# PSG COLLEGE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

## DESIGN AND DEVELOPMENT OF HIGH SPEED EPOXY GRANITE MICRO-MILLING MACHINE FOR TOOL AND DIE APPLICATIONS


| STUDENT DETAILS | |
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# MICRO MILLING MACHINE


- A machining tool used for precision milling operations.
- Advantages:
  - Great precision with tight tolerances
  - High-speed machining
  - Excellent surface finishes

Precision of About **5 $\mu m$**

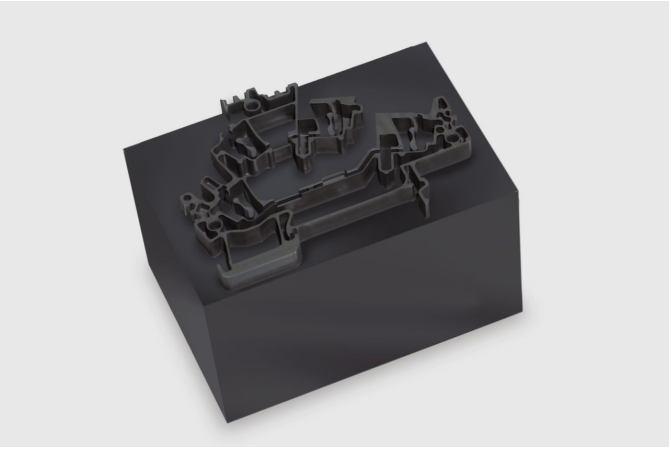
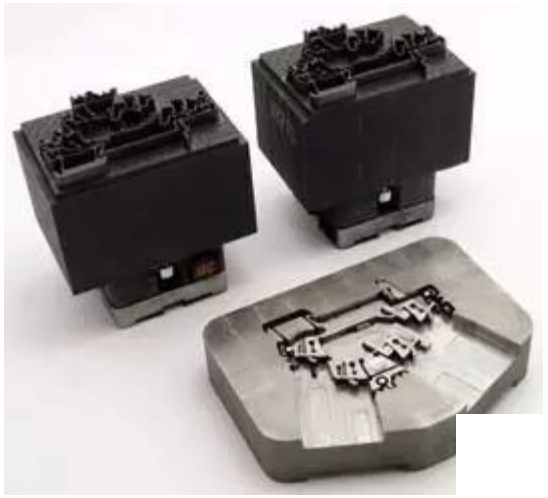
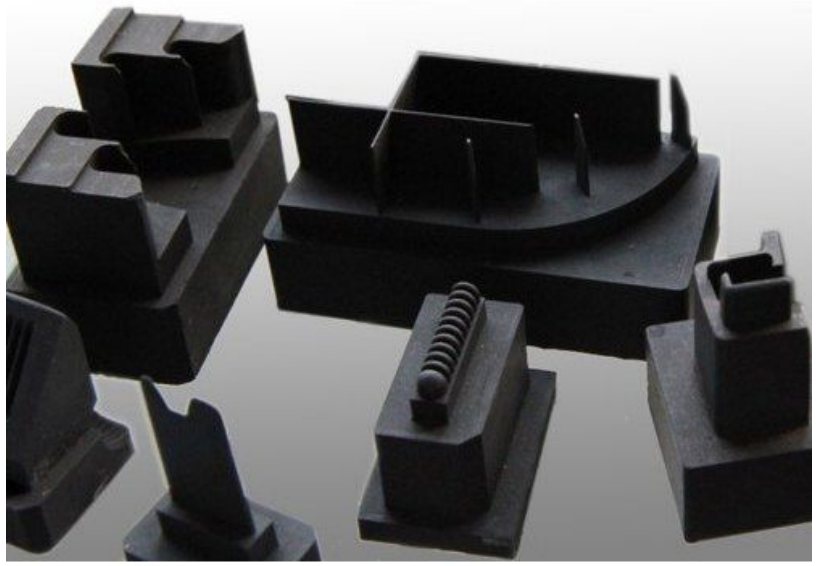
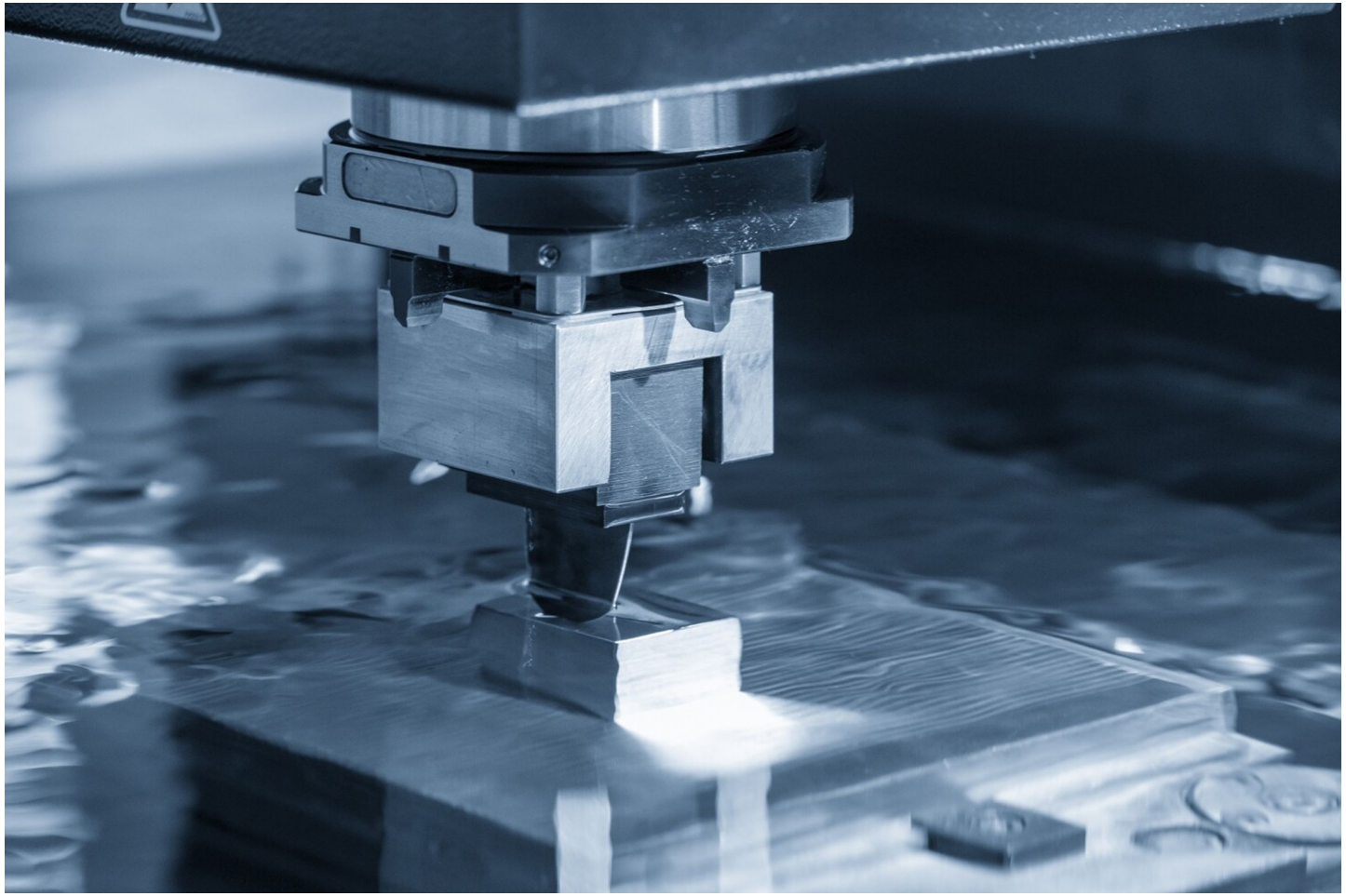


