THE DYNAMICS OF PACKED BEDS WITH INTRAPHASE HEAT TRANSFER

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ABSTRACT.

An exploratory experimental study and theoretical analysis of the relationships between various mathematical descriptions or 'models' of linear packed bed heat transfer dynamics has been carried out. Some contributions have also been made to the theory and practice of dynamic testing.

Physical phenomena allowed for included fluid phase axial dispersion, inter and intra-phase heat transfer and bulk fluid convection. 'Two phase' finite stage and continuous models were compared and shown to yield close correspondence over a wide range of parameters.

The conditions under which a single parameter may be used to characterise the dynamic response of a packed bed were clarified. It was found that the 'equivalent conductivity' model of Babcock and co-workers could be used only when a parameter known as the 'heat capacity ratio', V_H was near unity. For large values of heat capacity ratio, the Schumann model could be applied, lumping axial dispersion and solids conductivity effects into an equivalent Schumann heat transfer parameter by means of a simple equation, provided the 'bed length parameter', γx, defined by Babcock was greater than 5 to 10.

The criterion proposed by Handley and Heggs for assessing the importance of 'intraparticle' (or internal particle conduction)

effects on breakthrough curves was examined. The criterion was found to be incorrect since it did not distinguish between 'dispersive' and 'curve shape' effects.

General integral formulae for determining breakthrough curves in a packed bed from any linear transfer function were derived and used, through an orthogonal polynomial Fourier transform inversion procedure, to obtain theoretical breakthrough curves for a wide range of parameters. Points on the curve were then correlated empirically against the single parameter referred to above, allowing rapid construction of any breakthrough curve satisfying the constraints on bed length parameter and heat capacity ratio.

Relationships between frequency response testing and moments analysis were derived and orthogonal polynomial approximation procedures for pulse to frequency response conversion developed. A critical assessment of errors inherent in various methods of dynamic testing has been presented with emphasis on the cyclic test method of frequency response and on two step response procedures.

A technique for improving the reliability of pulse testing experiments was developed and used to apply thermal pulse and step inputs to packed beds of lead, soda glass and Perspex through which air was flowing. Theoretical conclusions regarding the effect of the bed length parameter γx on curve shape were verified although anomolous results were obtained for small values of γx. It is suggested that the models considered do not provide a good description of packed bed dynamics in this case. Comparison of experimental values of the Stanton number with those predicted by the steady state heat transfer correlations of Denton and others led to the conclusion that these correlations are 'contaminated' by axial fluid dispersion effects. Correction for axial fluids dispersion would therefore be expected to yield erroneous results in predictions of breakthrough curves, when those correlations are used. The theoretical effects of fluid phase axial dispersion on various steady state packed bed experiments were also considered by use of the F-factor approach of Epstein.

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