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CFD simulation for steam distribution in header and tube assemblies

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ABSTRACT

The study of the flow characteristics in manifolds (dividing, combining, parallel or Z-manifold and reverse or U-manifold) is a classic subject of engineering fluid dynamics and hydrodynamics. These manifolds are widely used in chemical processes, electronic cooling equipment, solar collectors, spargers, microchannels, fuel cells, heat exchangers and refrigerant distribution in multi-split type of air conditioner, etc. In the literature extensive work has been done for finding out flow distribution in plate-fin heat exchanger, microchannels and spargers. Present work focuses on the flow and pressure distribution in piping networks, which has gained importance in many areas such as air distribution in diffuser system of aerobic biological treatment, steam distribution in passive decay heat removal systems, etc.

The uniformity of flow rates among the parallel tubes of piping manifold is governed by the field of fluid pressure in the system under consideration. In present work, the flow and pressure distribution of pure steam in header and tube assemblies has been investigated with the help of CFD simulations. The effects of design parameters has been investigated over a wide range such as the tube pitch ($50 < D_{pt} < 150$ mm), header diameter ($50 < D_h < 200$ mm), tube diameter ($15 < D_t < 32$ mm), number of tubes ($8 < N_t < 50$), inlet or outlet pipe diameter ($15 < D_{in} < 65$ mm). The sensitivity of inlet mass flow rate ($0.033 < \dot{m} < 0.075$ kg/s) has been investigated on the extent of non-uniformity (%*ENU*) in steam distribution. For validating CFD predictions an experiments have been performed on scaled down geometry of header configuration 'C1' using air and water ($35{,}600 < Re < 68{,}500$) as a working fluid. A good agreement was observed between the predicted and the experimental values of %*ENU*. It is concluded that the tube diameter, number of tubes and their locational arrangement with respect to inlet and/or outlet pipe are most important design parameters affecting the flow and pressure distribution in the pipeline networks.

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Keywords: Flow maldistribution; Extent of non-uniformity (*ENU*); Header and tube assembly; Plate-fin heat exchanger; Computational fluid dynamics (CFD)

1. Introduction

There are many situations in the process design flow or heat transfer equipment where it is necessary to subdivide a large fluid stream into several parallel streams, to process these streams separately, and then to recombine them into one discharge stream before sending the fluid to another step in a process. The entering feed stream is subdivided by a header to which the parallel small tubes are connected at right angles. After treatment, the parallel streams are combined through ports leading into an output header. These manifolds are classified into four types: dividing, combining, parallel, and reverse flow manifolds as shown in Fig. 1. Parallel and reverse flow manifolds are those which combine dividing and combining flow manifolds and are most commonly used in plate heat exchangers. In a parallel flow manifold, the

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