**Fig.1** CNC Micro Milling Machine


54
58







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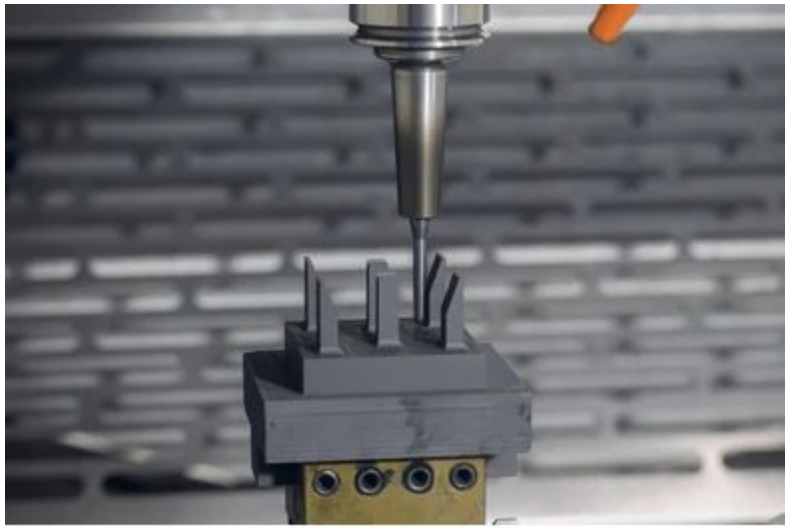

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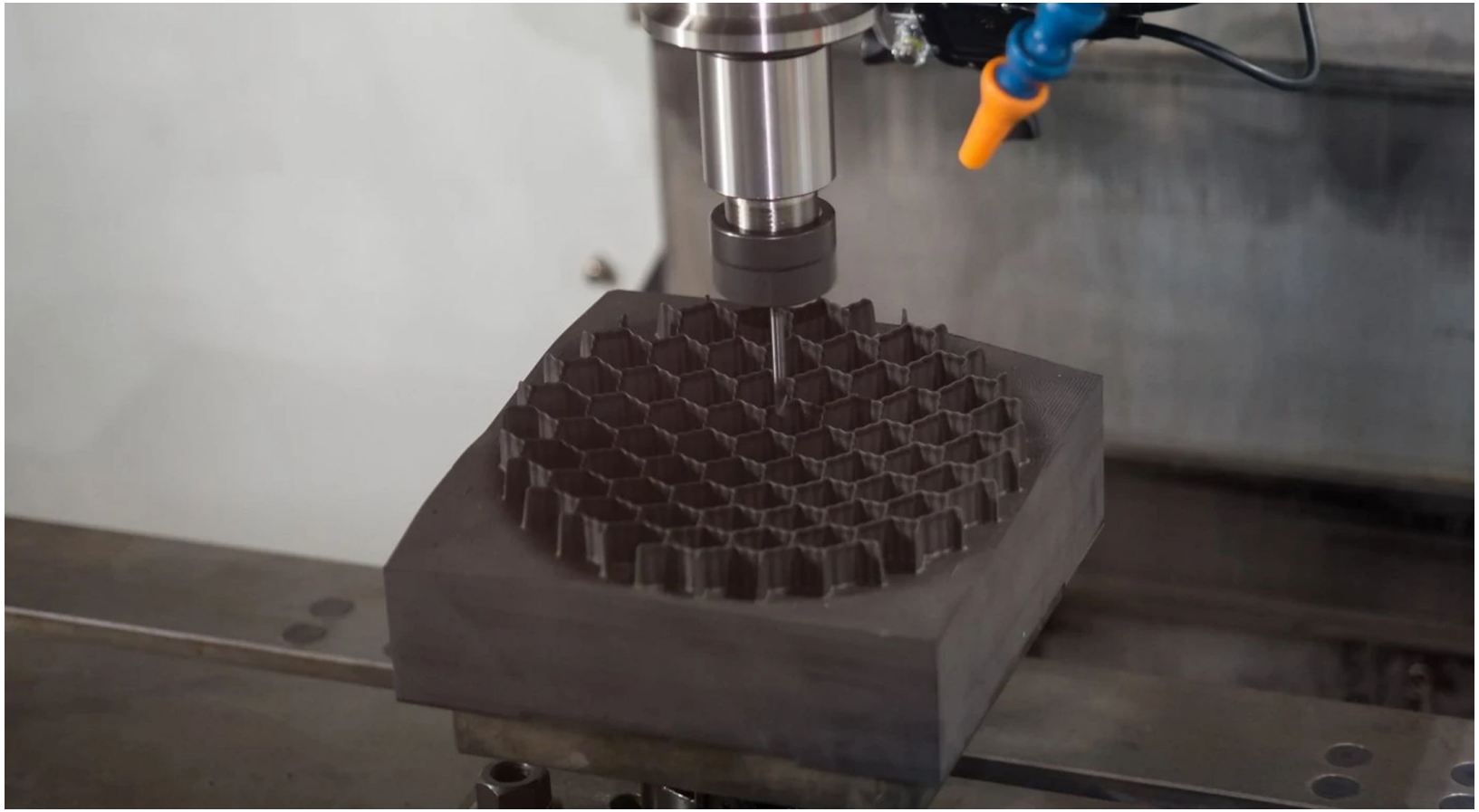
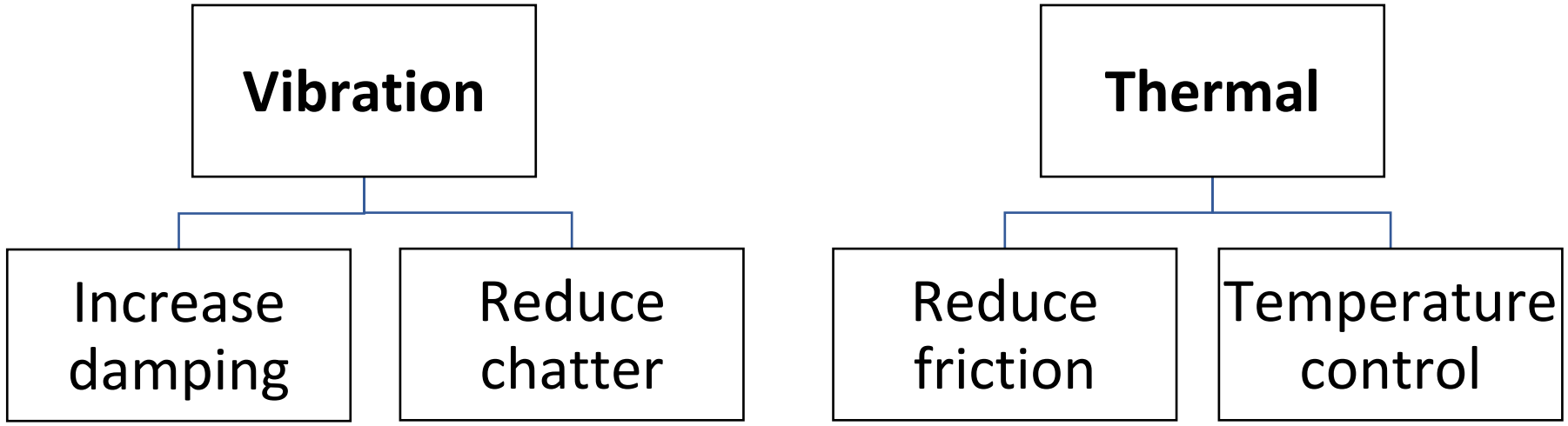


