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DEVELOPMENT AND EFFICACY EXAMINATION OF AN ELECTRIC POWERED BRASS MELTING FURNACE

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Abstract

Furnaces are essential equipment used to heat solid materials for altering their structure, shape, or properties. Melting furnaces are particularly important in the recycling and casting of non-ferrous metals. This study presents the design and fabrication of an electric-powered crucible furnace for melting brass scraps, thereby offering a practical, energy-efficient solution highly relevant to Technical and Vocational Education and Training (TVET) programs. The system consists of a 3500 W heating element, refractory insulating materials, mild steel casing, and a centrifugal blower for uniform air circulation within the heating chamber. The furnace was tested by melting varying masses of brass scraps ranging from 0.5 to 2.5 kg, including 0.5, 1.0, 1.5, 2.0 and 2.5 kg, with material thicknesses between 1.0 mm and 3.0 mm to evaluate the heating efficiency and melting performance of the furnace. Experimental analysis showed that the furnace required approximately 36 minutes to reach the melting temperature of scrap brass (about 909°C), and an average of 31.70 minutes to completely melt 2.5 kg of brass at 878°C. The overall thermal efficiency of the furnace was estimated to be 35%. This research confirms that electric-powered furnaces can effectively melt non-ferrous metals such as brass for laboratory and small-scale industrial applications, providing a cleaner, safer, and more energy-efficient alternative to fuel-fired furnaces. The method use is ideal for hands-on TVET curriculum and local foundry skill development.

Key words: Furnace, Crucible furnace, Brass, Thermal efficiency, Scrap,

1. Introduction

Aligned with the goals of Technical and Vocational Education and Training (TVET), this work emphasizes practical, locally adaptable technologies for skills development in modern foundry practices. A furnace is a thermal container that is used to process solid or liquid raw materials at extremely high temperatures. Furnaces are used in a variety of industries, including non-ferrous metal production, manufacturing, glassmaking, ceramic processing, and metal recycling, to transform electrical or chemical energy into heat for material melting or treatment (Purkayastha et al., 2022; Accio, 2025).

In non-ferrous metallurgy, melting furnaces are vital for transforming scrap or alloy feedstock into a liquid state to enable casting, recycling, or further fabrication, core competencies in TVET curricula. Furnace efficiency depends on design, insulation, and heat source (Hassan et al., 2023). Traditionally, fuel-fired melting furnaces have dominated small-scale foundry operations due to their simplicity, low initial cost, and ease of local maintenance, attributes often leveraged in TVET workshops (Kintek Furnace FAQ, 2024). However, these systems suffer significant heat losses through radiation and convection, resulting in low thermal efficiencies of 10 to 20 percent for crucible-type designs (Advanced Melting Technologies, 2025). In contrast, electric-powered furnaces, such as resistance-heated types, offer cleaner operation, precise temperature control, and better alignment with modern energy-efficiency and environmental standards (Accio, 2025; Okafor et al., 2022). They also feature reduced emissions, lower noise, and seamless integration with digital monitoring systems (Rahman et al., 2024), making them ideal for safe, up-to-date TVET training environments.

Recycling non-ferrous metals like brass supports sustainable resource use and reduces reliance on virgin materials (Adebayo & Singh, 2023). The global rise in demand for alloy reuse and small-batch casting underscores the need for efficient, laboratory-scale melting systems suited to TVET institutions and micro-foundries. Yet, a gap remains in locally fabricated, small electric furnaces optimized for brass, as most research has focused on aluminium and copper (Musa & Bello, 2025). This research addresses that gap by presenting the design, fabrication, and efficacy examination of an electric-powered crucible furnace tailored for melting brass scraps, a model directly applicable to TVET workshop training. The system integrates a 3500 W heating element, refractory insulation, a mild-steel casing, and a centrifugal blower for uniform heat distribution. Experimental tests using 1.0 to 5.0 kg brass scraps (1.0 to 3.5 mm thick) assessed heating time, melting time, and thermal efficiency. By delivering a functional, energy-conscious prototype, this study supports hands-on learning, promotes sustainable metal recycling skills, and enhances practical curriculum delivery in TVET programs focused on foundry technology and advanced manufacturing.

