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Heat transfer enhancement in industrial oven by increasing rate of convective heat transfer

Ms. Sakshi Birajdar Mr. Ankit Kapale Mr. Piyush Kadam Mr. Durva Matey

Under the Guidance of Prof. Dr. P.K. Katare

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ABSTRACT

There is an increasing demand, both from customers and regulatory sources, for safer and more energy efficient products.

Manufacturers are having to look to their design and development processes to service these demands. This study deals with the thermal characterization of an electrical static oven used for heating brake shoe bonding adhesive. The heating is provided by natural convection and conduction within inner cabinet of oven. Monitoring of temperatures at various points in the installation and of electrical power is carried out. Then, to characterize thermal exchanges around the inner cabinet. There are many options to improve efficiency in oven; however some options need deep understanding to prove the possibility of thermal performance.

Eliminating stored heat and rearranging airflow. The impact of different operating parameters such as air flow rates, oven temperature, exhaust flow rates and ambient temperature etc., on the product quality and overall oven performance were investigated. Here we used Computational Fluid Dynamics (CFD) method of analysis. The energy flows through the oven were modelled using experimentally determined inputs to estimate the reduction in heat losses. We used CFD method of analysis to understand the flow behavior in the system and lead to the optimal solution for the design problem

I. INTRODUCTION

Increasingly Computational Fluid Dynamics (CFD) is being used within industry to understand and aid the better design of products. There is still a tendency to use CFD to work out why the design did or did not work rather than where in the design space the design will or will not work. Computational fluid dynamics is very useful for predicting temperature and velocity fields in the oven. With the rapid progress of parallel computing and development of commercial codes, CFD has become an indispensable tool in the development of new products. Together with the experiment it allows for a significant reduction of time from the first design through the prototype to the finished product.

We have been assigned the project titled heat transfer enhancement in industrial oven and improve in efficiency. This is an industrial sponsored project by industry named **Kristech Automation**, headed by **Mr. Shailesh Kumar.**

PROBLEM STATEMENT

To enhance the heat transfer rate of given industrial oven by 30% energy reduction from current operating conditions. Without altering working range from 30 cto 110 C.

PRODUCT UNDERSTANDING

Oven Specification

Here the electric based heating method is used, in which indirect heating process is deployed to transfer heat through convection method of heat transfer. Indirect heating and melting method heats and melts, under working temperature range of 100 to 420 degree Celsius. Uni-flow airflow type of airflow pattern is selected as consideration for load configuration. Here the main aim to minimize the obstruction to the airflow for more uniform heat distribution and to maximize the product surface area with which airflow will come into contact.

The following are the specifications of oven:-

- The oven consists of inner cabinet, air chamber, centrifugal type of blower and has capacity of 5 trays.
- It has a hole at bottom of oven for fresh airinlet and also a centrifugal blower

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mounted on the top. For exhaust , hole is provided just behind the blower on the ceiling of oven

- The inner cabinet and air chamber is made up of MS Sheet. And the trays to place object is made up of aluminium sheet for better heat transfer.
- The blower is AC Centrifugal type of blower CB161270. It has aluminium impeller, rotates in clockwise direction, sheet metal fabricated MS body with diecast aluminium body.

BOUNDARY CONDITION

Boundary conditions are a very important aspect of modelling, they specify the flow and thermal variables at the boundaries of the model. To obtain an accurate simulation of the physical model, the boundary conditions have to be specified as close as possible to the real environment affecting the flow. There are four types of boundary conditions affecting the oven; they are temperature inlet, temperature outlet, velocity inlet and wall.

Boundary name	**Boundary type**	**Thermal condition**	**Temperature in ℃**	**Wall thickness mm**
Insulation	Wall	Convection	20	25
Perforated walls	Wall	Coupled	450	2

Table no. 1 Boundary conditions for walls

understanding the product its various parameters, features, advantages, disadvantages, its working, its functions and also the capabilities of oven allotted to us. After referring various research papers and sources we reached on few decisive points with helped us to firmly move ahead towards process parameter optimization, such parameters which can improve efficiency of system by altering design parameters and concluding on basis of analysis and testing over ANSYS software. The process parameter optimization approach is explained further in the coming part of report.

Material	**Density (kg/m^3)**	**Cp (J/kg.K)**	**Thermal conductivity(W/m.K)**	**Viscosity (kg/m.s)**
Air	0.552	1053	0.04395	56.9e-6
Insulation	80	1200	0.11	-
Steel	7801	473	43	-

Table no. 2 Material properties used in oven

PROCESS IMPROVEMENT

Process parameter optimisation is the final stage of the improvement approach.

Sigma DMAIC (design, measure, analyse, improve, control)-based methodology for parameter optimisation that is adapted for this application. When applying the DMAIC methodology to this oven, the aim identified is to establish optimal process parameters to reduce energy consumption by minimising system airflow and to improve temperature uniformity by minimising cold air ingress through the oven slots. Fans and dampers offer the most reliable and practical way to reduce energy consumption and improve temperature uniformity in this oven system.

