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Analysis of Different Heat Transfer Mechanisms Portions during Traditional Flatbreads Baking to Improve Quality of Breads and Reducing Fuel Consumption

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ABSTRACT: Accurate cognition of the portions of different mechanisms of heat transfer during the baking process is important and it can introduce useful solutions to improve quality of bread and reduce energy (fuel) consumption of oven. In this study, by experimental measurements and mathematical equations, portions of different mechanisms of heat transfer during the baking process of traditional hand-baking flatbreads are calculated. Then, based on results, optimization is carried out for ovens. The optimization includes modification of the geometry of the oven, control of excess air, and improvement of thermo-physical and radiant properties of oven walls. The obtained results showed that in Sangak and Barbari bakeries portions of convection heat transfer mechanism (natural and forced convection) and volume radiation are negligible against conduction and surface radiation mechanisms. The results of thermal diffusivity and emissivity optimization illustrated that fuel consumption for Sangak, Barbari and Taftun bakeries can be reduced about 26%, 28%, and 8%, respectively. Also, in optimal conditions for all bakeries, the reduction of excess air from current values to 10% is leading to reduce of more than 90% of excess air losses.

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1- Introduction

The authors of this study would like to continue and complete their previous studies [1–2] and to fulfill this demand they would like to investigate about optimization of furnace geometry, thermophysical and radiative properties of the furnace. The important point is that the basis of optimization is bread quality and the optimized factors that keep the quality of bread are considered as the optimization model. In order to optimize the furnace, the measurements and experiments have been done for three hand-baking bakeries in Kashan city and the temperatures of inner parts of the furnace, the input energy rate to the furnace, and the output energy rate were detected. Next, by using experimental results and empirical data and finally numerical and analytical measurements, the portion of different heat transfer mechanisms are specified. In the present work, by using the results, the appropriate furnace geometry,

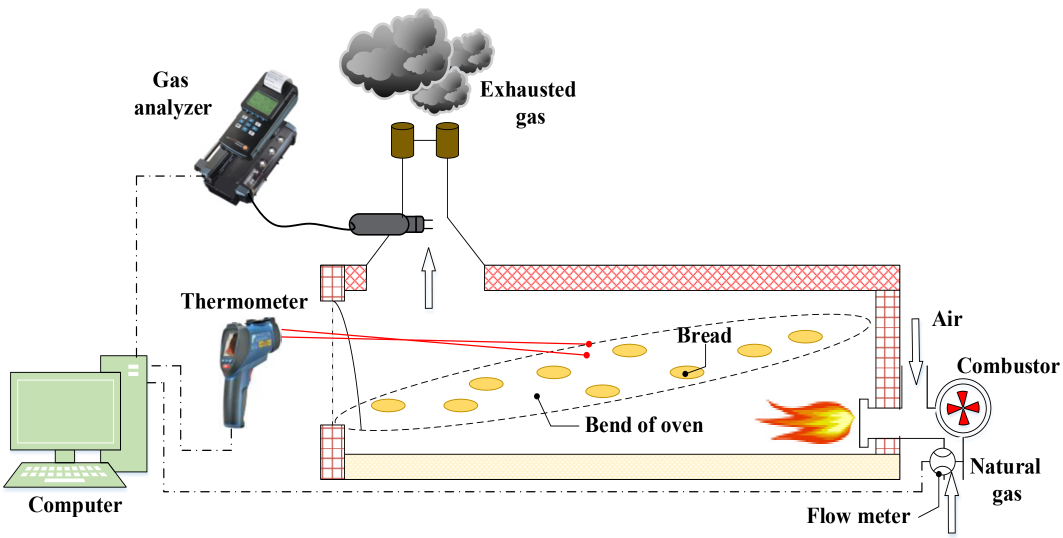

Fig. 1. Schematic diagram of Sangak hand-bakery and the applied measurement devices

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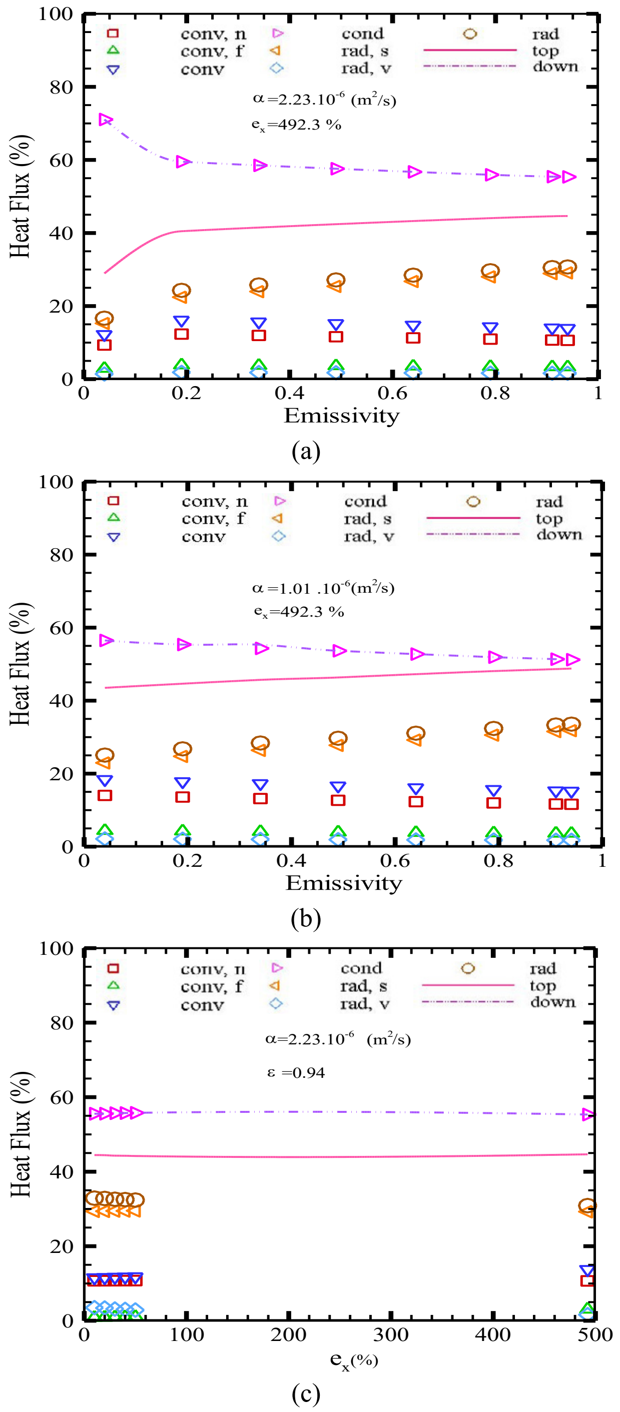

