A MODEL FOR HEAT TRANSFER TO HORIZONTAL TUBES IMMERSED IN A FLUIDIZED BED OF LARGE PARTICLES

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ABSTRACT

Clues from experiment are used to formulate a model for heat transfer between horizontal tubes and bed. The model assumes that when the emulsion is present at the tube surface, heat is transferred by particles and by gas percolating between particles and the surface; when bubbles are present heat is transferred across the gas film. This model is developed for large particle beds, \( d_p > 1 \text{ mm} \), and agrees with reported results over a wide range of conditions.

INTRODUCTION

Most of the published work on fluid-bed heat transfer has concentrated on fine particle systems and has employed the "packet" theory to explain the reported values. However, in recent years, mainly as a result of the interest in fluidized bed combustion, experimental results on heat transfer from immersed horizontal tubes to beds of large particles have appeared. This paper develops a model to represent such heat transfer, and tests the resulting equation with reported experimental results.
EXPERIMENTAL FINDINGS

Catipovic et al. (1978) and Catipovic (1979) measured the instantaneous heat transfer rates and simultaneous local voidages at multiple positions around an immersed horizontal heat transfer tube in a cold bed, with particle sizes in the range 0.8 to 6.6 mm. The results can be summarized as follows:

1. The maximum and minimum instantaneous heat transfer coefficients level off and become constant at gas velocities not much beyond $U_{mf}$. A typical example is shown in Fig. 1. The instantaneous maximum occurs just after fresh emulsion sweeps the surface; the instantaneous minimum comes when a bubble or slug is present at the surface.

2. For a given particle size, the instantaneous and (consequently) the time-averaged heat transfer coefficients are independent of bed height.

3. The difference in time-averaged coefficients for a single tube and for a closely packed tube array (pitch/diameter = 2) is small, at most 12%.

4. Voidage at the surface of a tube varies much less with gas velocity than the overall bed voidage. This is the information needed to develop a satisfactory model and an equation to represent the heat transfer from bed to tubes.

![Figure 1. Maximum, minimum and time-averaged heat transfer coefficient for the whole tube. Maximum and minimum values are practically independent of gas velocity.](image_url)