

# Design and Development of a Stirrer Set-up by using Drill Machine for Existing Resistance Coil Furnace

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**Abstract** - This paper presents the design and development of a stirrer set-up for an existing resistance coil furnace, aimed at producing metal matrix composites (MMCs). In conventional stir casting systems, electric motors are typically used for stirring. However, these motors are often expensive and require additional components like speed control systems, belt-pulley arrangements, or gear trains, which increase both cost and system weight.

To address these issues, this study proposes the use of a portable drill machine as an alternative stirring device. The drill machine offers a cost-effective and lightweight solution with a simplified design. The developed stirrer set-up mainly consists of a drill machine (as the motor), a stirrer blade and rod, a supporting frame, and clamps for secure mounting. This innovative approach provides an optimized and economical design for small-scale composite manufacturing.

**Keywords:** Stirrer Set-up, Stir Casting, Metal Matrix Composites (MMCs), Drill Machine, Resistance Coil Furnace

## I. INTRODUCTION

Metal Matrix Composites (MMCs) are increasingly gaining prominence due to their superior mechanical, thermal, and wear properties compared to traditional alloys. Among the various fabrication techniques, \*stir casting\* stands out as one of the most effective and economically viable methods for producing MMCs. This process involves mechanically stirring reinforcement materials such as ceramic particulates or fibers into molten metal, ensuring uniform dispersion and improved composite performance. Its versatility and simplicity make it highly attractive for applications in aerospace, automotive, and defense industries, where weight-to-strength ratio and thermal efficiency are critical.

Despite these advantages, the adoption of stir casting in academic laboratories and small manufacturing setups remains limited. The primary barrier is the prohibitive cost of dedicated stir casting equipment, which poses significant budgetary constraints. Compounding this issue, many existing Resistance Coil Furnace within research labs suffer from outdated designs and lack modular functionality, making them inadequate for modern composite processing requirements.

To address these challenges, this research explores a retrofit-based approach that repurposes conventional Resistance Coil Furnace by integrating a low-cost, motorized stirrer assembly. The proposed system features a single, high-temperature-resistant stirring blade driven by an electric motor, ensuring effective and reliable mixing of reinforcement materials within the molten matrix. The design emphasizes modularity, ease of installation, and cost efficiency allowing laboratories to maximize the utility of existing infrastructure rather than invest in new machines. Integrated safety mechanisms further enhance operational reliability, especially when

handling high-temperature molten metals.

Through careful material selection, prototyping, and economic analysis, this study aims to demonstrate the technical feasibility and cost-effectiveness of the stirrer retrofit system. By providing a sustainable alternative to equipment replacement, the project contributes to the advancement of composite manufacturing capabilities in resource-limited environments.

## II. PROBLEM STATEMENT

The demand for metal matrix composites (MMCs) continues to rise due to their superior mechanical strength, thermal stability, and lightweight characteristics—making them indispensable in sectors such as aerospace, automotive, and defense. Among various fabrication techniques, stir casting is widely recognized for its cost-effectiveness and relative simplicity. However, despite its industrial relevance, many educational and small-scale research laboratories struggle to implement stir casting due to the high capital investment required for specialized equipment.

Compounding this challenge is the widespread reliance on aging Resistance Coil Furnace, which often lack integrated stirring mechanisms and fail to meet modern manufacturing standards. As a result, these facilities are unable to efficiently produce MMCs, limiting experimental capabilities and innovation. This project aims to overcome these barriers by designing and developing a modular stirrer system that can be retrofitted into existing Resistance Coil Furnace. The system incorporates a single, motor-driven blade made from high-temperature-resistant material to enable uniform mixing of reinforcement particles. The design focuses on affordability, thermal durability, ease of integration, and safety—ensuring secure operation in high-temperature environments. By enabling the cost-effective upgrade of existing infrastructure, this solution seeks to revitalize laboratory-scale MMC production and extend the usable life of conventional Resistance Coil Furnace.

## III. OBJECTIVES

- A. To design a cost-effective stirrer system that can be integrated into existing Resistance Coil Furnace, reducing the need for expensive new stir casting machines.
- B. To ensure uniform mixing of reinforcement particles in molten metal by using a high-temperature-resistant, motor-driven stirring blade.
- C. To fabricate a modular and easy-to-assemble stirrer mechanism suitable for laboratory and small-scale manufacturing environments.
- D. To enhance the functionality of outdated Resistance Coil Furnace through retrofitting, thus extending their operational lifespan.
- E. To conduct material selection and prototyping aimed at optimizing thermal durability, mechanical performance, and

structural integrity.

F. To perform cost-benefit and feasibility analysis demonstrating the economic advantages of retrofitting over purchasing new equipment.

G. To support accessible MMC fabrication for educational institutions and small industries through affordable technological intervention.