# HOW TO INCREASE THE PRECISION IN MICRO MILLING MACHINES?




## PROPOSED SOLUTION

1. **Epoxy Granite**
2. **Active Magnetic Bearing**


**Fig.x Tooltech NP series Micro Milling Machine**

| Specification | BR5535 NP |
|---|---|
| Spindle Speed- MAX (RPM) | 24000 |
| Spindle Power (KW) | 2.2 |
| Construction material | Cast iron |
| Gantry Construction | Table Clamping Area (mm) |
| XYZ Movement (mm) | 450 x 300 x 160 |
| Guideways | All axes with Linear Motion Guide ways |
| Ball Screws | C5 Class Ground Ball Screws |
| Feed Rate (m/min) | 0-5 |
| Axes Motors | AC Servo motors on all axes |
| Axes Motor Torque (Nm) | 1.2 |
| Repeatability (Microns) | 0.01 |
| Positioning Accuracy (Microns) | 0.02 |
| Spindle Drive Type | AC Vector |


| Specification | Values |
|---|---|
| Model | PREMIUM 5030-3 |
| Spindle Speed- MAX (RPM) | 50000 |
| Spindle Power (KW) | 2 |
| Construction material | Polished granite |
| XYZ Movement (mm) | 450 x 300 x 160 |

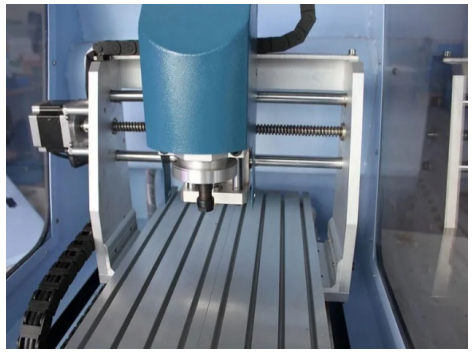


**Fig.x** Micro CNC Milling Machine

| Parameter | Value |
|---|---|
| Spindle Speed | 24000 rpm |
| Power (kW) | 1.49 |
| Construction material | Steel / Aluminium |
| Material of Rack | Aluminium Alloys 6061+6063 |
| Automation Grade | Automatic |
| Machine Type | CNC Milling Machine |
| Drive Unit | Trapezoidal Screw 1204 |
| Max Distance from Spindle Nose to Countertops | 60mm |
| Table Dimensions | 240 x 450 mm |
| Spindle Motor | 110V 240W DC motor (Runout ≤ 0.03mm) |
| Software | Mach3 System |

# ASSEMBLY DRAWING OF EG MICRO-MILLING MACHINE

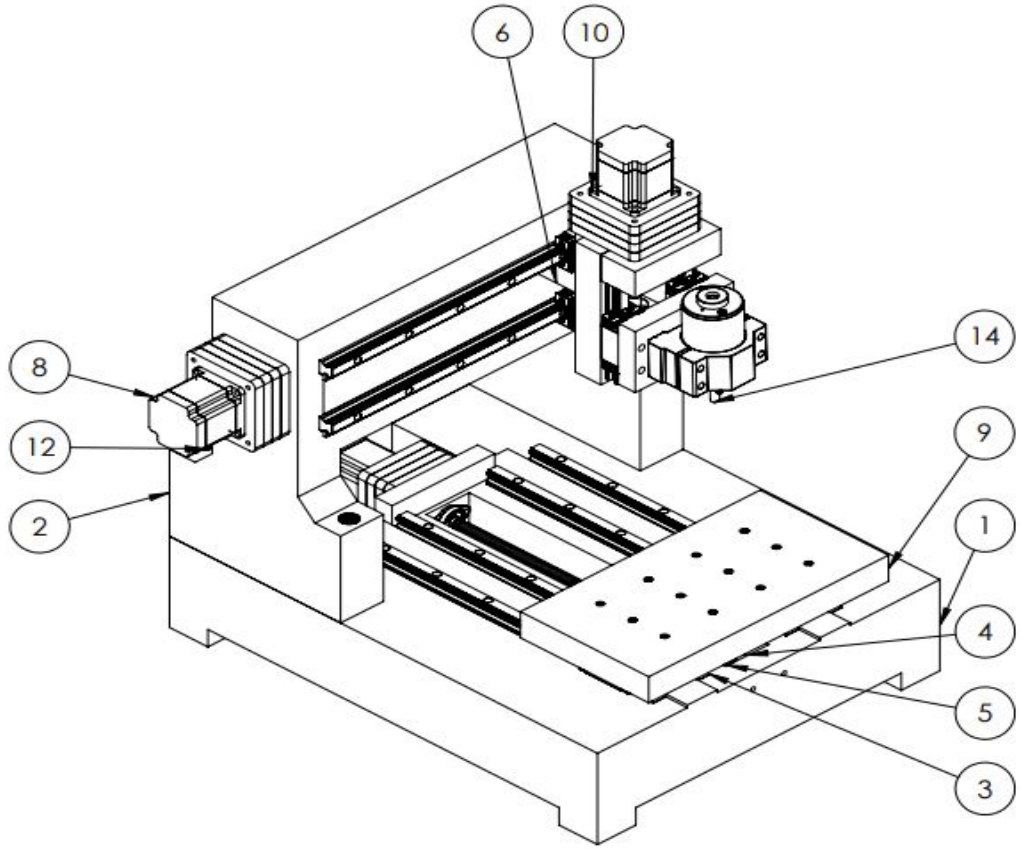



Fig. xx Assembly drawing of EG micro-milling machine Design-2

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

Table x Bill of Materials of EG micro-milling machine

# SPECIFICATIONS OF CI & EP MICRO-MILLING MACHINE

| Material | Cast iron | Epoxy granite |
|---|---|---|
| Machine Size | 600*600*575mm | 500*400*375mm |
| Working area (X, Y, Z) | 480*520*75mm | 250*200*100mm |
| Spindle | 9000r/min | 9000r/min |
| Step motor | 1.3A 0.25 Nm | 1.3A 0.25 Nm |
| Power supply | 24V 5.6A | 24V 5.6A |
| Machine Weight | 122.5kg | 75kg |
| Spindle | | 775 spindle motor, 36V : 9000r/min |
| Ball nose end-mill cutter diameter | 6mm | 6mm |

# MODAL ANALYSIS

| 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 |

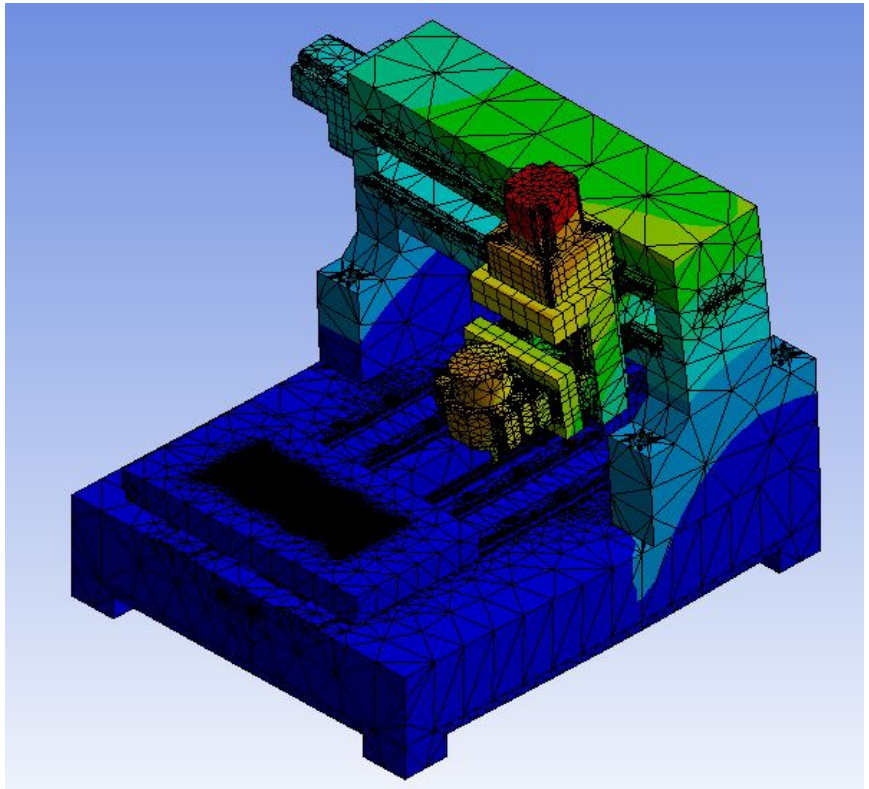


Table 3 Natural frequencies of EG micro-milling machine

# Introduction to Active Magnetic Bearing

## ROLE OF BEARINGS

- Reduce the **friction**
- **Support the spindle** and the cutting tool
- **Absorb the vibrations** during machining
- Provide a long service life

