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Intelligent Robotic Arm-Assisted Electrical Furnace for Efficient Metal Casting

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Abstract: ***This project proposes the development of an intelligent robotic arm-assisted electrical furnace system for efficient and precise metal casting. Electric furnace is used for heating purpose in various industrial production processes. Electric furnaces are used where more accurate temperature control is required. By combining the strengths of robotic automation with the clean and controllable environment of an electric furnace, the system aims to achieve Enhanced quality and reduced waste, Improved safety and reduced hazards, increased efficiency and productivity, Greater flexibility, and versatility, Reduced environmental impact. The project will explore the integration of sensors enhancing efficiency and quality control. The integration of these technologies aims to enhance productivity, precision, and safety while reducing operational costs. The robotic arm is designed to perform loading and unloading tasks, handling raw materials and moulds with exceptional accuracy and repeatability. The robotic arm can be attached to the electrical furnace. With the help of sensors, robots can manage to avoid obstacles on their paths and achieve their goals with or without prior planning, depending on the complexity of their implemented program.***
Keywords: Electrical furnace, Robotic arm, Arduino UNO, Limit switch, Start and stop switch and Temperature controller.

I. INTRODUCTION

A furnace is an equipment used to melt metals for casting or to heat materials to change their shape during the processing of the product or to enhance properties of the processed components. Electric furnaces are used where more accurate temperature control and relatively cleanliness is required. Melting furnaces are employed to overheat solid materials until they become liquefied.

MATERIAL	MELTING POINT
GOLD	1064℃
SILVER	1030℃
COPPER	1084℃
ALUMINIUM	600℃

A robotic arm for an electrical furnace is a specialized robotic system designed to handle tasks related to operating and maintaining electrical furnaces. They will be programmed to perform tasks such as loading and unloading materials, manipulating objects within the furnace, and monitoring temperature or other parameters. Robots can move about in the environment and take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behaviour, or cognition. With the help of sensors, robots can manage to avoid obstacles on their paths and achieve their goals with or without prior planning, depending on the complexity of their implemented program.

II. LITERATURE SURVEY

1) ELECTRIC MELTING FURNACE – A REVIEW (Sneha P. Gadpayle, Rashmi N. Baxi. International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-2 Issue-5, March 2014)

Electric furnace is used for heating purpose in various industrial production processes. Electric furnaces are used where more accurate temperature control is required. Melting of metals, glass, and other materials has been a vital manufacturing process for several thousand years, producing molten liquids that can be poured and solidified into useful shapes.

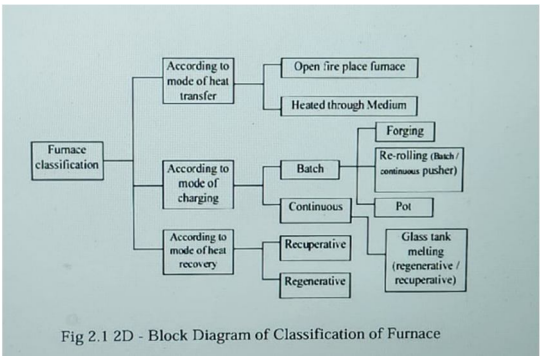


Fig 2.1 2D - Block Diagram of Classification of Furnace

2) DESIGN AND COMPUTATIONAL SIMULATION OF THE FURNACE (Tasnim Firdaus, Zairul Azrul Zakaria. The International Postgraduate Conference on Engineering Research (IPCER) January 2015)

The computational simulation shows that at the beginning of the heating process, the airflow inside the combustion chamber is in random movement. There is no temperature increased involved. The heat flow vector inside the combustion chamber. Meanwhile the air flow meeting the entire space in the furnace which is described as the Path line Colored by the Particles.

