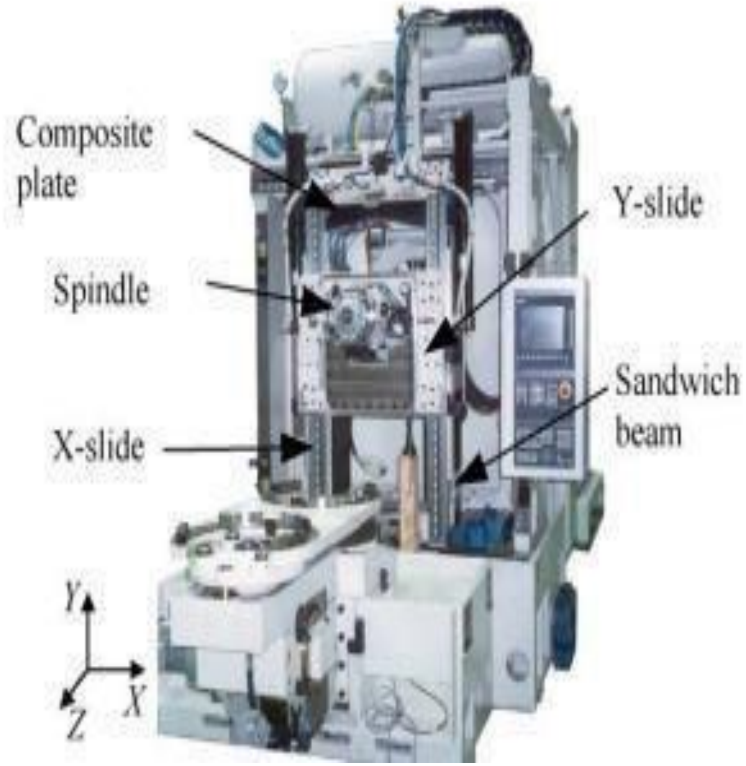


Fig. 2 Milling Machine Tool Structure (Source: Dai Gil Lee 2016)

LITERATURE REVIEW

- **Sung-Kyum Cho et al., 1992** reported that the polymer concrete bases are 1.5 times stiffer in torsion and 1.3 times stiffer in bending when compared to the plain cast iron bases
- The disadvantage is polymer concrete has a much lower fatigue strength therefore it can be said that polymer concrete is not suitable for manufacturing machine elements
- Polymer concrete is relatively high cost and the production process is more complicated

LITERATURE REVIEW

- **Jung Do Suh et al., 2016 [10]** identified that the damping factors of hybrid composite bed were improved by 4.5 %. Stiffness and damping have been increased by using sandwich structures composed of high stiffness steel faces.
- Use of steel skeletons results bimetallic effect

(Source: Jung Do Suh 2016)

Fig.3 Hybrid polymer concrete bed for gantry type milling machine

LITERATURE REVIEW

- The disadvantage is due to uneven heating internal and external distortion can happen at the areas of steel faces
- Fabrication of steel weldments are of high cost
- High strength to weight ratio is high leads inertial effects which may cause positional error
- There is a need to design and developed light weight moving elements x, y and z slides in modern machine tools

LITERATURE REVIEW

- **Kalayarasan et al., 2019** stated that EG was used an alternate material for vertical machining center
- Equivalent static stiffness and natural frequencies of epoxy-granite is about 12% – 20% higher than cast iron structure
- The increase in natural frequency is attributed to the reduction in mass of the structure of about 35% and the improvement in the structural stiffness

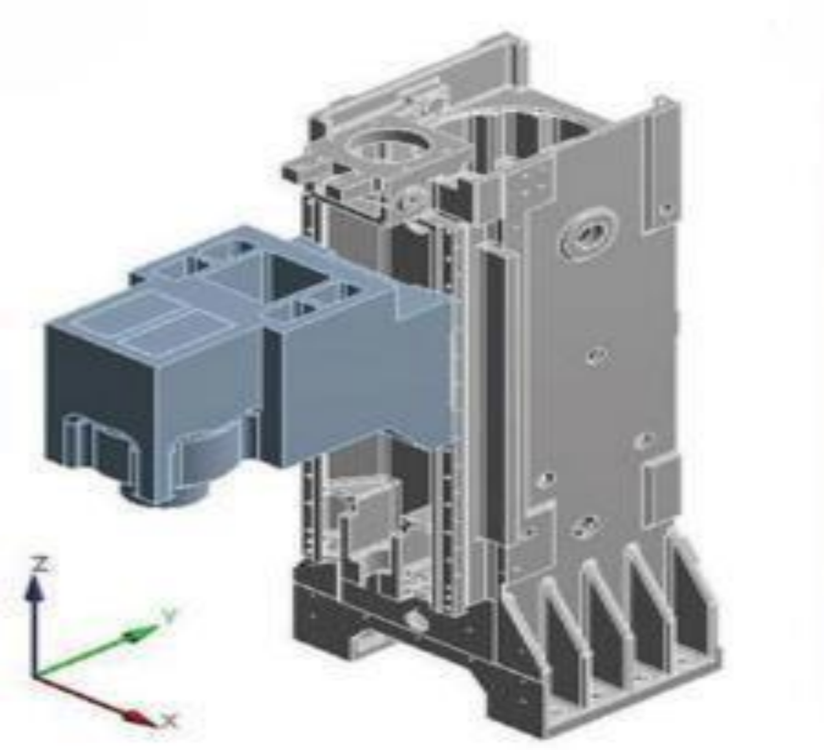


Fig. 4 Column with spindle head (Source: Kalayarasan et al. 2019)

LITERATURE REVIEW

- **P Dhanabal et al., 2019** used epoxy granite base with L-channels has significantly reduced the deformation by 36% considering milling operations in comparison to cast iron
- The natural frequency of this design configuration is 12% higher than that of the cast iron
- The highest natural frequency within the operating range is found to be 592 and 948 Hz for CI base and the proposed EG base, respectively

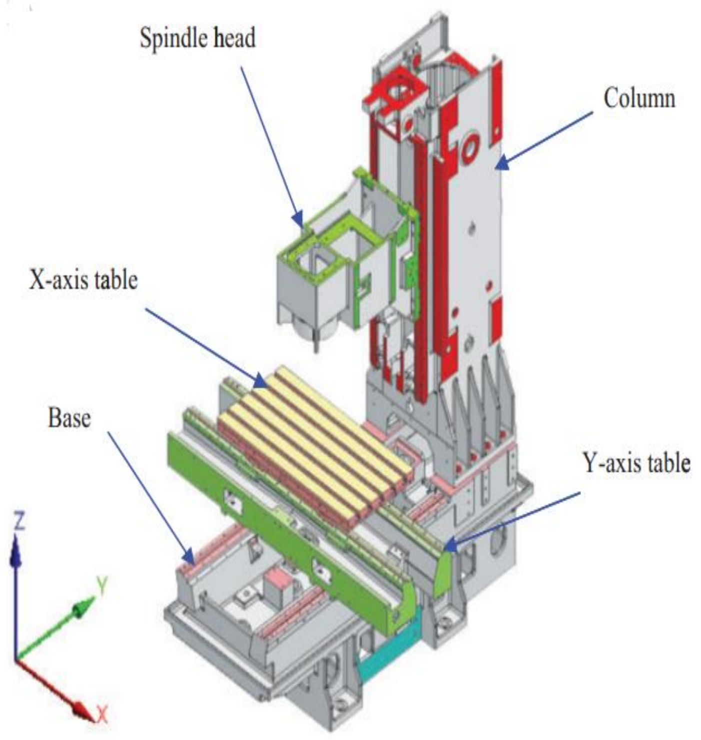


Fig. 5 VMC structure

(Source: Dhanabal et al. 2019)

LITERATURE REVIEW

- **Shanmugam Chinnuraj et al., 2020** made a study on the design and analysis of different steel reinforcements in the lathe bed made of the epoxy granite composite is studied
- The proposed design of the epoxy granite bed is found to have an improvement in dynamic characteristics by 4–10% with improved stiffness and offers a mass reduction of 22% compared to the cast iron bed

Table.1 Material properties of epoxy granite

Properties	Values
Granite aggregate mass fraction	0.80
Epoxy mass fraction	0.20
Density (kg/m^3)	2850
Elastic modulus (GPa)	47
Poisson's ratio	0.25
Compressive strength (MPa)	110
Flexural strength (MPa)	36
Split tensile strength (MPa)	25
Damping factor	0.0176

CONCLUDING REMARKS & SCOPE OF LITERATURE

- Cast iron structures are subjected to self-excited vibrations called 'chattering' while operating at high speeds
- Relatively high thermal expansion coefficients causing thermal deformation between the components
- These deflections cause positional errors between components
- Composite materials are emerging as alternate materials for machine tool structure

CONCLUDING REMARKS & SCOPE OF LITERATURE

- The low thermal conductivity of epoxy granite makes them stable and robust from thermal point of view
- Its structural damping is comparable to that of cast iron
- They are light weight materials, their densities are less than those of the metals
- The studies reported that epoxy granite materials have good damping and thermal stability and can be a promising alternate material for the conventional materials

CONCLUDING REMARKS & SCOPE OF LITERATURE

- The epoxy resin based concrete materials were observed to give better mechanical and thermal characteristics
- It was observed that polymer concrete materials exhibit better damping ratio, in the range 1.65% to 3.1%, which is 10 times better than that of cast iron and steel
- Nearly 40-80% of errors in machined components arise due to thermal errors
- Epoxy granite material offers better thermal characteristics such as low coefficient of thermal expansion compared to cast iron and steel

FUNCTIONAL REQUIREMENTS

- The work table should be able to hold a material of weight up to 5 kg
- The workpiece dimensions of X,Y,Z of about 260*150*100 respectively
- To be able to machine the materials with hardness value of 25 to 35 HRC
- Cutting tool to be used : Sandvik carbide ball nose endmill cutter of minimum diameter of 3mm to maximum diameter of 6 mm
- The maximum depth of cut of 1mm
- To obtain a good surface finish of about Ra1.5 microns
- And minimize the time consumption of various surface finishing operations

DESIGN CALCULATIONS

X AXIS MOTOR CALCULATION

- Single threaded power screw
- ISO metric trapezoidal threads
- cutting force of 44.62 N.
- Speed of 25 m/min
- Major diameter is 8 mm
- pitch is 2 mm.
- coefficient of friction at the screw threads is 0.15.