2. Material and Method

The brass scraps used for this research work were procured from a local metal recycling workshop in Lagos, Nigeria. The selection of materials and components for the construction of the brass melting furnace was guided by factors such as local availability, functionality, durability, cost-effectiveness, and suitability under laboratory and workshop operating conditions.

The furnace's main parts are a 3500 W electric heating element, a mild steel casing, insulating and refractory materials, a centrifugal blower, and a ceramic crucible. The cylindrical body of the furnace was fabricated from 2.5 mm thick mild steel sheet. The inner surface was lined with a combination of fireclay refractory and high-temperature insulation wool to minimize heat loss and sustain thermal stability within the melting chamber.

A ceramic crucible was chosen for its high resistance to thermal shock and it does not react with molten brass. The furnace cover was fabricated using the same material as the body, with an embedded viewing and pouring port for monitoring and controlling the melting process. The heating element was spirally wound around the inner refractory wall to achieve uniform heat distribution within the chamber.

An electric centrifugal blower was incorporated to enhance air circulation and heat transfer efficiency, ensuring that uniform temperatures were maintained during melting. The furnace was powered through a variable voltage regulator, enabling control of input power and temperature rise during operation.

Experimental testing involved melting brass scraps of different masses ranging from 0.5 kg to 1.5 kg, with thicknesses between 1.0 mm and 3.5 mm, to determine the heating rate of the furnace, total melting time, and overall thermal efficiency. The temperature rise within the chamber was monitored using a digital thermocouple thermometer placed near the crucible wall. The system was evaluated under controlled conditions until complete melting of brass was achieved.

Table I. Brass Melting Furnace Design Parameters

PARAMETER	VALUES
FURNACE CAPACITY	0.000177 m^3
HEAT INPUT	1410.5 KJ
HEAT OUTPUT	493.7 KJ
INITIAL TEMPERATURE	25°C
FINAL TEMPERATURE	895.6°C
EFFICIENCY	35.0%
HEAT LOSS	916.8 KJ
MEAN MASS OF BRASS MELTED	1.5 KG
SPECIFIC HEAT CAPACITY OF BRASS	380 J/KG°C
AVERAGE MAXIMUM TEMPERATURE OF THE FURNACE	895.6°C

3.0 Design Analysis

3.1 Capacity of the Furnace

The crucible's volume is determined using equation (1):

$$V = \frac{m}{\rho} = \frac{1.5}{8500} = 0.000176\ m^3 \quad (1)$$

V = 176000 mm^3

where, V, m and ρ are the volume (mm^3), average mass of brass melted (kg) and density of brass (kg/ m^3) of the internal chamber of the cylindrical crucible specifications

To ensure safe filling and splashing of the molten brass, 80% volume of the internal chamber of the cylindrical crucible was considered. The volume filled by molten brass is estimated by eequation (2):

$$V_{filled} = \frac{176000}{0.8} = 220000\ mm^3 \quad (2)$$

A height to diameter ratio of 1.2:1 was used to determine the height and diameter. This was calculated evaluated with the aid of equation (3)

solving $V = \pi R^2 H$ with $H = 1.2 \times (2R) = 2.4$ (3)

Radius = 31.5 mm

Height = 151 mm

3.2 Heat Input

The electric element's efficiency is 35%. Equation (4) was thus used to calculate the heat input to the furnace chamber through the electrical element.

$$Q_{input} = \frac{Q_{USEFULL}}{\eta} = \frac{493.7\ KJ}{0.35} = 1410.5KJ \quad (4)$$

3.3 Heat Output

The Heat Output is Estimated Using Equation (5):

$Q_{out} = m.c.\ \Delta T = 1.5 \times 380 \times (895.6 - 25) = 493{,}700J = 793.7KJ$ (5)

Where Q_{OUT}, M, C, and ΔT are the useful heat absorbed, mass of brass melted (1.5 KG), specific heat capacity of brass (380 J/KG°C), and temperature change (870.6°C)

3.4 Heat Loss

Equation (6) is used to compute the heat loss, which is the difference between the heat input and the heat output.

