BURNERS, COMBUSTION AND HEAT TRANSFER

(686) - (*) - NUMERICAL AND EXPERIMENTAL CHARACTERIZATION OF HEAT TRANSFER CHARACTERISTICS WITHIN A MODEL BAKING OVEN BASED ON REFLECTION OF NIR AND IR THERMAL RADIATION

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More than half of the total energy input to the pastry production is directed to baking, making it the most energy intensive process step. Still, ca. 60% of this energy dissipates to the environment, resulting in a significant CO_2 emission and costs, especially for SME. This implies the importance of enhancing the energy efficiency of the baking process. Innovation in baking oven technology in the direction of better resource management (energy, production time, space) could get us closer to this goal. E.g. various studies claim that when the thermal radiation component of heat transfer is intensified, the baking time reduces, leading to reduced energy input and costs.

Through their previous studies, authors demonstrated the advantages of a gas-heated volumetric ceramic burner (VCB) technology for direct baking in a batch deck oven, where comparable product quality was reached in a shorter time (20% reduction for 800g white bread) as compared to a conventional electric deck oven. Present work overviews the initial steps in the development of an innovative continuous baking oven concept, where stationary reflectors are applied to homogeneously distribute intensive thermal radiation from a strong radiative heat source (e.g. VCB) over a large baking area, to obtain a uniform temperature field. In this way, the advantages of VCB (e.g. baking time reduction, significant thermal load modulation, better process control suitable for a wide range of baking goods) can be fully utilized.

In the present work, the influence of the reflector shape (flat, parabolic and semicircular), the distance between the heat source and the reflector (high, medium, low), and the thermal load of the heat source (300, 600, 900 kW/m^2) on the temperature distribution over the baking area and baked goods were investigated numerically and experimentally. Numerical analysis, conducted using the software ANSYS FLUENT 2019R1, considers a simplified 2D model of a system consisting of a heat source, a reflector placed above it, and a baking area. Analysis also included the influence of the product geometry, surface temperature and emission coefficient on the thermal field over the baked goods. The numerical findings were evaluated in an experimental test set-up, set according to numerical simulations, with the goal to identify the optimal shape of the reflectors for obtaining a uniform temperature field over the baking area.

According to the numerical analysis, a semicircular reflector provides the most uniform temperature field over a baking surface among the tested reflector shapes, i.e. temperature difference for flat and parabolic reflectors was >20°C and >100°C, respectively. When the distance between the plate and the heat source decreased, the position of the temperature maximum for parabolic and flat reflectors shifted towards the symmetry axis, while for the semicircular reflector it was almost unaffected. The average temperature under the round and flat reflectors rose about 20°C, while for parabolic reflectors it remained approximately the same. In the scope of the experimental analysis, semicircular reflectors, which showed to be the most promising for obtaining a homogeneous temperature field over the baking area in the numerical analysis, were tested.

Palavras-chave : baking oven, gas burner, reflection, heat transfer