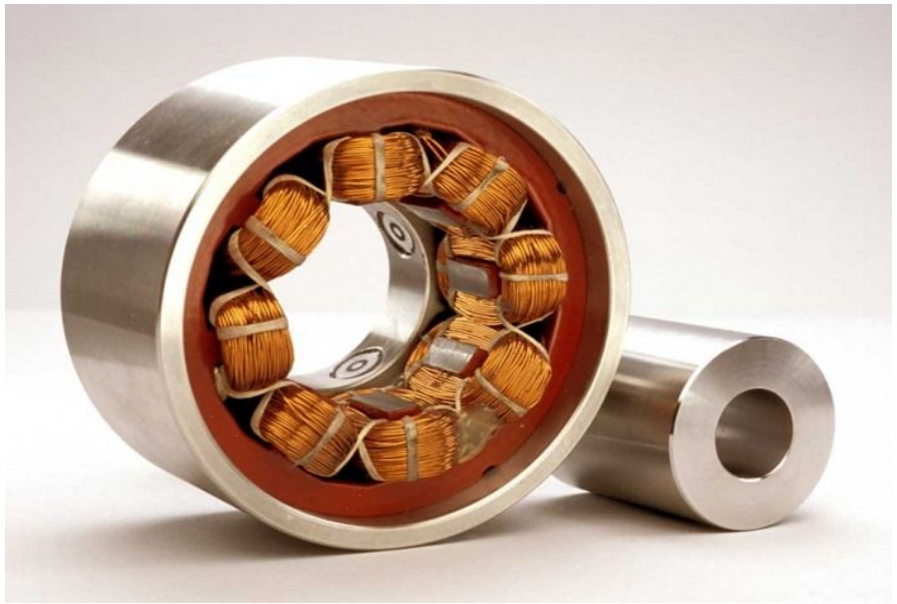
## DISADVANTAGES OF CONVENTIONAL BEARINGS

- Need for lubrication
- Susceptible to **wear** and **tear**
- Cannot operate in harsh environments
- Require more power

**Fig.4** Roller bearing

# INTRODUCTION-WHY MAGNETIC BEARING?

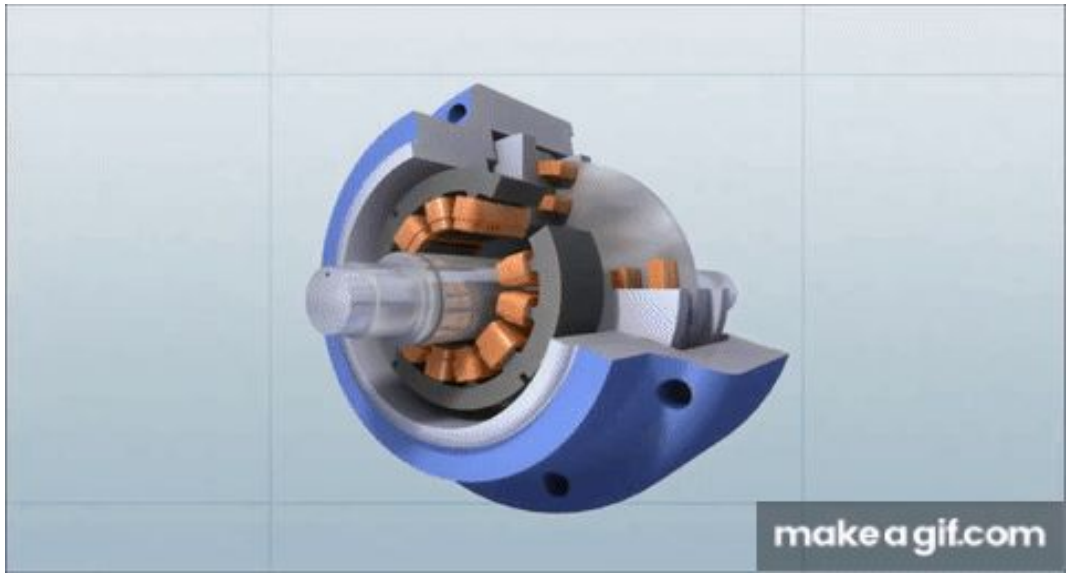
- **High-speed applications-Frictionless**
- **Variable speed** operations
- **Low energy consumption**



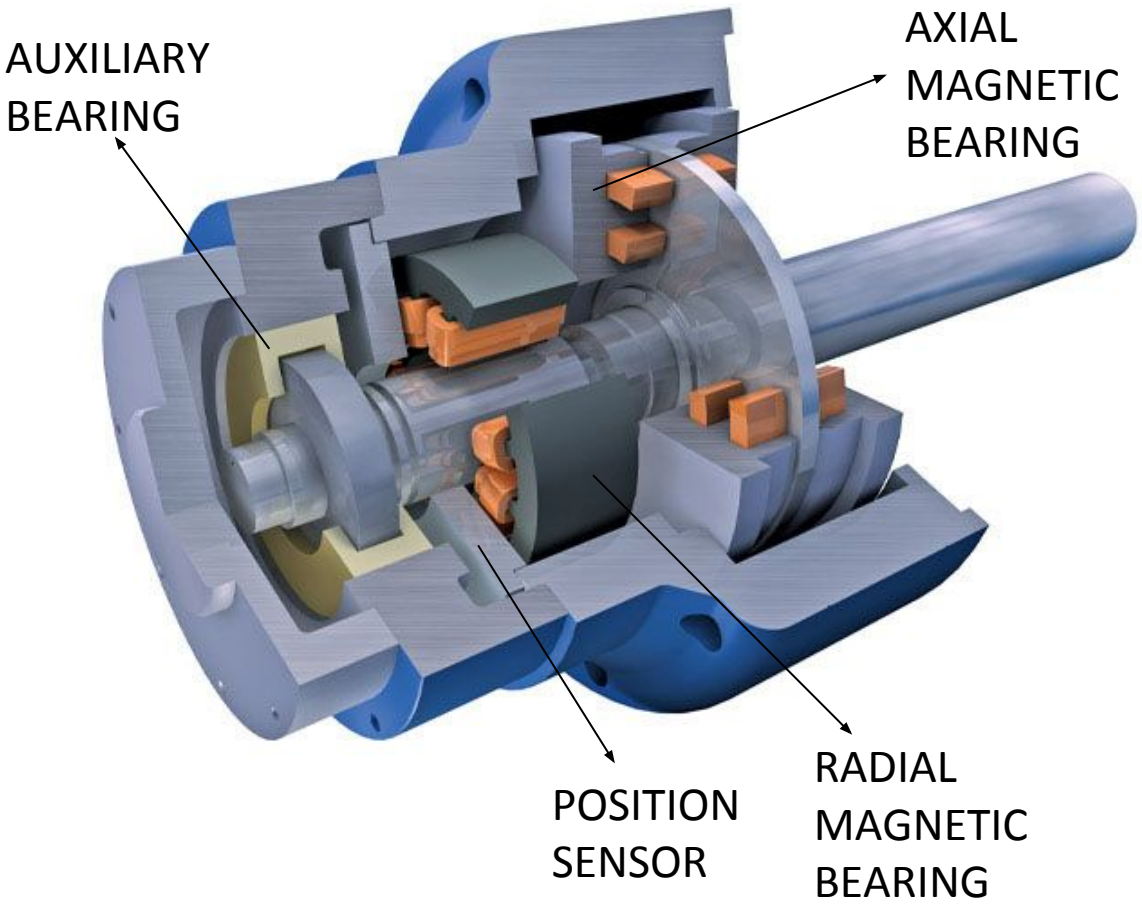
**<u>Working Principle</u>: Electromagnetic forces –**