TORQUE CALCULATION - Y AXIS

- For ISO metric Trapezoidal threads, θ= 15°
- Lead, l = 2(p) = 2(2) = 4 mm
- Mean diameter d_m = d- 0.5p = 8- 0.5(2) = 7 mm
- tan α= p /πd_m = 2/π(7) = 0.09096
- FORCE ,P $= W \tan(\alpha + \psi)$
- P = W [tan ∝ + tan ϕ]/[1 – tan α tan ϕ]
- P = 34.92[(0.09096+0.1)/1-0.009056]
- P=6.73N

Contd…

TORQUE

- T=P*d/2
- T=8.6*4=34N-mm = 0.034N-m

Power of motor

- N = speed/ pitch = 25/2 = 12500rpm
- **ω** = 2 π N/60= 1309rad/s

STEPPER MOTOR(X AXIS)

POWER = T. ω = 0.034*1309 = 44W

Y AXIS FEED DRIVE MOTOR CALCULATION

- Single threaded power screw
- ISO metric trapezoidal threads
- cutting force of 34.92 N.
- Speed of 25 m/min
- Major diameter is 8 mm
- pitch is 2 mm.
- coefficient of friction at the screw threads is 0.15.

Contd…

TORQUE CALCULATION - Y AXIS

- For ISO metric Trapezoidal threads, θ= 15°
- Lead, l = 2(p) = 2(2) = 4 mm
- Mean diameter d_m = d- 0.5p = 8- 0.5(2) = 7 mm
- tan α= p /πd_m = 2/π(7) = 0.09096
- Force, $\mathrm{P} = W\tan(\alpha+\psi)$
- P = W [tan ∝ + tan ϕ]/[1 – tan α tan ϕ]
- P = 34.92[(0.09096+0.1)/1-0.009056]
- P=6.73N

Torque

- T=P*d/2
- T=6.73*4= 0.026N-m

Power of motor

- N = speed/ pitch = 25/2 = 12500rpm
- **ω** = 2 π N/60= 1309rad/s

STEPPER MOTOR(Y- AXIS)

- POWER = T. ω = 0.026*1309
  = 34.034W

Contd…

TORQUE CALCULATION – Z AXIS

- For ISO metric Trapezoidal threads, θ= 15°
- Lead, l = 2(p) = 2(2) = 4 mm
- Mean diameter d_m = d- 0.5p = 8- 0.5(2) = 7 mm
- tan α= p /πd_m = 2/π(7) = 0.09096
- Force = $p = W \tan(\alpha + \psi)$
- P= W [tan ∝ + tan ϕ]/[1 – tan α tan ϕ]
- P = 13.3[(0.09096+0.1)/1-0.009056]
- P=2.5N

Torque

- T=P*d/2
- T=2.5*4= 0.016N-m

Power of motor

- N = speed/ pitch = 25/2 = 12500rpm
- **ω** = 2 π N/60= 1309rad/s

STEPPER MOTOR(Z - AXIS)

- POWER = T. ω = 0.016*1309 = 20.94W

CI MICRO-MILLING MACHINE

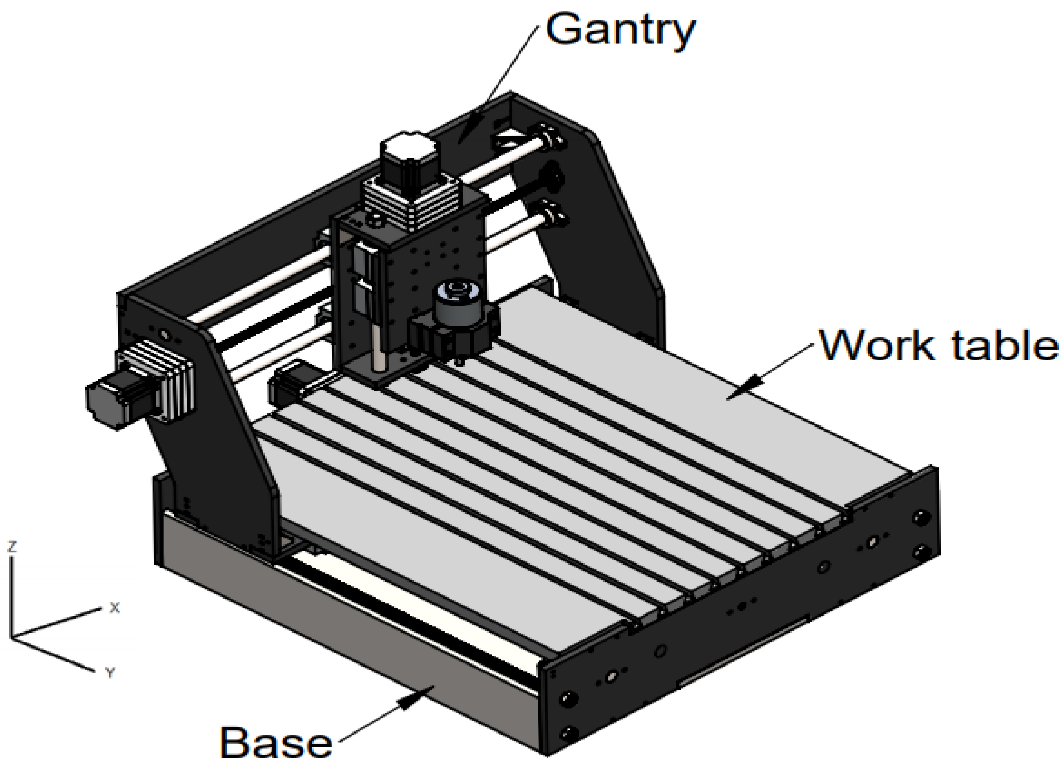


Fig. 6 CI micro-milling machine

- Micro-milling machine design –1 is designed using CI as the structural material
- Here in this design the thickness of base plate and column has been given 10mm

SPECIFICATIONS OF CI MICRO-MILLING MACHINE

Material	Cast iron
Machine Size	600*600*575mm
Working area (X, Y, Z)	480*520*75mm
Spindle	9000r/min
Step motor	1.3A 0.25 N.m
Power supply	24V 5.6A
Machine Weight	122.5kg
Ball nose end-mill cutter diameter	6mm

