Rectifying the uneven Temperature Distribution In an Electric Baking Oven

M. Srinivasan[1], V. Arul Prakash[2], V. Deekshith[2], M. Dineshkumar[2]
[1]Associate professor, Department of Mechanical Engineering, Jay Shriram Group Of Institution, Tiruppur, Tamilnadu, India.
[2]Undergraduate Student,Department of Mechanical Engineering, Jay Shriram Group Of Institution, Tiruppur, Tamilnadu, India.

***Abstract*— We all know everywhere there is a huge demand for the oven. They are the main appliances for baking. These ovens are much helpful at home and even in the industries. This project examined the working of electric baking oven in the industry for baking disc pads, which uses the theory of heat transfer through convection. The circulation of heat waves and occurrence of temperature difference in the oven is studied by us. In this project we are using blower as air input, 'U' type air heater as heating source and six thermocouple to measure the temperature in the baking chamber of oven. During the working of oven, we are encountering drastic changes in temperature of all the thermocouple, which leads to the uneven hardness in disc pads. Our project is to implement new ideas to maintain a constant temperature (below 300°C) throughout the baking oven.**

Keywords*— *Convection, Blowers, Heaters, Thermocouple Temperature, Disc Pads.

I. INTRODUCTION

An Oven is a thermally insulated chamber use for the heating, baking or drying of a substance, and most commonly used for cooking. Kilns and furnaces are special purpose ovens, used in pottery and metal working, respectively. The earliest ovens were found in Central Europe and dated to 29,000 BC, it was used as roasting and boiling pits located within yurt structures. They were used to cook mammoth. In Ukraine from 20,000 BC they used pit with hot covered in ashes. The food was wrapped in leaves and set on top then covered with earth. In camps found in Mezhirich, each mammoth bone house had a hearth used for heating and cooking. Ovens have been used since prehistoric times by cultures that lived in the Indus Valley and pre-dynastic Egypt. Settlements across the Indus Valley had an oven within each mud-brick house by 3200 BC. Hence, before the intervention of modern baking oven, people have alternative means of cooking and baking but the alternative they have chosen led to loss of lives and properties.

The different types of baking oven are:-

1. Earth oven
2. Ceramic oven
3. Gas oven
4. Mansonry oven
5. Electric oven

An electric baking oven is a heating chamber or an enclosed box- like space which is meant for baking foods. In science and Engineering laboratories, it is in form of a small furnace which is used in the removal of moisture from some Engineering materials in order to improve their physical properties such as ductility and hardness. It can also be used for the purpose of heat treatment of engineering materials such as steel and its alloy. An Electric baking oven has several advantages over other baking ovens. It is easy to install, more so relatively damp, portable and has a very easy mode of operation. It is also easy to maintain and has high durability. It is highly preferred to all other types of oven due to the availability of electricity over a wide range of places throughout the countries.

Technology advanced and further developments led to a baking oven that was polished and priced for the consumer kitchen. However, there were many myths and fears surrounding these mysterious new electronic "radar ranges" By the seventies, more and more people were finding the benefits of baking oven to outweigh the possible risks and none of the them were dying of radiation poisoning, going blind, sterile or becoming impotent. As fears faded, a swelling wave of acceptance began filtering into the kitchens of American and other countries.

Myths were melting away and doubt was turning into demand. By 1975, sales of baking ovens would for the first live exceed that of Gas ranges. An expanding market has produced a style to suit every taste; a size, shape and colour to fit any kitchen and a price to please almost every pocket book. Options and features, such as the addition of convention heat, probe and cooking meet the needs of virtually every cooking, heating or drying application. Over the years, improvements have been made in electric baking ovens and this trend still continues.

II. WORKING METHODOLOGY

Figure 1: Electric Baking Oven

LAYOUT OF BAKING OVEN
ELECTRIC BAKING OVEN

1. The chamber is made up of suitable reinforcement of 100*100*300mm thickness.
2. Electrical Operated "Hot Air Oven".
3. No. Of Chamber:- One
4. Material temperature range:- Upto 300°C

HEATING ELEMENT

1. Type:- 'U' type air heater
2. Length:- 900mm
3. Inside Hot zone:- 700mm
4. Power capacity:- 2KW
5. Diameter:- 6mm

AIR INPUT

1. Air circulation fan driven by belt and drive mechanism.
2. No of Fan:- One
3. Material construction:- Mild Steel
4. Capacity of fan:- 5HP
5. Rpm:- 1440 rpm
6. Company:- Bharat Bijilli

TEMPERATURE CONTROLLER

Eurotherm 2404 Programmable Ramping Controller with adjustment.

TEMPERATURE DIFFERNENCE

±2°C in no load condition after one hour soaking.

INTER LOCKING SYSTEM

1. In between fan motor and heating phase.
2. In between door closing and fan motor.

CONTROL PANEL

Wall mounted, provided with incoming isolate.

