Review on Systematic Approach to Industrial Oven Improvement for Process Performance

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Abstract-
Industrial ovens consume a considerable amount of energy and have a significant impact on product quality so that improving ovens should be an important objective for manufacturers. This review paper presents a novel and practical approach to oven improvement that emphasizes both energy reduction and enhanced process performance. The three-phased approach incorporates product understanding, process improvement and process parameter optimization. Finally, process parameters, such as temperature, air flow rate and cycle time, are optimized to reduce energy consumption.

Keywords: Industrial oven. Process parameters, Performance parameters, Optimization.

I. INTRODUCTION

Manufacturing companies continuously try to improve their processes and operations to improve customer satisfaction and reduce production cost. One of the key performances measurements is the lead time and is correlated with both customer experience and cost. In discrete manufacturing, lead time can be improved through continuous improvement and Investment in new more efficient equipment. In continuous manufacturing lines, however all processes are linked and the slowest process drives the lead time of the whole manufacturing lines. Usually the cost for replacing equipment is such that this cannot be considered. This is especially the case for products that require thermal treatment (such as curing) that require the use of long continuous ovens. The length of such ovens is decided based on the time that the product requires spending in a specific temperature setting. Obviously, the higher the speed of the line, the longer the oven needs to be for maintaining the temperature above the curing temperature. The performance, though can be increased if the efficiency of the oven is improved. A variety of heat treatment chambers such as furnaces, kilns and ovens are widely used in different industries. Among the numerous heat transfer technologies developed, thermal transfer from hot air nozzles within convection ovens are extensively used, including the glass temper, product Industrial ovens are commonly used in the manufacturing industry for curing, drying or baking. An oven’s performance, compared to the best available practice, can decrease over time due to structural/mechanical degradation, technology advancements or changing process requirements. There is potential for functionality improvement, in terms of energy and process performance, in many existing industrial ovens. As technology advances, the need for small size of the components has been increasing with complexity in shapes and sizes, and with reduction in size of the manufacturing machine itself. These operations are not possible with conventional machining processes. Site-wide energy saving within heating processes is relatively common throughout give an overview of start of the art energy efficiency methods in manufacturing operations. Although potentially beneficial, site-wide process improvement via retrofitting is often unfeasible due to limitations in existing technologies, space availability, layout restrictions, heat losses, disruption to production, financial viability, etc. Reducing energy consumption of oven units offers a focused and feasible approach to energy saving. The aim of improving industrial oven should be to increase product quality, production efficiency and worker safety, as well as to reduce energy consumption and waste. Process variation of operating conditions has a significant impact on product quality, performance, cost, safety and operational efficiency. The cost reduction associated with lean manufacturing is important for businesses in increasingly competitive markets products over the energy consumption, and this prioritization affects how energy reduction is pursued within industry. Therefore, linking energy and product quality deserves attention in the research present quality and energy performance analysis in the food manufacturing industry; however, there is little evidence of emphasis on both dimensions for heating processes in the light manufacturing industry. Understanding of process variation has many benefits and is critical for manufacturers to be competitive. It can be used to develop better products, avoid excess precision in certain Aspects of a process, minimize defects, allow for a faster transition from one product to another, deliver cost reduction and reduce scrap

