Modeling of air distribution in high-efficiency plate heat exchangers used in air-conditioning systems

The commercial market is dominated by air conditioning systems based on vapor compression systems powered by electricity. Their efficiency tends to thermodynamic limits. The need to develop new alternative cooling solutions was noticed because thermal compressors are characterized by relatively low coefficients of efficiency and large dimensions, which makes it difficult to use them in air conditioning. Promising technology are open sorption systems (OSS) based on the evaporation of water into the air and its removal from the air, which are powered by thermal energy and can potentially be used in air-conditioning units. To enable that their dimensions are adjusted, and high efficiency factors are achieved compared to other systems powered by thermal energy. Increasing the system efficiency COP (Coefficient of Performance) is possible using dew point evaporative coolers.

The aim of the work is to analyze the distribution of air in dew point indirect evaporative coolers and to develop a device with dimensions and shape that allows increasing the efficiency of the OSS while locating it in the standard section of the air-conditioning unit. The aim of the work was carried out based on the developed research plan based on a detailed analysis of three different structures of evaporative coolers, which can potentially be used to increase the efficiency of OSS.

The first commercial structure of the built-in exchanger enabling the implementation of the idea of dew point evaporative cooling was used for experimental verification of the increase the OSS efficiency. Based on numerical calculations, it was shown that the use of the exchanger has a beneficial effect on increasing the COP of the system and lowering the required temperature range of sorbent regeneration, which increases the potential for commercialization of the system. Based on the above structure, a method of analyzing pressure losses and air distribution in the exchanger based on computational fluid dynamics (CFD) was also proposed and verified.

The second structure of the exchanger was analyzed numerically based on CFD methods supplemented with numerical calculations of heat and mass transfer in the exchanger. The proposed structure was used to demonstrate the influence of uniformity of air distribution in the device on selected efficiency factors. A characteristic feature of the proposed structure is the possibility of installation in the air handling unit section and a relatively simple construction in terms of the exchanger and water supply to the wet channels.

The third proposed structure of the exchanger was developed using the methods of efficiency analysis and air distribution in evaporative coolers presented in the study. The structure is based on materials that enable the maximum use of space in the air handling unit section, and its shape and efficiency coefficients prove its potential to be used as an element increasing the efficiency of an open sorption system.

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