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Heat Transfer Analysis on Number of Heat Sources Used for Fly Ash Bricks Manufacturing Chamber

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Abstract—*The uniform temperature distribution is very important factor for making quality bricks in brick manufacturing industries. In this paper the minimum number of heat sources are required to maintain the temperature distribution inside the brick manufacturing chamber have been discussed. Insufficient numbers of heat sources are leads to uneven temperature distribution inside the chamber. The curing temperature is playing major role in the bricks production. Neither excess amount of heat nor minimum amount of heat leads to poor strength bricks. The correct or required quantities and positions of heat sources must be identified for getting the proper curing temperature. Normally the fly ash bricks are curing at atmosphere conditions for 21 days. The curing temperature of 80 ℃ is enough in chamber for giving same strength as that of atmosphere for curing fly ash bricks. The objective of the paper is to obtain the uniform air temperature at 80 ℃ throughout chamber for 24 hours. It is achieved by changing the position and reduced the number of heat sources. Here electric heating elements are used as heat sources. The chamber is made of MS plate and rectangular in shape. The temperature distribution inside the chamber was analyzed by using ANSYS fluent software.*

Keywords*: Curing temperature, Strength, Fly ash bricks, ANSYS.*

1. INTRODUCTION

Heat transfer describes the exchange of thermal energy, between physical systems depending on the temperature and pressure, by dissipating heat. Systems which are not isolated may decrease in entropy. Heat transfer always occurs from a region of high temperature to another region of lower temperature. Heat transfer changes the internal energy of both systems involved according to the first law of thermodynamics. Heat transfer by convection is the concerted, collective movement of groups or aggregates of molecules within fluids, either through advection or through diffusion or as a combination of both of them. Natural convection occurs due to temperature differences which affect the density, and thus relative buoyancy, of the fluid. More dense components will fall, while less dense components rise, leading to bulk fluid movement. A common example of natural convection is the rise of smoke from a fire.

1.1 Drying and firing system in brick production

Drying system is used to dry the wet bricks through drying chamber and drying cart, which makes them ready for firing. The heat source of drying chamber is from firing kiln, the heat is sent into drying chamber through the pipeline by heating fan, the moisture produced in drying process will be discharged by moist-releasing fan. According to the structure, the drying chamber can be divided into single-layer dryer, small section dryer and big section dryer. Drying cart is used for loading wet bricks. Firing system is a system for firing dried bricks, which consisting of tunnel kiln, kiln car and operating equipments. Kiln wall structure: from inside and outside, it is fire clay brick, light insulating brick, aluminum silicate thermal insulation material and red bricks. A certain distance apart, the kiln should be equipped with expansion gaps to ensure the flexibility of kiln body. The main fuel is heavy oil, light diesel oil, natural gas, coal gas or coal.

2. LITERATURE REVIEW

Steady state natural convection from the outer surface of horizontal ducts in air was discussed in five different ducts with respect to the ratio of duct height and width [1]. These ducts were heated at constant heat flux heating elements. The temperatures along the surface and peripheral directions of the duct wall were measured. Longitudinal heat transfer coefficients along the side of each duct were obtained for laminar and transition regimes of natural convection heat transfer. The heat transfer coefficients were observed. It is decreased in the laminar region and increases in the transition region. In the experiment setup, duct was made from steel, the thermocouple locations in the longitudinal (axial) direction on three sides of the duct. Finally this paper concluded at laminar regime the convection heat flux was low and characterized by a decrease in Nusselt numbers at any fixed longitudinal station x on the duct's surface. A three-dimensional numerical study of natural convection heat transfer from multiple protruding heat sources simulating electronic components was conducted [2]. The analysis was carried out by varying the heat fluxes and outlet areas. The total numbers of heat sources were 20, arranged in an in-line manner with 5 in each row and thus there were 4 rows and 5 columns. The heat sources were mounted on the bottom wall of a square enclosure of side 350 mm and height 96 mm. This size was general dimension for the cabin of desk top PCs. This problem studied by two methods. In the first method, a prescribed heat flux was applied and second method maintains the heat sources at prescribed temperatures. The maximum temperature was restricted to 80°C as most of the electronic equipment operates below this temperature. The numerical results were close to experimental values with a maximum error of less than 10%. It was found that maximum temperature occurs in the third row and minimum in first row.