CI MICRO-MILLING MACHINE

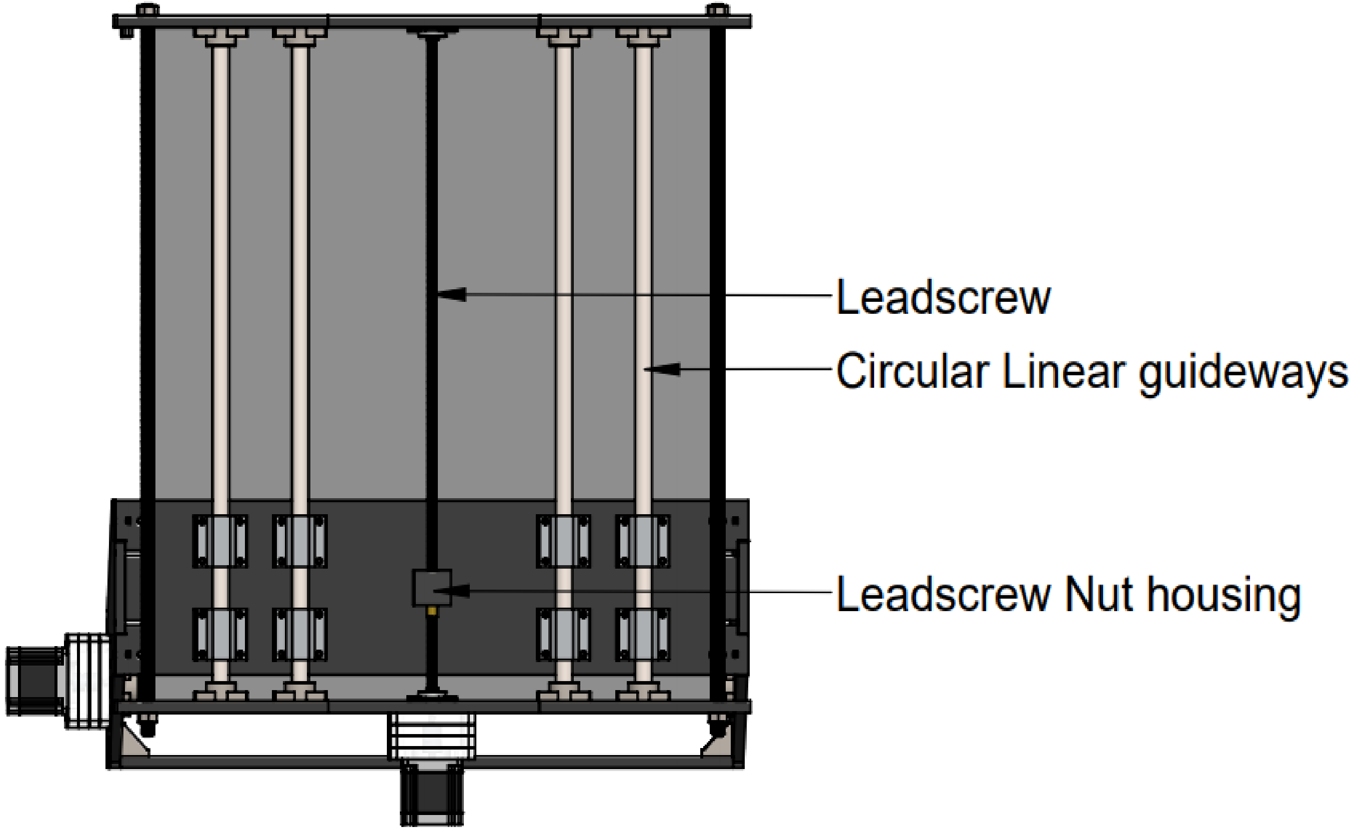


Fig. 7 CI micro-milling machine drive assembly

- In this design, four circular linear motion guideways were used
- Lead screw of 8mm diameter has been used in this design
- Stepper motor direct drive technology have been used on all linear axes.

CI MICRO-MILLING MACHINE

The limitations of using CI in micro-milling machine are:

- Relatively high thermal expansion coefficients causing thermal deformation between the components
- These deflections cause positional errors between components.
- CI structures are subjected to self-excited vibrations called ‘chattering’ while operating at high speeds
- Compared to epoxy granite material, the CI does not exhibit better mechanical and thermal characteristics.

CI TO EG MICRO-MILLING MACHINE

- CI provides compact structure with reduced mass due to high elastic modulus but is limited by poor damping characteristics.
- Epoxy granite material has an internal damping factor up to ten times better than cast iron
- Epoxy granite is unaffected by coolants, has excellent long-term stability, improved thermal stability, high torsional and dynamic stiffness, excellent noise absorption, and negligible internal stresses.
- Therefore, the design of micro-milling machine has been changed from CI to epoxy granite

EPOXY GRANITE DESIGN - 1

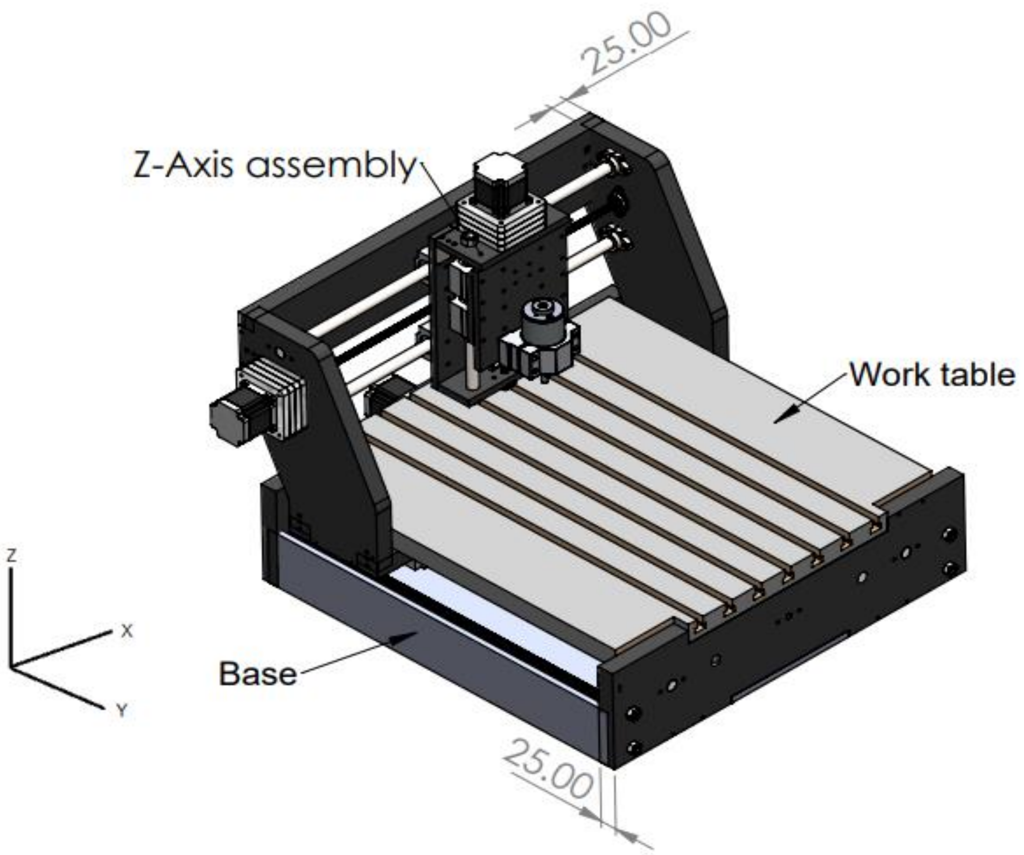


Fig.8 EG micro-milling machine Design - 1

- In this design, epoxy granite has been used as the structural material.

- Here in this design the thickness of base plate and column has been increased to 25mm according to the design guidelines of epoxy granite.

EPOXY GRANITE DESIGN - 1

- The young's modulus of epoxy granite is comparatively lesser than that of cast iron, so the thickness has to be increased considerably
- As compared to CI design, the entire structure of epoxy granite micro-milling machine has been changed. Three stepper motors is used for x, y, z axis feed drive
- The EG composite can reduce the weight of structures by 50% and improve the damping characteristics by seven to ten times that of CI structures and is an added advantage for high-speed machine tool structures

EPOXY GRANITE DESIGN - 1

- The greater number of individual components causes complications in assembly
- In dynamic conditions, while the machine is operated at high speeds the circular guideways might cause stick-slip movement, due to the heavy loads
- As like cast iron structures the assembly cannot be done with help of fasteners, as it is difficult to machine the epoxy granite structures because epoxy granite has high hardness value of 630BHN

EPOXY GRANITE DESIGN - 1

- So, the bush inserts are to be placed based on the requirements in the necessary contact points
- In this design the manufacturing feasibility is less and the insertions of mould-in-inserts for assembly is not viable
- So epoxy granite design- 2 is done

EPOXY GRANITE DESIGN - 2

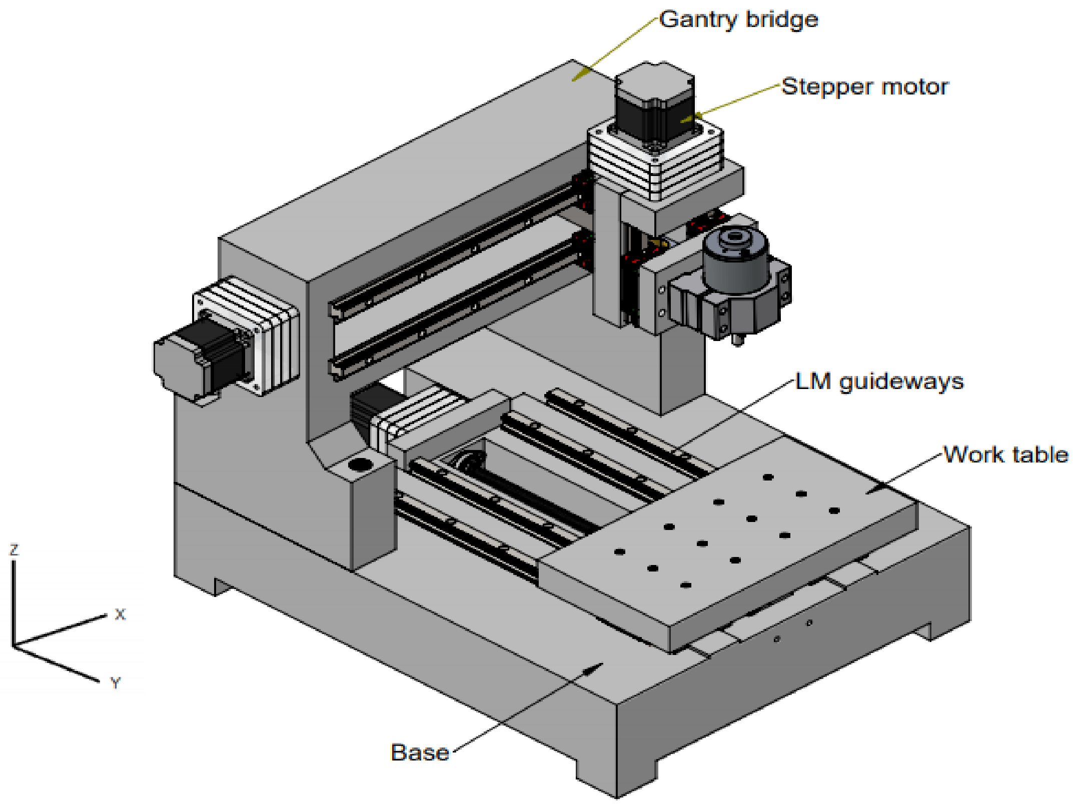


Fig. 9 Epoxy granite design - 2

- This micro-milling machine is designed for engraving purpose and workpiece of 250*150*100mm can be machined
- M6 hexagonal bushes are used in this design for mounting LM rails
- LM rails used here are of 15 mm width from Hiwin