II.THE TECHNOLOGY AND PROCESS MECHANISM OF INDUSTRIAL OVEN

Industrial ovens function by blowing a hot steam jet through a heating panel. This allows the contents to heat up quickly and improves the functional and operational efficiency of the oven. Once the components have been placed in the heating area of the oven, the heating knob is adjusted to the desired heating temperature. Industrial ovens need their knobs adjusted for each heating task. For instance, the process of curing produces different heating temperatures for each product. On the other hand, processes such as broiling and roasting require consistent, but high temperatures for optimal results. Every industrial oven is different and has terminology that applies specifically to the manufacturer‘s design. Regardless of the terms used to describe them, there are basic features that are found on the majority of industrial ovens. In general, every industrial oven includes a motor, exhaust system, a duct network, flame or temperature control, and some type of burner or heating element. Each of the various parts is described below. Every industrial oven has a different motor depending on its application. The basic motor drives the oven‘s systems and provides energy for temperature control, fans, and heating coil. In most cases, the motor activates the heating process and controls all oven functions. A key part of any type of heating process is the exhaust and recirculation systems. Industrial ovens require this part of the system to be well designed since it can serve the purpose of maintaining constant heat and make the oven energy saving. In convection, electric, and gas ovens, air circulation is essential for the oven‘s efficient operation. The critical importance of the duct distribution network is to maintain constant air flow for venting. All industrial ovens depend on a well-designed ducting system to keep the oven in working order. The type of system varies between manufacturers and depends on the type of heating application. For every industrial oven, purging is required prior to the oven being heated. It is part of the function of the recirculation system and removes flammable vapors or gases that may have entered the oven while it was not in use. It is essential that purging be completed prior to engaging the motor or activating the burner. Flame safety and spark ignition controller manage the ignition and startup of the oven. It sends a high voltage signal to the ignition system, which opens a gas valve to the pilot. Once the pilot flame is detected, the voltage shuts down and the main gas valve opens. If the flame is not detected, the system closes. This form of control is found on gas ovens. Electrical ovens have temperature controls to monitor the heat of the resistor coil. The type of burner varies between the types of ovens with direct fired types being supported by an electric motor, while others use radiant tube burners. Direct burners do not use a heat exchanger. The burner fired air is circulated directly into the oven. With a semi-indirect oven the burner is in a separate firing chamber with a blower system to direct the heat. The major emphasis with a burner is safety. Stipulations regarding the standards and specifications are supplied by manufacturers in compliance with federal regulations. Highly efficient burners produce very low nitrogen oxide waste. Schematic diagram of a production oven is shown in Figure 1

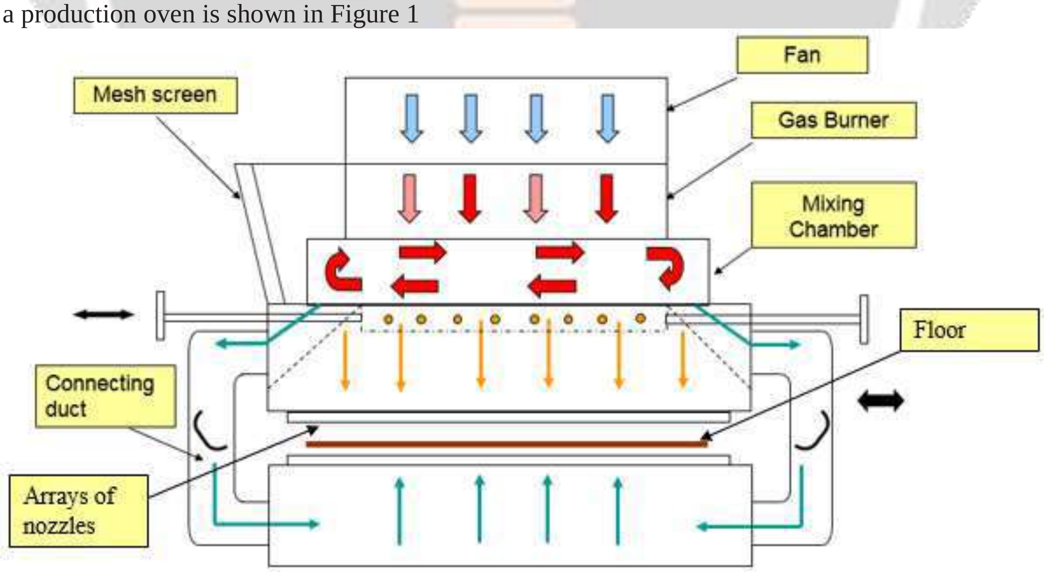

Figure1. Schematic diagram of a production oven

III. APPLICATIONS, ADVANTAGES AND LIMITATIONS

Application of Industrial oven:

Industrial ovens are widely used in various industries such as food production, electronics, chemical processing, oil and gas, pharmaceutical, and automotive.