INPUT POWER SUPPLY

3 phase AC power supply, 50 Hz

The electric baking oven chamber is made up of suitable reinforcement material of 100*100*3mm thickness. When the tray trolley filled with 1327 components of disc pads is placed inside the heating chamber, the door is locked with interlocking system. A worksheet is available with the operator, this worksheet has a bar code and a specific component number. The number is saved in the control panel to the right. As the bar code is read with the help of a barcode reader then this data is sent to the main server in form of signals. The input data number is compared with the stored number in the server, if it gets match the machine access key blinks and if its not then error is shown.

As the access key blinks air circulation motor and 'U' type air heater start working. The hot air from the heater get circulated throughout the chamber First the temperature is increased to a level and then it is maintained for a specific time interval and again start increasing, this is a cyclic process till the temperature reaches 280°C. The heating chamber can withstand temperature from 0-300°C only. In between of this cyclic process the temperature is sense by the thermocouple installed in different corner of the chamber. This temperature values are given as an input to the temperature controller which read the temperature in every specific time interval. The temperature read by this thermocouple varies from one to another. The tolerance limit of the temperature read by these Thermocouple is ±7. So, our aim is to decrease this tolerance limit to ±2 which is a negligible one or we can say it is nearer to constant temperature.

A single process of this baking chamber is carried for 9'O'hours. As the process gets completed an alarm is raised, then the operator approaches to the machine and keeps it open for a specific time say upto 5min to let some amount of heat get dissipated into the surrounding. Then he load these trolleys and keep them outside so that it gets cooled by the help of natural convection

III. LIST OF IDEAS FOR MAINTAINING A CONSTAN TEMPERATURE IN THE CHAMBER

LOUVERS (Selection, Design Considerations and Details)

Louvers are a basic and simple part of many systems and buildings, but they are often overlooked or not given the proper amount of design time and consideration. The purpose of this paper is to describe the proper way to select louvers, as well as point out application issues and common louver features and accessories. To prevent the paper from being too long, some topics are only briefly mentioned. Additional conversations, details and supporting documents may be necessary to address specific applications.

Basic Selection

Determine the air flow, direction of air flow and maximum air pressure drop.

On the Airflow Resistance chart, start at the selected static pressure and draw a horizontal line across, until it intersects either the intake line or the exhaust line. At the intersection point, draw a line straight down to the free area velocity line.

Calculate the free area required on the louver by taking the air flow amount and divide it by the recently determined free area velocity.

As a minimum, louver schedule should include: manufacturer's name, louver model number, width, height, depth, free area, air flow amount, direction of air flow, static pressure drop and free area velocity.

More Advanced SelectionConcerns

The data calculated and reported in the Airflow Resistance Chart is based on a louver withouta bird or insect screen. Most bird screens have a nominal pressure drop, but there are circumstances when their effects should not be overlooked. Insect screens have very high pressure drops, clog with dirt quickly and are rarely cleaned. We recommend insect screens only be usedwhen required by the FDA or for other special applications.

When a louver is used with a fan, size the louver for air performance, not as required to match the physical size of the fan. This usually results in the louver being about twice the size of the fan and the need for a plenum box on the back side of the louver. Also, a certain distance must be maintained between the fan discharge and the louver (or damper) for proper fan performance. For a typical wall prop fan, the distance should be about one fan diameter.

IV. MODIFYING THE TYPE OF AIR FLOW

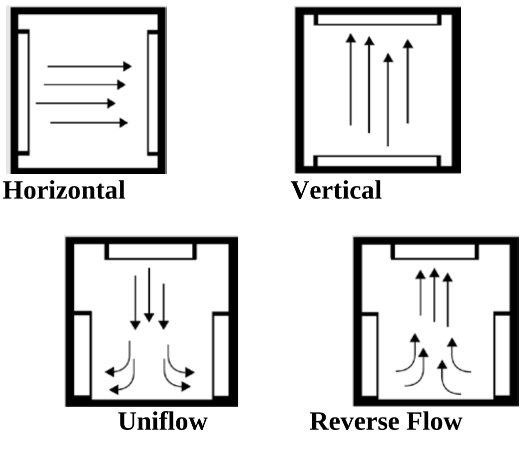


Figure 2:Type Of Air Flow

Gravity Convected Heat

The simplest, most economical approach. Heated air rises, then returns to the heat source as it cools. Perfect for powders and other products that may be disturbed by forced air. Use when chamber temperature uniformity and time-to-temperature specifications are not critical.

Horizontal Air Flow Diagram

A high volume blower system circulates air though stainless steel air ducts, providing horizontal one pass airflow. This horizontal airflow provides superior temperature uniformity and fast heat-up capabilities. The air ducts should move heated air and direct it to the right side of the chamber. This slightly pressurized air escapes through the small perforations in the chamber wall, flows across each shelf picking up moisture and then this is gently cushioned through large openings on the opposite chamber wall.