SPECIFICATIONS OF EG MICRO-MILLING MACHINE

Material	Epoxy granite
Machine Size	500*400*375mm
Working area (X, Y, Z)	250*200*100mm
Spindle	9000r/min
Step motor	1.3A 0. 25N.m
Power supply	24V 5.6A
Machine Weight	75kg
Spindle	775 spindle motor, 36V: 9000r/min
Ball nose end mill cutter diameter	6mm

EPOXY GRANITE DESIGN - 2

- In epoxy granite design – 2 the aesthetic point of view is also considered
- Wall thickness of the molding form depends on the biggest grains of the grain distribution.
- The use of minimum wall thickness is five to eight times of the largest grain
- The thickness is arrived based on EG machine tool structure design guidelines i.e., 8 times the maximum granite particle size in 80:20 EG composite

EPOXY GRANITE DESIGN - 2

- As epoxy granite has less elastic modulus (30GPa), we need thicker structural elements. The structure thickness has been increased to 50mm
- Since the proposed epoxy granite micro-milling machine can be casted to the near-net shape, it eliminates the secondary machining activities and results in less cost machine tool structure
- Since the inherent material damping ratio of EG is four to seven times that of CI, the newly proposed EG micro-milling machine offers better dynamic stability

EPOXY GRANITE DESIGN - 2

The advantages of using epoxy granite in micro-milling machine are,

- The extremely low thermal diffusivity of epoxy granite makes them stable and robust from thermal point of view
- Its structural damping is comparable to that of cast iron
- Mineral-cast elements are resistant against oils, coolants and other aggressive liquids
- They are lightweight materials; their densities are less than those of the metals
- Its low thermal conductivity is preferred in machine tool structures, to avoid thermal deflections

ASSEMBLY DRAWING OF EG MICRO-MILLING MACHINE

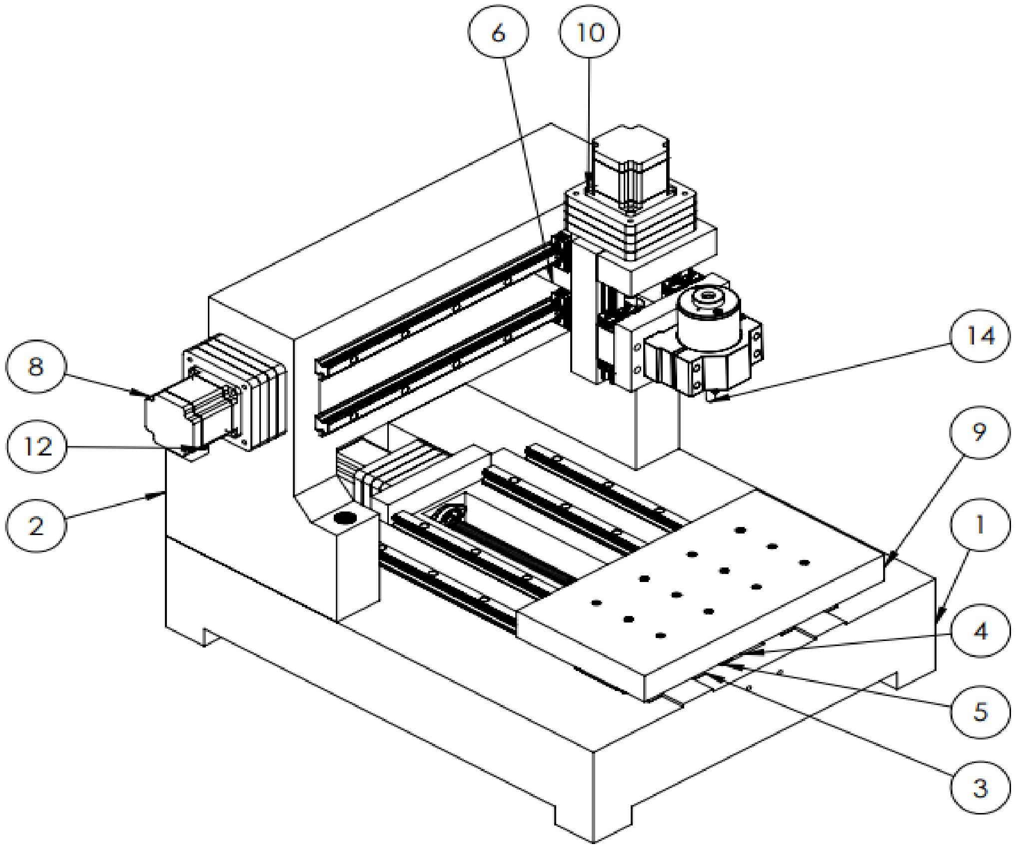
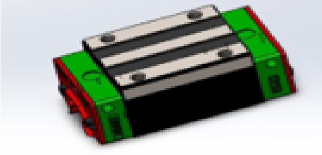
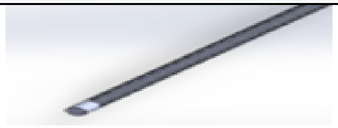
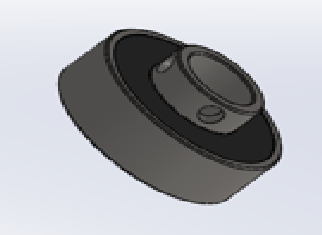
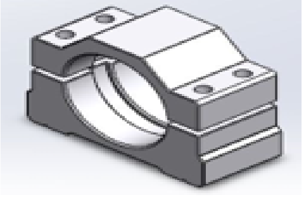


Fig. 10 Assembly drawing of EG micro-milling machine Design-2

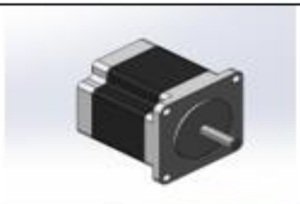
Table 2 Bill of Materials of EG micro-milling machine

Item no.	Part number	Quantity
1	Base	1
2	Gantry	1
3	Hiwin LM rail	6
4	Bearing	4
5	Leadscrew	1
6	X – axis lead screw	1
7	Flexible coupling	2
8	Motor	2
9	Table	1
10	Z - axis assembly	1
11	M6 bush	36
12	Gantry M12 bush	4
13	M12 bush	4
14	Spindle sub assembly	1

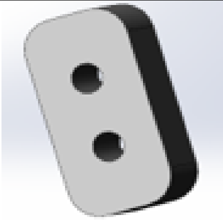
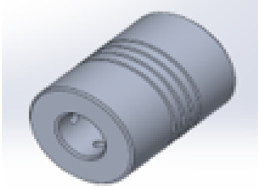
COST ANALYSIS

S.No	ITEM	MODEL	QTY	COST (Rs)
1	15mm HIWIN LM GUIDE BLOCKS		8	12000
2	15mm HIWIN LM GUIDES (1M)		2	6800
3	LEAD SCREW DIA 8MM THREAD T8		3	1650
4	608-2RS 8MM BALL BEARINGS		6	250
5	SPINDLE MOUNTING FIXTURE 80MM		1	2200

COST ANALYSIS

6	NEMA23 SERVO MOTOR 22KGCM WITH DRIVER		3	12000
7	CNC SPINDLE 220V 24000RPM		1	13650
8	NEMA23 SERVO MOTOR MOUNT		3	1350
9	STANDALONE CNC CONTROLLER		1	28000
10	POWER SUPPLY 48V		1	2500

COST ANALYSIS

11	POWER SUPPLY 24V		1	800
12	WIRE CARRIER		3	3750
13	MAGNETIC END STOPS		3	200
14	FLEXIBLE COUPLING 8*8mm		3	900
	TOTAL ESTIMATE			**86050**

COST ANALYSIS

- The total amount of Rs. 88,550 was estimated for the bought-out components of cast iron machine tool
- In addition to this, the cost of raw material and machining cost are considered and then the total cost is found to be Rs.2,07,000 for cast iron micro-milling machine
- The cost of raw material and manufacturing cost are considered and then the total cost is found to be Rs.1,63,000 for EG micro-milling machine
- Since epoxy granite can be casted to near net shape it eliminates machining cost so the cost of epoxy granite micro-milling machine is found to be less than cast iron machine