Levitation of shaft

Suspending rotor in air with controlled magnetic force (Cushioning)



# CONSTRUCTION DETAILS-AXIAL AND RADIAL MAGNETIC BEARINGS



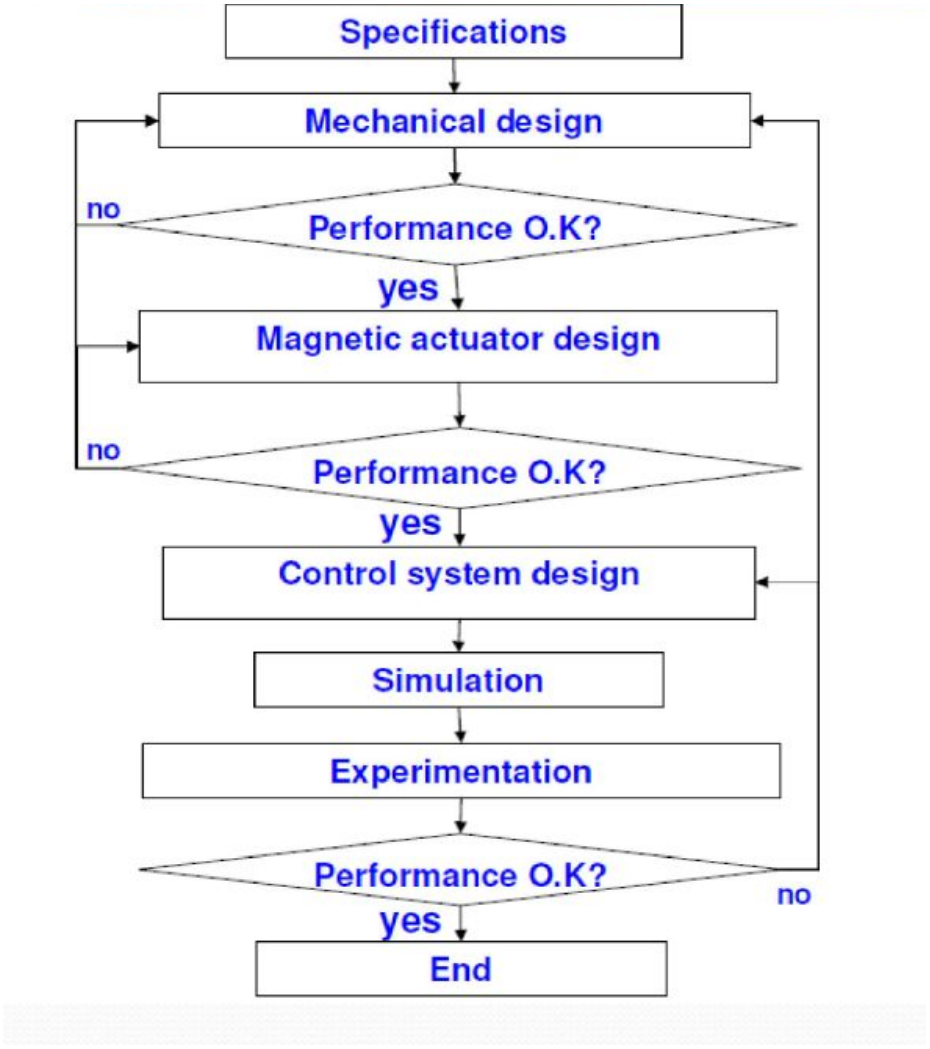

**SPINDLE SPEED: 50,000rpm**

**APPLICATIONS**:

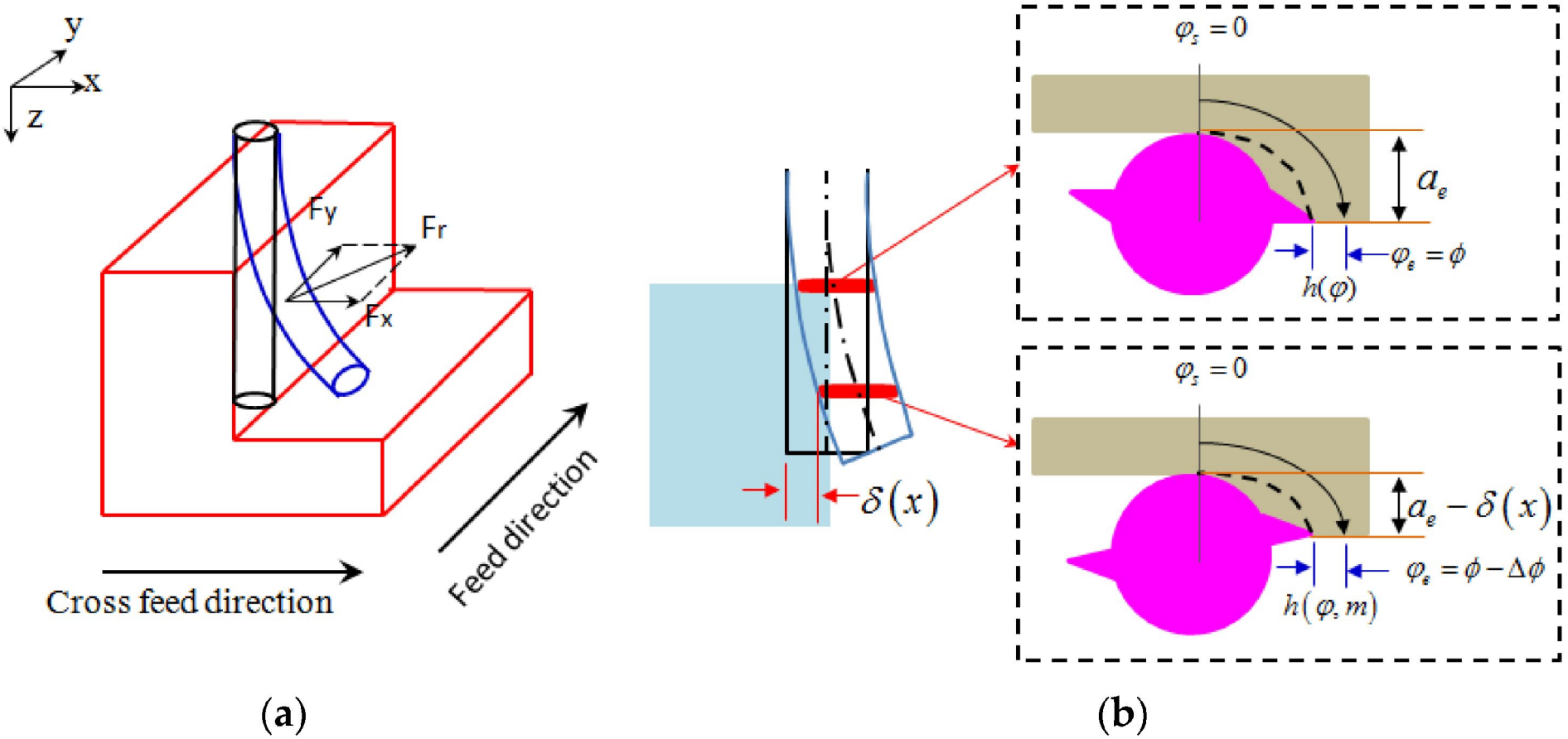
- Aerospace - Gas Turbines
- Manufacturing - High-Speed Machine Tools
- Energy - Flywheel Energy Storage Systems
- Medical - Magnetic Resonance Imaging (MRI) Machines
- Oil & Gas – Compressors
- Renewable Energy - Wind Turbines
- Semiconductor Manufacturing - Wafer Handling Systems
- Rail Transportation - Maglev Trains
- Marine - Shipboard Cooling Compressors

| Features | Conventional Bearing | Magnetic Bearing |
|---|---|---|
| Type of bearing | Contact bearing | Non-contact bearing |
| Principle of operation | Friction between the bearing and the shaft | Magnetic levitation |
| Lubrication | Required | Not required |
| Wear and tear | Subjected to wear and tear | Not subjected to wear and tear |
| Lifespan | Shorter | Longer |
| Efficiency | Lower | Higher |
| Cost | Lower | Higher |
| Applications | General-purpose applications | High-precision applications, harsh environments |