The experimental measurements versus the results from the available correlations in the literature that are commonly used to predict the free convection heat transfer coefficient between the surfaces and the flowing air [3]. The experimental investigations were accomplished using a rectangular duct comprising a flat plate-glass cover as the solar air heater with the following dimensions: 0.48-m width _ 0.07-m depth _ 2-m length. The absorber plate was made of 1-mm gauge of aluminium. The measurements were performed at inclination angles of 30°, 50°, and 70° to determine the optimum angle of the absorption-free convection mechanism in a solar air heater. The comparison is presented and discussed in terms of the Nusselt number. The optimum inclination angle to achieve the best collector performance was found to be 50°. The efficiency of these collectors in air heating was low due to the low convection heat transfer coefficients between the absorber and the flowing air that increases the absorber plate temperature, resulting in higher heat losses to the ambient atmosphere. The bottom and side walls of the duct were made of 20-mm-thick wood. To minimize the top losses, a double glass cover was used to cover the rectangular duct. Each cover was 3 mm thick, and the gap in between the components was 5 mm. The collection of the data for each tilt angle of the collector was repeated for 4 days to improve the reliability of the result by taking the average reading. Two goals were targeted in this work. The first goal was to determine the most suitable empirical correlation to predict the natural convection in a rectangular solar air heater, and the second goal was to determine the optimum inclination angle of the collector for solar air heating. The results were presented in terms of the Nu values. The experimental measurements were performed to evaluate the Nu number over the range of $60{,}000 < Ra < 280{,}000$ and the inclination angle range of $30° < h < 70°$.

Numerical investigation of free convection heat transfer in an attic shaped enclosure with differentially heated two inclined walls and filled with air is performed in this study [4]. The left inclined surface is uniformly heated whereas the right inclined surface is uniformly cooled. There was a heat source placed on the right side of the bottom surface. Rest of the bottom surface is kept as adiabatic. Various low parameters of fluid flow and heat transfer was analyzed including Rayleigh number, Ra ranging from103to 106, heater size from 0.2 to 0.6, heater position from 0.3 to 0.7 and aspect ratio from 0.2 to 1.0with a fixed Prandtl number of 0.72. The output was reported in terms of temperature and stream function contours and local Nusselt number for various Ra, heater size, heater position, and aspect ratio. Right and left inclined walls have constant cold and hot temperatures while the bottom heater is heated to the same temperature as left wall. From the analysis found out a sudden differential heating, temperature variation at a point adjacent to the bottom heater was divided into 3 distinct sections: (1) initial rising, (2) transitional stage (3) steady state and also the bottom heater has significant effect on the thermal behavior of the left heated wall. A numerical study was performed in order to analyze the effect of adding a chimney to a vertical open channel [5]. The channel was heated asymmetrically at uniform heat flux while the chimney was symmetric and wider than the channel. The main objective of this work was to determine the optimal geometric parameters of the chimney. The flow structure and the pressure field were also analyzed to elucidate why the increase of the chimney width can improve or deteriorate the mass flow rate and the heat transfer. The appropriate correlations were proposed for determining the optimal configurations and the corresponding enhancement of the mass flow rate and the heat transfer coefficient. The flow through the channel-chimney system was induced entirely by buoyancy. All the thermo physical properties were assumed to be constants. The increase of the chimney width beyond a critical value makes the channel-chimney system inefficient. Indeed, this situation was equivalent to the case of a channel open into a large reservoir, i.e., a channel without chimney. The channel-chimney system enhances more significantly the convective heat transfer for low Rayleigh numbers.