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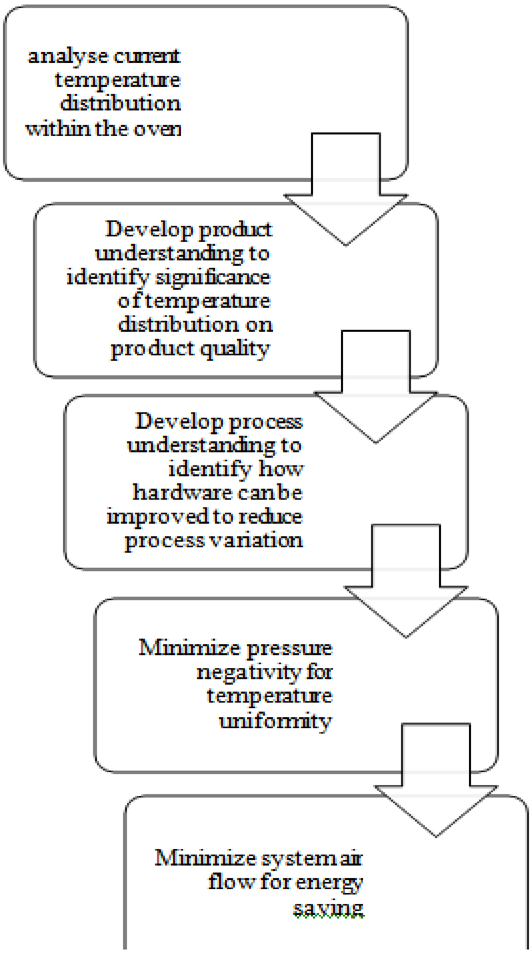

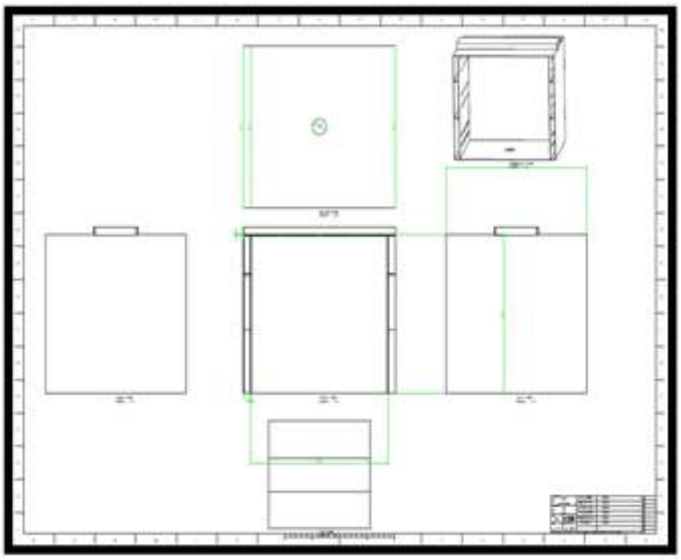

Figure. Drafting of given Oven model

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Material properties
There are three types of materials that data is required in order to model the oven using Fluent.

They are the heated air, the insulation, and the steel inside the oven. The following table displays the material properties.understanding the product its various parameters, features, advantages, disadvantages, its working, its functions and also the capabilities of oven allotted to us. After referring various research papers and sources we reached on few decisive points with helped us to firmly move ahead towards process parameter optimization, such parameters which can improve efficiency of system by altering design parameters and concluding on basis of analysis and testing over ANSYS software. The process parameter optimization approach is explained further in the coming part of report.

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PARAMETERS OF GIVEN AND IMPROVED OVEN MODEL
The given oven has dimensions given below:-
L= 500mm; B= 500mm; H = 510mm
Holes of three variable diameter, 10mm, 6mm and 4mm.
The holes were arranged on the opposite walls of oven. On the bottom of both the walls, hole of 10mm diameter were spread evenly in longitudinal direction. In the middle of the wall hole of 6mm and at the top hole of 4mm spread in longitudinal direction.

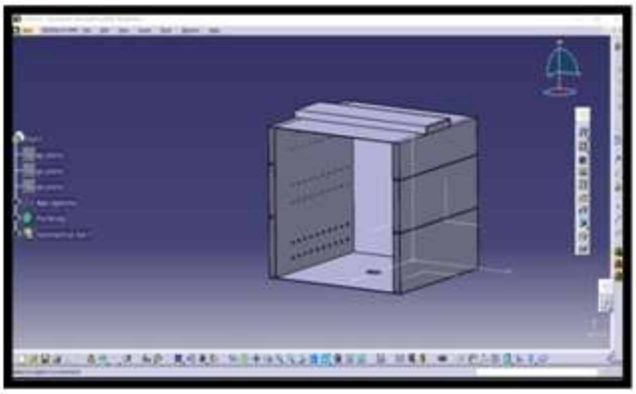

Figure. CAD model of given Oven

The improved oven has dimensions givenbelow:-
As it was instructed to keep the volume of oven same as that of old one. So, without major variation in volume and its cubical shape, the position and size of holes for transfer of heat energy from heater to air volume were made.
The holes of size 20mm and circular in shape were spwa read longitudinally only at the bottom of opposite
lls of oven.