Forced Circulating

Incorporates a fan to create a vertical or horizontal airflow pattern. Best for products that air may pass vertically through or around. Significantly speeds time-to-temperature and heat transfer to parts. Requires proper spacing of parts to ensure optimal vertical or horizontal airflow. Despatch ovens feature a unique fan design that improves temperature uniformity and performance by directing air to all areas of the chamber.

Forced Recirculating

Ideal for applications involving tray-loaded or shelf-loaded products that require precise temperature uniformity. The fan is strategically positioned so air moves across the heater and into the duct in the one side, and returns through the duct in the opposite wall. Creates a true horizontal/vertical airflow that ensures fast, consistent heat transfer. Provides precise and consistent process results, even when product is densely loaded.

EFFICIENT, LOW MAINTENANCE MOTOR

To protect from motor burn out and oven downtime, we use a dual blower system. One blower is used to dissipate heat away from the motor and bearings, while the other is used to move the heated air throughout the chamber. Large motors with oversize bearings provide long-life and low maintenance. Because stainless steel does not conduct heat efficiently, a half inch stainless steel wall separates the motor from the chamber to minimize heat transfer.

PROJECT METHODOLOGY

During a lot of research we found that the air flow inside the oven chamber is uneven, rather than the specified limit i.e. 2.0m/s to 3.5m/s, which result in lack of constant temperature inside the baking chamber of the oven.

According to the brainstorm, these may be the reasons for the specific cause:

<u>Temperature High Reasons:</u>

- Air flow
- Wet scrubber inefficiency
- Controller failure
- Thermocouple failure or not sense
- Thermostat failure

<u>Temperature Low Reasons:</u>

- Poor air flow
- Temperature controller failure
- Poor heat insulation
- Thermostat failure

Heater failure
Improper insulation (glass wool insulated)

The cause and effect diagram, and the Validation table gives the outstanding view of the uneven temperature difference in an electric baking oven.

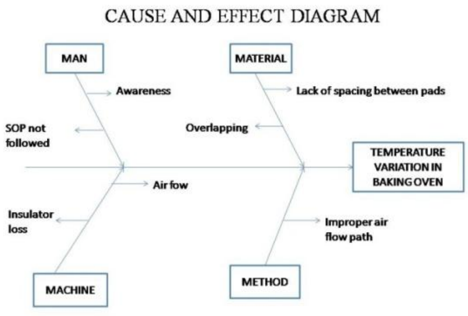


Figure 3: Cause and Effect Diagram

ANALYSIS FOR THE CAUSE

Sl No.	CAUSE	VALIDATION	REMARK
1	Hot air leakage from oven	Fumes and heat observed	Need Improvement
2	Allignment of trolley	Stable section	No need of improvement
3	Air fow not uniformly distibuted	Checked in different position	Need Improvement
4	Insulation Loss	Checked in diferent position	Need improvement
5	Product Spacing	Checked within the trolley	May or may not be improved
6	Improper loaing temperatue	Checked in all oven	Need Improvement

Figure 4: Analysis for the cause

After analyzing the above datas it's visible that the following factors are identified as major causes for uneven temperature distribution:

1. Improper loading temperature
2. Blower Diameter
3. Blower RPM
4. Alignment of louvers

V. IMPROPERLOADING TEMPERATURE

The loading temperature of the baking oven should be equal to the room temperature rather than 34-45°C.

BLOWER DIAMETER

While measuring Air velocity in 480mm blower diameter, results are(2-2.5)m/sec, lower side of specification (2-3.5)m/sec. To Improve from 2.5 to 3.5m/sec, Decided to increase diameter by trial and error method from original size. Since Blower diameter is directly proportional to air velocity.

BLOWER RPM

To Improve air velocity from 2.5 to 3.5 m/sec decided to increase Blower RPM by 20% from original value.
Standard motor RPM = 1500 RPM
Increased motor RPM (20%) = 1800 RPM

CALCULATION FOR THE AMOUNT OF HEAT ABSORBED FOR A SINGLE PAD

Required formula: $Q = mc\Delta T$

where,
Q= amount of heat absorbed, J

m= mass of the pad, g
ΔT= temperature difference, ^{o}C
c= specific heat of air, J/g ^{o}C

Given,
m=375g
ΔT= 1.14^{o}C/ min

Solution:
$Q = mc\Delta T$
= 375*(4.2)*33
=51.97KJ

VI. EXPERIMENT PROCEDURE:

- The sequence of trials was determined through a random process.

Factors	Operating (existing) level	Decided to maintain the level
Blower Diameter (mm)	480	510
Blower RPM	1500	1800

- All the experiments were conducted on same baking oven with same empty trolley condition.
- At Baking, all the other parameters were maintained & monitored.
- Each experiment conducted with same cycle time (Raising & soaking time).

