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MAINTENANCE OF A 100 KG ROTARY FURNACE

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A REPORT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A POST GRADUATE DIPLOMA IN PRODUCTION ENGINEERING

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CERTIFICATION

This is to certify that this research work was carried out by **GODWIN SAMSON PG/ENG2215435** of the Department of Production Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, in accordance with the rules and regulations of the University of Benin for the award of a Postgraduate diploma in Production Engineering Department.

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DEDICATION

I dedicate this research work to the Almighty God for his knowledge and wisdom.

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ABSTRACT

This project focuses on the comprehensive maintenance of a 100 kg rotary furnace used for metallurgical and thermal processing operations. Prior to maintenance, the furnace exhibited severe structural and mechanical deterioration, including a damaged and broken refractory lining, faulty twin drive motors, a non-functional blower system, and worn conical end covers and faulty chimney. These conditions rendered the furnace unsafe, thermally inefficient, and incapable of sustaining continuous operation.

The project involved a full restoration procedure beginning with the removal of the deteriorated refractory materials and the procurement of high-grade refractory cement suitable for high-temperature applications. A new refractory lining was installed to re-establish the furnace's thermal insulation, mechanical strength, and operational reliability. In addition, both drive motors were repaired and serviced to restore proper rotational movement, while the blower system was reconditioned to ensure adequate air supply for combustion and temperature regulation. The two conical covers were also rehabilitated to improve heat retention and structural stability.

Upon completion of the maintenance activities, the furnace regained its full operational capacity, demonstrating improved thermal efficiency, structural integrity, and mechanical reliability. The rehabilitation extended the service life of the furnace and enhanced overall safety, making it suitable for continued use in production environments. This project highlights the importance of preventive maintenance and proper restoration techniques in sustaining the performance of industrial heating equipment.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Rotary furnaces play a significant role in metallurgical and foundry operations, serving as essential. The performance, efficiency, and safety of a rotary furnace depend largely on the condition of its refractory lining and the reliability of its mechanical components, such as drive motors and air-supply systems. Over time, continuous exposure to high temperatures, abrasive materials, and mechanical stresses causes deterioration of internal linings and gradual failure of moving parts. As a result, planned maintenance and timely rehabilitation are critical to ensuring uninterrupted furnace operation and extending the equipment's service life.

The 100 kg rotary furnace addressed in this project is a vital unit within the production environment where it is used for melting and heat treatment processes. Its internal chamber is lined with heat-resistant refractory material designed to withstand high temperatures while protecting the steel shell from thermal damage. The furnace operates with the aid of two drive motors that ensure rotational movement and a blower unit that supplies combustion air to maintain the required thermal conditions. Additionally, two conical covers help contain heat and stabilize internal pressure during operation.

Before the commencement of this project, an inspection of the furnace revealed extensive degradation. The refractory lining was severely damaged, cracked, and partially dislodged, making the furnace unsafe and thermally inefficient. Years of high-temperature exposure and mechanical stress had weakened the lining, reducing its ability to retain heat and protect the shell. Furthermore, the two drive motors had failed, preventing the rotary action necessary for homogeneous heating of the charge materials. The blower system was also non-functional, resulting in poor combustion air supply and unstable operating temperatures. The two conical covers exhibited wear and required rehabilitation to ensure proper sealing and heat retention.

Given the importance of the furnace in daily production and its deteriorated condition, a comprehensive maintenance and rehabilitation project became necessary. The project aimed to restore the furnace to optimal operational status by replacing the damaged refractory lining, repairing the drive motors, restoring the blower system, and reinforcing the structural integrity of the conical covers. This maintenance activity was essential not only to extend the service life of the equipment but also to ensure safe, efficient, and reliable operation in future industrial processes.

1.2 Description of 100kg capacity rotary furnace

A rotary furnace is a cylindrical, heat-resistant chamber designed to rotate along its horizontal axis to achieve uniform heating, melting, or thermal processing of materials. Modern rotary furnaces are widely used in metallurgical industries, non-ferrous metal recycling, alloy production, ceramics, and thermal treatment due to their high efficiency, controlled heat distribution, and ability to handle a wide range of materials. The primary advantage of rotary furnaces lies in their continuous rotational movement, which ensures thorough mixing, even temperature distribution, and improved process consistency.

The 100 kg rotary furnace involved in this project reflects the common structural and functional characteristics of modern rotary furnace systems. Its main body consists of a cylindrical steel shell lined internally with high-temperature refractory material designed to resist thermal shock, abrasion, and chemical attack from molten materials. This lining plays a crucial role in protecting the furnace shell from heat damage while maintaining internal temperatures necessary for melting and processing operations.

The furnace operates through the action of two drive motors mounted on either side of the cylindrical body. These motors work together to provide steady rotational movement, enabling the charge materials inside the furnace to mix thoroughly as they melt or heat up. Modern rotary systems often rely on variable-speed motors to allow precise control of rotation speed, enhancing process flexibility and energy efficiency. The furnace in this project follows the same mechanical principle, although its motors required repair to restore functionality.

A blower system forms another important component of the rotary furnace. This unit supplies combustion air to promote efficient fuel burning, stabilize the internal temperature, and support control heating. In contemporary designs, blowers are often integrated with automated control systems for air-fuel ratio management, which contributes to improved thermal performance and reduced emissions.

The furnace is also equipped with two conical end covers, which enclose the cylindrical chamber during operation. These covers help retain heat, prevent heat loss, and maintain internal pressure and airflow patterns. Modern rotary furnaces typically use robust, insulated covers designed to minimize thermal leakage and enhance energy efficiency.

Overall, the furnace combines mechanical rotation, controlled combustion, and high-temperature insulation to achieve efficient thermal processing. Although the unit in this project had experienced significant deterioration, its design remains consistent with modern rotary furnace principles—emphasizing durability, energy efficiency, and uniform heat distribution. The maintenance work performed aimed to restore these key functional attributes by rehabilitating both the mechanical and thermal components of the system.

1.3 Statement of the problem

Rotary furnaces are critical equipment in thermal processing and metallurgical operations, and their performance depends heavily on the condition of their refractory lining, mechanical drive system, and air-handling components. However, prolonged exposure to high temperatures, continuous rotation, and abrasive materials leads to natural deterioration over time. Without timely maintenance, these issues can compromise safety, efficiency, and overall operational reliability.

The 100 kg rotary furnace examined in this project had experienced significant degradation prior to the commencement of rehabilitation work. A detailed inspection revealed that the internal refractory lining was extensively damaged, cracked, and partially detached, making it incapable of providing adequate thermal insulation and structural stability. This condition posed serious risks, including excessive heat loss, shell overheating, and potential refractory collapse during operation. In addition to thermal deterioration, the furnace suffered from major mechanical failures. Both drive motors were non-functional, preventing the rotational movement necessary for proper mixing, uniform heating, and efficient melting of materials. The blower system, responsible for supplying combustion air and maintaining consistent furnace temperature, was also defective, resulting in poor air–fuel mixing and unstable thermal conditions. Furthermore, the two conical end covers, which serve to retain heat and ensure sealing during furnace operation, were worn and compromised.

These combined issues rendered the furnace unsafe, inefficient, and unfit for operation. The degraded refractory lining increased heat losses and energy consumption, while the mechanical failures eliminated the furnace’s ability to rotate and maintain stable temperatures. Without comprehensive rehabilitation, the furnace could not support production activities or meet operational performance standards.

Therefore, a complete maintenance intervention was required to restore the furnace to its optimal functional state. This project aims to address the identified problems through relining the furnace with durable refractory materials, repairing the drive motors, restoring the blower system, and rehabilitating the structural components to ensure safe, reliable, and efficient operation.

1.4 Scope of the project

The scope of this project encompasses all activities required to restore the 80 kg rotary furnace to full operational condition, addressing its thermal, mechanical, and structural deficiencies. The project covers the assessment, removal, replacement, repair, and testing of critical furnace components to ensure safe, efficient, and reliable performance. The specific areas included in the scope of work are outlined below:

1. Inspection and assessment

   I. Conducting a detailed evaluation of the furnace to identify damaged refractory lining, faulty drive motors, blower defects, and deterioration of the conical end covers.

   II. Documenting the extent of wear, mechanical failures, and thermal inefficiencies.

2. Removal of damaged component

   I. Dismantling and removing the cracked, detached, and worn-out refractory lining from the inner chamber.

   II. Detaching faulty mechanical components such as the drive motors and blower for repair and servicing.

3. Refractory lining rehabilitation

   I. Procuring high-grade refractory cement suitable for high-temperature operations.

   II. Preparing the furnace interior for relining by cleaning, smoothing, and ensuring proper surface bonding.

III. Installing and curing a new refractory lining to restore thermal insulation, structural strength, and high-temperature resistance.

4. Mechanical system restoration

I. Repairing and servicing the two faulty drive motors to restore reliable and steady rotational movement.

II. Ensuring correct alignment, mounting, and operational balance of the motors.

III. Testing and adjusting rotational speed to suit operational requirements.

5. Blower system repair

I. Repairing or replacing defective components of the blower unit to restore consistent and adequate airflow.

II. Ensuring proper air delivery for combustion and stable internal temperature control.

6. Rehabilitation of conical covers

I. Inspecting, repairing, or reinforcing the two conical end covers to ensure secure sealing and heat retention.

II. Ensuring proper alignment and fitting to minimize heat loss during operation.

7. System assembly and reinstallation

I. Reassembling all components after repair and relining.

II. Ensuring secure installation and proper integration of the furnace's mechanical and thermal systems.

8. Documentation and reporting

I. Recording all maintenance procedures, materials used, observations, and test results.

II. Preparing a detailed report on the rehabilitation process and furnace performance after maintenance.

1.5. Aim of the study

The aim of the study was to fully restore the 100 kg rotary furnace to safe, reliable, and optimal operational condition by addressing all thermal, mechanical, and structural deficiencies, thereby ensuring efficient and continuous performance for industrial metallurgical and thermal processing applications.

1. Mechanical system rehabilitation

    I. Repair and restore the functionality of both drive motors to achieve smooth, reliable, and controlled rotational movement of the furnace.

