RADIANT RECUPERATOR: MODELLING AND DESIGN

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Recuperators are frequently used in glass production and metallurgical processes to preheat combustion air by heat exchange with high temperature flue gases. Mass and energy balances of a 15 m high, concurrent radiant recuperator used in a glass fiber production process are given. The balances are used: (i) for validation of a cell modelling method that predicts the performance of different recuperator designs and (ii) for finding a simple solution to improve the existing recuperator. Three possible solutions are analyzed: (i) to use the existing recuperator as a countercurrent one, (ii) to add an extra cylinder over the existing construction and make a system that consists of a central pipe and two concentric annular ducts. In the latter, two air streams flow in opposite directions, whereas air in the inner annular passage flows concurrently or countercurrently to flue gases. Compared with the concurrent recuperator, the countercurrent has only one drawback: the interface temperature is higher at the bottom. The advantages are: lower interface temperature at the top where the material is under maximal load, higher efficiency and smaller pressure drop. Both concurrent and countercurrent double pipe-in-pipe systems are only slightly more efficient than pure concurrent and countercurrent recuperators, respectively. Their advantages are smaller interface temperatures whereas the disadvantages are their costs and pressure drops. To implement these solutions, the average velocities should be: for flue gas around 5 m/s, for air in the first passage less than 2 m/s, and for air in the second passage more than 25 m/s.

Key words*: recuperator, radiation, convection, heat transfer, concurrent, countercurrent, double pipe-in-pipe system*

1. Introduction

The higher the temperature, the larger the heat potential to perform work, i.e. its exergy. The maximum theoretical efficiency for the conversion of heat into power is given by the formula for a reversible Carnot process: $E_Q = ((T - T_o)/T)Q$, which means that 80% of the heat at 1217 °C could be theoretically transferred into power when the environment is at 25 °C. The highly valuable heat at high temperatures leaves metallurgical and glass production furnaces as the sensible heat of flue gases. In a glass fiber production process, flue gas exit temperatures greater than 1200 °C are usual [1]. The preferable use of high temperature heat is for power production, but in these industries it is more energy efficient, economically justified, and technically simpler to use this heat to maintain high