#### IV. DESIGN

Design of Stirrer System: - The stirrer system was designed using CATIA V5 software to ensure accurate 3D modeling and assembly validation before fabrication. The system consists of the following major components: [5]

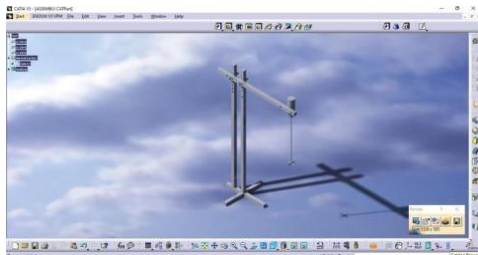


Fig. 1: Assembly design of stirrer system

Stirrer Stand and Frame (Fig. 1):

- Constructed using mild steel square hollow pipes.
- Provides structural support and stability during operation.
- Height adjustment holes allow the stirrer rod to be set at different depths in the crucible. [2]

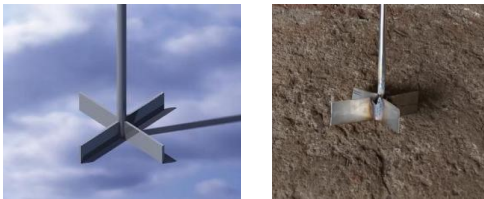


Fig. 2: Stirrer shaft and Blades

Stirrer Rod and Blade (Fig. 2):

- The rod is made of stainless steel for high-temperature resistance
- The blade is cross-shaped to ensure uniform mixing and reduce particle agglomeration.
- Designed for minimal turbulence while achieving homogeneous dispersion. [6]

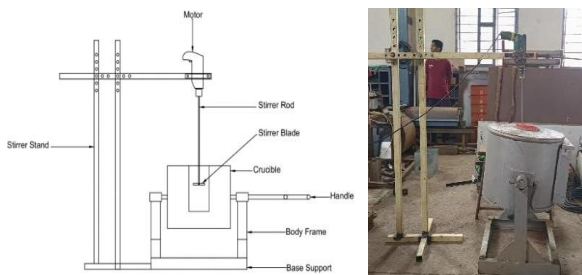


Fig. 3: Assembly and Integration

- The stirrer system is positioned over the crucible of an existing resistance coil furnace.
- The rod is inserted into the molten metal, and the blade agitates reinforcement particles to form MMCs.
- The modular design allows easy attachment and removal for

maintenance.

#### V. DESIGN CALCULATIONS

##### A. Stirrer Shaft (Rod)

- Material: SS304
- Diameter = 8 mm = 0.008 m
- Length = 600 mm = 0.6 m
- Density = 8000 kg/m<sup>3</sup>

Volume:

$$V = \pi \cdot (d/2)^2 \cdot L$$

$$V = \pi \cdot (0.008/2)^2 \cdot 0.6 = 3.0159 \times 10^{-5} \text{ m}^3$$

Mass:

$$m = \rho \cdot V = 8000 \cdot 3.0159 \times 10^{-5} = 0.241 \text{ kg}$$

##### B. Stirrer Blades (4 Blades)

- Material: SS304
- Density = 8000 kg/m<sup>3</sup>
- Dimensions:  
 (45 mm × 16 mm × 2 mm) = (0.045 m × 0.016 m × 0.002 m)

Volume per Blade:

$$V = 0.045 \cdot 0.016 \cdot 0.002 = 1.44 \times 10^{-6} \text{ m}^3$$

Mass per Blade:

$$m = 8000 \cdot 1.44 \times 10^{-6} = 0.0115 \text{ kg}$$

Total Mass for 4 Blades:

$$m_{\text{blades}} = 4 \times 0.0115 = 0.046 \text{ kg}$$

##### C. Total Stirrer Mass & Weight

$$m_{\text{total}} = 0.241 + 0.046 = 0.286 \text{ kg}$$

$$W = m \cdot g = 0.286 \times 9.81 = 2.81 \text{ N}$$

##### D. Molten Aluminum Properties

- Density: 2375 kg/m<sup>3</sup>
- Melting Point: ~660°C

##### E. Torque Calculation

$$T = K \cdot \mu \cdot \rho \cdot N^2 \cdot D^5 \dots \text{ (Empirical Formula)}$$

Where:

- K = 16 (empirical constant for flat blades)
- $\mu = 1.2 \times 10^{-3} \text{ Pa}\cdot\text{s}$  (viscosity of molten aluminum)
- $\rho = 2375 \text{ kg/m}^3$  (Density)
- N = 1440 RPM = 1440/60 = 24 rps (Rotational speed)
- D = 0.098 m (blade diameter)

$$T = 16 \times (1.2 \times 10^{-3}) \times 2375 \times 24^2 \times (0.098)^5$$

$$T = 0.24 \text{ Nm}$$

##### F. Motor Selection

- A standard drill machine-based gear motor is used.
- RPM range: 10 – 1440 RPM
- Torque capacity: Typically 1–1.2 Nm (Sufficient)