Fig. 2. Effects of different parameters on transferred heat flux to Taftun bread

the optimized thermophysical and radiative properties that should be used in the furnace walls and the right portion of excess air in combustion are specified.

2- Methodology

The schematic diagram of Sangak hand-bakery and the applied measurement devices are shown in Fig. 1. As it is clear the measurement devices include non-contact thermometer, smoke analysis device and flow meter. For measuring different parts of the furnace, the infrared video thermometer, ST-9861, is used. This thermometer is equipped with the digital monitor and measures the temperature between –30 and 2000 °C through infrared. Furthermore, this device can save pictures and thermal properties and transfer them to computers. In addition, for measuring the combustion efficiency (the remained heat inside the furnace) and hot gases analysis inside the furnace the TESTO 350 M/XL gas analysis device that is made in Germany was used. This device can measure the concentration of nitrogen oxides and carbon monoxide up to 3000 ppm and 1000 ppm, respectively. Moreover, the existing Thermocouple inside the device can bear the temperature up to 1200°C. The measurement accuracy of this device for nitrogen oxides for concentrations less than the 100 ppm is 5 ppm and this accuracy for carbon monoxides in concentrations less than 100 ppm, equals to 10 ppm. The schematic diagrams of these two devices are shown in Fig. 1.the smoke analysis device can save the data and transfer them to computers.

3- Discussion and Results

The goal of optimization in this study is first, improving the bread quality and second, decreasing the fuel consumption in bakeries.in the case of flatbread, the share of received energy should be the same from top and bottom in order to increase the bread quality and decrease the amount of unused part of the bread. Furthermore, the time of baking should be done in an appropriate range and time more or less than this permitted range decrease the bread quality. Due to special geometry of Taftun furnace, there is no possibility of changing the geometry and it is only possible to investigate the thermal diffusivity and emissivity of sidewalls and the excess air as well. According to Fig. 2, the current condition of Taftun ovens are thermal diffusivity equals to 1.01×10-6 m2•s-1 and emissivity equals to 0.91.by changing the thermal diffusivity from the current value to 2.23×10-6 m2•s-1, 8% saving in fuel consumption occurs. as it is clear from Fig. 2 by decreasing 10% in excess air from the current value of 492.3% it is possible to save 98% in losses related to the excess air.

4- Conclusions

In the present study, first the features of different kinds of manual furnaces for baking flat traditional bread (Sangak, Barbari and Taftun) like the temperatures of inner walls of furnaces and also the combination of hot gases inside the furnace were specified by doing experiments and measuring with infrared video thermometer, ST-9861 and gas analysis device, TESTO 350M/XL. Then by using the analytical correlations and mathematical computations, the share of different heat transfer mechanisms was detected in the baking of traditional bread. The results revealed that the share of convection in baking Sangak and Barbari is insignificant (almost 5%) and it is possible to neglect it comparing to conduction and radiation. The share of different heat transfer mechanisms in baking traditional bread is as follows:

- Sangak: conduction 44.52%, radiation 49.92%, and convection 5.56%
- Barbari: conduction 43.29%, radiation 51.54%, and convection 5.17%
- Taftun: conduction 51.36%, radiation 33.32%, and convection 15.32%

The accurate recognition of different heat transfer mechanisms share in baking different bread, leads to suggesting solutions to improve bread quality and fuel consumption decrease. Therefore, the optimization of thermophysical and radiative properties of various furnaces walls has an important role in saving fuel consumption and improving the bread quality. For this reason, first the thermal diffusivity of the floor and emissivity of the roof were optimized and in the next step, the effect of excess air reduction in the optimum condition of the first step was investigated. The results revealed that for Sangak, Barbari, and Taftun bakeries the optimum values for thermal diffusivity of the floor are 1.80×10-6 m2•s-1, 2.53×10-6 m2•s-1 and 2.23×10-6 m2•s-1 the emissivity values are 0.94, 0.94 and 0.91 these optimum values save 26%, 28%, and 8%, respectively, in fuel consumption. Moreover, by decreasing the excess air by 10% for the optimum values of floor thermal diffusivity and roof emissivity for Sangak, Barbari and Taftun bread, it is possible to decrease 94%, 96% and 98% in the losses related to the excess air. After different investigations on the reduction of roof height to the floor furnace, it was concluded that if the new furnace with new dimensions is built for new data gathering, the study of height reduction is useful.

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