Table 1: Operating Ranges and their Level

Exp No.	Blower RPM	Blower Diameter (mm)
1	1500	480
2	1500	510
3	1800	480
4	1800	510

Table 2:Random Order For Experiments

Exp No.	Blower Diameter	Blower RPM	Trial response in Deg C	Avg value in Deg C
1	480	1500	21	204.4
2	480	1800	18	205.5
3	510	1500	8	209.5
4	510	1800	10	208.6

Table 3: Results of Experimentation

INFERENCES/OPTIMUM PARAMETERS

- When Blower diameter & Louver diameter at high level leads to low temperature variation in baking oven (Response = 9) and average value = 209.1 deg (Near to specification = 210 Deg).
- Result shows effect of Blower diameter is more significant towards lower temperature than louver diameter.
- Decided to do trial by varying Blower diameter to higher side and

  (By keeping other factor – Constant) analyze trial result further.

Factor	Level 1	Level 2
Blower Diameter (mm)	510	550

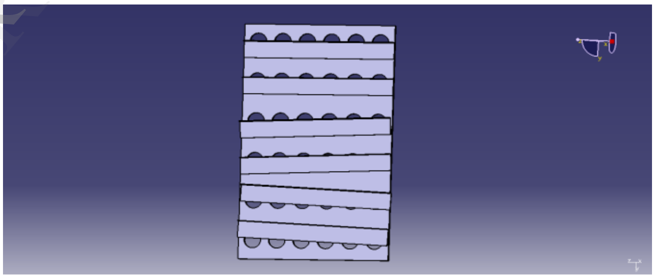
Table 4: Operating Ranges & Their Levels (second case)

Blower Diameter (mm)	Trial 1	Trial 2	AvgDeg C in Trial 1	AvgDeg C in Trial 2
510	9	8	208.2	208.6
550	5.4	5.5	209.6	209.5

Table 5: Result Of Experiments

Result Analysis:

The change in the blower diameter gave the tolerance of 5.5 Deg C, so to decrease the tolerance for more accuracy we can change the alignment of louvers by trial and error method.



The graphical representation drawn between temperature and time as shown below displays the result of uneven temperature tolerance due to improper air flow in an oven.

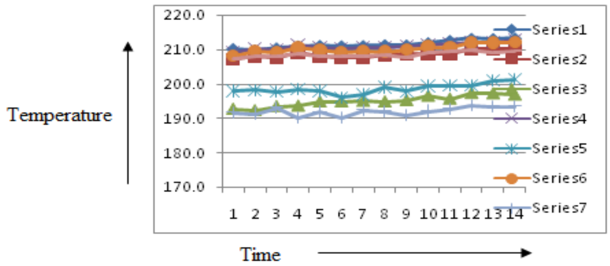


Figure 6: Graphical Representation For Uneven Air Flow

The data shown below is after calibrating louvers and increasing the blower diameter to 550mm.

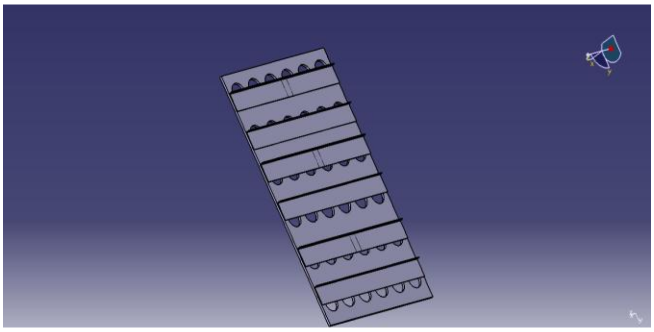


Figure 7: After Calibrating Louvers

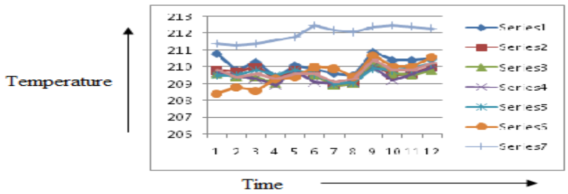


Figure 8: Graphical Representation For Even Air Flow

The two graphical representations implies that the calibration or the calculation performed by us to reduce the tolerance limit is correct and can be implemented in all the electric baking oven in the industry.

VII. CONCLUSION

This project is set upon with a view to maintain a constant temperature in an electric baking oven. The circulation of heat waves and the louvers velocity difference in an oven is studied by us.Now we are maintaining the oven temperature variation in soaking point within 6 DegC by providing higher blower diameter(550mm) and changing the alignment of the louvers for the proper air flow. The process parameter of oven(Temperature) is continuously measured & monitored by thermocouple & data logger.

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