##### G. Frame Design Justification

- **Material:** Mild Steel (MS)
- **Column Cross Section:** 40 mm × 40 mm
- **Load applied:** ~2.81 N (very low)
- Max bending occurs at 880 mm overhang

##### Stress Check for stirrer frame ( $\sigma = M/Z$ ):

• Z (section modulus) for square:

$$Z = b \cdot h^2 / 6 = 40 \times 40^2 / 6$$

$$= 10666.67 \text{ mm}^3 = 1.066 \times 10^{-5} \text{ m}^3$$

• Max Bending Moment:

$$M = W \cdot L = 2.81 \cdot 0.88 = 2.47 \text{ Nm}$$

• Stress:

$$\sigma = M / Z = 2.47 / 1.066 \times 10^{-5}$$

$$\sigma = 0.2316 \text{ MPa} \ll 250 \text{ MPa (yield)}$$

#### VI. TESTING & ANALYSIS

This chapter describes how the developed resistance coil furnace with a stirrer was tested under different conditions. The main parameters examined were melting temperature, stirrer speed, and stirring time each plays an important role in achieving good mixing and better quality of metal matrix composites.

### 8.1. Effect of Stirrer Speed:

Stirrer Speed (rpm)	Findings
250	Inadequate mixing; particles tended to clump together, resulting in poor bonding.
450	Better mixing; particles spread out more evenly.
650	Achieved the best results; uniform particle distribution with very little clumping; improved mechanical properties.
850	Too fast; caused vortex formation and trapped air inside the melt, leading to porosity.

**Table 8.1. Results for different stirrer speeds**

Based on these results, the most suitable stirring speed was found to be around **250–350 rpm**. Lower speeds were unable to mix the particles properly, while higher speeds introduced air into the melt, which created unwanted pores.

### 8.2. Effect of Temperature

Temperature (°C)	Findings
750	Metal didn't melt completely; stirring was harder.
850	Proper melting; liquid metal flowed well; suitable for adding reinforcement particles.
950	Fully melted; noticed some oxidation due to exposure to air.
1150	Risk of overheating; possible damage to crucible and stirrer if kept too long.

**Table 8.2: Results for different melting temperatures**

The ideal temperature range for melting aluminum alloys was around **750–850°C**. Beyond **950°C**, there was increased oxidation and wear on the crucible. Thus, careful temperature control was important to protect the equipment and maintain metal quality.

### 8.3. Effect of Stirring Time

Stirring Time (minutes)	Findings
3	Not enough time; mixture remained uneven.
7	Better mixing; particles were spread more uniformly.

Stirring Time (minutes)	Findings
11	Best results; highly uniform distribution and stronger composite.
15	Mixing quality declined; longer exposure increased oxidation.

**Table 8.3: Results for different stirring times**

The best results were seen with a stirring time of **7–11 minutes**, which provided thorough mixing without significant oxidation or heat loss. Stirring for too long caused oxidation and wasted energy.

## VII. CONCLUSION

This study successfully demonstrates the design and development of a stirrer set-up using a drill machine for an existing resistance coil furnace, aimed at producing metal matrix composites (MMCs). Traditional stir casting systems often rely on electric motors with complex and costly speed control mechanisms. In contrast, the use of a portable drill machine provides a cost-effective, lightweight, and compact alternative without compromising functionality. The developed system consists of essential components such as a drill machine (as the motor), stirrer blade and rod, support frame, and mounting clamps. Its simplified design ensures easy assembly, operation, and maintenance, making it a practical solution for small-scale production and research applications. This innovative approach holds potential for further development and can contribute to accessible and affordable composite manufacturing techniques.

## VIII. FUTURE SCOPE

- **Automation and Remote Monitoring:** Integration of IoT (Internet of Things) technologies to monitor and control stirring speed, temperature, and stirring time remotely through mobile or computer interfaces.
- **Variable Stirring Mechanisms:** Designing stirrers with adjustable blade angles or telescopic rods to optimize stirring action based on the type and volume of reinforcement material.
- **Energy Efficiency Improvements:** Development of motor systems with variable frequency drives (VFDs) to further optimize power consumption depending on material viscosity and load.
- **Multi-Stage Stirrer Designs:** Implementation of multi-stage or multi-blade systems to achieve better mixing for highly viscous or heavily loaded composites without increasing energy consumption significantly.
- **Safety Enhancements:** Addition of emergency shutdown features, thermal sensors, and vibration monitors to further enhance operational safety.
- **Cost-Effective Commercialization:** After successful prototyping, scaling up the design for commercial markets as a low-cost retrofitting solution for aging induction furnaces across universities and small industries.

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