$Q_{loss} = Q_{in} - Q_{out} = 1410.5 - 493.7 = 916.8KJ$ (6)

Where $Q_{in} = 1410.5KJ$ and
$Q_{out} = 493.7KJ$

3.5 Efficiency of the Furnace

The furnace efficiency is estimated as found in equation (7):

$$\eta = \frac{Qout}{Qin} \times 100 = \frac{493{,}7}{1410.5} \times 100 = 35\% \quad (7)$$

where ŋ = efficiency,
Q_{in} is the heat input = 1410.5 KJ, and Q_{out} is the heat output = 493.7KJ

4. Furnace Efficacy Examination

Batches of brass scrap weighing 0.5kg, 1 kg, 1.0 kg, 1.5 kg, 2.0 kg, and 2.5 kg were melted in order to test the designed brass melting furnace. Figure 1 depicts the experimental setup.

The furnace was turned on with each test, and the amount of time needed to heat the charge to 830°C, a temperature high enough to begin melting brass was carefully recorded

The full results, including heating time, holding time, total melting time, and the final furnace temperature achieved for each batch, are summarized in Table II. These trials demonstrated the furnace's ability to consistently reach brass melting temperatures (up to 909°C) and fully melt the scrap within a practical timeframe, confirming its suitability for small-scale brass recycling and foundry applications.

Figure 1: Experimental setup

Table II. Results Obtained During the Experimental

Experimental Run	**Mass of Brass (kg)**	**Time to Reach 830°C**	**Holding Time (minute)**	**Melting Time (minute)**	**Melting Furnace Temperature(°C)**
1	0.5	25.50	3.00	28.50	846
2	1.0	24.00	5.00	29.00	861
3	1.5	25.50	6.00	31.50	877
4	2.0	26.00	8.00	34.00	896
5	2.5	25.50	10.00	35.50	909
Average Values	**1.50**	**25.30**	**6.40**	**31.70**	**877.8**

Equation (6) is used to Estimate the melting rate.

$$\text{Melting Rate} = \frac{\text{Average mass of brass melted (kg)}}{\text{Average melting time (min)}}$$

$$\text{Melting Rate} = \frac{1.50}{31.70} = 0.047 \text{ kg/min}$$

5. Results and Discussion

The design criteria indicated in Table 1 were followed in the construction of the developed brass melting furnace. The furnace's main specification are an average melting pot capacity of 1.50 kg, an average working temperature of 877.8°C, an operating voltage of 230 V, and a power usage of 3500 W. Based on the result obtained, the furnace's efficiency was calculated to be 35.0%, and the melting rate was found to be 0.047 kg/min. This performance aligns with the findings of Ahmed (2009), Abed (2013); and Adeolu (2017), who emphasized the importance of controlled melting and heat treatment of non-ferrous metals in sustainable manufacturing processes.

The modest melting rate reflects the thermal inertia of the refractory lining and the significant heat losses (916.8 kJ for 1.5 kg charge), which are typical of small-scale resistance-heated crucible furnaces. The consistent time to reach 830°C (25.3 minutes) across varying charge masses (0.5 – 2.5kg) demonstrates stable heating characteristics, while the linear increase in holding time with mass ensures complete melting and homogenization, a behavior consistent with conventional electric melting systems reported in foundry technology literature.

6. Conclusion

This study developed an electric-powered brass melting furnace that can melt 1.50 kg of brass scraps on average in 31.70 minutes (1902 seconds) at a maximum temperature of 877.8°C.

The system, powered by a 3500 W heating element, achieved a thermal efficiency of 35.0%, confirming its suitability for Technical and Vocational Education and Training (TVET) laboratories, hands-on foundry instruction, and small-scale industrial training. The furnace offers a cleaner, safer, and more controllable alternative to traditional fuel-fired units, enhancing workshop safety and promoting modern, energy-efficient practices in TVET curricula. This work contributes a practical, locally fabricable model for brass melting in resource-constrained settings, directly supporting skills development, sustainable metal recycling, and the integration of green technologies in TVET programs focused on metallurgy and manufacturing.

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