MODAL ANALYSIS

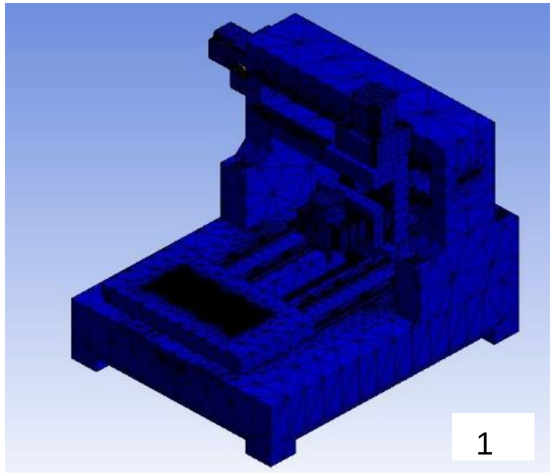
- A fixed–free modal analysis was carried out by using FEM to determine first six fundamental natural frequencies of the structure.
- The geometrical model of the micro-milling machine is meshed with hexahedral elements. The meshed model consists of 791180 elements and 1401901 nodes.
- The results of the modal analysis of the proposed epoxy granite micro-milling machine show that the fundamental natural frequencies are 232.55Hz, 243.21Hz, 400.33Hz, 517.61Hz, 517.75Hz, 625.87Hz.

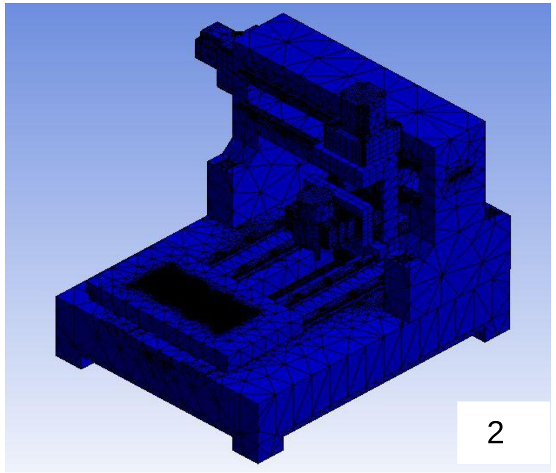
MODAL ANALYSIS

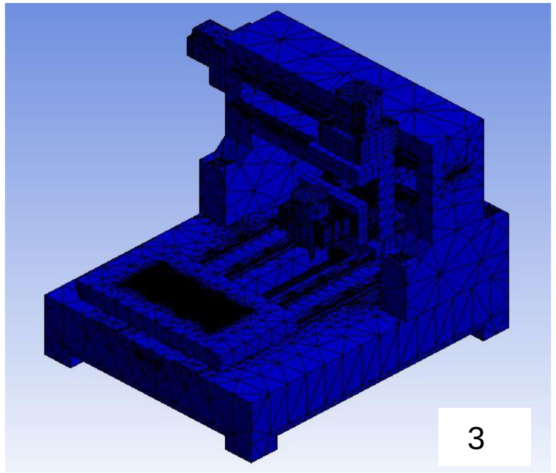
Table 3 Natural frequencies of EG micro-milling machine

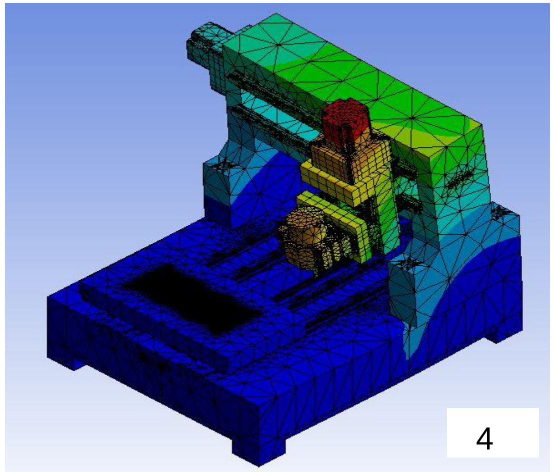
Mode number	Natural frequencies of micro-milling machine made of EG(Hz)
1	232.55
2	243.21
3	400.33
4	517.61
5	517.75
6	625.87

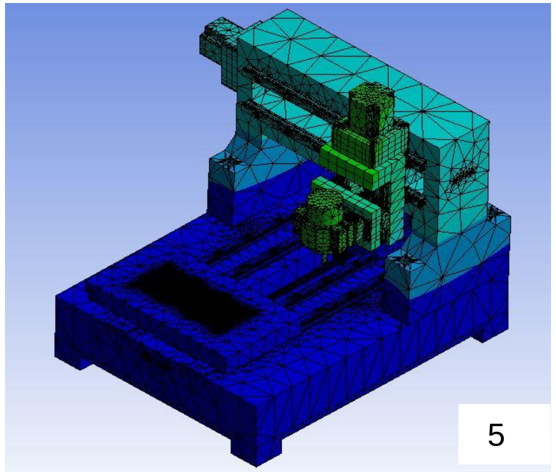
MODE SHAPES OF EG MICRO-MILLING MACHINE

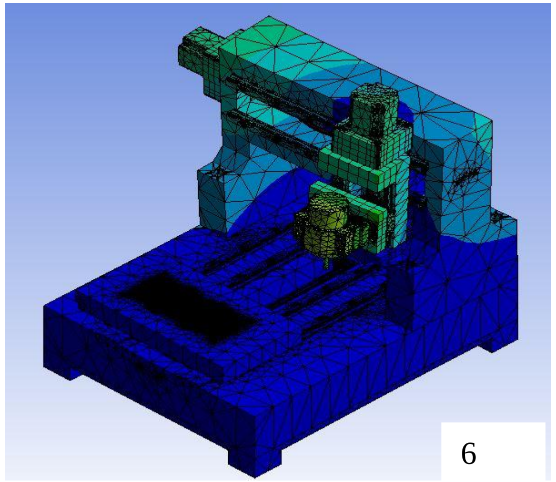

1


2


3


4


5


6

STATIC STRUCTURAL ANALYSIS

- In order to prove the stability of the epoxy granite machine tool structure, the deformation analysis on epoxy granite micro-milling machine was performed.
- Geometry of the EG micro-milling machine created using Solid works 2020 modelling software was imported to Ansys workbench static structural software in the IGS file format.

Table 4 Material properties of EG

Property	Value	Unit
Density	2500	$Kg.m^{-3}$
Coefficient of Thermal Expansion	$1.45E^{-05}$	C^{-1}
Young's Modulus	$7E^{+13}$	Pa
Poisson's Ratio	0.25	-
Bulk Modulus	$4.6667E^{+13}$	Pa
Shear Modulus	$2.8E^{+13}$	Pa

STATIC STRUCTURAL ANALYSIS

Table 5 Material assignment for EG machine tool structure

Geometry	Material
Base	Epoxy granite
Work table	
Column	
Z – axis frame -1	
Z – axis frame -2	
Z – axis table	
All other geometries	Structural steel

Table 6 Mesh element size and mesh type.

S.no	Geometry	Mesh element size (mm) respectively	Mesh type
1.	Column	1. 200	Hex dominant method
2.	Work table	2. 150	
3.	Z – axis table	3. 100	
4.	Z – axis frame -1	4. 75	
5.	Z – axis frame -2	5. 50	
6.	Base	6. 40 7. 20 8. 10 9. 5	Automatic selection
7.	All other geometries	Automatic selection	

CASE – 1 IDLE CONDITION ANALYSIS

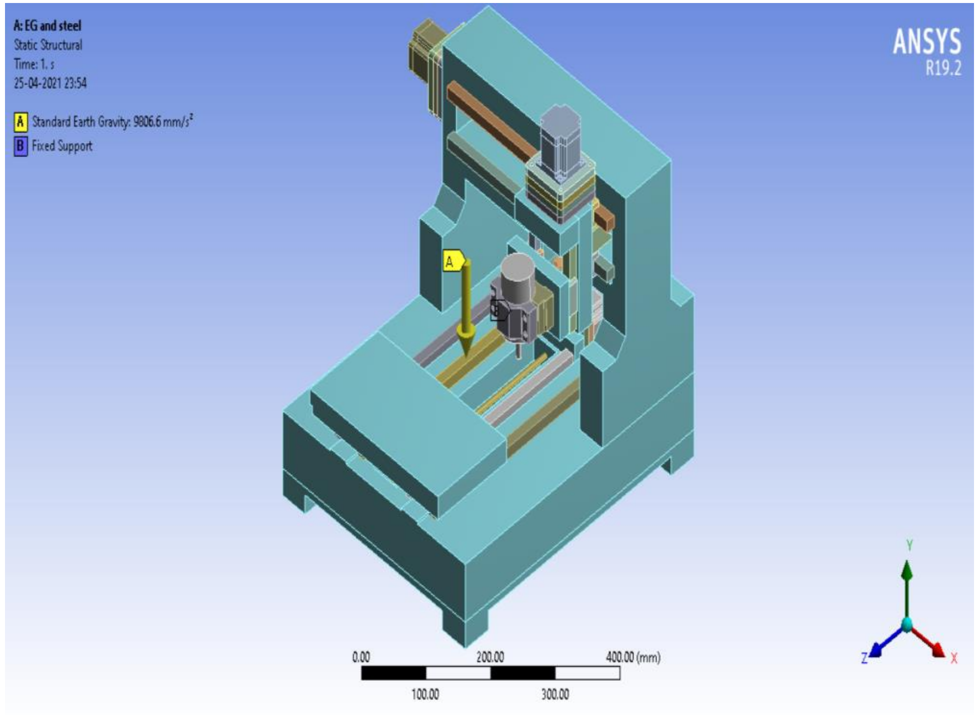


Fig.11 Boundary condition for idle condition

- In this idle condition, the input parameters as shown in Figure 10 were given.
- The standard earth gravity of -9806.6 $mm.s^{-2}$ was set for the y – component of force on all the bodies and fixed support was inserted on the four faces that are to be grounded.
- The total number of nodes and elements in the meshed model were 1401901 and 791180 respectively.
- The boundary conditions are kept the same as that of clamped condition