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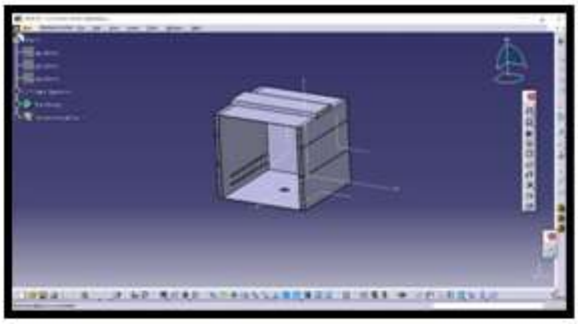

Figure. CAD model of improved oven

Figure. Drafting of improved oven model

The cross sectional area of the duct is A= Dim A* Dim B
=62*165

=10230 mm^2

=10230*10^{-6} m^2

The density of air at inlet conditions is

$$\rho = \frac{P}{RT}$$

where

ρ = density (kg/m^3)

P = standard atmospheric pressure (101.3 kPa)

R = gas constant; its value for air is 286.9 $\left(\frac{J}{kg \cdot K}\right)$

T = air temperature in Kelvin

$$= \frac{0.45\ kPa}{(0.287)*(23+273)} = 5.29*10^{-3}\ kg/m^2$$

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Then mass flow rate of air through the duct and therate of heat gained

$$\dot{m} = \rho \dot{V} = \frac{\dot{V}}{v} = \rho A \vec{V} = \frac{A \vec{V}}{v}$$

where $\dot{m}$ is the mass flow rate $\left[{}^{kg}/_{s}\right]$

$\dot{V}$ is the volumetric flow rate $\left[{}^{m^3}/_{s}\right]$

ρ is the density $\left[{}^{kg}/_{m^3}\right]$, v is the specific volume $\left[{}^{m^3}/_{kg}\right]$

$\vec{V}$ is the velocity $\left[{}^{m}/_{s}\right]$ A is the flow area $\left[m^2\right]$

CALCULATIONS:
Heat Gained By Air in DuctDimensions:
A=165mm
B=62mm Length=560mm**Assumptions:**
1. Steady operating conditions exists.
2. Air can be treated as an ideal gas with constantproperties at room temperature.

Analysis:
We take the side section of the heating system as our system which is a steady flow system.The rate of heat gained by air in the duct can be determinedfrom

$$\dot{Q} = \dot{m}\ C_p \triangle t$$

= $(5.29*10^{-3})*19.38*10230*10^{-6}$

=$1.04878*10^{-3}$ kg/s

$$\dot{Q} = \dot{m}\ C_p \triangle t$$

=$1.04878*10^{-3}$ *(1.007) (28-25) =$3.1683*10^{-3}$ kJ
s

II. FUTURE SCOPE:

Energy reduction within the manufacturing sector has a role to play in reducing global energy consumption. The research presented addresses the energy consumption of industrial ovens, which use a considerable proportion of energy associated within manufacturing. The systematic methodology guides an engineer from the basic understanding of an oven to optimization for energy saving. The stages include define, measure, analyze, improve and control. Combining process & product understanding with consideration of physical and engineering constraints is a powerful tool which can deliver significant energy savings. The velocity pressure and temperature field in the oven cavity have been dealt with the use of CFD simulation. Natural convection, forced convection mechanisms of heat transfer were used. The comparison of old and improved models is showed. Variation in velocity, temperature and flow conditions were used. Control of the circulating hot air velocity in the oven cavity has emerged as the decisive impact factor on the baking quality. Predictions from numerical simulations are confirmed by the positive results from the validation and the functional testing of the oven prototypes and they allowed fast optimization of the temperature field in the oven cavity.

III. CONCLUSION:

This paper represents an approach for industrial manufacturing ovens to reduce energy consumption and enhance product quality. The achievement of efficient heat transfer and thermal air management is becoming important in all energy intensive industries. An experimental analysis was conductedon this oven to optimize the operating conditions. The optimization trials indicate an 11.57% improvement in heat transfer rate of oven.

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[9]. Systematic approach to industrial oven optimization for energy saving, By F. Pask,

[10]. J. Sadhukhan, P. Lake:- the systematic approach presented here , aims to guide an engineer through five stages of oven optimisation . These involves defining the scope of the optimisation project , measuring and analysing process variable in order to develop fundamental understanding of the system so that an optimisation plan can be established and then implemented .

[11]. Engineer's guide to effective heat transfer , By Despatch thermal engineering technology :- here we understood the various parameters which influence the heat transfer process , various types of flows and the terminologies used such as temperature uniformity , wall losses , air distribution and requirement for designing, construction and selection of oven .

[12]. Achieving operational excellence for industrial baking oven, By Sanjay Mukherjee, Abhishek Asthana, Martin Howarth, Ryan Mcneil:- the impact of different operating parameters such as air and fuel flowrates , oven temperature , exhaust flowrates and ambient temperature. The work also provides a balance between the baking temperatures and heat transfer coefficient that can help to establish optimum conditions and to design ovens with enhanced efficiencies.

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