Geopolymer based concrete was highly environment friendly and the same time it can be made a high performance concrete [6]. Here fly ash, blast furnace slag and catalytic liquids have been used to prepare geopolymer concrete mixes. This study was continued to investigate the behavior of such geopolymer concrete under high temperature ranging from 100°C to 500°C. Cubes of size 100mm × 100mm × 100mm are tested for their residual compressive strengths after subjecting them to these high temperatures. Geopolymer concrete was a type of inorganic polymer composite, which has recently emerged as a prospective binding material based on novel utilization of engineering material. It has the potential to form a substantial element of an environmentally sustainable construction industry by replacing supplementing the conventional concrete. The conventional concrete was exposed to elevated temperatures, an increase up to 10% in the residual compressive strength and loss in weight of specimen increases when the test temperature was raised to 200°C.

Portland cement concrete posses problems such as durability and carbon dioxide emission [7]. Many concrete structures have shown serious deterioration, way before their intended service life, especially those constructed in a corrosive environment. Geopolymer was a class of aluminosilicate binding materials synthesized by thermal activation of solid aluminosilicate base materials such as fly ash, metakaolin, GGBS etc., with an alkali metal hydroxide and silicate solution. It had high performance, environmental friendly and sustainable alternative to Portland cement. Based on the mixture design process eighty one test cubes of 150×150×150mm of low-calcium fly ash-based geopolymer concrete were cast to study the effect of various parameters on compressive strength of low-calcium fly ash-based geopolymer concrete. Fly-ash based geopolymer concrete cubes were placed in universal hot oven for 24 hours with mould. The moulds were removed after 24 hours and the cubes were kept at room temperature for further 24 hours after which compressive strength test was performed. The curing temperature was fixed at 40°C, 60°C, 80°C and 100°C. In that curing temperature region, the compressive strength of fly-ash based geopolymer concrete was increased.

3. PROBLEM IDENTIFICATION

Due to uneven temperature distribution the quality of bricks will be reduced. The heat sources arrangement is lead to uniform heat distribution throughout the chamber/oven. Also consider the quantity of heat sources like electric heaters for getting the required air temperature inside the chamber. The air temperature will be high when using the heat sources beyond the particular amount. The major problem in brick manufacturing industries is uniform temperature distribution inside the chamber by heat sources. In this paper the above said problem was solved by placing the heaters in proper numbers by trial and error. The amount of heat sources are reduced by 10, 9, 8, 7.

4. MODELING

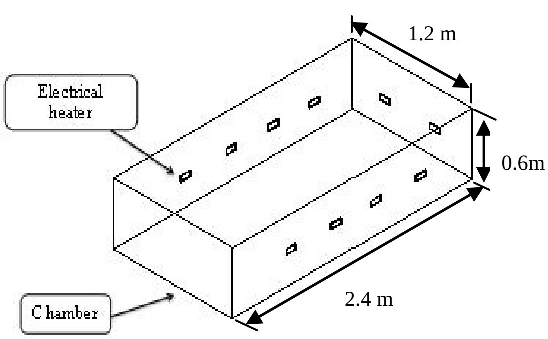
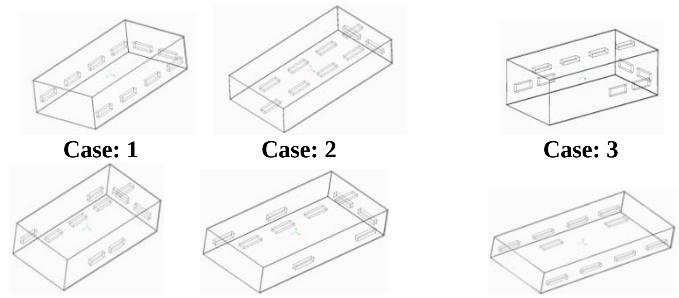


Fig. 1: Physical Problem

4.1 Boundary Conditions

Initial condition inside the chamber:

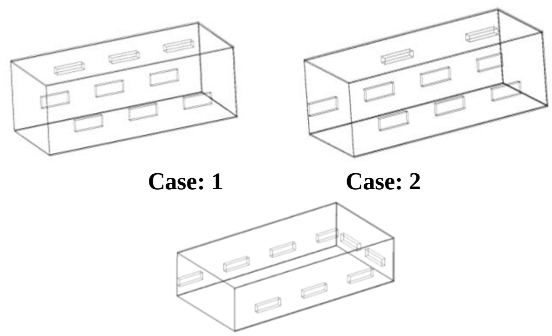
1. Pressure : Atmosphere pressure
2. Temperature : Atmosphere temperature
3. Heat transfer : Natural convection
4. Insulation : Teflon
5. Position of chamber: Horizontal
6. Required air Temperature : 80°C



Case: 1 **Case: 2** **Case: 3**

Case: 4 **Case: 5** **Case: 6**

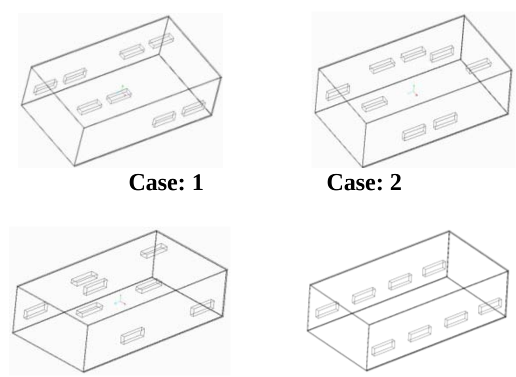
Fig. 2: Number of heaters ten



Case: 1 **Case: 2**

Case: 3

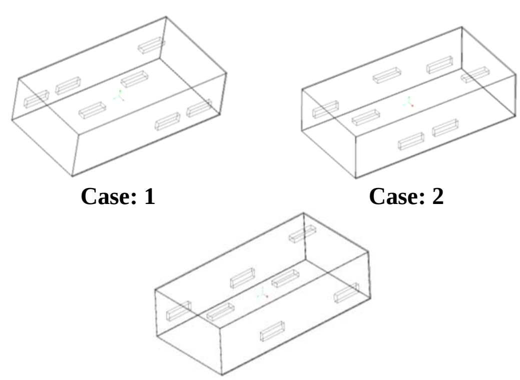
Fig. 3: Number of heaters nine



Case: 1 **Case: 2**

Case: 3 **Cases: 4**

Fig. 4: Number of heater eight



Case: 1 **Case: 2**

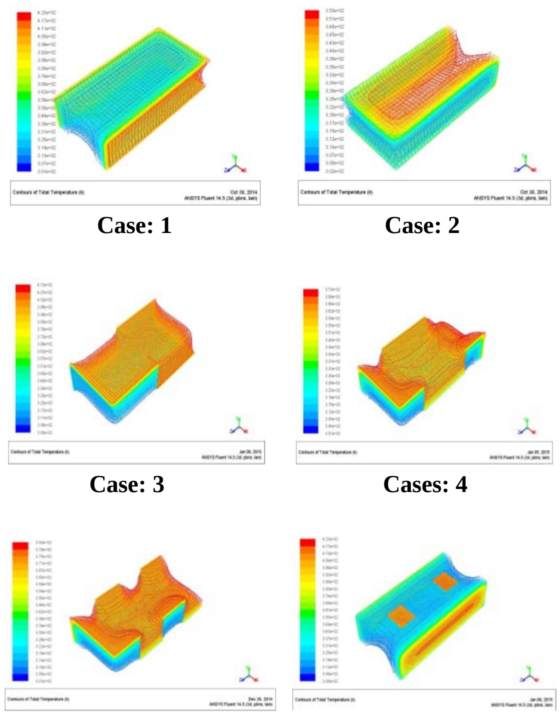
Case: 3

Fig. 5: Number of heaters seven

The above Fig. s show the various cases of positions of heater inside the chamber. By trial and error method the heaters are placing. The modeling is done by PTC creo parametric software. After that is imported in to ansys fluent software for analysis.