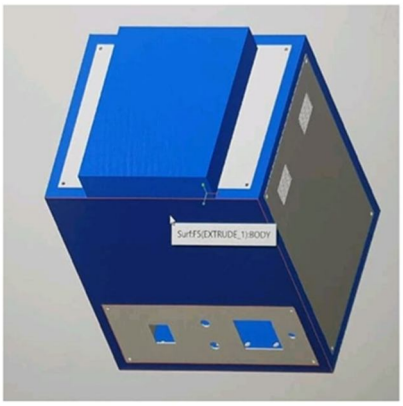
3) FURNACE PERFORMANCE & EVALUATION (Dipak Kumar, Abhishek Kumar, Rajesh Kr. Pandey. Journal Of Emerging Technologies and Innovative Research (JETIR) ISSN: 2349- 5162, ESTD Year: 2014)

An Electrical furnace is that generates heat by electric current. In these furnaces, gold, silver, brass, copper, and other metals are melted. In 4 comparisons to most other methods of metal melting, the electrical furnace provides a clean, energy-efficient, and well-controlled melting process. Heat-treating mild steel at temperatures ranging from 35 to 1200 for 2000 seconds was used to determine the performance of the Electric heat treatment furnace. The furnace's temperature was sustained at 1200 degrees for over 2000 seconds, showing that the furnace was meant to attain that temperature.

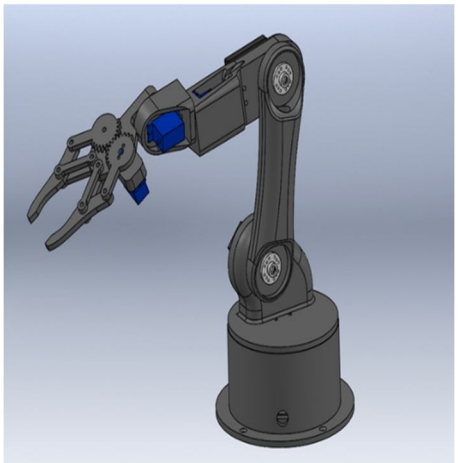
A. Objective

The key innovation lies in the incorporation of an intelligent robotic arm, which provides automation and process control throughout the metal melting and casting operations. The robotic arm is designed to perform loading and unloading tasks, handling raw materials and molds with exceptional accuracy and repeatability. It assists in maintaining optimal temperature conditions during the melting process, ensuring consistent quality in the final product. Additionally, the robotic arm plays a crucial role in pouring molten metal into molds, optimizing casting accuracy, and minimizing waste. Its dexterity enables precise movements, reducing the need for human intervention and thereby improving workplace safety.

B. Design in Creo Software:



Electrical Furnace


Robotic Arm

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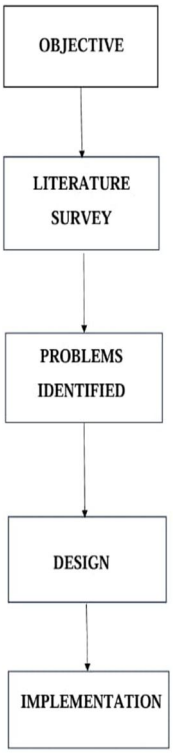
III. METHODOLOGY



Flow Chart of Methodology

TABLE 1
CAUSES AND EFFECTS

PROBLEMS IDENTIFIED	LEADS TO	SOLUTIONS
Checking the molten metal while the process by opening the door	Small electric shocks to the handler	Limit switches are attached so that the machine stop working while opening the door
Continuous process of the machine after the power cut	No proper shut down	Start and stop switches are attached so that the machine stops working after the power cut
Molten metal must be taken out manually using tongs	Unsafe to handler	Robotic arm is attached so that the molten metal can be taken out automatically

IV. CONSTRUCTION

A. Steps to Assemble an Electrical Furnace:

1) Step 1: Design an electrical furnace according to the requirement.

