DESIGN AND DEVELOPMENT OF HIGH TEMPERATURE HEAT PIPES AND THERMOSIPHONS FOR PASSIVE HEAT REMOVAL FROM COMPACT HIGH TEMPERATURE REACTOR

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INTRODUCTION

Compact High Temperature Reactor (CHTR) is $^{233}$U-Th fuelled, lead-bismuth eutectic (LBE) cooled and beryllium oxide moderated reactor. This reactor with 100 kWth power is being designed to operate at 1000 °C to facilitate demonstration of technologies for high temperature process heat applications. The reactor design incorporates several passive features. This includes primary heat transport by natural circulation of coolant. The heat from the primary to the secondary side is transferred by means of a set of high temperature heat pipes using sodium as working fluid. The design also incorporates heat pipes for heat removal under postulated accident scenarios. It is important to design and demonstrate reliable and long term operation of these heat pipes. Technologies for design, manufacture and testing of high temperature heat pipes and thermo siphons have been developed and the required facilities have been setup. This paper provides an outline of these developmental activities.

The initial design of the heat pipe is carried out by means of a user friendly in-house computer code HPDATA. The code has two modules, a computational backend and a GUI (Graphical User Interface) front end. The user can carry out various types of analysis, like one point calculation, parametric analysis to optimise the design by changing various parameters of heat pipe, wick, evaporator and condenser. A similar code TSDATA was developed for design of thermo siphons. In addition, for detailed system level analysis, where heat pipes form a part of the entire system, a simplified model was developed, which makes use of finite element method to model the normal operation of the heat pipes. This model can be readily incorporated into existing FEM codes and can therefore be readily utilised to model entire system. The same has been done for CHTR. A heat pipe model was developed by augmenting a commercial CFD code and using user defined functions to model the mass flow into and out of the vapour space due to evaporation and condensation. A kinetic theory based model was used. The salient results of this model are presented in the paper. In addition to the theoretical modeling, fabrication of sodium heat pipe and thermo siphons has also been investigated. For proper operation, leak proof joints and out-gassing of the heat pipe envelope are the most important aspects. A thermo siphon envelope was fabricated from stainless steel and subjected to helium leak testing. The out-gassing of the envelope was carried out by heating the envelope inside a long muffle furnace under high vacuum and monitoring the evolved gasses using a residual gas analyser. The results would be presented in the paper. After completion of outgassing, sodium is transferred and the thermo siphon sealed. The paper would also cover fabrication aspects of parallelepiped heat pipe.

RESULTS AND DISCUSSIONS

The screen shots for the HPDATA code is shown in Fig 1, whereas the predictions of the TSDATA code for thermo siphons operating in conditions similar to CHTR is shown in Fig 2. This shows that sufficient margin to any of the operating limits exists when using sodium as working fluid. A schematic of the simplified model developed for system modelling of heat pipes is shown in Fig 3. The vapour side nodes of the wick are coupled together, which represents the very low temperature drop in vapour space during normal operation. The results obtained using this model is compared with experimental data published in literature (Fig 4), which shows a reasonably good match. Advanced model is on CFD which is underdevelopment as illustrated in Fig 5.
CONCLUSIONS
Design, simulation and fabrication of sodium based high temperature heat pipes, and thermo siphons, as systems for passive heat removal from CHTR under normal as well as postulated accident condition has been carried out. Heat pipes have potential application for passive heat removal from other advanced reactors.

REFERENCES