5. RESULTS

5.1 Result for ten heaters



Case: 1 Case: 2

Case: 3 Cases: 4

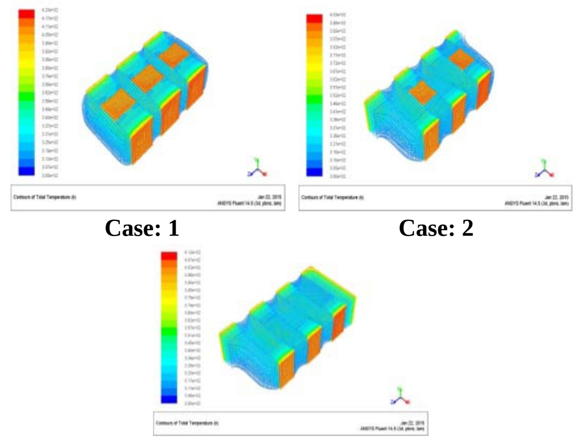
Case: 5 Cases: 6

Fig. 6: Result for 10 number of heaters

From the analysis identify various air temperatures inside the chamber. The heat sources are operated at the temperature of 423K, 353K, 413K, 373K, 383K and 423K with respect to case 1, case 2, case 3, case 4, case 5 and case 6. In case 2 the heat sources are operated at 353K (80°C). it is equal to the required curing temperature of the bricks. Compare to the other cases, the case 2 is give best temperature distribution inside the chamber. The analysis results are shown below.

5.2 Result for nine heaters

The heat sources are operated at the temperature of 423K, 403K and 413K with respect to case 1, case 2 and case 3. The difference between operated temperature and required curing temperature is high in all cases. When heat sources are operating at high range, it leads to poor quality bricks. So the arrangements of heaters in all cases are not give efficient heat for curing the bricks.



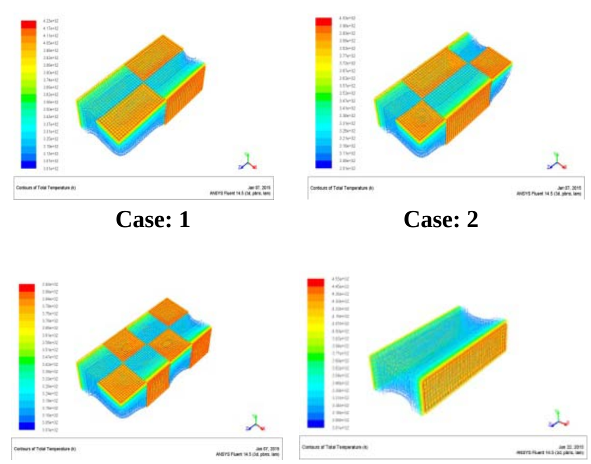
Case: 1 Case: 2

Case: 3

Fig. 7: Result for 9 number of heaters

5.3 Result for eight heaters

When using eight numbers of heaters, there are possible four cases. In case 1, case 2, case 3 and case 4 the heat sources are operating at the temperature of with respect to 423K, 403K, 393K and 453K. Consider the case 3, the heat sources operating range 393K (120°C) is low compare with other cases. Here, the case 3 is give best analysis result compare to the all cases when chamber have nine numbers of heater.



Case: 1 Case: 2

Case: 3 Cases: 4

Fig. 8: Result for 8 number of heaters

5.4 Result for seven heaters

When using the seven numbers of heaters the operating temperature is 483K, 423K and 453K. In all cases the air temperature is very high. So, these are not suitable for generating the proper curing temperature.