    II. Ensure correct alignment, mounting, and operational balance to facilitate uniform heating, effective material mixing, and consistent thermal processing.

    III. Minimize mechanical wear and reduce the risk of future motor failures through proper servicing and lubrication.

2. Structural component rehabilitation

    I. Inspect, repair, and reinforce the two conical end covers to improve sealing, prevent heat loss, and maintain proper internal pressure.

    II. Strengthen the structural integrity of the furnace to withstand thermal and mechanical stresses during operation.

    III. Ensure the furnace meets safety standards for personnel and equipment during high-temperature processes.

3. Service life extension and reliability improvement

    I. Implement preventive maintenance measures that extend the furnace's operational lifespan.

II. Reduce the frequency of future breakdowns, minimize unplanned downtime, and enhance overall reliability of furnace operations.

III. Promote energy-efficient and sustainable operation by maintaining optimal thermal and mechanical performance.

1.5. Significances of the study

The purpose of the maintenance work carried out on the 80 kg rotary furnace was to restore the equipment to a safe, reliable, and efficient operational condition. Due to extensive wear, mechanical failure, and thermal deterioration, the furnace had become incapable of supporting production activities, posing both operational risks and energy inefficiencies. As the furnace is an essential component in metallurgical and thermal processing operations, its rehabilitation was necessary to ensure continuous and effective performance.

A primary purpose of the maintenance work was to re-establish the thermal integrity of the furnace by removing the damaged refractory lining and installing a new lining using high-quality refractory cement. This was essential for improving heat retention, maintaining stable operating temperatures, and protecting the furnace shell from excessive heat exposure. Proper relining also enhances the furnace’s durability, resistance to thermal shock, and ability to withstand repeated heating cycles.

Another key objective was to restore mechanical functionality by repairing the two drive motors responsible for the rotation of the furnace. The rotational movement is crucial for achieving uniform heating, proper material mixing, and consistent melting performance. Repairing the motors ensured that the furnace could operate smoothly and effectively without mechanical interruptions.

The maintenance work also aimed to revive the furnace’s air-handling system, particularly the blower unit, which plays a vital role in supplying combustion air and controlling the internal temperature. A functional blower ensures efficient combustion, optimal fuel utilization, and improved thermal performance. Restoring this system helped to stabilize the furnace’s heat distribution and overall efficiency.

Additionally, the rehabilitation of the two conical end covers was necessary to enhance the furnace’s structural integrity and heat containment. Properly functioning covers help minimize heat loss, maintain pressure balance, and improve the overall performance of the furnace during operation.

Overall, the purpose of the maintenance project was to fully rehabilitate the furnace by addressing its thermal, mechanical, and structural deficiencies. By restoring it to operational standards, the maintenance work aimed to extend the furnace’s service life, improve energy efficiency, enhance safety, and ensure reliable performance for future industrial processes.

CHAPTER TWO

LITERATURE REVIEW

2.1. Overview of industrial furnaces

Industrial furnaces are high-temperature processing systems widely used in metallurgical, manufacturing, chemical, and waste-management industries. Their primary function is to heat, melt, calcine, dry, or thermally treat materials under controlled atmospheric and temperature conditions. Unlike domestic heating systems, industrial furnaces are distinguished by their large scale, high temperature capability, engineered fuel systems, robust structural design, and application-specific performance requirements.

Furnaces may be classified based on fuel type, heating method, or industrial application. Regardless of category, the fundamental purpose of any furnace is to raise materials to a target temperature uniformly, efficiently, and safely.

1. Function and applications

A furnace is typically used to:

I. Melt metals for *casting*

II. Heat materials for *rolling, forging,* and other forming processes

III. Alter physical and mechanical properties during heat treatment

IV. Process non-metals in operations such as drying, calcination, and sintering

Since the furnace atmosphere directly contacts the material being processed, fuel selection is critical. Certain materials are sensitive to impurities such as sulfur or particulate matter from combustion, making some fuel types unsuitable.

2. Fuel types and their industrial use

Because flue gases interact with the product, the choice of energy source must minimize contamination:

I. Electricity
   a. *Induction and arc furnaces* for steel and cast-iron melting
   b. Offers clean, precise, and contamination-free heating

II. Liquid Fuels
   a. *Fuel oil* is commonly used for melting non-ferrous metals
   b. *Furnace oil* widely used in reheating and heat-treatment operations
   c. *Light Diesel Oil (LDO)* selected when low sulfur content is required

III. Gaseous Fuels
   a. Provide clean combustion and good temperature control

IV. Solid Fuels (less common)
   a. Typically avoided in modern designs due to particulate emissions

3. Efficiency and combustion considerations

An ideal furnace heats the maximum possible load to a uniform temperature using the least fuel and labor. Efficiency depends heavily on combustion quality:

I. Complete combustion with minimal excess air is necessary for efficient operation.

II. Furnace efficiencies can be as low as 7%, far lower than boiler efficiencies (>90%).

III. High operating temperatures (e.g., 1200 °C) cause flue gases to exit at similar or higher temperatures, resulting in significant heat losses through the chimney.

4. Essential components of industrial furnaces

All furnaces incorporate several key components:

I. Refractory Chamber

   a. Lined with insulating refractory materials

   b. Retains heat and withstands high operating temperatures

II. Hearth

   a. Supports the material being processed

   b. Constructed from refractories, often supported by water-cooled steel structures

5. Refractories: definition and requirements

A refractory is any material capable of withstanding abrasive, corrosive, and high-temperature environments. Because operating conditions vary widely across furnace systems, refractory materials are engineered in multiple grades, compositions, and shapes to suit specific applications.

6. Desired properties of refractory materials

A good refractory material should:

I. Withstand very high temperatures
II. Resist thermal shock (sudden temperature changes)
III. Endure attack from molten metals, slag, glass, and hot gases
IV. Carry load under service conditions
V. Resist abrasion and mechanical wear
VI. Offer low thermal conductivity to conserve heat
VII. Exhibit low thermal expansion to maintain structural stability
VIII. Avoid contaminating the processed material

7. Comparison of refractory types

Refractories are generally categorized as:

I. High-density refractories – stronger, durable, used for structural integrity

II. Low-density (insulating) refractories – provide excellent insulation and reduce heat loss

5. Furnace classification by fuel source

Industrial furnaces may operate on various energy sources depending on availability, cost, and process requirements:

I. Gas-fired furnaces (natural gas or LPG) offer high flame temperatures and quick response times.

II. Oil-fired furnaces are used in regions lacking gas infrastructure.

III. Electric furnaces provide precise temperature control and clean operation, making them ideal for metallurgical applications such as induction furnaces and electric arc furnaces.

While fuel choice affects operating cost and energy efficiency, the furnace design selected for metal melting or heat treatment is determined primarily by the temperature range and thermal uniformity required.

6. Furnace classification by industrial application

I. Industrial furnaces can also be categorized according to their specific function:

II. Blast furnaces for smelting iron ore

III. Electric arc furnaces (EAFs) for steel melting

IV. Induction furnaces for precise and rapid melting using electromagnetic induction

V. Heat-treating furnaces for annealing, hardening, and tempering

VI. Rotary kilns and rotary furnaces for calcining, drying, recycling, and metal melting

Among these, rotary furnaces are particularly valued for processes requiring continuous material agitation and uniform heating.

A rotary furnace is a cylindrical, rotating, and often slightly inclined chamber used for high-temperature industrial applications. The continuous rotation ensures thorough mixing and uniform exposure of materials to heat, making rotary furnaces versatile for metals processing, chemical reactions, waste treatment, and mineral processing.

Working principle of the 100 kg rotary furnace

The working principle of the 100 kg rotary furnace is based on the combined action of mechanical rotation, controlled heating, and regulated airflow to achieve uniform melting and thermal processing of materials. The furnace operates through the following coordinated processes:

5.1. Charging of material

The furnace is first loaded with the required quantity of metallic or mineral material (up to 100 kg). The material is introduced through one of the conical end openings, which is then securely closed to maintain proper sealing and heat retention during operation.

5.2. Mechanical rotation

Once charged, the furnace drum is rotated by two drive motors connected through shafts, gears, or couplings.

I. The rotation causes the material inside the furnace to tumble continuously.

II. This tumbling action ensures uniform exposure to heat, prevents localized melting, and improves mixing of the charge.

III. The rotational speed is kept moderate to avoid spillage while ensuring efficient agitation.

Rotation is essential for achieving homogeneous melting and consistent thermal treatment.

5.3. Heating process

Thermal energy is supplied by burners or heating elements positioned near the furnace chamber.

I. The heat generated raises the internal temperature to the required level for melting or heat treatment.

II. The newly installed refractory lining absorbs heat and reflects it back into the charge, increasing thermal efficiency.

III. The cylindrical shape and constant mixing ensure that heat is distributed evenly throughout the entire charge.

This process continues until the desired temperature and melting point are achieved.

5.4. Air supply and combustion control

The blower system supplies a controlled stream of air into the furnace.

I. Adequate air supply ensures efficient combustion of the fuel.

II. Airflow also influences the heating rate, flame stability, and internal temperature distribution.

III. By regulating the blower speed, operators can control the intensity of combustion and overall furnace temperature.

Proper airflow ensures complete combustion, reduces fuel wastage, and maintains consistent heating conditions.

5.5. Heat transfer mechanism

Heat transfer inside the furnace occurs through three modes:

I. Conduction: Heat travels through direct contact between the refractory lining and the charge material.

II. Convection: Hot gases circulate within the rotating chamber, transferring heat to the material surfaces.

III. Radiation: High-temperature refractory surfaces emit radiant heat that penetrates the charge.

The combination of these mechanisms results in a highly efficient heating process.

5.6. Melting and chemical reactions

As the charge absorbs heat:

I. Metals begin to melt uniformly due to tumbling and continuous heat exposure.

II. Impurities may separate or float depending on the material processed.

III. Any required chemical or metallurgical reactions occur under controlled conditions.

The furnace's design supports consistent melting with minimal hot spots or unmelted regions.

5.7. Discharging the melt

Once the material reaches the desired molten or processed state:

I. The rotation is slowed or stopped.

II. The conical covers are opened.

III. The molten or heated material is discharged manually or through auxiliary tools, depending on the application.

Proper handling ensures safe and efficient removal of the processed material.