CONTD…

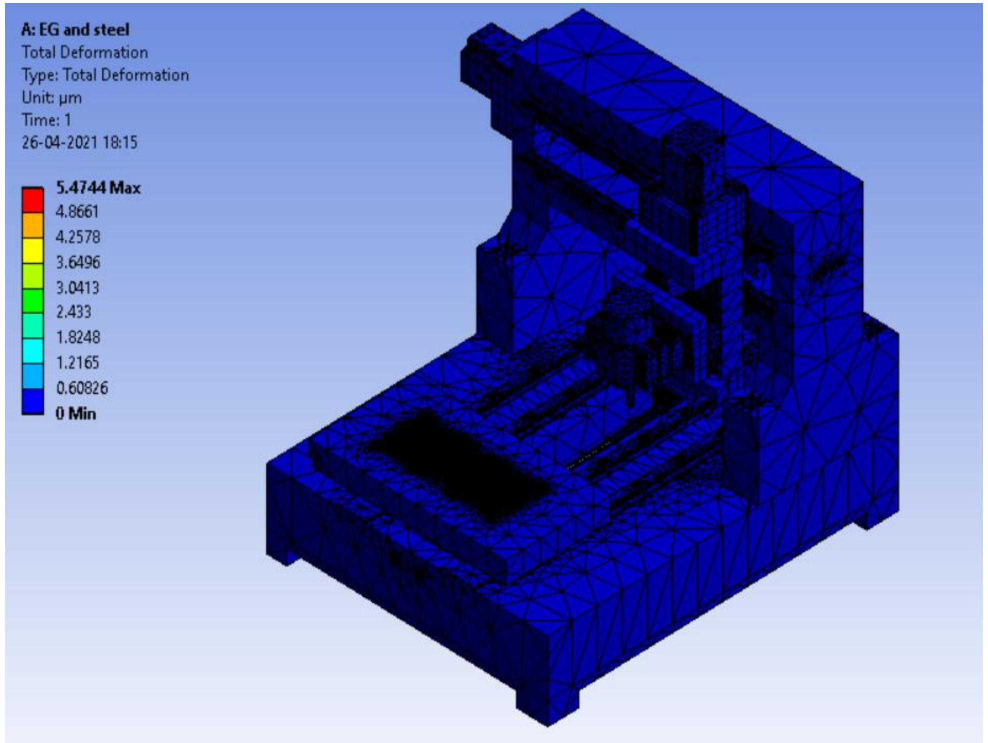


Fig.12 Total deformation plot of EG structure in idle condition

- Total deformation is extracted from idle condition static structural analysis and a typical plot of total deformation, for a load of 9806.6mm/s^2 is shown in Figure 11
- The total deformation of Epoxy granite structure is found to be 5.47 microns
- The fact that the maximum deformation of epoxy granite structure was observed in the x-axis lead screw and the rest of the structure has negligible amount of deformation

CASE – 2 OPERATING CONDITION ANALYSIS

- Static structural analysis of the micro-milling machine under worst case cutting forces is carried out.
- For static structural analysis, in addition to the cutting forces at worst case condition, weight of important Z – axis assembly (4.17 kg) were also considered.
- Table 7 summarizes the force inputs for operating condition analysis
- The FE model was meshed using hexahedral elements and final mesh size was arrived at through mesh convergence (elements: 34,178 nodes: 477676)

CONTD…

Table 7 Force inputs for operating condition

S.no	Constrain	Defined by	Value (N)	Location
1.	Force - 1	X component	44.62	Bottom tip of the spindle
		Y component	-44.62	
		Z component	44.62	
2.	Force - 2	X component	44.62	Centre of the work table
		Y component	-44.62	
		Z component	44.62	

Contd…

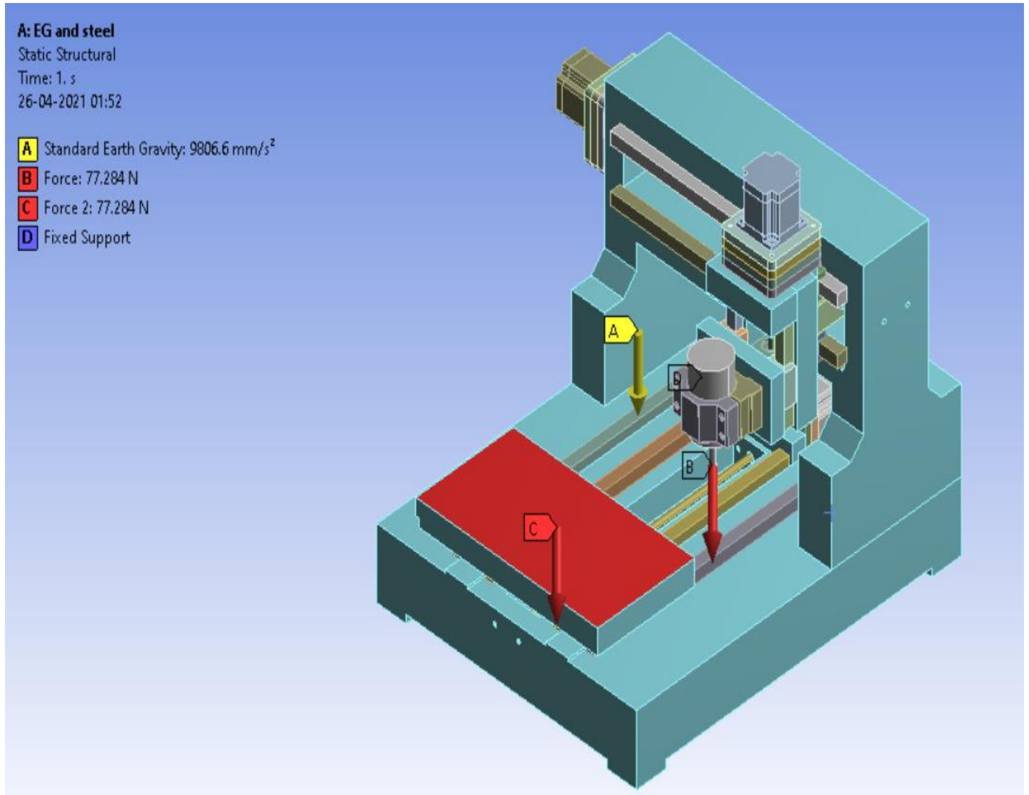


Fig. 13 Boundary condition for operating condition

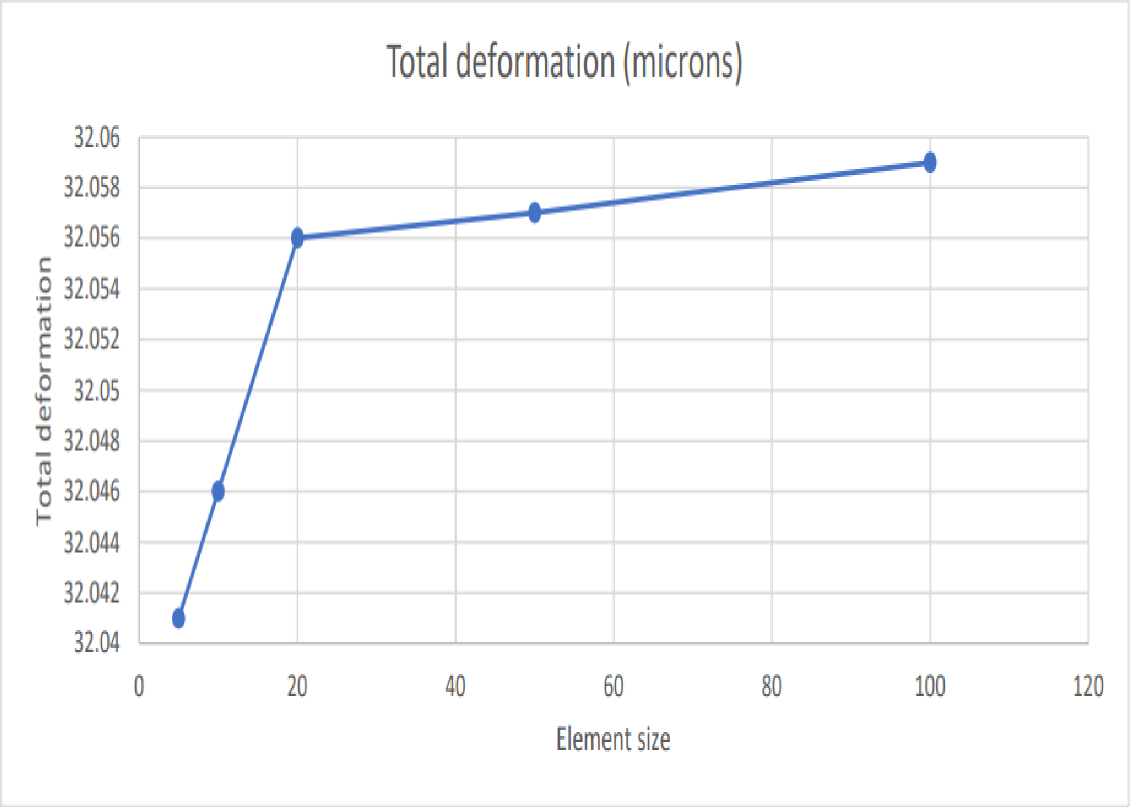
- The cutting forces are specified in terms of (x, y, z) components to the Ansys workbench static structural analysis
- The Figure 12 shows all the input parameters, standard earth gravity on all bodies, Force-1 on the bottom tip of the spindle, Force-2 on the centre of the work table, Fixed support on the four faces which are to be grounded

