Computational fluid dynamics study of helium-air heat pipe heat exchanger for application in nuclear reactors

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The use of green high temperature heat sources in industry is now increasing in several industries including plastics, ammonia and fertilizers, hydrogen, and coal-to-liquid fuel [1]. Currently, high temperature nuclear reactor technology can produce high fluid temperatures up to about 950°C or more. However, considering the activating environment, and at the aforementioned high temperatures, tritium, a radioactive contaminant found in the helium coolant stream, can diffuse through the steel retaining wall of the helium-to-steam heat exchanger [2]. To prevent the radioactivity problem, there is need for intermediate heat exchange loop between the helium and the final heat streams. Consequently, there is need to design a heat pipe heat exchanger with minimum energy loss, which can have a high efficiency and eliminate intermediate heat loss in the heat exchange process. Computational fluid dynamics is a sophisticated computing tool for fluid dynamics and thermal design in industrial applications. CFD has been successfully used to model the heat transfer analysis for an originally designed energy efficient heat pipe heat exchanger (HPHE) for waste heat recovery in buildings [3]. In this study, the CFD was used to model helium to air HPHE. The HPHE has two pipes, a hot and a cold pipe, where the cold pipe is positioned above the hot pipe in a liquid pool. In this case the hot fluid is helium, the cold fluid is air and the heat transferring liquid is a eutectic mixture of lead-bismuth (LBE) liquid metal [4]. The natural convection driven flow inside the cold and hot streams are modeled to incorporate conductive and convective heat transfer with the working fluid. The number of pipes due to the specific heat capacity of the working fluid were about 650 m. The high temperature helium fluid exchanges heat with the incoming cold air, via convectional processes. The starting point is a simplified CFD model informed by conventional calculations, and the final point will be after many iterations exploring further complexity in the geometry, the numerical procedures and the physics modelled. This designed will therefore be further developed for specific use in nuclear reactor technology.

References

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