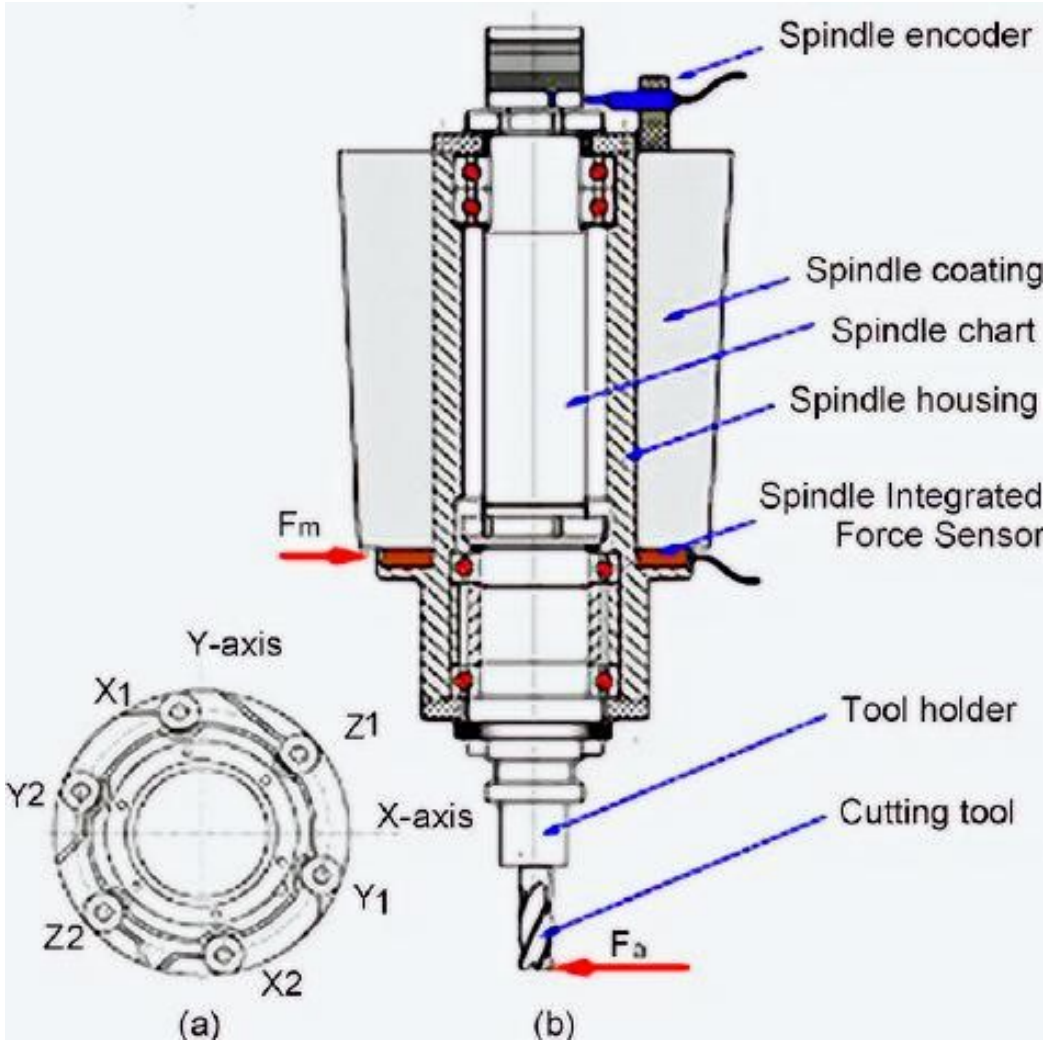
# DESIGN ASPECT OF MAGNETIC ACTUATOR



# FREE BODY DIAGRAM OF SPINDLE UNIT AND FORCE ANALYSIS



# FREE BODY DIAGRAM OF SPINDLE UNIT AND FORCE ANALYSIS



# FREE BODY DIAGRAM OF SPINDLE UNIT AND FORCE ANALYSIS

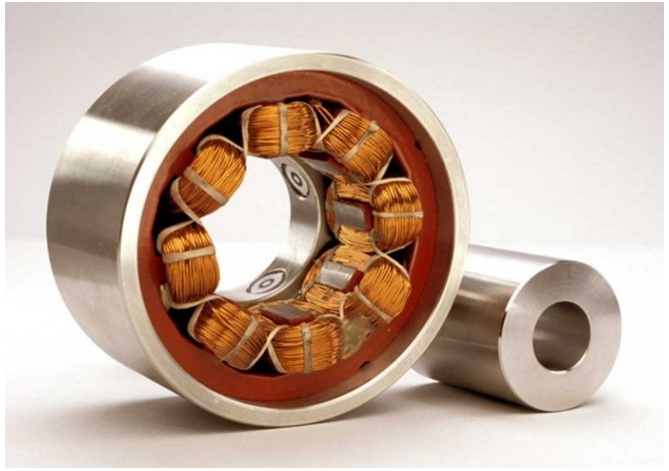
**INFERENCE**: The force analysis confirms that the primary load exerted on the spindle unit is predominantly in the radial direction.

The force analysis conducted on the spindle unit of our micro milling machine reveals a predominant prevalence of radial forces over axial forces. Radial forces are notably more significant, indicating that the spindle unit experiences the majority of its load in the radial direction during operation.

# SELECTION OF BEARINGS

1. **TYPE OF LOAD**: Radial force dominating Axial Force
2. **SPEED OF SHAFT**: 50000 rpm
3. **CONDITIONS OF LOADING**: Steady and continuous radial load