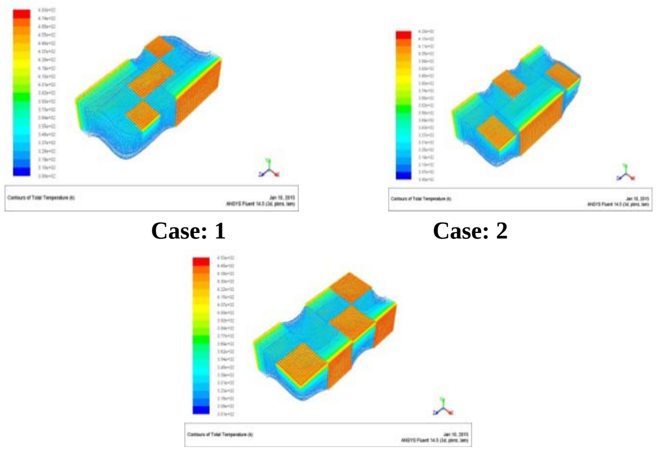


Fig. 9: Result for 7 number of heaters

6. COMPARISON OF RESULTS

From chart, when using the ten numbers of heaters, the case 2 have lowest operating temperature, most economical for attain the required air temperature inside the chamber compare to all other cases.

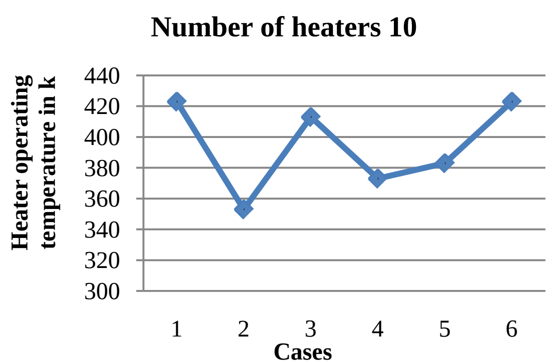


Fig. 10. Performance of 10 heaters

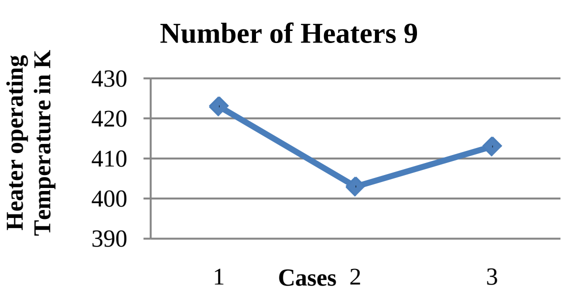


Fig. 11: Performance of 9 heaters

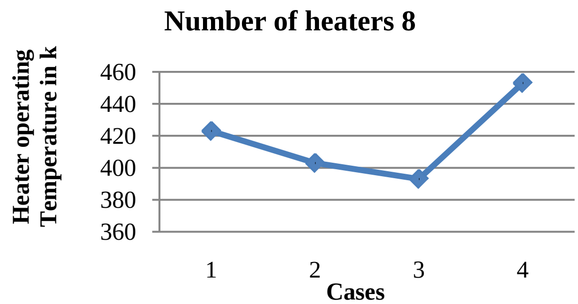


Fig. 12: Performance of 8 heaters

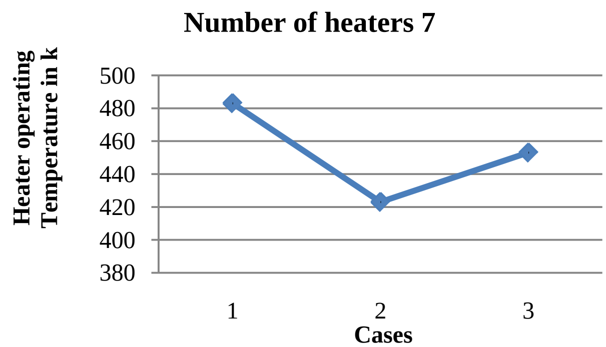


Fig. 13: Performance of 7 heaters

7. CONCLUSION

The various position of heat sources are placed inside the chamber finds out possible curing temperature. From the results of analysis, identify and select the suitable the number of heat sources for curing the fly ash bricks. When the chamber has ten numbers of heaters, case 2 have lower operating temperature compare with other cases. In the absence of placing the heat sources at the bottom, case 4 gives best temperature distribution inside the chamber. Remaining all other cases is give high temperature of air throughout chamber. This high temperature of hot air is not give sufficient strength for bricks.

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