HYDRAULIC RESISTANCE AND HEAT TRANSFER IN LONGITUDINAL FLOW PAST STAGGERED TUBE BUNDLES WITH WALLS OF DIVERGENT-CONVERGENT PROFILE

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The results of an experimental investigation into the effect of the characteristic dimensions of staggered convergent-divergent tube bundles on hydraulic resistance and heat transfer in a longitudinal flow are presented.

As before, the enhancement of heat transfer in different-purpose tubular heat exchangers remains an urgent applied problem in the theory of heat and mass transfer [1-5].

In the case of the single-phase heat carrier transverse flow past tube bundles, the problem of heat transfer enhancement is usually unambiguously solved by applying finned tubes, because the use of different types of turbulizers, just as the change in the shape of the walls, does not give desirable positive results as compared with smooth-wall tube bundles [3-5].

By the present time, the most developed and verified method for the enhancement of heat transfers is during the turbulent flow of various heat carriers in tubes with different types of turbulizers or with the shape and geometric dimensions of the cross section varying along the flow path. The relevant literature contains voluminous information relating to the thermo-hydraulic characteristics of heat-exchanging tubes with annular knurling [1], helical tubes [2, 6], tubes with a divergent-convergent profile [7-10], etc. This has made it possible to start a wide practical incorporation of tubes with heat transfer amplifiers into real heat exchangers with a substantial improvement in their characteristics.

As a rule, the application of turbulization mechanisms to the internal walls of tubes leads inevitably to the deformation of the outer walls. The question then naturally arises as to the estimation of the extent of heat transfer intensification on these walls in the case of longitudinal flow past tube bundles. This attempt was made in a comprehensive study [2] where the characteristics of the ovaly-coiled tubes that ensured heat transfer enhancement both in tube and intertube space were investigated. However, the gain in energy with the use of ovaly-coiled tubes is relatively small, while they are very difficult to manufacture and have insufficiently reliable strength characteristics.
Fig. 1. Schematic of a test section with a staggered tube bundle (a), without a displacement of tubes (b), with a displacement of tubes (c), divergent-convergent tube (d); (1), heated tube; (2), tube plates; (3), (4), inlet and outlet branch pipes; and (5), casing.

Fig. 2. Heat transfer and hydraulic resistance of longitudinal bundles of smooth-wall and corrugated tubes: (1) a smooth-wall tube bundle; (2) a symmetric bundle of corrugated tubes, s/d = 1.114; (3) a bundle of corrugated tubes with a mutual displacement by one diffuser or converger module, s/d = 1.114.

In our opinion, based on the available information, the use of divergent-convergent tubes arranged in longitudinal tube bundles seems to be an alternative variant to ovaly-coiled ones [2]. For the first time this problem was considered in [4] in application to the air heaters of boilers. Therefore, the task has been set to investigate experimentally the hydraulic resistance and heat transfer in longitudinal flow past staggered bundles of tubes of divergent-convergent profile in comparison with other familiar variants. In this paper the experimental data are presented on the characteristics of twelve staggered smooth-wall and divergent-convergent tube bundles with relative spacings s/d = 1.114, 1.22, 1.432, and 1.64 immersed in a longitudinal flow.

The investigations were carried out on a rig the schematic diagram of which is similar to that given in [11] and which is depicted in Fig. 1. The method of local simulation was used, which is also described in detail in [11] in application to longitudinal flow past tube bundles.