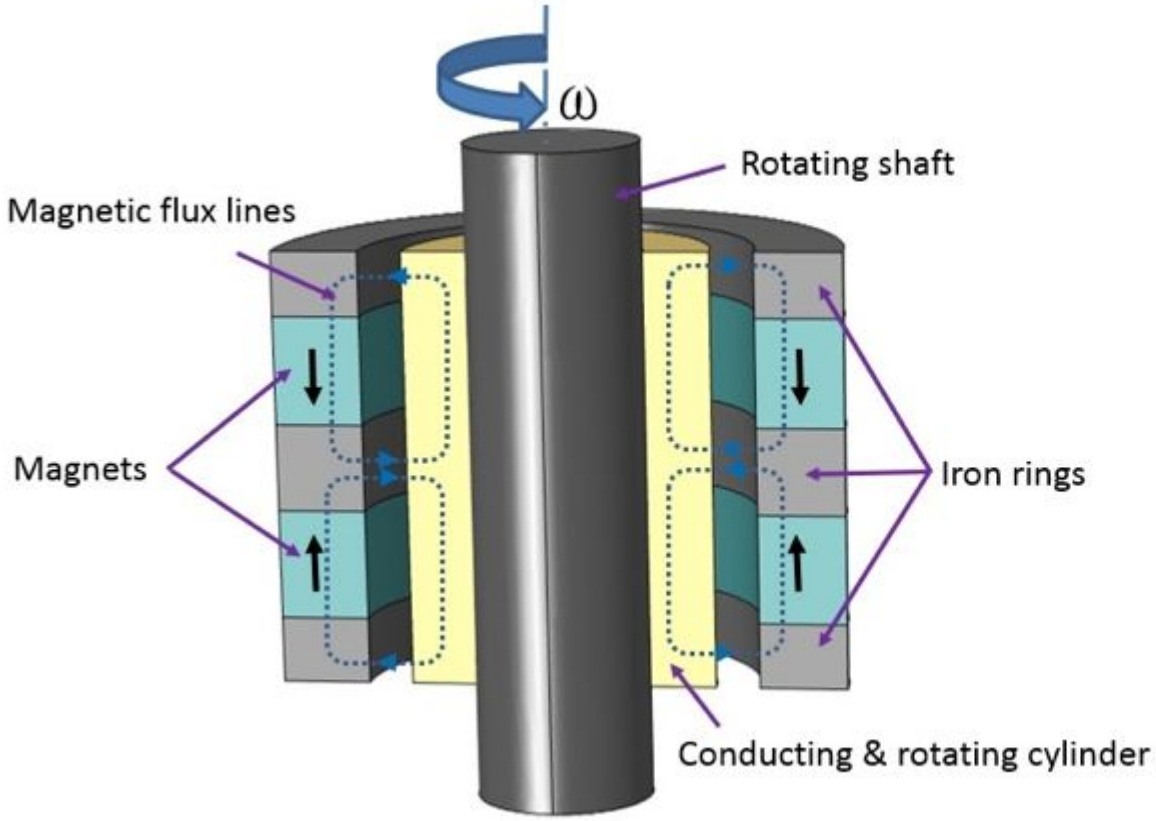
## BEARINGS SELECTED

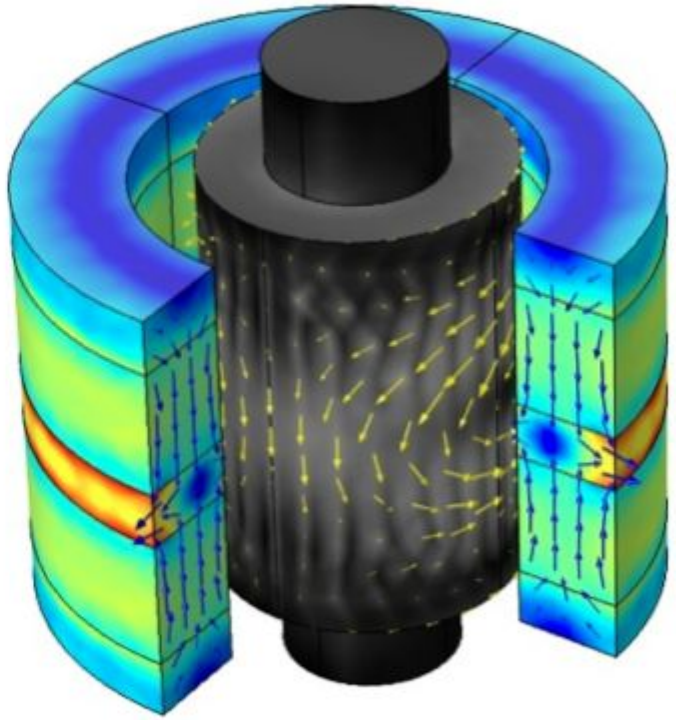


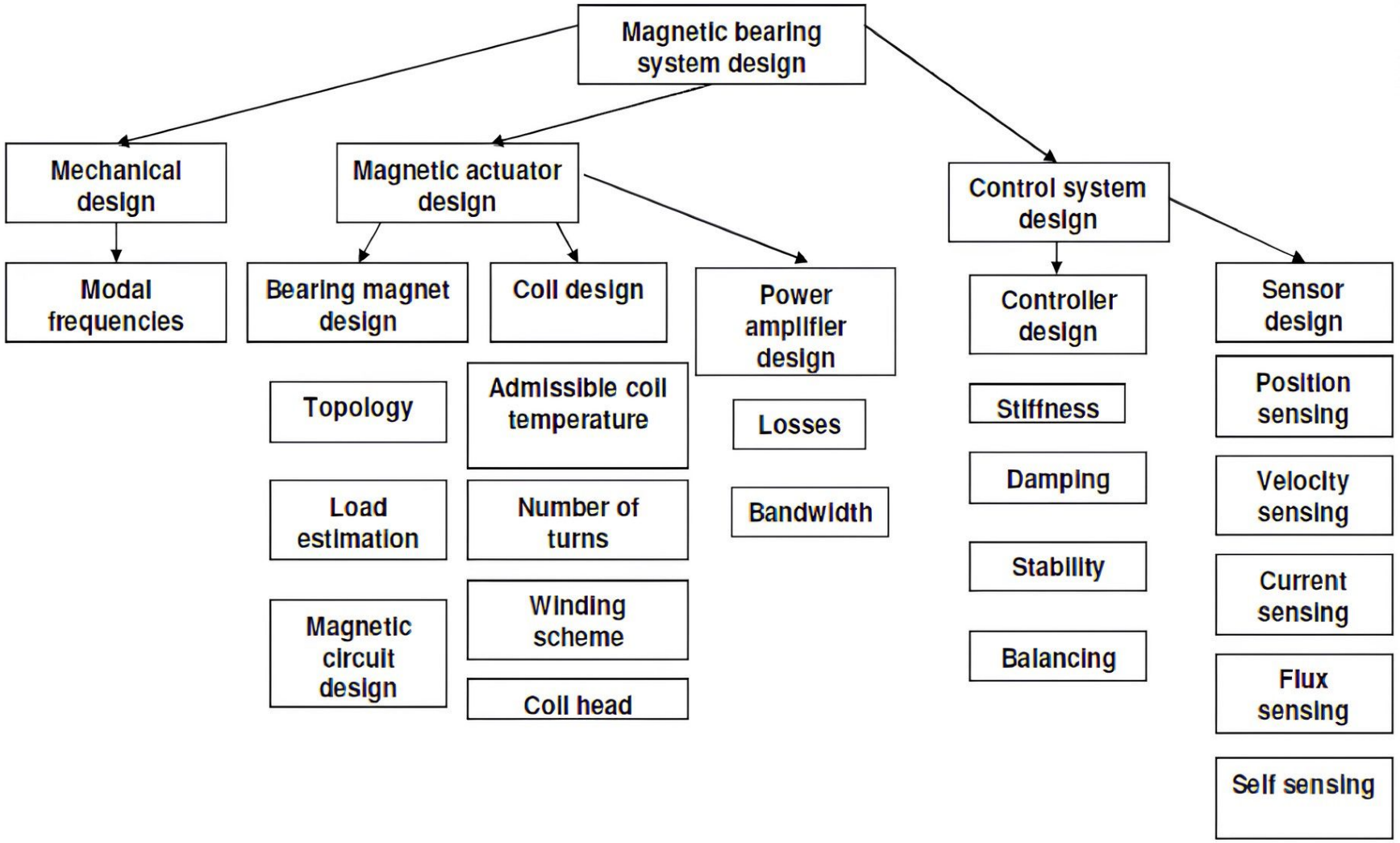
**RADIAL ACTIVE MAGNETIC BEARING**

**AUXILIARY BEARING**

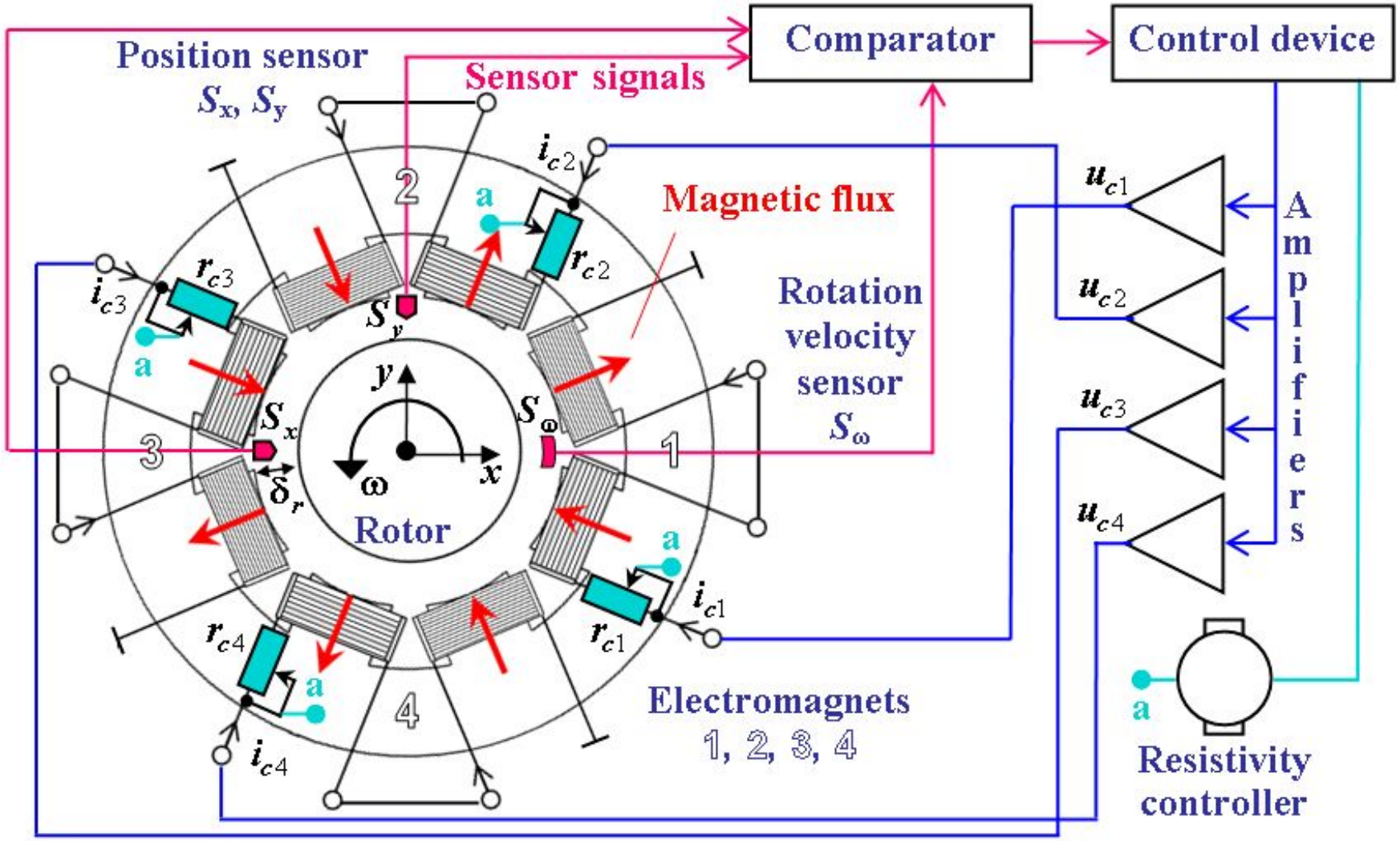
# CONSTRUCTION OF RADIAL MAGNETIC BEARINGS




Magnetic bearing system design
Mechanical design
Magnetic actuator design
Control system design
Modal frequencies
Bearing magnet design
Coil design
Power amplifier design
Controller design
Sensor design
Topology
Admissible coil temperature
Losses
Stiffness
Position sensing
Load estimation
Number of turns
Bandwidth
Damping
Velocity sensing
Magnetic circuit design
Winding scheme
Stability
Current sensing
Coil head
Balancing
Flux sensing
Self sensing

# CIRCUIT DIAGRAM OF RAMB AND CONTROL SYSTEM



# FUTURE WORK-STAGES

1. **Modelling and Simulation of Radial Active Magnetic Bearing**: Our first step involves the intricate design and optimization of radial active magnetic bearings, emphasizing their load-carrying capacity and precision to meet the exacting demands of micro milling applications.