5.8. Cooling and shutdown

After operation:

I. The furnace is allowed to cool gradually to avoid thermal shock to the refractory lining.

II. Blower and motors are switched off sequentially.

III. A post-operation inspection may be performed to ensure readiness for the next cycle.

Summary of the working principle

The 100 kg rotary furnace operates by rotating the charge material inside a refractory-lined cylindrical shell while applying controlled heat and airflow. Mechanical rotation ensures uniform mixing, the refractory lining retains heat, the blower provides combustion air, and the burners supply the required temperature. Through this integrated process, the furnace achieves consistent and efficient melting or thermal treatment of materials.

Applications of rotary furnaces

Rotary furnaces are used extensively in:

I. Metal processing and recycling: melting aluminum, lead, copper, and other non-ferrous metals
II. Iron ore reduction: pre-reduction and metallization processes
III. Chemical and mineral processing: calcination of lime, alumina, and catalysts
IV. Hazardous waste treatment: incineration of medical and industrial waste
V. Heat treatment: drying, annealing, and thermal conditioning of bulk materials

Their versatility, high throughput, and uniform heating make them indispensable in high-temperature industrial operations.

7. Key components of rotary furnaces

Rotary furnaces incorporate several critical components that affect performance, efficiency, and durability:

1. Furnace Body/Refractory Lining: A steel cylindrical shell forms the chamber where thermal processing occurs. Its thickness varies with temperature requirements and material load. The interior is lined with castable refractory cement or bricks that:

Protect the steel shell from extreme temperatures, reduce heat loss resist corrosion, abrasion, and chemical attack

Refractory degradation—cracking, spalling, or detachment—is one of the most common failure modes in rotary furnaces.

2. Drive mechanism

This includes motors, gearboxes, rollers, or gears that rotate the furnace. Variable-speed drives allow precise control over tumbling intensity and process time. Literature indicates that motor breakdowns due to overheating, misalignment, or lubrication failure are frequent causes of furnace downtime.

3. Heating system

Thermal energy is supplied by:

I. gas burners
II. oil burners
III. electric heating elements

A stable and controlled heat supply is essential for process efficiency.

4. Tilting mechanism (for combined rotary–tilting furnaces)

Some rotary furnaces incorporate tilting features to:

I. improve charging and discharging
II. facilitate pouring of molten metals
III. reduce labor and enhance process safety

Such designs are common in aluminum scrap recycling.

5. Seals, feeders, and discharge systems

Inlet and outlet seals prevent heat loss and material escape, while feeder systems ensure continuous loading.

Advantages of rotary furnace design

Research identifies several performance advantages:

I. Uniform heating: Continuous rotation eliminates temperature gradients.
II. Continuous operation: Enables high productivity and shorter processing cycles.
III. Efficient heat transfer: Gas flow and tumbling action increase thermal efficiency.
IV. Versatility: Suitable for a wide range of materials—solid, liquid, or gaseous.
V. Durability: Engineered to withstand extreme temperatures and harsh conditions.

These strengths make rotary furnaces ideal for processes involving recycled metals, ore processing, calcination, and hazardous waste disposal.

Relevance of literature to the rehabilitation project

The reviewed literature emphasizes that the performance of a rotary furnace depends primarily on:

I. integrity of the refractory lining
II. functionality of the drive motors and mechanical systems
III. efficiency of combustion air/blower systems
IV. structural condition of covers, seals, and insulation

The deterioration observed in the project furnace—including refractory failure, motor malfunction, and blower breakdown—aligns with common issues identified in industrial furnace literature. Comprehensive rehabilitation—including new refractory lining, mechanical repairs, and restoration of airflow systems—is therefore consistent with best practices for ensuring long-term reliability, thermal efficiency, and operational safety.

CHAPTER THREE

METHODOLODY AND MATERIAL USED

3.1 Introduction

This chapter presents the systematic methodology adopted for diagnosing, evaluating, and rehabilitating the 100 kg rotary furnace. The approach involved detailed inspection of the mechanical and thermal components, identification of faults, technical analysis of their causes, and the implementation of the appropriate corrective procedures. Rehabilitation activities were carried out sequentially to restore the furnace to optimal performance. The methodology is organized component by component, beginning with the rehabilitation of the two conical covers, followed by restoration of the blower system, repair of the drive motors, and replacement of the refractory lining.

3.2 Maintenance of the Two Conical Covers

3.2.1 Problem Identification

Inspection revealed that the two conical end covers exhibited the following defects:

I. Severe wear and deterioration of the internal refractory cement lining and bricks.

II. Surface erosion caused by prolonged exposure to high temperatures and thermal cycling.

III. Loss of structural rigidity due to mechanical deformation.

I. Gaps between the cover edges and the furnace body, resulting in heat leakage.

II. Corrosion and thinning of the metal surfaces from oxidation and chemical attack.

III. Damaged hinges and locking mechanisms that reduced sealing efficiency.

3.1.2 Technical Analysis of the Problem

The identified deterioration resulted from:

I. Thermal fatigue: Continuous expansion and contraction caused cracking and displacement of the refractory lining.

II. High-temperature oxidation: Long-term exposure to furnace gases weakened both the refractory and the metal shell.

III. Mechanical stress: Frequent opening and closing caused misalignment and wear, affecting sealing.

IV. Ageing and inadequate maintenance: The refractory lining had exceeded its service life without reinforcement.

These defects resulted in significant operational inefficiencies, including:

I. Excessive heat loss and increased fuel consumption.

II. Unstable internal furnace temperatures and airflow patterns.

III. Reduced thermal efficiency and inconsistent melting performance.

3.2.3 Repair and Rehabilitation Procedure

The rehabilitation of the conical covers involved both metal repairs and complete replacement of the internal refractory lining.

Step 1: Removal of Old Refractory Lining

I. The conical covers were detached from the furnace structure.

II. The worn refractory bricks and damaged cement lining were manually removed using chisels, hammers, and mechanical tools.

III. Residual refractory dust, debris, and slag deposits were thoroughly cleaned from the inner surfaces.

Step 2: Surface Preparation and Structural Assessment

I. The internal metal surface was cleaned with wire brushes and grinders to remove corrosion.

II. Metal thickness was measured to identify weakened sections requiring reinforcement.

III. Cracks, distortion, and corrosion spots were marked for corrective welding.

Step 3: Metal Repair and Reinforcement

I. Identified cracks were welded using high-temperature resistant electrodes.

II. Reinforcement plates were fabricated and welded to areas with reduced thickness.

III. Distorted surfaces were corrected using controlled heating and hydraulic pressing.

Step 4: Mixing and Application of New Refractory Cement

I. A commercially sourced fire-resistant cement was mixed with water and a bonding chemical according to manufacturer specifications.

II. The mixture was stirred to achieve a uniform, workable consistency.

III. The refractory cement was carefully applied and evenly spread along the inner walls of the conical covers.

IV. The lining was leveled and compacted to achieve uniform thickness and proper bonding.

Step 5: Curing and Drying of the Refractory Lining

I. The newly applied lining was allowed to air-dry for the recommended duration to ensure proper hydration.

II. The covers were then subjected to slow, controlled heating to cure the refractory and enhance its thermal strength.

Step 6: Sealing Surface Resurfacing

I. The sealing edges were ground and machined to ensure proper alignment with the furnace shell.

II. A high-temperature gasket or sealing compound was added to minimize heat loss during operation.

Step 7: Hinge and Locking Mechanism Repair

I. Damaged or worn hinges were replaced with new high-strength steel components.

II. Locking clamps were realigned, welded where necessary, lubricated, and tested for smooth operation.

Step 8: Reinstallation and Functional Verification

I. The rehabilitated conical covers were reinstalled onto the furnace.

II. Alignment was checked to ensure full contact with the furnace body.

III. Pressure and heat-leak tests were conducted to confirm proper sealing and thermal performance.

Figure 3.1: Preparation of Materials for the Casting of the Furnace

Figure 3.2: Continued Preparation of Materials for the Casting of the Furnace

3.3 Repair of the drive motors

3.3.1 Problem identification

Both drive motors responsible for rotating the furnace were found to be non-functional due to:

I. Burnt motor windings.

II. Worn bearings and damaged shafts.

III. Faulty electrical terminals and loose connections.

IV. Poor lubrication of moving components.

3.3.2 Technical analysis

The drive motor failure resulted from:

I. Excessive rotational load caused by debris obstructing the furnace rollers.

II. Overheating due to poor ventilation and thermal buildup.

III. Bearing wear caused by prolonged friction and inadequate lubrication.

IV. Electrical faults leading to winding burnout and terminal failure.

These problems resulted in:

I. Complete loss of rotational movement.
II. Non-uniform heating of the charge.
III. Increased melting time and reduced melting efficiency.

3.3.3 Repair Procedure

Step 1: Motor Disassembly

I. Motors were disconnected from the power supply and mounting frames.
II. Casings were opened to expose the internal components.
III. Shafts, windings, and bearings were inspected.

Step 2: Rewinding and Electrical Repairs

I. Burnt windings were removed and replaced with new insulated copper windings.
II. Terminals and insulators were cleaned or replaced.
III. Electrical continuity and insulation tests were conducted.

Step 3: Replacement of Mechanical Components

I. Worn bearings were removed and replaced with heavy-duty, high-temperature bearings.
II. Bent or worn shafts were straightened or replaced.
III. Pulley and roller alignment was corrected.

Step 4: Lubrication and Reassembly

I. All rotating parts were lubricated with high-temperature grease.

II. The motor housing was cleaned, sealed, and reassembled.

III. Motors were mounted back on the frame and connected to the furnace.

Step 5: Functional Testing

I. Motors were tested under no-load conditions to confirm smooth rotation.

II. Voltage and current readings were checked for electrical stability.

III. Motors were gradually coupled to the furnace drum to confirm proper operation under load

Figure 3.3: Uninstallation of the Electric Motors for Offsite Repairs

Figure 3.4: The Electric Motors on the Ground after Removal from the Base

3.4 Replacement of the Refractory Lining

3.4.1 Problem Identification

Inspection of the furnace interior revealed:

I. Cracks and spalling in multiple sections of the lining.
II. Completely missing areas where the lining had detached.
III. Weak bonding between the existing refractory and the steel shell caused by thermal fatigue.
IV. Significant loss of insulation leading to excessive heat escape during operation.

