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A review on transient test techniques for obtaining heat transfer design data of compact heat exchanger surfaces

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ABSTRACT

Accurate and reliable dimensionless heat transfer characteristic is very essential for the analysis of heat exchangers. It is also required for the rating and sizing problems of heat exchangers. One of the important experimental methods used to determine the heat transfer coefficient between the heat transfer surface of the heat exchanger and the flowing fluid is transient test techniques. The transient test techniques are usually employed to establish Colburn factor versus Reynolds number characteristics of a high NTU heat exchanger surfaces like compact or matrix heat exchangers. In those situations, a single-blow test, where only one fluid is used, is employed to conduct the transient test. The transient technique may have the fluid inlet temperature having a step change, periodic or an arbitrary rise/drop. In this paper, various transient test techniques that are used for the determination of heat transfer characteristics of high NTU heat exchanger surfaces are discussed.

1. Introduction

For the design and analysis of a heat exchanger, it is very important to know the heat transfer coefficient in dimensionless form of the heat transfer surface. Generally, the dimensionless experimental heat transfer characteristics are presented in terms of the Colburn factor, j, versus the Reynolds number, Re. The single-blow transient testing has been widely used to measure heat transfer coefficients between fluids and heat transfer surfaces. The technique uses only one fluid stream which flows through the test core at a constant flow rate. The test procedure is relatively simple: a fluid flows steadily through a test core. Then a transient state perturbation in the inlet fluid temperature is induced and the inlet and outlet fluid temperature histories are measured continuously. These data are then compared with the theoretical model to obtain the corresponding heat transfer coefficient between the test core and the fluid. The major disadvantage of single-blow transient technique is that its accuracy is very much depending upon how accurately the mathematical model describes the experiment.

2. Transient test techniques for compact heat exchangers

The original mathematical model for transient method was formulated by Hausen [1]. Schumann [2] obtained the analytical solution for a transient problem for the first time. Locke [3] showed that for a step change for the fluid at the inlet of the heat exchanger core, the number of transfer units (NTU) is a function of the maximum slope of the outlet temperature profile but the effect of axial conduction was ignored.

Kohlmayer [4–8] formulated an integral equation for the single-blow transient problem and derived analytical solutions using double Laplace transform method that reduces the number of necessary steps in the derivation. He pointed out that the maximum slope method has limitations for small values of NTU. For NTU < 2, no point of inflection exists and hence there exists no maximum slope and for 2 < NTU < 3, the magnification of relative errors is substantial. A method known as centroid method that permits the reduction of transient matrix heat-transfer test data in the low NTU-range (0.5 < NTU < 5.0) was suggested. This method is based on (i) the analytical solution of the single-blow problem for monotonously decreasing upstream fluid temperature changes and on (ii) the indirect matching of downstream fluid temperature response curves by a single-valued functional which decreases monotonically with NTU, specifically by the centroid coordinate of the area under the difference of those two temperatures. The caution to be taken for the heat exchanger core having NTU < 2, has been mentioned by other authors.

Pucci et al. [9] have described the single-blow transient testing technique for determining the heat transfer characteristics of heat exchanger surfaces with a good explanation of underlying theory. They improved Locke's analysis by including the axial conduction effect and presented the maximum slope value for various values

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