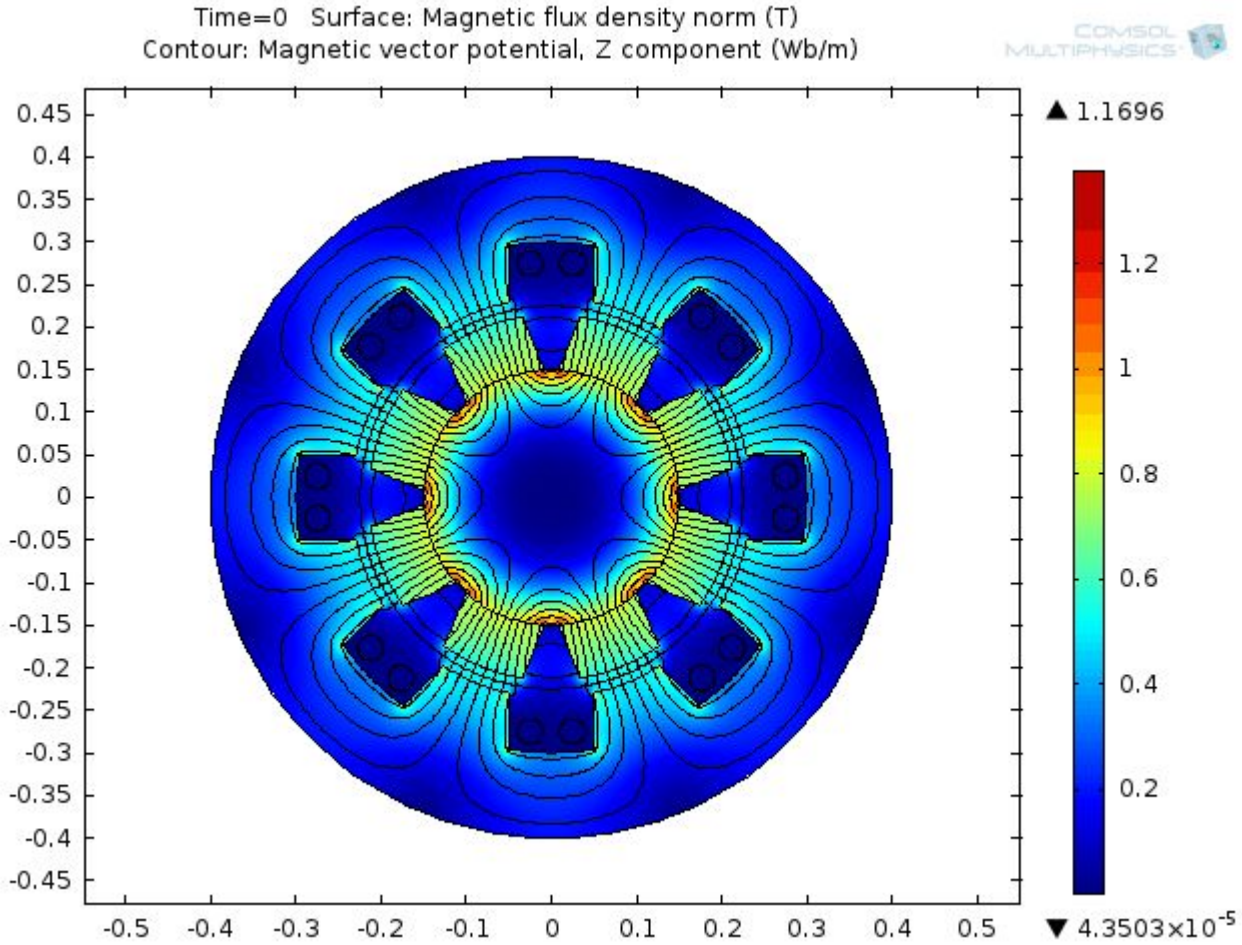
2. **Precision Control System**: We will develop a sophisticated control system equipped with sensors and advanced control algorithms, ensuring that the magnetic bearings can precisely position and manage the applied forces.

3. **Validation through Testing**: Rigorous vibration analysis and testing protocols will be employed to rigorously validate the efficacy of our magnetic bearing system in significantly reducing the unwanted chatter during micro milling operations.

4. **Enhancing Sensing Technology**: Investigating the enhancement of sensor technologies and feedback systems will further refine our precision and control, ultimately leading to exceptional performance.

5. **Safety, Efficiency, and Documentation**: Concurrently, we'll be implementing robust safety measures, exploring energy-efficient strategies, and maintaining meticulous documentation to ensure the smooth progress and transparency of this vital project.

# FUTURE WORK-STAGE-1-MODELLING AND SIMULATION OF RADIAL ACTIVE MAGNETIC BEARING

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