3.4.2 Technical Analysis

The degradation of the refractory lining was due to:

I. Thermal shock: rapid heating and cooling cycles caused cracking and disintegration.
II. Mechanical abrasion: continuous contact with scrap metal and molten charge wore down the lining.
III. Chemical attack: slag and furnace gases reacted with the lining, weakening its structure.

IV. Aging and natural wear: prolonged operation reduced the lining's strength and adherence.

A compromised lining resulted in:

I. Excessive heat loss and higher fuel consumption.

II. Risk of overheating and deforming the steel shell.

III. Reduced melting efficiency and unsafe working conditions.

3.4.3 Lining replacement procedure

Step 1: Removal of Damaged Lining

I. All old refractory bricks, castable material, and cement were manually chipped out using chisels and power tools.

II. Loose material, slag, and dust were removed from the steel surface.

III. The interior shell was brushed and cleaned thoroughly to expose the metal base.

Step 2: Shell Repair and Preparation

I. The steel shell was inspected for corrosion, cracks, and deformation.

II. Weak or corroded sections were repaired through welding and grinding.

III. The surface was primed to improve refractory bonding and prevent oxidation.

Step 3: Application of New Refractory Material

I. High-temperature fire cement (castable refractory) was prepared by mixing with water and chemical binders according to manufacturer specifications.

II. The mixture was applied evenly inside the furnace using trowels and hand tools.

III. The lining was compacted and smoothed to achieve uniform thickness.

IV. Metallic anchors were installed where necessary to enhance bonding strength and prevent future detachment.

Step 4: Drying and Curing Process

I. The applied refractory lining was allowed to air-dry for 24–48 hours to remove surface moisture.

II. A controlled heating schedule was carried out:

a. Initial low-temperature heating to remove internal moisture.

b. Gradual temperature increases to fully cure and strengthen the refractory material.

III. This process ensured maximum durability and thermal resistance.

Step 5: Final Inspection

I. Lining thickness, smoothness, and uniformity were measured and verified.

II. Any small voids or cracks were patched with additional fire cement.

III. A low-temperature test firing confirmed effective heat retention and structural stability.

Figure 3.5: The Furnace, After Decommissioning in Preparation for Casting.

Figure 3.6: Ongoing Casting of the Rotary Furnace

3.5 Lining of the Chimney

3.5.1 Problem Identification

Inspection of the furnace chimney revealed:

I. Cracks and spalling in the inner surface.

II. Loss of thermal insulation leading to heat loss and potential structural damage.

III. Accumulation of soot and debris due to rough or deteriorated lining.

IV. Weak bonding between existing lining and metal surfaces.

3.5.2 Technical Analysis

The deterioration of the chimney lining was primarily caused by:

I. Thermal shock: repeated heating and cooling cycles caused cracking and material fatigue.

II. Corrosion from flue gases: acidic or hot gases degraded the inner surface.

III. Aging: prolonged operation without maintenance weakened the lining.

Consequences of a compromised chimney lining included:

I. Increased heat loss reducing overall furnace efficiency.

II. Risk of structural damage to the chimney.

III. Inefficient exhaust flow leading to unstable combustion.

3.5.3 Lining Procedure

Step 1: Surface Preparation

I. The old lining was removed manually using chisels and scrapers.

II. Dust, soot, and loose particles were cleaned from the chimney walls.

III. Metal surfaces were inspected for corrosion or deformation and repaired where necessary.

Step 2: Fire Cement Preparation

I. High-temperature fire cement was mixed with water and chemical additives to achieve the proper consistency for application.

Step 3: Application of Fire Cement

I. The mixture was evenly applied to the inner surface of the chimney using trowels and brushes.

II. Layers were applied gradually to ensure uniform thickness and avoid air pockets.

III. Proper compaction was performed to ensure strong bonding with the chimney walls.

Step 4: Drying and Curing

I. The lining was air-dried for 24–48 hours to allow initial setting.

II. A gradual heating schedule was applied to cure the fire cement fully and enhance its thermal resistance.

Step 5: Final Inspection

I. The lining was checked for cracks, voids, and uniformity.

II. Any imperfections were patched with additional fire cement.

III. A low-temperature test firing verified heat retention and structural stability.

3.6 Design of the furnace: capacity and process requirements

Designing a 100 kg rotary furnace requires a clear understanding of the material handling capacity, thermal load, operational parameters, and the specific industrial processes the furnace must perform. These considerations form the foundation for selecting the appropriate structural materials, heating system, refractory lining, rotation mechanism, and control components. This section outlines the major factors influencing the furnace design.

3.7 Furnace capacity requirements

1. Material Charge Capacity

The furnace is designed to accommodate a 100 kg batch of metallic or mineral material. This capacity influences the internal volume of the furnace, the strength of the shell, and the required heat input. Factors considered include:

I. Bulk density of the charge material

II. Volume expansion during heating

III. Allowance for tumbling and mixing during rotation

To prevent overfilling and to ensure efficient material agitation, the working chamber is sized to hold 120–140 kg of material volume, even though the operational charge is 100 kg.

2. Operation Mode

   The furnace is intended for batch or semi-continuous operation, depending on the application. Batch processing allows complete melting or treatment before unloading, while semi-continuous operation is possible with controlled feeding and gradual discharge.

3.8 Design for furnace shell

The core of the furnace is a horizontal cylindrical shell (steel drum), fabricated from welded mild-steel plates. The plate thickness depends on furnace size and expected thermal/mechanical stresses; for small-to-medium furnaces (under 1 tons capacity), typical shell thickness may be in the range of 5–10 mm, adjusted upwards if structural reinforcement is needed.

Design calculations & assumptions for your 100 kg rotary furnace shell

Below is a worked-out example of how to size and check a mild-steel cylindrical shell for your furnace, given:

I. Internal diameter (ID): 0.7 m (nominal, between 0.6 – 0.8 m)

II. Shell length (effective heated length): 1.4 m (midpoint of 1.2–1.6 m)

III. Material: Mild steel plate, shell thickness to be determined

IV. Operating internal temperature (refractory inside) up to ~1,200–1,400 °C → shell metal temperature will be much lower due to refractory + insulation, but must still handle heat + mechanical loads

V. Shell is supported on rollers/trunnions, at two or more points

We'll consider static mechanical load (self-weight + refractory + load) and bending / sagging between supports, and add a factor of safety (FoS).

3.8.1. Estimate loads

I. Weight of shell: Assume shell thickness t (to be determined), shell internal radius = r = 0.35 m → shell outer radius ~ r + t.

II. Weight of refractory lining + insulation + charge load: For a 100 kg batch, plus lining ~ (approx estimate) maybe 200–300 kg distributed along the shell. (Exact mass depends on lining thickness/material density.)

III. Support reaction loads: When supported at two rollers, roughly half the weight on each, but bending moment between supports must be checked.

Because precise loads depend on refractory mass, lining thickness, material density, we treat them in design as a combined uniformly distributed load plus concentrated loads at supports.

3.8.2. Bending / sagging (beam-on-supports model)

The shell acts like a beam supported at its riding rings (rollers). Between supports, it will tend to sag under its own weight and internal load — this can cause deformation and lining damage. This is described in literature on kiln design.

To limit sagging / bending, choose shell thickness and possibly stiffening rings (riding rings). Many kilns use riding rings / tyre reinforcement welded to the shell at support positions to distribute load, reduce stress concentration, and protect the shell from wear.

Given the small size (0.7 m diameter, 1.4 m long), one may compute bending stress using basic beam theory:

Where M = bending moment at midspan, y = distance from neutral axis (shell thickness/2), I = moment of inertia.

But given shell is "thin" (shell thickness << radius), a safer approach is to treat it with thin-shell + shell-ring + stiffening (riding rings) + ensure the plate + ring design resists both bending and local deformations.

3.8.3. Thermal considerations & expansion

Because interior temperature is very high (up to melting / high-temperature processing), the shell senses significant thermal gradient. In large rotary kilns, studies show shell outside can reach ~500 °C in burning zones, leading to thermal stress, possible elastic or even plastic deformation if not properly cooled/insulated.

For a small furnace:

I. Use a thick refractory + insulation layer so shell temperature remains moderate (ideally <200–300 °C) — this reduces thermal stress on shell.
II. Provide clearance for thermal expansion (especially at riding rings), and ensure the shell can expand without distorting the lining.
III. Optionally: use stiffening rings or "tyres" / riding rings to support shell and help maintain circularity under thermal/mechanical load.

3.8.4. Factor of safety (fos)

Given thermal cycling, rotational stresses, weight loads, it is prudent to adopt a conservative FoS when sizing shell thickness. For small furnaces, a FoS between 2.0 to 3.0 (or more) is reasonable. Many industrial designs add corrosion/wear allowance plus FoS. Some design examples for furnaces/walls use modest thickness (e.g. 5 mm) when pressure or loads are low — but those may not be appropriate for a rotating, high-temperature furnace shell.

Given your earlier specification (6–10 mm mild-steel shell), using the upper end (e.g. 8–10 mm) is justified to ensure robustness.

3.8.5. Recommended shell thickness & reinforcement

Recommended baseline:

I. Shell thickness: 8 mm (mild steel) — as a minimum for your size and operating conditions.
II. Use welded riding rings / shell-rings / stiffening rings at support points to distribute load and protect the shell from wear. This is standard in rotary kiln/furnace design.
III. Provide thermal insulation and refractory lining sufficiently thick to keep steel shell temperature moderate.

If the furnace will experience heavy loads, frequent cycling, or high vibrations/thermal gradients: consider 10 mm shell thickness or reinforcement (e.g. external stiffening rings).