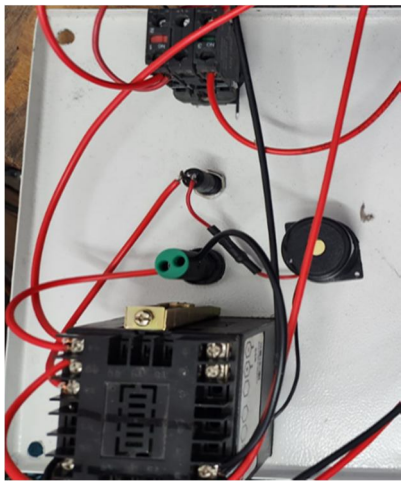
2) Step 2: If the Coil Type Machine is made. First, fix coil inside the machine and take Glass wool and pack it on coil and keep it on MS Body Box.

3) Step 3: If the Rod Type Machine is made. First, take ceramic board and pack it on the top of the MS Body Box. And by using Glass wool pack the Ceramic Board.

4) Step 4: Fix Temperature Controller, and wire it. Then fix 2 – way connector and 2 – pole 40A MCB and connect it in series for all the components.

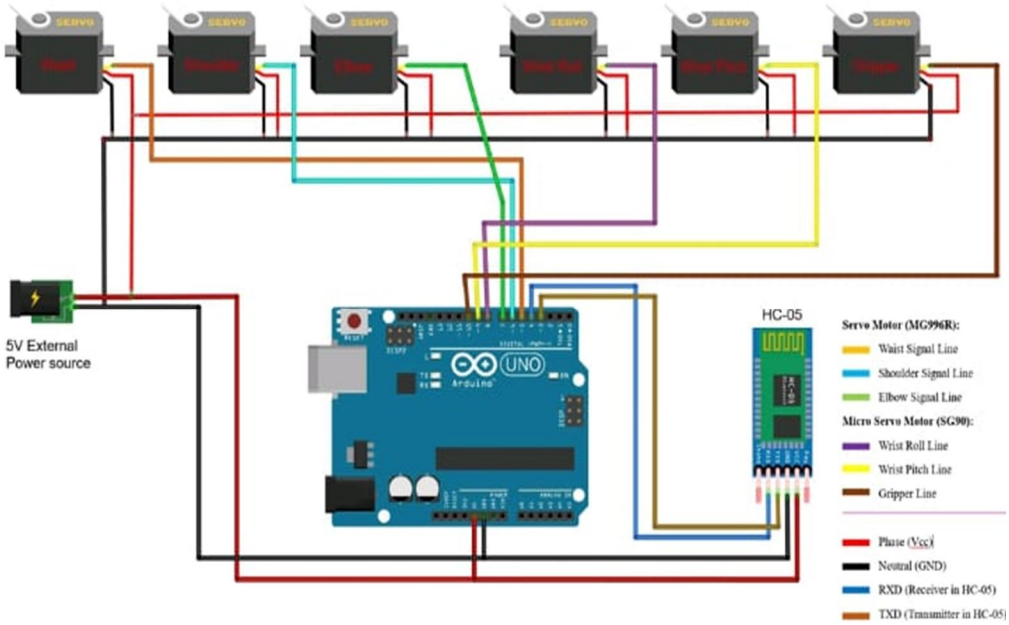
5) Step 5: Fix Indicator lamp and connect it in series for power supply.
6) Step 6: From Temperature Controller take a line and connect it to the Thermocouple Open Sensor.
7) Step 7: If the machine is Coil Type, give input to Contactor (the input should be given from the above components and take an output from the contactor and connect it to the Coil).
8) Step 8: If the machine is Rod Type, give input to Contactor
9) Step 9: Connect 3 – pin top by using 3 – core wire for power supply to the

Machine and join another end of 3 – core wire in 2 – pole 4A MCB. Finally fix the door.

