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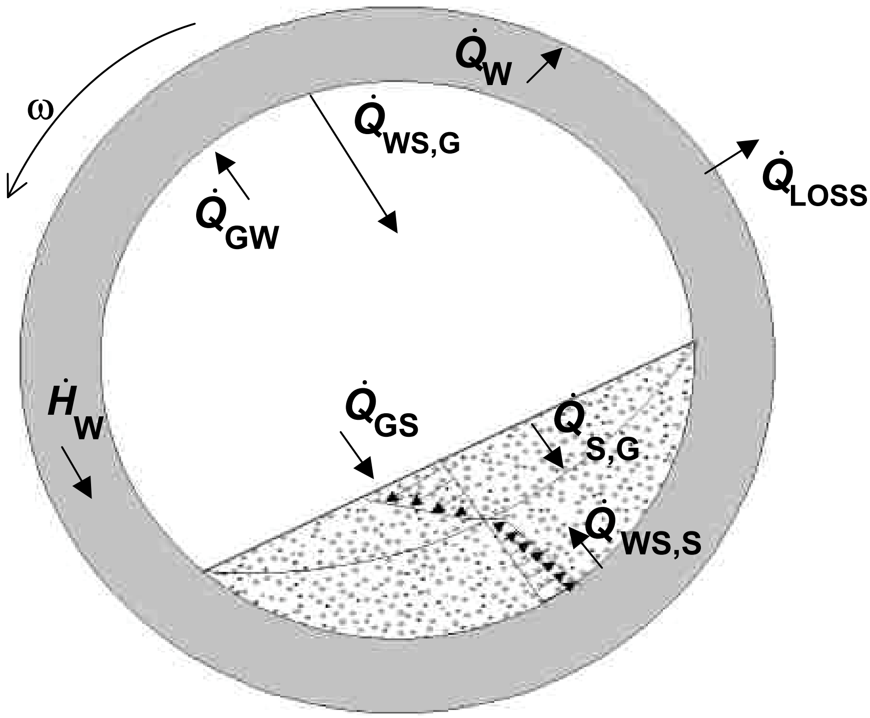
Modelling and Measurement of Heat Transfer in direct fired rotary kilns

Keywords: Heat transfer, rotary kiln, thermal active layer, agitated bed

PROBLEMS

Rotary kilns are most commonly used in areas where granular and lumpy materials are processed. For example, cement and lime burning, aluminium oxide process, coke and petroleum coke calcinations, waste treatment, and pyrolysis process. In a direct fired rotary kiln the solid temperature is raised up to reaction temperature by hot combustion gas flowing above the solid bed. The heat transfer is complex because it involves not only the gas and solids, but also the rotating kiln wall.

Figure 1 (Heat Flow Paths)