Table 3.1: shell thickness and reinforcement

PARAMETER	SYMBOL	VALUE	NOTES / FORMULA
FURNACE CAPACITY	–	100 kg	Material to be processed
SHELL MATERIAL	–	Mild steel	Yield stress ~250 MPa
INTERNAL DIAMETER	D	0.7 m	Nominal
SHELL LENGTH	L	1.4 m	Nominal
SHELL THICKNESS	t	8–10 mm	Selected based on load + FoS
INCLINATION	θ	1–5°	Slight tilt for material movement
REFRACTORY LINING + INSULATION	–	~50–70 mm	Protects steel from heat
ESTIMATED TOTAL WEIGHT	W	300 kg → 3000 N	Shell + lining + material
SUPPORT REACTIONS	R	1500 N per roller	Two rollers at ends
MAXIMUM BENDING MOMENT	M	≈ 375 N·m	Simple uniform load, M = wL/8
MOMENT OF INERTIA (THIN SHELL APPROX)	I	I = (π/4)(r_outer^4 – r_inner^4)	r_outer = 0.354 m, r_inner = 0.346 m
BENDING STRESS	σ_b	σ_b = M·y/I	Compare with allowable stress (σ_allow = 125 MPa for FoS = 2)
FACTOR OF SAFETY	FoS	2–3	Accounts for mechanical + thermal stress
RIDING RINGS	–	Yes	Welded at roller supports for load distribution
SHELL TEMPERATURE (OUTSIDE)	–	<300 °C	Ensured by insulation

3.9 Design for conical end covers (frustums) –

The conical end covers are simply mild-steel frustums welded to the shell, lined with refractory, providing structural support, thermal protection, and functional openings for material and gases. The design is robust, safe, and complements the cylindrical shell.

1. Material

   I. Steel: Mild steel, 6–10 mm thick (same as shell).

   II. Refractory lining: High-temperature castable refractory (50–70 mm thick).

2. Dimensions & shape

   I. Shape: Frustum (conical section).

   II. Angle: Slight taper for smooth flow of materials.

   III. Diameter: Matches cylinder end (ID = 0.7 m), tapering to desired port diameter.

   IV. Thickness:

      a. Steel: 6–10 mm

      b. Refractory lining: 50–70 mm

3. Design considerations

   I. Mechanical strength:

      a. Must withstand thermal expansion and internal load.

      b. Factor of safety: 2–3 (same as cylinder).

   II. Thermal protection:

      a. Refractory lining prevents steel from overheating.

   III. Ports / Openings:

      a. One end: feed + burner port

      b. Other end: exhaust or discharge

c. Ports sized for material flow and gas velocity

IV. Mounting:

a. Welded to cylinder shell for rigidity

b. Optionally bolted for easy maintenance

4. Refractory Lining Procedure

I. Clean steel surface and prepare for bonding.

II. Apply refractory castable to inner surface (~50–70 mm).

III. Use formwork to shape lining to frustum geometry.

IV. Allow curing (24–48 hours).

V. Slowly heat furnace to remove moisture and prevent cracks.

Table 3.2: Conical End Cover

COMPONENT	MATERIAL	THICKNESS	NOTES / FEATURES
CONICAL END COVER	Mild steel	6–10 mm	Frustum, welded/bolted to shell
REFRACTORY LINING	Castable refractory	50–70 mm	High-temperature, protects steel
FEED / BURNER PORT	–	Sized per process	One end for feed/burner
EXHAUST / DISCHARGE PORT	–	Sized per process	Other end for material exit
ANGLE / TAPER	–	Slight	Allows smooth material flow
FACTOR OF SAFETY	–	2–3	Handles thermal & mechanical stress

3.10 Design for refractory lining:

Inside the shell and cones, a refractory lining is installed. This lining serves as thermal insulation, protects the steel shell from high temperatures, abrasion, corrosion from molten materials, and thermal shock.

3.10.1. Purpose of refractory lining

I. Protects the steel shell from high temperatures (up to 1200–1400 °C).
II. Reduces heat loss, improving thermal efficiency.
III. Resists abrasion, corrosion, and chemical attack from molten or heated materials.
IV. Provides structural support to maintain cylindrical shape during operation.

3.10.2. Material selection

I. Common materials:

a. Firebricks (high alumina or silica-based)
b. Castable refractory cement (high-temperature cement)

3.10.3. Recommended for small rotary furnace:

I. High-temperature castable refractory cement, 50–70 mm thick.
II. Properties to consider:
III. Max service temperature: ≥ 1400 °C
IV. Thermal conductivity: Low, to reduce heat loss
V. Mechanical strength: Can withstand tumbling material
VI. Thermal shock resistance: Can handle repeated heating/cooling

3.10.4. Design considerations

I. Thickness: 50–70 mm, depending on max temperature and heat retention requirements.

II. Bonding: Use refractory cement to adhere lining to shell and end covers.

III. Expansion allowance: Leave small gaps (2–5 mm) between lining and steel shell for thermal expansion.

IV. Shape:

a. Cylindrical inside the shell

b. Frustum shape in conical ends

V. Insulation: Optional layer outside lining for energy efficiency.

3.10.5. Simplified design procedure

I. Clean shell surface: Remove rust, dirt, and debris.

II. Apply anchor system (if needed): Metal pins or anchors can help hold lining.

III. Mix refractory castable: Follow manufacturer instructions.

IV. Trowel lining inside cylinder: Start with bottom, gradually build up to desired thickness (50–70 mm).

V. Form conical ends: Use formwork to shape lining to match frustums.

VI. Curing: Let the lining cure for the recommended time (usually 24–48 hours).

VII. Drying & firing: Slowly heat the furnace to gradually remove moisture and prevent cracks.

3.11 Design riding rings and rollers

The furnace shell is fitted externally with riding rings (tyres) machined from mild steel; these ride on support rollers, which are mounted on a robust structural steel base frame. This roller-support system bears the furnace's weight and facilitates rotation with minimal friction.

1. Rollers:

I. Carry the weight of the furnace (shell + refractory + material).

II. Provide a low-friction surface for rotation.
III. Maintain alignment and tilt angle of the cylinder.

2. Material

I. Riding Rings: Mild steel, 8–12 mm thick
II. Rollers: Cast steel or forged steel (hard, wear-resistant)

3. Design considerations

Riding Rings:

I. Welded to the cylinder at roller positions.
II. Diameter slightly larger than shell to allow clearance.
III. Width: 50–100 mm (depends on furnace size and load).
IV. Must align with roller centers for even load distribution.

Rollers:

I. Diameter: Typically 150–200 mm for small furnaces.
II. Mounted on fixed trunnions.
III. Designed to carry half the furnace load each (for two rollers).
IV. Surface should be hardened or coated to reduce wear.
V. Include adjustment mechanism for tilt and alignment.

4. Load calculation (simplified)

I. Total weight of furnace: ~300 kg → ~3000 N
II. Each roller supports: 3000 N ÷ 2 = 1500 N
III. FoS: 2–3 → rollers and rings designed for 3000–4500 N per roller

Table 3.3: Riding Rings and Rollers

Component	Material	Dimensions / Specs	Notes / Features
Riding rings (tyres)	Mild steel	Width 50–100 mm, thickness 8–12 mm	Welded to shell at roller points, slightly larger diameter than shell
Rollers	Cast / forged steel	Diameter 150–200 mm	Supports shell weight, allows smooth rotation
Load per roller	–	1500 N (actual), 3000–4500 N with FoS	Two rollers per furnace
Mounting	–	Fixed trunnions	Adjustable for tilt and alignment
Function	–	–	Prevent shell sagging, ensure smooth rotation

Design for mechanical & electrical systems (drive, rotation, combustion)

I. Drive mechanism: Rotation is achieved by friction between the furnace shell's riding tyres and the rollers. The driving torque is supplied by an electric motor connected to a gearbox or worm-gear reducer; the gearbox reduces motor speed and increases torque, producing slow, controlled rotation — typical rotation speeds are in the range of 1–2 revolutions per minute (rpm) for melting furnaces.

II. Bearing / support system: The furnace shell rests on rollers supported by a structural frame. Bearings or pillow-block supports ensure smooth rotation and accommodate axial and radial loads.

III. Combustion / Heat source: Heating is achieved via a burner mounted on the charging-door/conical end, using suitable fuel (gas, oil, etc.), depending on design. The burner supplies heat which radiates/conducts to the charge material inside the refractory-lined drum.

IV. Exhaust / Venting & Fume Handling: On the opposite side, an exhaust block or vent is provided for flue-gas removal; for metal-melting furnaces, a tapping hole or slag discharge port may also be included.

V. Control and Safety Systems (optional/modern): Advanced furnaces may incorporate temperature sensors, airflow/combustion control, tilting mechanisms (for tilting rotary furnaces), variable frequency drives (VFDs) for motors, emergency/manual drive systems in case of motor failure, and structural anchoring to concrete base for stability.

3.12 Furnace motor & drive design

3.12.1. Design Objectives

The motor and drive system of a rotary furnace must provide:

I. Smooth rotation of the furnace cylinder under full load

II. Sufficient torque to overcome friction and start-up resistance

III. Continuous operation at the desired rotational speed

IV. Durability under thermal, mechanical, and dynamic stresses

Proper design ensures uniform heating, operational reliability, and safety during furnace operation.

Table 3.4: Design Assumptions

Parameter	Symbol	Value / Notes
Mass of furnace shell + lining	M_shell	200 kg (example)
Mass of material charge	M_load	80 kg
Total mass	M_total = M_shell + M_load	280 kg
Radius (roller center to axis)	R	0.4 m
Coefficient of friction (steel–steel)	μ	0.2
Desired furnace speed	n	2 rpm
Gearbox / drive efficiency	η	0.75 (75%)
Gearbox reduction ratio	GR	40

I. Torque Calculation

The load torque required to rotate the furnace is calculated using:

$$T_{load} = M_{total} \times g \times R \times \mu$$

$$Where\ g = \frac{9.81\, m}{s^2}$$

Calculation Example:

$$T_{load} = 280 \times 9.81 \times 0.4 \times 0.2$$

This torque represents the force needed at the drum–roller interface to rotate the loaded furnace.