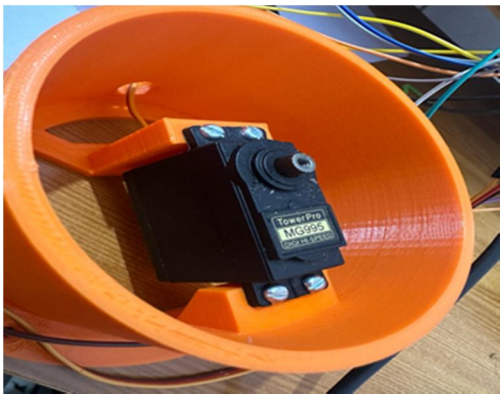


B. Steps to Assemble a Robotic Arm:

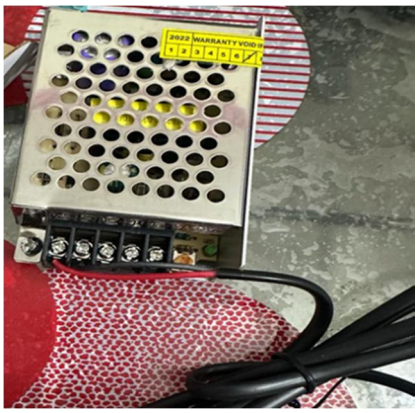
1) *Step 1:* Gather all the components required for the robotic arm assembly, including servo motors, brackets, joints, control board, power supply, and connecting cables.
2) *Step 2:* Start with the mechanical structure by attaching the joints and brackets. Ensure proper alignment and tight connections.
3) *Step2:* Mount the servo motors to their designated positions on the robotic arm. Secure them tightly, and pay attention to the motor orientation specified.
4) *Step 3:* Use connecting pieces to link the joints together. Follow the guidelines to ensure the correct order and alignment for smooth movement. Connect the servo motor wires to the control board. Pay attention to colour coding or labelling to avoid wiring errors.
5) *Step 4:* Connect the power supply to the control board, ensuring the correct voltage and polarity. Be cautious to prevent short circuits or overloading.
6) *Step 5:* Upload the necessary code to the control board using a computer or other programming device.
7) *Step 6:* Conduct initial tests to check the movement and functionality of each joint. Ensure that the robotic arm operates smoothly without any unusual noises or malfunction



Circuit Diagram

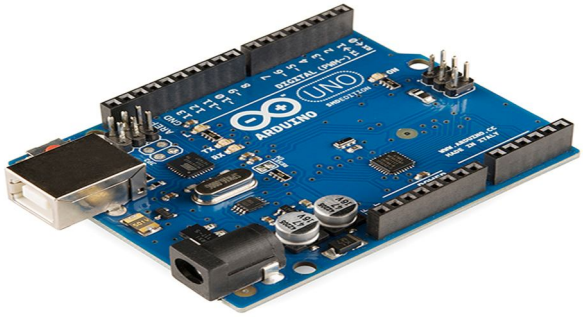


Servomotor



Smps (Power Supply)

HC-05 Blutooth module



Arduino UNO R3

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V. WORKING OF ARM-ASSISTED ELECTRIC FURNACE

1) Melting furnaces are employed to overheat solid materials until they become liquefied. Typically, thermal processing equipment is utilized to change the internal characteristics or the surface of materials by elevating their temperature carefully.
2) In the instance of metals, this usually heightens ductility at the expense of both strength and hardness. By comparison, a melting furnace produces over hot temperatures which go above the metal's melting point and cause decomposition of its physical structure which results in liquefaction. This phase transition is wholly dependent on both pressure and temperature.
3) And with the combination of a robotic arm, it is easier to take out the crucible without any human effect. The arm works as a human hand and holds the tong and lift the crucible and pour the liquid metal into a container. The robotic arm also used for the purpose of stirring the liquid metal which done manually.

A. Implementation of The Solutions

1) Start And Stop Switch:

As for start and stop switch, it is used to prevent the machine from discontinuous process. The following table shows the importance of start and stop switch.

TABLE 2
IMPORTANCE OF START AND STOP SWITCH

S.No	Problems	Importance
I	Machine runs continuously even after the power cut	To prevent uneven melting
II	Even after the three cut offs the machine still runs	To make the machine to have a proper shutdown

2) Limit Switch:

As for limit switches, it is used to cut off the power when the door is opened and continue working when the door is closed. The following table shows the effects of limit switch in the melting machine.