Contd…

Table 8 Mesh convergence for EG micro-milling machine

Element Size	Total Deformation Maximum(microns)	Total Deformation Average(microns)
100	32.059	0.129
50	32.057	0.128
20	32.056	0.122
10	32.046	0.089
5	32.041	0.034

Fig. 14 Element size vs total deformation plot for EG structure



Contd…

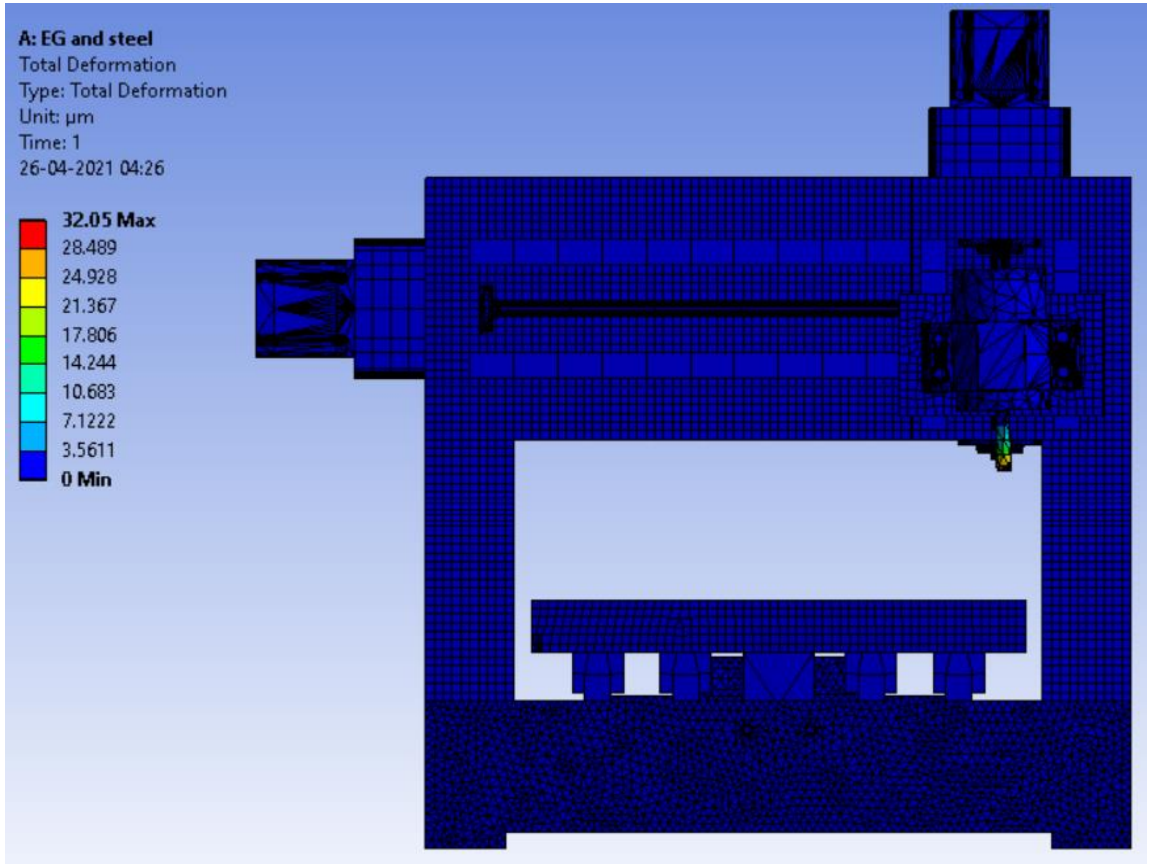


Fig. 15 Total deformation plot of EG structure in operating condition

- The Table 8 indicates the mesh convergence values for different mesh sizes carried out on the structure to determine the total deformation of the epoxy granite machine tool structure.
- The Figure 14 shows the total deformation of the epoxy granite machine tool structure.
- From the Figure 14 the maximum deformation is found to be occurring the bottom tip of the spindle

Contd…

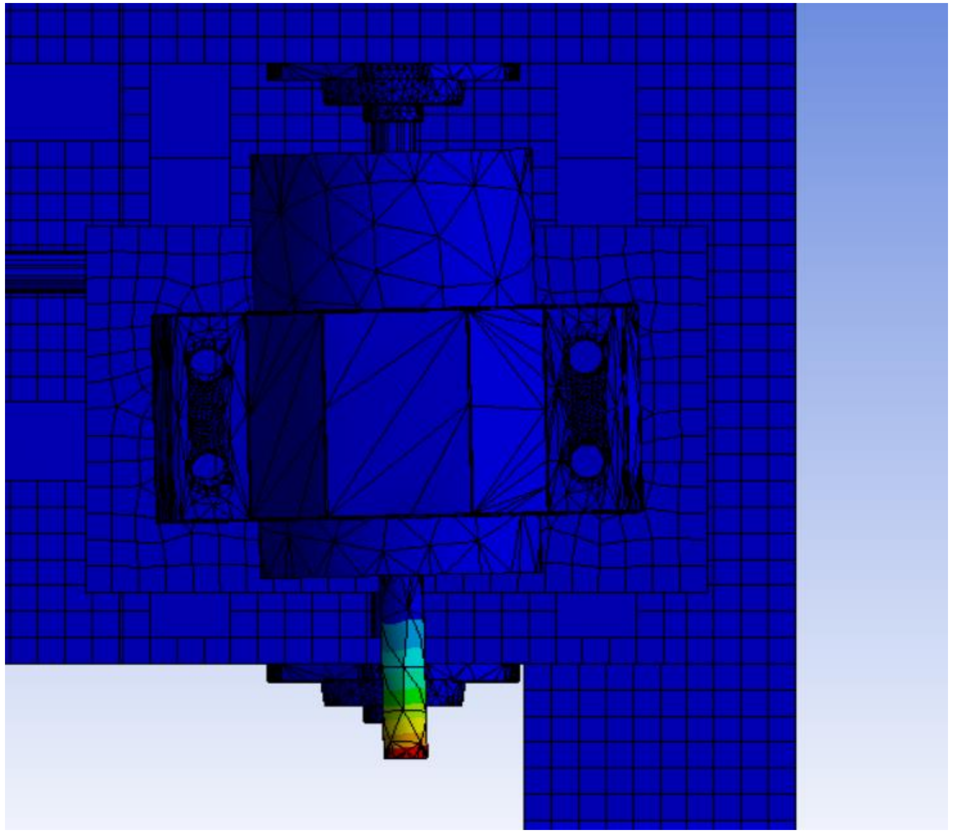


Fig. 16 Area of maximum total deformation in EG structure in operating condition

- The total maximum deformation of epoxy granite machine tool structure was found to be 32.04 microns.
- The deformation was found to be occurring only to the spindle of the machine where the cutting tool is to be mounted

DESIGN FOR MANUFACTURE AND ASSEMBLY

- The optimization of the design of the micro-machine tool structure is to be done for its ease of manufacturing and assembly process.
- The merging of design requirements of the product with its production method, employing design for manufacture tactics reduces the cost and difficulty of producing a product while maintaining its quality.
- The foundation of a structure should be rigid enough to receive and transfer to the ground
- So, the design optimizations are done on the base of the epoxy granite micro-milling machine tool structure.

Contd…

- In the epoxy granite machine tool structure, the assembly for various parts of the machine is advisable to be made through the bush insertions which are placed in the required areas during moulding process itself.
- Since, it is difficult to machine the epoxy granite structure like tapping, drilling, milling, etc for assembly of the structures with the help of fasteners, we prefer bush inserts.
- The hexagonal bushes are available in standard dimensions, they are hexagonally shaped in the exterior and their interior is a threaded hollow part.