II. Motor Torque Requirement

Considering a gearbox with ratio GR and efficiency η, the motor torque is:

$$T_{motor} = \frac{T_{load}}{}(GR \times \eta)$$

Calculation Example:

$$T\_motor = 219.5 / (40 \times 0.75)$$

$$\approx 7.32\, N$$

Type equation here.

This is the torque required at the motor shaft under steady-state operation.

III. Motor Power Calculation

The rotational speed of the drum: n = 2 rpm → angular speed:

$$\omega drum = 602\pi n \approx \frac{0.209\, rad}{s}$$

Assuming a motor speed of 960 rpm with the gearbox:

$$\omega motor \approx \frac{100.5\, rad}{s\,(after\, reduction)}$$

The theoretical motor power is:

$$P = Tmotor \cdot \omega motor$$

$$P \approx 7.32 \times 100.5 \approx 736\, W \approx 1\, HP$$

Where:

Tmotor = motor torque (Nm)

}ωmotor = motor angular speed (rad/s)

PPP = theoretical motor power (W or HP)

Note: In practice, motors are oversized (10–15 HP) to handle start-up torque, dynamic loads, and long-term reliability.

IV. Safety Factor & Design Considerations

a) Apply a torque/power safety factor of 2–3× to account for:

   i. Start-up load
   ii. Inertia of shell and material
   iii. Friction variations and jamming
   iv. Shell adhesion with refractory/melt

b) Ensure structural integrity of:

   i. Furnace shell, riding rings, rollers, base frame, bearings

c) Allow thermal expansion gaps and use high-temperature materials at the shell–lining interface.

d) Include mechanical lock or brake to prevent unintended rotation during idle or material handling.

Table 3.5: Motor & Drive Requirements

Parameter	Value / Notes
Total furnace mass (shell + lining + charge)	280 kg
Load torque (T_load)	219.5 Nm
Gearbox ratio (GR)	40
Motor torque (T_motor)	7.32 Nm
Drum speed	2 rpm
Motor speed	960 rpm (after reduction)
Theoretical motor power	736 W (~1 HP)
Recommended motor size	10–15 HP (oversized for safety)
Safety factor	2–3×

VI. Motor torque & power calculation (design estimation)

To properly size the motor and drive system for a rotary furnace, we must estimate the torque required to rotate the furnace shell under load. This depends on several factors:

Mass of shell, lining, and material charge

Friction at rollers

Gearbox or drive efficiency

Desired rotational speed

VII.Safety factors

Below is a simplified calculation suitable for an 80–100 kg furnace.

Table 3.6: Assumptions for Estimation

Parameter	Symbol	Typical Value / Notes
Mass of shell + lining	M_shell	kg
Mass of material charge	M_load	kg
Effective total mass	M_total = M_shell + M_load	kg
Radius from roller center to axis	R	m (e.g., 0.4 m)
Coefficient of friction	μ	0.2 (steel–steel, lubricated)
Desired drum speed	n	rpm (e.g., 2 rpm)
Gearbox & drive efficiency	η	0.7–0.8 (70–80%)

VIII.Torque Calculation

The load torque required to overcome friction:

$$Tload = Mtotal \cdot g \cdot R \cdot \mu$$

Where:

g=9.81 m/s²g (gravitational acceleration)

Mtotal = total mass of the furnace (kg)

R = radius at which torque acts (m)

μ = coefficient of friction

Example Calculation:

$$Mshell + MliningMloadMtotalR = 200\ kg = 80\ kg = 280\ kg = 0.4\ m, \mu = 0.2\ Tload$$

$$= 280 \times 9.81 \times 0.4 \times 0.2 \approx 219.5\ NmT_{\{\backslash text\{load\}\}}$$

$$= \ 280\ \times 9.81\ \times 0.4\ \times 0.2\ \approx 219.5\ \backslash text\{Nm\}Tload$$

$$= 280 \times 9.81 \times 0.4 \times 0.2 \approx 219.5\ Nm$$

This is the torque required at the drum–roller interface to rotate the loaded furnace.

Motor Torque Requirement

If a gearbox is used (ratio GRGRGR) with efficiency η\etaη:

$$Tmotor = GR \cdot \eta Tload$$

Example:

GR = 40, η = 0.75

$$GR = 40, \eta = 0.75\ Tmotor \approx 219.540 \cdot 0.75 \approx 7.32\ NmT_{\{\backslash text\{motor\}\}}$$

$$\approx \backslash frac\{219.5\}\{40\ \cdot 0.75\} \approx 7.32\ \backslash text\{Nm\}Tmotor \approx 40 \cdot 0.75219.5$$

$$\approx 7.32\ Nm$$

IX.Motor Power Calculation

Step 1:Drum rotational speed:

$$n = 2\ rpm \Rightarrow \omega drum = 602\pi n \approx \frac{0.209\ rad}{s}$$

Step 2: Motor Angular Speed

Motor speed after gearbox reduction:

$$\omega motor \approx \frac{100.5\ rad}{s}$$

Step 3: Theoretical Motor Power

Motor speed (after gearbox reduction): ω_motor ≈ 100.5 rad/s

Theoretical power required:

$P = Tmotor \cdot \omega motor\ P \approx 7.32 \times 100.5 \approx 736\ W \approx 1\ HPP\ \approx 7.32\ \times 100.5$

$\approx 736\ \backslash text\{W\} \approx 1\ \backslash text\{HP\}P \approx 7.32 \times 100.5 \approx 736\ W \approx 1\ HP$

Note: Small-to-medium rotary furnaces often use 10–15 HP motors to account for start-up torque, dynamic loads, and safety margin.

X. Safety factors & design margin

i. Use a torque/power safety factor of 2–3× to account for:
   a. Start-up load
   b. Inertial load of furnace and material
   c. Friction variations
   d. Shell adhesion forces with refractory/melt inside
   e. Possible jamming or uneven loading

ii. Ensure structural strength of:
   a. Shell, tyres, rollers, base frame, and bearings
   b. Accommodate thermal expansion, vibration, and dynamic stresses

iii. Use high-temperature materials for shell–lining interface and allow for thermal expansion gaps.

iv. Include a mechanical lock or brake to prevent unintended rotation during idle, charging, or discharging.

3.12.3. Working Principle (Basic Operational Flow)

i. Raw material (scrap, metal charge, ore, etc.) is fed into the furnace via the charging door at one conical end.

ii. A burner ignites, supplying heat to the interior; the refractory lining insulates and sustains high temperatures.

iii. The motor-gear drive rotates the furnace shell slowly (1–2 rpm), causing contents to tumble and mix, ensuring uniform heat exposure and melting or thermal processing.

iv. Combustion air provided by blower (if equipped) ensures proper combustion and temperature stability. Exhaust gases escape via the vent/exhaust block at the opposite end.

v. Once melting or processing is complete, molten metal or processed material is tapped/discharged via the central tapping hole or discharge port. Slag or residual waste may be removed similarly.

3.12.4.Thermal system and combustion design

Thermal system and combustion design is critical for industrial furnaces, boilers, and heating systems. It involves calculating the heat required to raise the temperature of materials, selecting appropriate fuel, determining the air supply for combustion, and sizing mechanical components like blowers and motors. A proper design ensures energy efficiency, safety, and operational reliability.

Rotary furnaces are widely used for metal heating, sintering, or chemical processing. They consist of a rotating drum, material feed, fuel supply, and exhaust system. The design combines thermal energy calculations and mechanical considerations to ensure uniform heating and optimal fuel consumption.

I. System Specifications

For design purposes, consider a small rotary furnace with the following parameters:

a) Furnace type: Rotary

b) Material: Steel shell + refractory lining + load

c) Mass of shell + lining: 200 kg

d) Mass of load: 80 kg → Total mass Mtotal=280M = 280Mtotal=280 kg

e) Initial temperature: T_i = 25\,^\circ\text{C}

f) Final temperature: T_f = 600\,^\circ\text{C}

g) Specific heat of steel: cp=0.46 kJ/kg\cdotpKc_p = 0.46 \ \text{kJ/kg·K}cp =0.46 kJ/kg\cdotpK

h) Furnace efficiency: η=0.85\eta = 0.85η=0.85

i) Fuel: Natural gas (HHV = 50,000 kJ/kg)

j) Stoichiometric air for CH□: 17.2 kg air/kg fuel

k) Excess air: 20 %

l) Material density: ρ=7,800 kg/m³\rho = 7,800 \ \text{kg/m³}ρ=7,800 kg/m³

m) Residence time: 30 minutes (1800 s)

II. Fuel requirement

The fuel mass is determined using the higher heating value (HHV) of the fuel and furnace efficiency:

Fuel mass = *HHV* · *ηQ Fuel mass* = 73,94050,000 × 0.85

≈ 1.74 *kg of natural gas*{*Fuel mass*} = *frac*{73,940}{50,000 × 0.85}

≈ 1.74 *text*{*kg of natural gas*}*Fuel mass* = 50,000 × 0.8573,940

≈ 1.74 *kg of natural gas*

This ensures the furnace receives enough energy to achieve the target temperature while accounting for efficiency losses.

III. Air requirement for combustion

Stoichiometric Air

The mass of air required for complete combustion:

$$Air\ mass = Fuel\ mass \times Stoichiometric\ AFR\ Air\ mass = 1.74 \times 17.2$$

$$\approx 29.9\ kg\{Air\ mass\} = \ 1.74\ \times 17.2\ \approx 29.9\ \{kg\}Air\ mass = 1.74 \times 17.2$$

$$\approx 29.9\ kg$$

Excess Air

To ensure complete combustion, excess air is added (typically 10–30%):

Air supplied=29.9×(1+0.2)≈35.9 kg air

Proper air supply prevents incomplete combustion, soot formation, and reduces CO emissions.

IV. Furnace volume and residence time

The furnace volume is determined to provide enough residence time for material heating:

$$Vfurnace = \rho Mtotal = 7{,}800280 \approx 0.036\ m^3$$

The volume ensures that material stays in the furnace long enough to reach the desired temperature.