TABLE 3
EFFECTS OF LIMIT SWITCH

S.No	Problems	Effects Of Limit Switch
I	Unsafe to handler while stirring the molten metal	Cuts off the power while stirring the molten metal
II	Unsafe to handler while opening the door	Cuts off the power while opening the door
III	Small shocks when the door is handled	Cuts off the power even at the unusual handling

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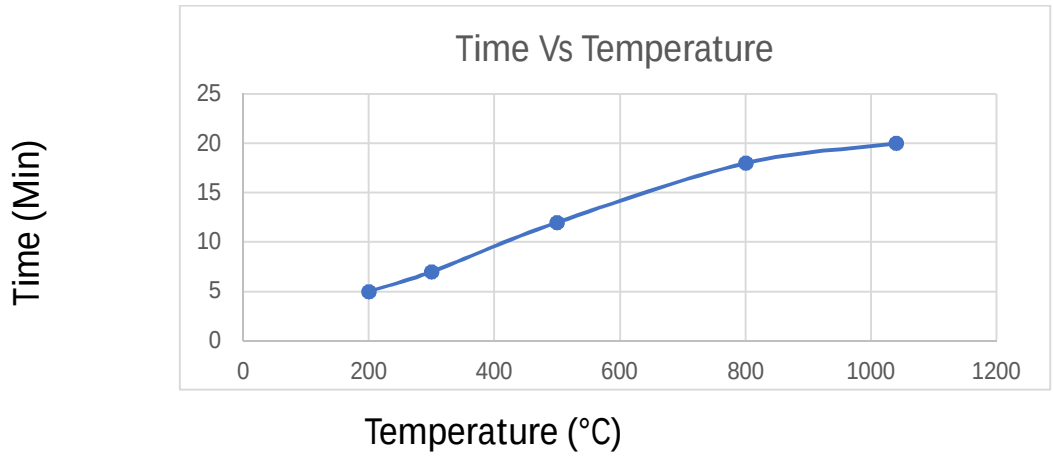
VI. PERFORMANCE TEST

The performance test is to determine the efficiency of the furnace and the specific energy consumption for comparing with design values of this furnace. There are many factors affecting furnace performance such as capacity utilization of furnaces, excess air ratio, final heating temperature etc. It is the key for assessing current level of performances and finding the scope for improvements and productivity.

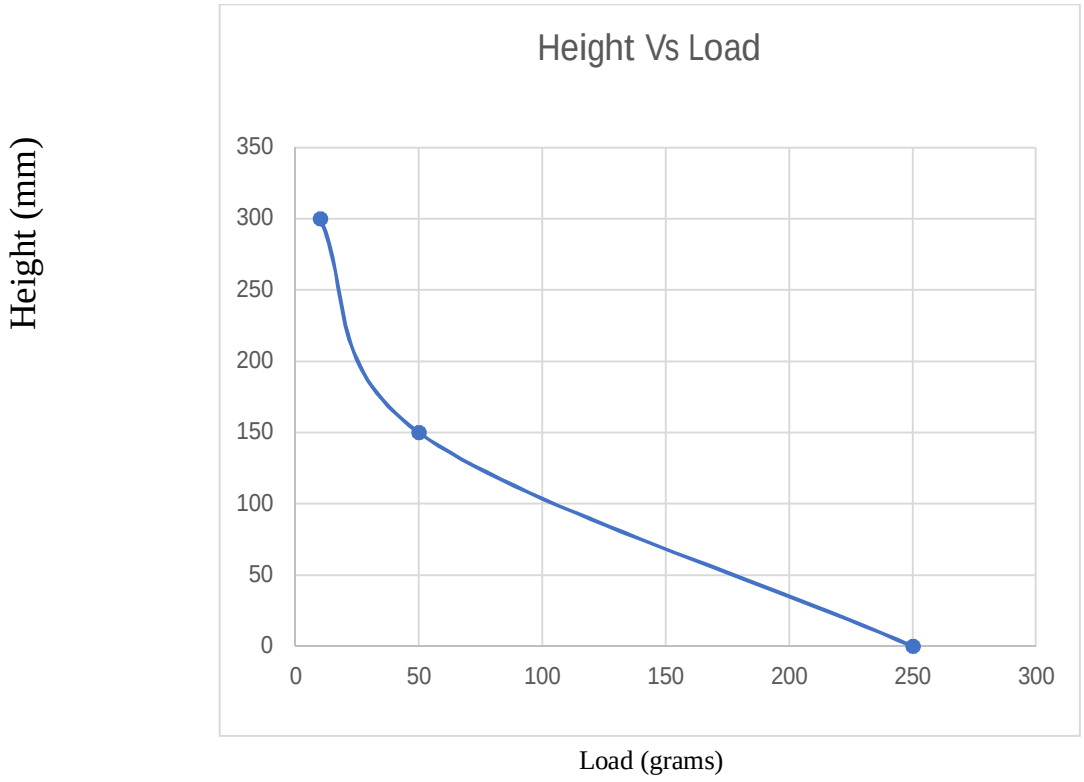
$$\text{Furnace efficiency} = \frac{\text{Heat Output}}{\text{Heat Input}}$$