- Baking: Baking, as it pertains to food manufacturers, is the process of heating a product in low temperatures to expel the gasses within it.
- Brazing: Brazing is the process in which parts or metal components are joined using a dissimilar material with a lower melting point than the two materials being joined. An alternative to the welding process, brazing is used in the aerospace, automotive, electronic device manufacturing, medical and scientific engineering process, and more.
- Curing: The curing process is one of the most common applications of industrial heat. Used to set coatings (both liquid and powder) or to harden adhesives, the curing process is used in nearly every industry.
- Composite Curing: Composite Curing is the process of setting in place high-strength, low weight carbon materials. With carbon fiber and other composites being used more frequently in a variety of industries, the composite curing process requires uniform heat and exceptional airflow control to achieve complete product uniformity.
- Drying: Drying encompasses multiple definitions and serves many different purposes. For pharmaceuticals, this could mean the curing of tablets from a slurry. Drying could also refer to the sterilization of lab equipment, or the traditional “industrial dryer,” which includes float dryers, web dryers, or tower dryers designed for packaging, printing, coating, and more.
- Heat Treating: Heat treating is the application of heat to metal in order to achieve a desired effect. Heat treating includes annealing, stress relief, aging, and tempering, and takes place at set temperatures dependent on the material being treated.
- Sintering: Sintering is the process in which a material is compacted, bonding with itself without reaching a melting point. Through the sintering process, materials gain density and increase strength. Used in multiple industries including the dental industry, powdered metallurgy, and metal injection molding, the sintering process includes pre-heating, high heat, and cool-down.
- Sterilization: Sterilization is a necessary part of the pharmaceutical and medical device manufacturing industry. In this, industrial ovens are used to destroy bacteria present on glass and metal—including vials, syringes, surgical rods and staples, and more—before sealing and shipping the products.

Advantages of Industrial Oven:

- High heat dissipation: Conventional ovens have the capacity to produce extreme heat. This means that the oven will always produce more heat without exhausting too much power. Our industrial ovens are known to provide superior heating temperatures in comparison to their competitors.
- Temperature management and control: Our installation of temperature management allows our clients to easily control the temperature levels of their industrial oven. The temperature is controlled by using the knobs. Our simple operating system allows users to easily manage their industrial ovens. At Eastman Manufacturing, we focus on designing user-friendly industrial ovens that are durable, reliable, and high-functioning. We prioritize our clients and strive for exceptional customer care and quality results. Contact us today for more information about our exceptional services.

Limitation of Industrial Oven:

- Heat Loss: When industrial ovens are operated at high temperature then chances of heat loss are pretty much higher or it has to be adjusted again to shape the metal properly. For the thermal process where meal has to be cool down inside chamber only, there is necessary to fix exhaust fans to speed up the cooling cycles of product.
- Uneven Heating: Another biggest issue to consider is uneven heating when oven are overloaded or materials are not distributed properly. In this case, industrial ovens manufacturers design custom trays to fit the materials well inside chamber. Custom trays hold the materials perfectly in desired configurations and distribute heat properly throughout the chamber. These are major features and drawbacks of industrial ovens that help you in deciding on the right product for your industry. To know more on industrial ovens or furnaces, you should contact leading manufacturers and suppliers right away.

IV. LITERATURE REVIEW

The specific analysis is performed in the different areas as discussed by this review paper

Prof. Kalpana D. Vidhate et.al. (2020): An oven is required to heat up lead acid battery components. Conveyorised oven which consist of 44.625KW total power. The oven is 850mm high x 1150mm wide x 10000mm long and is lagged with 100mm of Rockwool insulation. On top of th oven is an extraction duct, and air is exhausted from the oven through the duct at the rate of 4800m³ per hour. Inside the oven are steel trays with contained in these trays are lead battery components weighing a total 3000kg. The trays and components are to be raised from 40°C to 250°C in 30 minutes. In above conveyorised oven consist total 5 working zone. Total power of 5 zone is 37.5kw and 7.5 kw power,10 A current per zone. We can operate zone as per the requirement of product. The desired Set Temperature value is achieved. The continuous conveyor oven is running smoothly with effective speed control. With the help of PID, we can achieved accurate results i.e. maintain temperature, controls the speed of rotary system also Controls the blower's speed.

Pieter verboven et.al. (2020): This article discusses the application of computational fluid dynamics (CFD) to calculate the three-dimensional isothermal airflow in an industrial electrical forced-convection oven. The governing fluid flow equations were expanded with a fan model and a turbulence model. The standard and the renormalisation group (RNG) version of the k–ε turbulence model produced comparable results. The performance of the CFD model was assessed by means of point measurements of the velocity with a directionally calibrated hot-film velocity sensor. From the validation it was found that important aspects of the model are the fan head-capacity relationship, the fan swirl and the oven geometry. The calculation error was on an average 22% of the actual velocity, caused by the limitations in turbulence modelling and numerical grid density.