Contd…

- The inserts of required diameter are to be chosen according to our conditions.
- These inserts are placed in such a way that their top surface is at least 1 mm lower than that of the outer surface of the cast part.
- The inserts of internal diameter of 6 mm are chosen for mounting of linear motion rails, guide blocks, worktable, spindle holder, etc. and inserts of internal diameter of 12 mm are chosen for assembling the major parts of the machine tool structure such as column, base, etc.

Contd…

- In order to meet the dimensional requirements of the standard mould box, some minor design modifications are done to the existing machine design shown in Figure 16

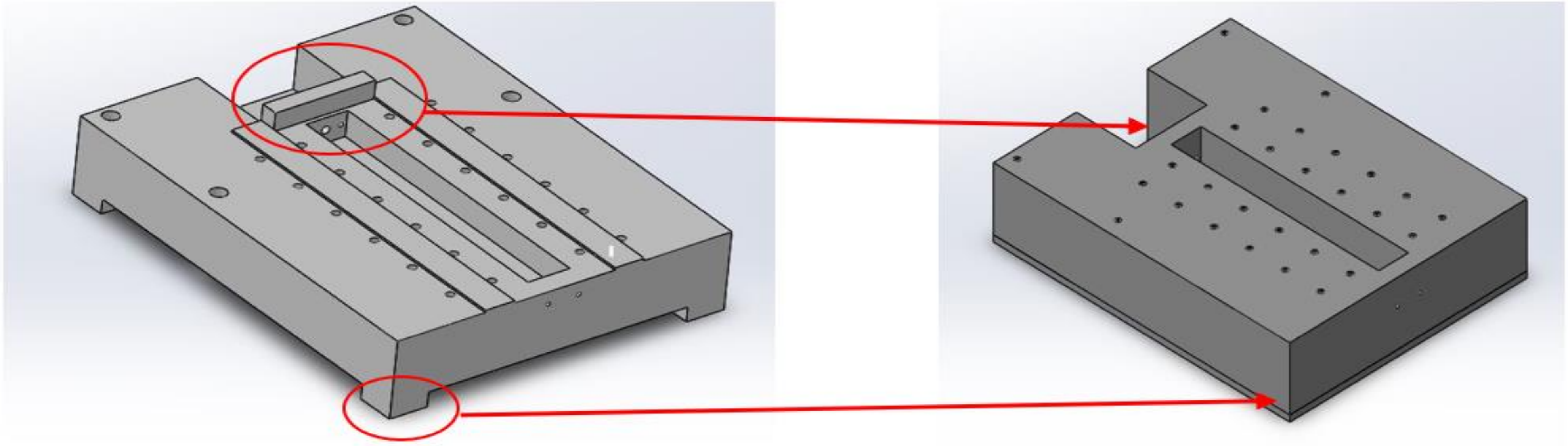


Fig. 17 Modified base design of epoxy granite micro-milling machine

Contd…

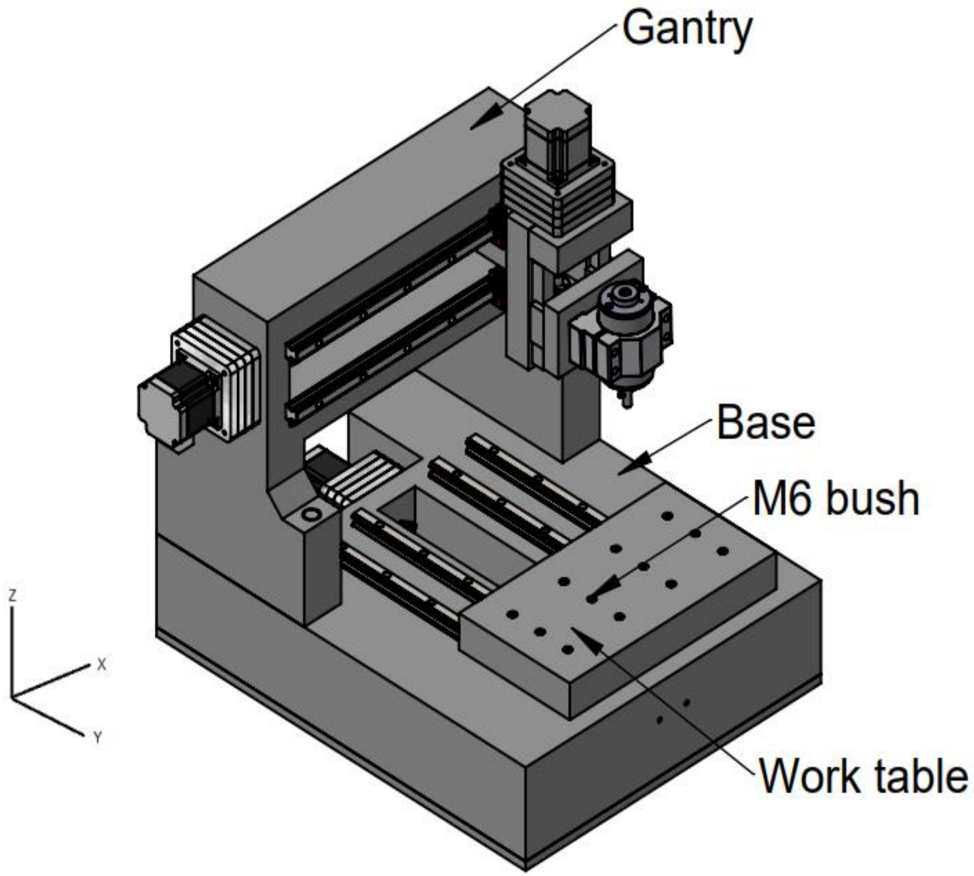


Fig. 18 Assembly after Modified base design of micro-milling machine.

- The 3mm projection on the top of the base previously provided for assembly of linear motion rail is removed, it can be provided with the help of a slot of same dimension if required and the clamping method can be altered.
- This change eliminates the projection provided in the previous design and ensure the ease of moulding.

Contd…

- The epoxy granite composition shall be obtained with the ratio of 80% Granite to 20% of epoxy resin.
- The epoxy resin is to be added in the ratio of resin to hardener as 10:1
- Resin Manufacturer : Huntsman Corporation
- The aluminium mould box of size 500*400*110mm is selected for fabrication of the epoxy granite machine base.
- Figure 19 shows the match plate that is chosen for our mould. The match plate is the main component where the various insertions into the moulds are to be placed.

Contd…

Fig. 19 Mould box

Fig. 20 Match plate

CONCLUSION

- In this project work, epoxy granite composite was chosen as the alternate material owing to its high damping characteristics, low density and comparable strength to weight ratio
- The micro-milling machine structure of cast iron material was initially designed to find assembly complications and to understand the fundamental requirements of the micro-milling machine.
- Later the same was redesigned with epoxy granite design guidelines
- This design was later converted according to the epoxy granite design guideline, but this EG Design-1 isn't practically feasible for manufacturing

Contd…

- It was identified that the complex geometric features which were taken from that of the CI design was not feasible for manufacturing an EG Design-1 machine tool structure.
- Then finally the new design of EG Design-2 machine tool structure was designed according to the guidelines and the feasibility
- The finite element model of the epoxy granite micro-milling machine were developed, and their static and dynamic behaviours were performed through numerical simulation using finite element analysis.

Contd…

- Modal analysis where performed to find fundamental natural frequency of the machine, in idle condition the total deformation of the machine due to the self-weight were analysed and in operating condition analysis the total deformation of the machines under worst case cutting conditions were analysed.
- With finite element analysis, the epoxy micro-milling machine tool structure was analysed under worst case cutting condition the maximum deformation was found to be 32.05 microns respectively.

Contd…

- It is to be noted that only the bottom tip of the spindle, epoxy granite structure was found to be deformed.
- From the results of the analysis, we can infer that the newly designed epoxy granite machine structure (EG design -2) is stable under both idle and operating conditions.
- Also, under design for manufacture and assembly concept the base of the epoxy granite micro-milling machine was redesigned with some minor changes to the existing design for ease of moulding.

REFERENCES

- Jin X, Altintas Y. Slip-line Field Model of Micro-cutting Process with Round Tool Edge Effect. Journal of Materials Processing Technology(2011) 211: 339–355.

- X. Jing, H. Li, J. Wang, Y. Tian. Modelling the cutting forces in micro-end-milling using a hybrid approach, Int. J. Adv. Manuf. Technol. 7 (2014) 9–12

- Shanmugam Chinnuraj , PR Thyla , S Elango et al. Static and dynamic behavior of steel-reinforced epoxy granite CNC lathe bed using finite element analysis. (2020) J Materials: Design and Applications 0(0) 1–15

- Prabhu Raja Venugopal, , M Kalayarasan et al. ‘Structural investigation of steel- reinforced epoxy granite machine tool column by finite element analysis’,(2019) Journals of materials design and applications, pp. 1-13.

- Prabhu Raja Venugopal , P Dhanabal et al. ‘Design and analysis of epoxy granite vertical machining centre base for improved static and dynamic characteristics’,(2019) Journals of materials design and applications, pp. 1-15.

THANK YOU