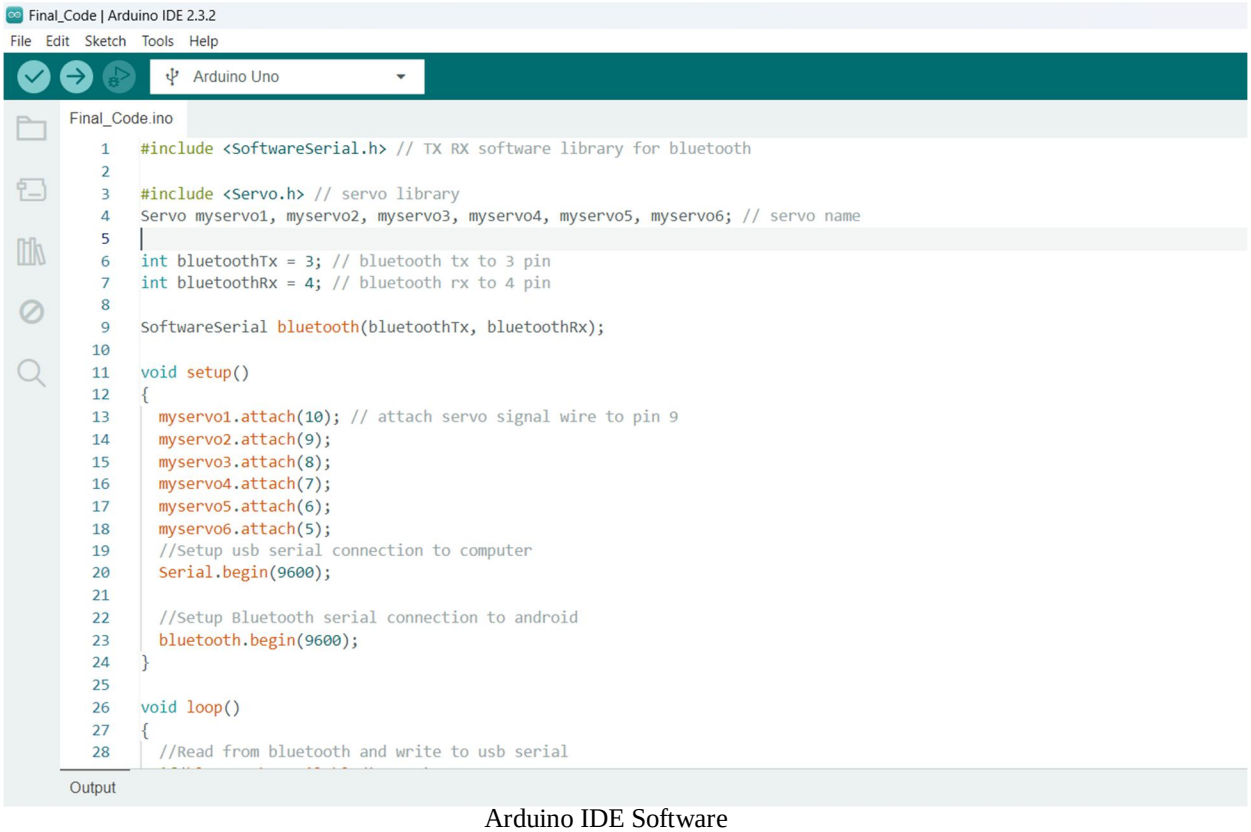


Here in this graph, the temperature increases as the time goes by and increases. Thus, the temperature of the crucible raised to melt the metal with a short period of time.

A. Robotic Arm:

As for the robotic arm, it is used to load and unload the crucible from the furnace. The following graph shows the weight of the crucible the arm carries and the height it can lift to.





Arduino IDE Software

VII. MARKET POTENTIAL

Electric furnaces are used in a variety of industries, including engineering, food processing, chemical processing, and laboratories. The furnace is developed and built to the specifications of the customer. The different characteristics, such as the heating chamber's highest attainable temperature, automatic or semi-automatic temperature regulation, and so on, are determined by the customer's requirements. The expansion of industrialization affects the demand for this item. The current rate of growth in demand for this product is around 10% per year. This commodity is produced by 15 to 20 SSI units in Kerala and Tamil Nadu. Because this is industrial machinery, quality is paramount. For this experimental evaluation has reduced the human task and time and has many advantages when compared to the charcoal burner and blow pipes. And this invention has proved that the man's intelligence is as vast as sea. And brought a new change in the practice of early days.

VIII. ADVANTAGES

1) *Precision:* Robotic arms can perform tasks with high precision, ensuring consistent and accurate handling of materials within the furnace, leading to better quality control.
2) *Safety:* By replacing human workers in high-temperature environments, robotic arms reduce the risk of injuries and exposure to hazardous conditions.
3) *Efficiency:* Robotic arms can operate continuously without breaks or fatigue, leading to increased productivity and throughput in furnace operations.
4) *Flexibility:* Robotic arms can be programmed to perform various tasks, such as loading and unloading materials, adjusting furnace settings, and conducting inspections, providing versatility in furnace operations.