Julio cesar et.al. (2018): The present paper discusses an experimentally validated three-dimensional CFD analysis of the flow and thermal processes in a laboratory drying oven with a forced air circulation. The thermal field within an oven has significant impact on the quality of cooked food and reliable predictions are important for a robust design and performance evaluation of an oven. A numerical simulation was carried out to predict the three-dimensional isothermal airflow in an industrial electrical forced convection oven using a computational fluid dynamics code. The CFD model is based on the fundamental equations for the conservation of mass, momentum, and the k-ε turbulence model. The performance of the CFD model was assessed by means of point measurements of the velocity with a directionally hot-film velocity sensor. The simulated results were consistent with the actual velocity measurements from the industrial oven. The calculation error was on average 18.14% of the actual velocity, caused by the limitations in turbulence modeling and numerical grid density.

Yuan Yia et.al. (2017): Drying, curing, baking are few of the manufacturing processes that require the use of impingement ovens. For the manufacturing of large batches typically continuous flow ovens are used that are part of an automated conveyor processing line. The retention time for a product to be treated in the oven usually drives the production efficiencies (i.e. energy usage or lead times). In many processing lines though, the ovens are not designed and run in the most efficient way, and as a result become the "bottleneck" process phase. In such ovens, usually the hot air is ejected from rows of nozzles perpendicularly to the moving product. In the most advanced designs the ovens are divided in zones, with each zone having different targeted operating temperature. The optimization of the manufacturing process is difficult to be experimentally determined due to several reasons: the length of the ovens and the complexity of the movement of the product in and out of the oven are the challenging ones. The main objective of this paper thus is the development of a Computer Fluid Dynamics model for simulating the

Thermal - transfer efficiency of an existing hot-air convection oven used to produce continuous products. The model is used for the estimation of the maximum speed that the conveyor belt can be run, and further investigate possible improvements on the design of the oven for the reduction of the cycle time. The results can be useful during the overview of the actual production and manufacturing rules.

F. Pask et.al. (2016): Industrial ovens consume a sizable proportion of energy within the manufacturing sector. Although there has been considerable research into energy reduction of industrial processes throughout literature, there is not yet a generalized tool to reduce energy within industrial ovens. The systematic approach presented aims to guide an engineer through five stages of oven optimization. These involve defining the scope of the optimization project, measuring and analyzing process variables in order to develop fundamental understanding of the system so that an optimization plan can be established and then implemented. The paper gives an application example of the methodology to a curing oven within a masking tape manufacturing facility. This approach showed an estimated annual saving of 1,658,000 kWh (29% reduction of the oven's energy consumption and a 4.7% reduction of the whole plant's energy consumption) with very little capital expenditure. As the methodology can be tailored to accommodate individual optimisation options for each oven scenario, while still providing a clear pathway, it has potential applications within the wider manufacturing industry.

Frederick Pask et.al. (2017) Industrial ovens consume a considerable amount of energy and have a significant impact on product quality; therefore, improving ovens should be an important objective for manufacturers. This paper presents a novel and practical approach to oven improvement that emphasizes both energy reduction and enhanced process performance. The three-phased approach incorporates product understanding, process improvement and process parameter optimisation. Cure understanding is developed using Dynamic Mechanical

Analysis (DMA) and CIE-Lch colour tests, which together highlight the impact of temperature variation on cure conversion and resulting product quality. Process improvement encompasses thermodynamic modeling of the oven air to evaluate the impact of insulation on temperature uniformity and system responsiveness. Finally, process parameters, such as temperature, pressure negativity and air flow, are optimised to reduce energy consumption. The methodology has been effectively demonstrated for a 1 MW festoon oven, resulting in an 87.5 % reduction in cooling time, saving 202 h of annual downtime and a reduction in gas consumption by 20–30 %.

Y Bie et.al. (2017): Drying is one of the important steps in the deep processing of agricultural andsideline products. It is a main tendency to research and develop the high-efficient and energysaving drying pattern and technology. However, it is found that drying uneven phenomenon often exists in the material-drying oven in the production practice of hot air flow drying process. In order to explore the causes of the formation of uneven phenomenon, and to propose the ways to eliminate the inhomogeneity, experimental research was conducted concerning a multifunctional drying equipment with the hot air circulation. The temperature distribution uniformity and drying efficiency in the oven were tested under no-loaded and loaded
conditions, in aspect of oven tray structure improving, wind direction switching and moisture
controlling of exhaust air. Experimental results show that the drying inhomogeneity and thermal efficiency could be improved by the ways of changing the wind direction from crossflowing to cross-swept-flowing, and as well as proper moisture controlling of exhaust air.