V. Motor and blower power calculation

Blowers supply the combustion air. Assuming:

Blower efficiency: ηfan=0.7

Pressure rise: ΔP=2,000 Pa

$$m\dot{}air = residence\ timeAir\ supplied = 180035.9 \approx \frac{0.02\ kg}{s} Pblower = m\dot{}air \cdot \Delta P\eta fan$$

$$= 0.02 \times 20000.7 \approx 57\ WP_{\{\backslash text\{blower\}\}}$$

$$= \backslash frac\left\{\ \dot{}\ \{m\}_{\{\backslash text\{air\}\}} \cdot \Delta P\right\}\left\{\eta_{\{\backslash text\{fan\}\}}\right\} = \backslash frac\{0.02\ \times 2000\}\{0.7\}$$

$$\approx 57\ \ \backslash text\{W\}Pblower = \eta fanm\dot{}air \cdot \Delta P = 0.70.02 \times 2000 \approx 57\ W$$

This is the electrical power required to drive the air blower.

VII. Thermal system and combustion procedure

To design a rotary furnace thermal system:

a) Define material and operating parameters: mass, specific heat, initial/final temperature, residence time.

b) Calculate heat required: Q=m·cp·ΔTQ

c) Estimate heat losses: conduction, convection, radiation.

d) Determine fuel requirement: Fuel mass=Q/(HHV·η)

e) Calculate air requirement: stoichiometric + excess air.

f) Size furnace volume: based on residence time and material flow.

g) Determine blower/motor power: for air supply and rotation if necessary.

h) Check energy balance: Qfuel=Quseful+QlossesQ

i) Optimize design: consider insulation, fuel type, safety margins

Table 3.7: Thermal system and combustion

Calculation	*Formula*
Heat required	*Q=m·cp·ΔTQ*
Fuel mass	*Fuel=QHHV·η*
Stoichiometric air	*Air=Fuel·AFR*
Air supplied	*Air=Air(1+Excess air fraction)*
Furnace volume	*V=MtotalρV*

Table 3.8: Summary Table

Parameter	Value
Heat required	73,940 kJ
Fuel mass	1.74 kg

Parameter	Value
Air supplied	35.9 kg
Furnace volume	0.036 m^3
Blower power	57 W

3.13 Materials selection

Material selection is a critical aspect in designing a rotary furnace because the furnace must endure mechanical loads, high temperatures, abrasion, corrosion, and thermal cycling while ensuring operational safety, durability, and efficiency. The choice of materials affects structural integrity, thermal performance, service life, and cost-effectiveness.

i. Shell & structural steel: Mild steel (MS) plates for the drum/cylinder and conical ends; structural steel (angle irons, channels, beams) for the base frame and supports.
ii. Riding rings and rollers: Machined mild steel, with smooth finish to minimize friction and wear.
iii. Refractory lining materials: High-temperature resistant refractory castables or bricks: e.g., silica-based or alumina-based materials, low-cement castables, semiplastic ramming masses, or precast refractory shapes depending on application (ferrous, non-ferrous, chemical environment).
iv. Insulation/backing (optional): In some designs, additional insulation backing or insulation layers may be used behind the refractory lining to improve thermal performance and reduce heat loss.
v. Drive & mechanical components: Electric motor, gearbox or reduction drive (worm gear or gearbox + chain/gear), shaft, couplings, bearings or pillow-block bearings mounted on base frame, bolts, brackets, fasteners.

3.13.1 Criteria for material selection

The primary factors influencing material selection for the furnace components include:

1. Mechanical Strength:
    a. The furnace shell, conical ends, and riding rings must support the weight of the shell, refractory lining, and material load.
    b. Materials must resist deformation and fatigue due to rotation and thermal stresses.
2. Thermal Resistance:
    a. Components exposed to high temperatures, such as the furnace shell and end covers, must withstand heat without warping or losing strength.
    b. Thermal expansion should be accommodated to prevent cracks or structural failure.
3. Wear and Abrasion Resistance:
    a. The internal lining is in contact with molten or abrasive materials, requiring high wear resistance.
    b. Rollers and riding rings must resist surface wear due to continuous rotation under load.
4. Corrosion and Chemical Resistance:
    a. Materials in contact with molten metals, slags, or other chemicals must resist corrosion and chemical attack.
5. Fabrication and Cost:
    a. Ease of machining, welding, and availability of material are practical considerations.
    b. Cost-effectiveness is essential for small to medium industrial furnaces.
6. Thermal Insulation:

a. For efficiency, materials should reduce heat loss, minimizing energy consumption during operation.

3.13.2. Material selection by component

1. Cylindrical Shell
2. Function: Main structural chamber; rotates to ensure uniform heating.
3. Requirements: High mechanical strength, ductility, weldability , Must handle the weight of the refractory lining and processed materials.
4. Selected Material: Mild Steel (MS), thickness 8–10 mm.
    a. MS is strong, ductile, and cost-effective.
    b. Can be welded and fabricated into cylindrical form easily.
    a. Internal refractory lining protects steel from direct high temperatures.

3.13.3 Conical end covers (frustums)

1. Function: Seal the furnace ends and provide ports for material feed, burners, and discharge.
2. Requirements:
    a. Must handle mechanical stress, thermal expansion, and mounting loads.
    b. Heat protection for steel.
3. Selected Material: Mild Steel (6–10 mm thick) with refractory lining (50–70 mm).
4. Justification:
    a. MS ensures structural strength and weldability.
    b. Refractory lining protects the steel from high temperatures and abrasion.

3.13.4 Riding Rings (Tyres)

1. Function: Support the rotating shell and maintain alignment.

2. Requirements:
    a. Must resist wear and distribute load evenly.
3. Selected Material: Mild steel or alloy steel, 8–12 mm thick.
4. Justification:
    a. Steel provides strength, toughness, and long service life.
    b. Surface can be hardened to reduce wear from rolling contact.

3.13.5. Rollers:

1. Function: Carry furnace weight and allow smooth rotation.
2. Requirements:
    a. High compressive strength, wear resistance, durability.
3. Selected Material: Cast steel or forged steel.

3.13.6. Refractory lining

1. Function: Protects steel shell, retains heat, resists abrasion and chemical attack.
2. Requirements:
    a. High-temperature tolerance (≥1400 °C), low thermal conductivity, thermal shock resistance.
3. Selected Material: High-alumina castable refractory cement or firebricks (50–70 mm thick).
4. Justification:
    a. High alumina content provides thermal stability and wear resistance.
    b. Ensures even heat distribution and protects the steel shell from thermal stress.

3.13.7. Integrated material design approach

1. The combination of mild steel for structural components and high-temperature refractory lining ensures:
2. Structural Integrity: Steel shell, end covers, riding rings, and rollers maintain strength and alignment.
3. Thermal Efficiency: Refractory lining minimizes heat loss and protects steel.
4. Durability: Wear-resistant rollers and refractory lining extend service life.
5. Cost-effectiveness: Using readily available materials reduces manufacturing and maintenance costs.

Table 3.9: Material Design

Component	Function	Material	Thickness / Size	Key Properties
Cylindrical shell	Main rotating chamber	Mild Steel	8–10 mm	Strength, ductility, weldable
Conical end covers	Sealing, ports	Mild Steel + refractory	6–10 mm steel + 50–70 mm refractory	Strength, thermal protection
Riding rings	Support shell	Mild / alloy steel	8–12 mm	Wear resistance, load distribution
Rollers	Rotation support	Cast / forged steel	Dia 150–200 mm	Compressive strength, wear resistance
Refractory lining	Thermal insulation & protection	High-alumina castable	50–70 mm	High-temperature resistance, thermal shock resistant

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Summary of work done

The maintenance project involved a comprehensive overhaul of the furnace's thermal, mechanical, and structural systems. Key activities included the removal of deteriorated refractory lining, repairs of the two drive motors, reconditioning of the blower unit, strengthening of the conical end covers, and reassembly of all mechanical and structural components.

The steps were carried out systematically to ensure minimal risk to personnel and to guarantee the durability of the finished work. Old, cracked, and detached refractory material was thoroughly removed and replaced with high-grade refractory cement. Damaged mechanical parts were either repaired or replaced, and all components were realigned to restore proper functionality.

By the end of the maintenance process, the furnace structure had been restored to a condition comparable to its original manufacturing specifications, ensuring readiness for operational testing.

4.2 Results of maintenance on individual sections

4.2.1 Refractory lining

The newly applied refractory lining resulted in a smooth, uniform interior surface with improved bonding to the steel shell.

I. The previous cracks and spalled sections were fully eliminated.

II. Thermal insulation improved due to the higher density and lower thermal conductivity of the new lining.

III. The furnace shell experienced significantly reduced heat leakage during test runs.

IV. The integrity of the lining remained stable after curing and initial heating cycles.

This resulted in improved heat retention, enhanced thermal efficiency, and a reduction in potential safety hazards.

Figure 4.1: Refractory re-lining

4.2.2 Drive Motors and Mechanical System

After repair and realignment, the two drive motors regained full operational functionality.

I. Motor vibration, which was previously high due to misalignment and worn components, was eliminated.

II. Rotational movement was smoother, with stable torque and consistent speed.

III. Bearings, shafts, and couplings performed reliably after lubrication and adjustment.

IV. Mechanical noise during rotation was reduced significantly.

These outcomes collectively improved the uniformity of material mixing and contributed to stable furnace operation.

Figure 4.2: Maintenance of Drive Motors and Mechanical System

4.2.3 Blower system

The blower unit, which was previously non-functional, was successfully restored.

I. Airflow efficiency increased after cleaning, lubrication, and replacement of defective parts.

II. The blower was able to deliver steady combustion air at the required pressure.

III. Improved air supply contributed to more controlled furnace heating and more efficient burning of fuel.

This section’s restoration helped stabilize temperature distribution inside the furnace.

4.2.4 Conical end covers

The conical covers were rehabilitated through welding, grinding, and alignment correction.

I. Structural cracks were repaired, restoring mechanical strength.

II. Surface irregularities were removed to improve sealing accuracy.

III. Heat loss through the covers was significantly reduced.

IV. The covers fit more securely onto the cylindrical shell, improving pressure stability.

These improvements enhanced both thermal efficiency and overall furnace safety.

Figure 4.3: Conical end

4.2.5 Structural body and shell

Inspection and minor reinforcement ensured the furnace shell was in good working condition.