5) *Cost-effectiveness:* While the initial investment in robotic arms may be high, they can ultimately reduce labour costs and improve overall operational efficiency, resulting in long-term cost savings.

IX. TECHNOLOGY

1) *Sensors:* Integration of sensors allows robotic arms to detect and respond to changes in temperature, pressure, and other environmental factors within the furnace, ensuring safe and efficient operation.

2) *Automation:* Advanced programming and automation technologies enable robotic arms to perform complex tasks autonomously, such as loading and unloading materials, adjusting furnace settings based on real-time data, and optimizing energy consumption.
3) *Machine Learning:* Utilizing machine learning algorithms enables robotic arms to learn from past experiences and optimize their movements and actions over time, leading to increased efficiency and productivity.
4) *Remote Monitoring and Control:* Integration with remote monitoring and control systems enables operators to supervise furnace operations and adjust remotely, enhancing flexibility and convenience.
5) *Predictive Maintenance:* By analysing data collected from sensors and monitoring systems, predictive maintenance algorithms can anticipate potential issues with the robotic arm or furnace components, enabling proactive maintenance to prevent costly downtime.

X. CONCLUSION

Integrating robotic arms with electric furnaces offers a synergistic approach that combines the precision and efficiency of automation with the reliability and versatility of electric heating technology. By harnessing advanced sensors, automation algorithms, and remote monitoring capabilities, these systems can enhance safety, productivity, and quality control in furnace operations. Furthermore, predictive maintenance techniques ensure optimal performance and minimize downtime. Overall, the combination of robotic arms and electric furnaces represents a transformative solution that optimizes processes, reduces costs, and drives continuous improvement in industrial heating applications.