V. SOME CURING PARAMETERS OF OVEN

Parameters of curing oven can be measured and controlled during the curing step. Understanding their interactions and role in producing high quality products is considered both an art and science. The parameters include:

1. **Air Velocity**

The term air velocity implies the flow of hot air inside the curing chamber, usually expressed in m/sec or ft/min. In a convection oven, air velocity directly controls the amount of heat delivered to the product. It also influences the baking time, weight loss as a consequence of water extraction, and color of baked products.

Even distribution of airflow across the width of the oven chamber is vital for even heat distribution and optimum product bake. The higher the air velocity, the faster the product loses water and hence the shorter the bake time needed to achieve full bake.

2. Cycle time

Within manufacturing, cycle time is defined as the average successive time between completions of successive units. It is a measure of Throughput (units per time), which is the reciprocal of Cycle Time. Since the production is continuous and not in discrete products, the cycle time needs to be related to the production of a set length of product, in this case a meter of length of product. In the production line presented in the present paper, as has been already mentioned, the cycle time is driven by the amount of time the product must be retained at the elevated curing temperature.

3. Temperature

The data from the exploratory tests of the effect of temperature on moisture content determination from research. It was observed that a moisture content value determined by a given curing temperature at a given moisture content level was different from the moisture content value determined by another drying temperature and time by a consistent amount over the range of moisture content levels. This observance led to an analysis in which each set of moisture content values determined at a given curing temperature

4. Air flow rate

From above studied concluded that, moisture content increases with increasing air flow rate up to certain level. Oven air flow rate is the measurement of air flow inside the oven. It is important to measure it because, along with other parameters, air flow rate influences the coloration, texture, firmness, and baking time of the final product.

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6. Heat flux

Heat flux is the amount of energy transferred per unit area per unit time from or to a surface. It has three components: radiation, convection and conduction. It can be expressed in Btu/hr·ft2 or W/m2. Both the total amount of heat flux and the ratios of the three components influence the baked product's quality. This parameter is probably

less commonly measured. It's controlled on a real-time basis in the normal operation of a high-speed oven. However, it is very important during the oven design phase, such as prior to equipment onsite commissioning.
In pan bread production, convective and radiant heat is absorbed by the pan, which also serves as the conduction mechanism to the product. It can be said that heat flux is a direct consequence of how the heating mechanisms work. For example, ribbon burners in direct gas-fired ovens.

7. Humidity
This influences the energy (in the form of heat) transferring into the food, which causes starch gelatinization, enzyme reaction, etc.; and the moisture migrating from product interior to the surface and evaporating.

VI. CONCLUSIONS

This paper presents an approach for industrial manufacturing ovens to reduce energy consumption and enhance product quality, simultaneously. The methodology develops product understanding, process improvement and process parameter optimization also survey reveals that a lot of work has been done on curing oven; now this paper present brief summary of published research work based on the experimental investigation on curing process parameters in oven. Few following conclusions From above papers study some conclusions came outside which is given below

- In the present works, various optimization techniques used for Curing process parameters are studied and effects of these parameters on the output parameters have been reviewed. The aim of this work is to study the output of various conventional and nonconventional optimization techniques on curing process so as to allow choose the most suitable approach for a particular application
- The experiments were carried out and on the basis of comparison with the results & the analysis, it was concluded that the predicted values match the experimental values reasonably well for Hardness, Moisture content, curing time, humidity, power consumption, relative humidity
- The key parameters affecting Hardness, Moisture content, curing time, humidity, power consumption, over are identified as the air flow rate, oven temperature oven pressure, cycle time, Thermal oxidizing flow, oven exhaust flow, heat flux the literature available.
- The optimization techniques used by various researchers with different techniques are Taguchi method, RSM (Response Surface Methodology), Algorithm, Grey rotational analysis were mentioned in the review.
- Minitab software is an important application for the evaluation of result.
- Moisture test meter testing Machine can be used for moisture contents.

VII. ACKNOWLEDGMENT

I would like to express my deepest gratitude and sincere thanks to my guide **Dr. S.K.Biradar**, Principal of Matsyodari Shikshan Sanstha's College of Engineering and Technology Nagewadi, Jalna for thier valuable time and keen interest in my research work. thier intellectual advice has helped me in every step of my research work and motivated my efforts

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