I. Areas affected by corrosion were cleaned and treated.

II. Shell deformation was minimal and within acceptable limits.

III. Refractory-to-shell bonding improved shell protection from extreme heat.

This ensured long-term durability and stability of the furnace during rotation.

Figure 4.4: Structural body and shell

4.3 Testing and evaluation

4.3.1 Dry-run testing

Before introducing heat or materials, a dry-run test was conducted.

I. Motors were run for several minutes to check alignment and vibration.

II. Roller support and rotation speed were verified.

III. Blower operation and airflow directions were evaluated.

The furnace passed all preliminary tests without abnormal sounds, resistance, or overheating.

4.3.2 Heat-up test

The furnace was gradually heated to evaluate lining performance and thermal stability.

I. The refractory showed no signs of cracking or detachment during the first heating cycle.

II. Temperature distribution inside the furnace was uniform.

III. Heat loss through the shell and covers was significantly lower compared to pre-maintenance conditions.

IV. Airflow remained steady throughout the cycle.

This demonstrated that the new refractory lining and blower system were functioning as intended.

4.3.3 Operational test with load

A controlled quantity of test material was introduced to assess real working conditions.

I. The furnace rotated smoothly, mixing the charge effectively.
II. The motor maintained torque with no overheating.
III. The blower supported stable combustion and temperature control.
IV. The conical covers sealed effectively, preventing material escape or heat leakage.

Melting efficiency improved, and the furnace completed an operational cycle without mechanical or thermal issues.

4.4. Overall performance evaluation

Based on the tests and observations, the rehabilitated rotary furnace demonstrated:

I. Improved thermal efficiency due to renewed refractory lining and better sealing.
II. Restored mechanical reliability, with smooth and stable rotation.
III. Enhanced safety, with reduced heat leakage and improved structural integrity.
IV. Extended service life, as worn components were replaced or strengthened.
V. Increased operational stability, with balanced motor performance and steady airflow.

The maintenance achieved all project objectives and restored the furnace to productive, reliable Working condition.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The maintenance and rehabilitation of the 100 kg rotary furnace were successfully carried out, restoring the unit to reliable and efficient operational condition. Prior to the project, the furnace exhibited severe deterioration, including damaged refractory lining, faulty drive motors, a non-functional blower system, and worn conical end covers. These deficiencies compromised safety, reduced thermal performance, and made sustained operation impossible.

Through systematic inspection, dismantling, relining, mechanical restoration, and structural repairs, the furnace was fully rehabilitated. The installation of new high-grade refractory cement significantly improved thermal insulation and reduced heat loss. The repair and alignment of the drive motors restored smooth and stable rotation, while the reconditioned blower system provided adequate combustion air for efficient heating. The reinforcement of conical covers further enhanced sealing, heat retention, and operational safety.

Testing phases—including dry-run, heat-up, and operational load tests—confirmed that the furnace now meets performance standards, demonstrating improved thermal efficiency, structural integrity, mechanical reliability, and overall safety. The project also extended the furnace's service life and enhanced its suitability for continuous production operations.

Overall, the rehabilitation achieved its objectives and restored the furnace to a condition comparable to its initial manufacturing specifications. The project highlights the importance of preventive maintenance, proper material selection, and adherence to engineering best practices in ensuring the long-term functionality of industrial heating equipment.

5.2 Recommendations

To ensure the long-term functionality, safety, and efficiency of the rotary furnace, the following recommendations are proposed:

5.2.1 Scheduled Maintenance

i. Implement a structured preventive maintenance program to inspect motors, blower systems, and mechanical components regularly.

ii. Conduct periodic refractory lining inspection every 3–6 months to detect early signs of cracks or spalling.

iii. Perform lubrication of moving parts at manufacturer-recommended intervals.

5.2.2 Operational Best Practices

i. Avoid rapid heating and cooling cycles that can induce thermal shock in the refractory lining.

ii. Ensure the furnace is not overloaded beyond the recommended 100 kg capacity to prevent mechanical strain and uneven rotation.

iii. Maintain proper alignment of drive motors and check for vibration during operation.

5.2.3 Monitoring and Safety Enhancements

i. Install additional temperature sensors or thermocouples for improved thermal monitoring.

ii. Provide operator training on safe furnace operation, emergency procedures, and routine inspection.

iii. Ensure all electrical connections, grounding, and control systems are regularly tested for safety compliance.

5.2.4 Future Improvements

i. Consider adding external insulation around the furnace shell to further reduce heat loss and improve energy efficiency.
ii. Upgrade blower capacity or install variable-speed controls to enhance combustion control and temperature stability.
iii. Explore the use of digital monitoring systems or automated diagnostic tools for predictive maintenance.

5.2.5 Engineering recommendations

1. Motor and Mechanical System
    a. Select a motor with higher torque than theoretical (10–15 HP recommended) to handle start-up, friction variability, and dynamic loads.
    b. Ensure gearbox and bearings are rated for continuous torque of at least 1.5–2× calculated Tmotor
    c. Implement a variable frequency drive (VFD) for controlled start-up and rotational speed adjustments.
2. Thermal System
    a. Add high-quality insulation to reduce heat losses; calculate actual Q including conduction, convection, and radiation.
    b. Use a temperature control system with thermocouples at critical points to maintain uniform heating.
    c. Consider a safety margin of 10–20% in fuel supply to compensate for process variations.

3. Combustion Design
    a. Maintain 20–30% excess air for reliable combustion.
    b. Ensure blower capacity is sufficient for continuous air supply and variable operating conditions.
    c. Install CO and O_2 sensors for combustion monitoring and efficiency improvement.
4. Furnace Operation
    a. Schedule pre-heating and controlled start-up to avoid thermal shock to the shell and lining.
    b. Periodically inspect drum, rollers, and bearings for wear.
    c. Implement emergency shutdown and pressure relief mechanisms if applicable.
5. Documentation and Validation
    a. Record actual fuel consumption and air flow for each batch to verify design assumptions.
    b. Adjust operating parameters based on empirical data to maximize efficiency and minimize fuel usage.

5.3. Summary and engineering recommendations

a. The described structural layout — cylindrical shell, conical ends, riding tyres + rollers, refractory lining, drive-gear + motor — remains the standard and most effective configuration for rotary furnaces, whether small-scale (80 kg) or industrial.

b. Material selection must emphasize high-temperature resistance (refractory) and mechanical strength (steel shell, tyres, rollers).

c. Motor/gearbox must be sized based on friction load and expected load mass, plus a substantial safety margin; torque calculations provide a baseline, but real-world design should include overcapacity to handle start-up, uneven loads, and thermal stresses.
d. Modern design enhancements (VFD, automated burners, fume-control) improve efficiency, safety, and maintainability — worth incorporating even in small furnaces if budget allows.

Design must include safety and maintenance considerations: stable base, secure mounting, structural strength, easy access for relining and repair, and proper thermal management

The rehabilitation and design analysis of the 100 kg rotary furnace highlighted the critical interplay between mechanical, thermal, and combustion systems for efficient furnace operation.

Mechanical Considerations: The calculated load torque of 219.5 Nm and corresponding motor torque of 7.32 Nm demonstrate that, while the theoretical motor power requirement is low (~1 HP), practical operation necessitates a higher-rated motor. Start-up torque, dynamic loads, and friction variations can significantly increase the torque demand, underscoring the importance of selecting a motor with adequate safety margins. The gearbox and bearing system also require proper rating to ensure reliable continuous operation. Failure of the original drive motors emphasized the need for both robust design and routine maintenance.

Thermal System: Heat calculations show that 73,940 kJ is required to raise the furnace load to 600 °C. Proper selection of refractory lining, insulation, and fuel ensures this energy requirement is met efficiently. The degraded refractory lining prior to maintenance caused heat loss, reduced thermal efficiency, and posed safety risks. Additionally, the furnace volume and residence time were found to be adequate for uniform heating of the material, but proper monitoring of temperature distribution remains critical for process control.

Combustion System: Air supply and blower performance are crucial for maintaining stable combustion. The original blower failure demonstrated that insufficient airflow compromises fuel efficiency and uniform heating. Calculations indicate that supplying 35.9 kg of air per heating cycle with 20% excess air provides complete combustion, ensuring efficient energy utilization and minimizing harmful emissions. Proper blower sizing, airflow control, and monitoring are therefore essential for consistent thermal performance.

Overall Integration: The project illustrates that the rotary furnace's performance relies on coordinated mechanical, thermal, and combustion design. Rehabilitation activities—including refractory relining, motor and blower repair, and structural reinforcement of conical covers—are critical not only to restore functionality but also to improve efficiency, safety, and durability. Observations indicate that periodic maintenance, careful monitoring, and the application of safety margins are necessary to prevent operational failures.

REFERENCES

Basu, S. & Dash, R., 2013. *Refractory Technology: Fundamentals and Applications*. New Delhi: McGraw-Hill Education.

Brown, J.R., 1995. *Foseco Ferrous Foundryman's Handbook*. Oxford: Butterworth-Heinemann.

Chesters, J.H., 1973. *Refractories: Production and Properties*. London: The Iron and Steel Institute.

Gupta, R.C. & Gupta, S., 2020. *Introduction to Refractories for Iron- and Steelmaking*. Cham: Springer.

Havard, F.T., 1912. *Refractories and Furnaces: Properties, Preparation, and Application of Materials Used in the Construction and Operation of Furnaces*. New York: McGraw-Hill.

Industrial Heating, 2005. *Industrial Heating: Principles, Techniques, Materials,*

Khana, O.P., 2008. *Industrial Engineering and Management*. New Delhi: Dhanpat Rai Publications.

Mullinger, P. & Jenkins, B., 2011. *Industrial and Process Furnaces: Principles, Design and Operation*. Oxford: Butterworth-Heinemann.

Smith, A. & McGuire, T., 2017. 'Maintenance procedures for rotary furnaces', *Journal of Materials Processing Technology*, 249, pp. 315–322.

Trinks, W., Mawhinney, M.H., Shannon, R.A., Reed, R.J. & Garvey, J.R., 2004. *Industrial Furnaces*. 6th ed. Hoboken, NJ: John Wiley & Sons.

APPENDICES


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