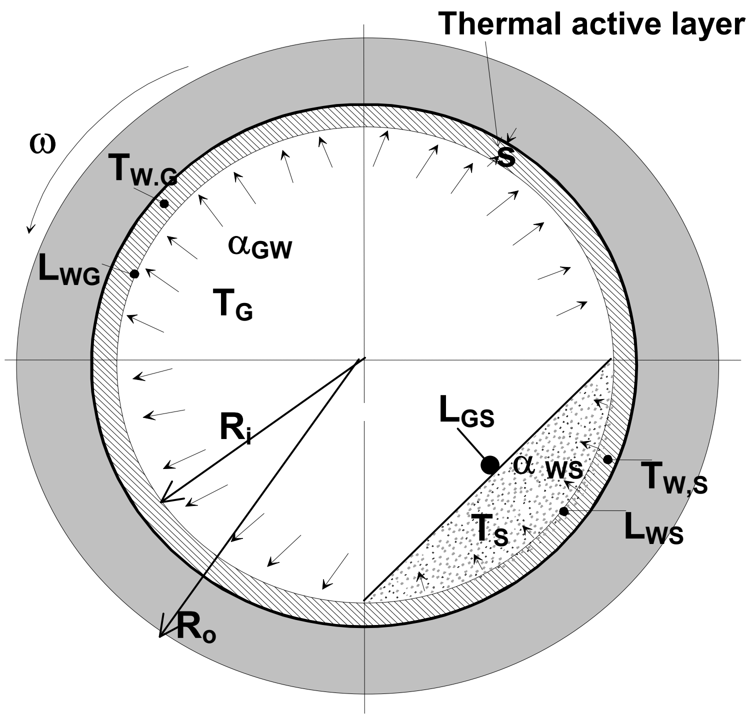


The exposed solid bed surface receives heat directly by radiation and convection from the freeboard gas ($\dot{Q}_{GS}$) whereas at the covered solid surface, heat flows by a combination of radiation and conduction from the wall to solids ($\dot{Q}_{WS,S}$). This latter heat transfer path is part of the regenerative heat transfer of the kiln wall which, as it rotates to the freeboard gas also receives thermal energy via radiation and convection from the hot combustion gas ($\dot{Q}_{GW}$) which is stored in the kiln wall and transported back as enthalpy flow ($\dot{H}_W$) to the covered solid surface. A part of the heat which is stored in the wall is reflected exclusively back to the solid bed by radiation ($\dot{Q}_{WS,G}$). A portion of the heat is lost to the surroundings by convection and radiation ($\dot{Q}_{LOSS}$).

Part 1. Modeling of Regenerative Heat Transfer

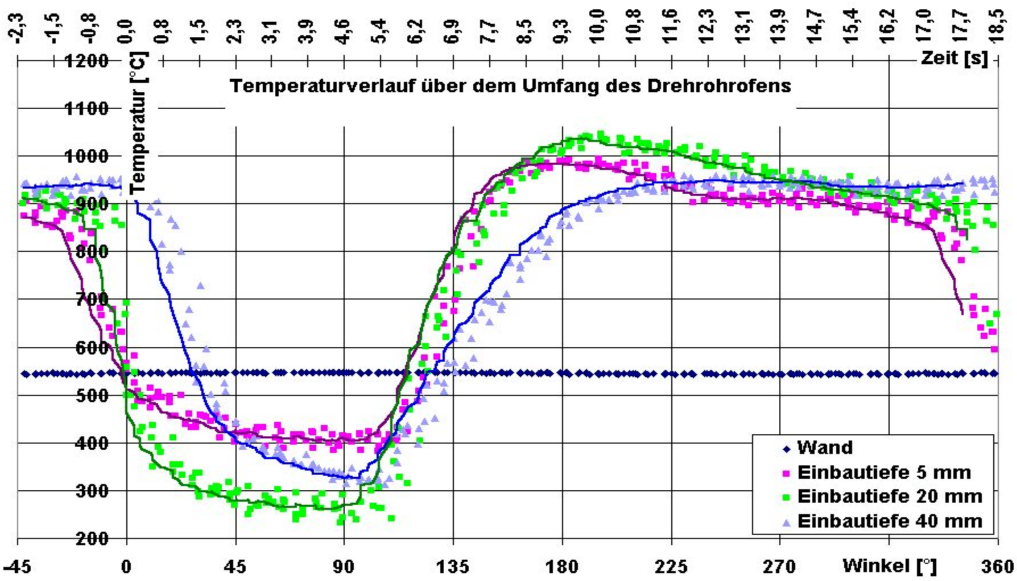
In a rotary kiln, heat is transferred to the solids bed by two paths, across the exposed upper surface and the covered lower surface of the bed. The last heat transfer path is part of the regenerative heat transfer of the kiln wall which, as it rotates through the freeboard gas, also receives thermal energy via radiation and convection from the hot combustion gases. However owing to the high temperatures attained in the freeboard gas, radiation is believed to be the dominant heat transfer mechanism. A radiation linearization of heat transfer coefficient is necessary to compare later between analytical and numerical result. Although some studies are cited in literature about the regenerative heat transfer of the kiln wall, but there are still some uncertainties concerning its importance relative to the other heat transfer steps, the effect of different kiln variables, and the possibility of employing a simplified model to predict the variation of inside wall temperature. Therefore, a simplified mathematical model is developed to predict the effect of different kiln variables on the regenerative heat transfer in a rotary kiln.

Figure 2 (Used symbols for modeling heat transfer)



Part 2. Measurement of Heat Transfer in the Agitated Bed of a Rotary Kiln

The rotary kiln is shown in Figure 3 (Photograph of rotary kiln pilot plant). The internal diameter is 250 mm and the external diameter is 400 mm. The inner wall is lined with refractory of thickness 70 mm and the metal shell covering the outer wall is 5 mm thick. The kiln has a constant speed of 3.25 rpm and inclined at 1.9° to the horizontal. The kiln proper is 6.735 m long and divided into 12 sections but only four sections is used for the experiment. At each section, five thermocouples are inserted through the kiln wall and rotated with the kiln wall. One thermocouple measured only the gas temperature, three thermocouples measured the solid and gas temperature, and the last measured the inner kiln wall temperature. The purpose of these installations is to get an accurate measurement of solids, gas and wall temperature which is essential to characterise the various heat flows within the kiln.



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