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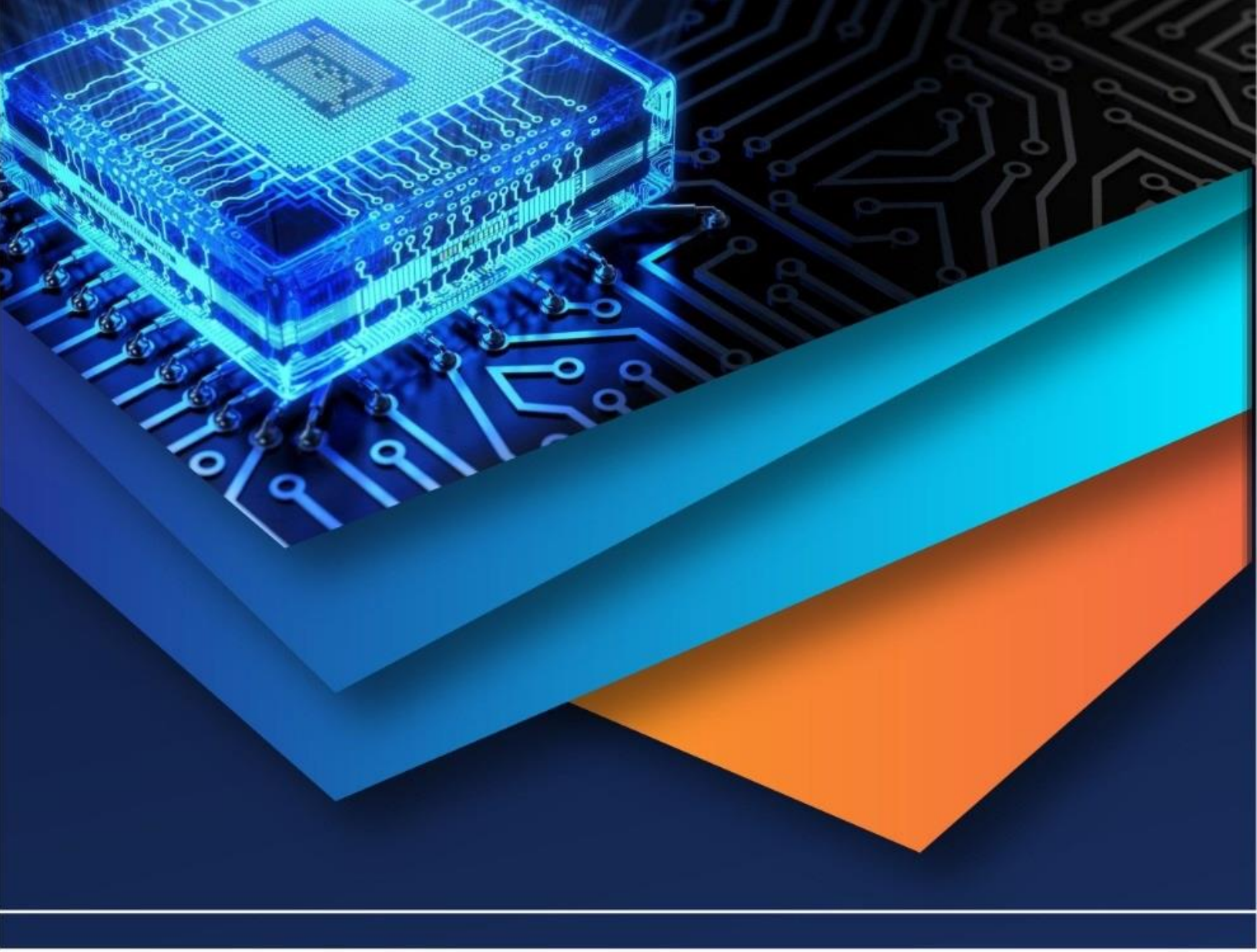

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