INVESTIGATION OF FREE CONVECTION HEAT TRANSFER IN MISSOURI S&T PRISMATIC SCALED DOWN FACILITY (MSTF)

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Abstract

This document investigates free convection heat transfer in the core (channels) of Missouri S&T prismatic scaled down facility (MSTF).

Keywords

Prismatic modular reactor, heat transfer, natural convection

Introduction

The prismatic modular reactor (PMR) is a proposed design of very high temperature reactors (VHTRs) which are designated to be the basis of next generation nuclear plants (NGNPs). This generation is deployed to be more safe, secure, and versatile than previous generations. Safety is achieved through a combination of inherent safety characteristics and design choices. This reactor focuses on developing inherent safety features to remove the decay heat naturally in case of accidents and off-normal conditions. Occurrence of any accident initiates natural circulation and normal flow reversal due to the density difference in different parts of the medium. Hence, the coolant gas moves upward through the core channels and recirculated downwards through some of the channels and the annular space between the core and reactor vessel. Recently, computational fluid dynamics (CFD) commercial codes have been used to predict the flow behavior through PMRs. However, there is a lack in a detailed experimental study in the open literature for experimental work that addresses the gas dynamics and heat transfer in the prismatic core during natural circulation by using advanced novel techniques.

Description of Work

Missouri S&T has designed, developed, and tested a unique scaled down experimental setup with reference to Oregon State University – High Temperature Test Facility (OSU-HTTF). This experimental setup is developed to characterize heat transfer during natural circulation phenomena occurring during accident scenarios in prismatic modular reactors. The core of first phase of design consists of two channels: one is electrically heated and the other one along with the upper plenum are subjected to cooling to stimulate natural circulation in the system. Cooling is carried out by pumping water from an external chiller into the shield covering the upper plenum and copper tubes surrounding the channel. This method is considered the most appropriate method for causing natural circulation within a system. Heat transfer along both channels is characterized by using a series of flash mounted foil sensors with thermocouples at different axial locations along each channel. The natural circulation intensity varies with changing water coolant temperature pumped from chiller (surface temperature of upper plenum). In the current study, the experiments are carried out by using air as the primary coolant medium circulation within the system. The heated cannel is subjected to a constant supplied power of 530 w/m2. Heat transfer investigations are carried out at different water coolant temperatures (5oC, 10oC, 15oC, 20oC, 25oC, 30oC, and 35oC). Also, the effect of varying the coolant gas operating pressure on heat transfer is also investigated.

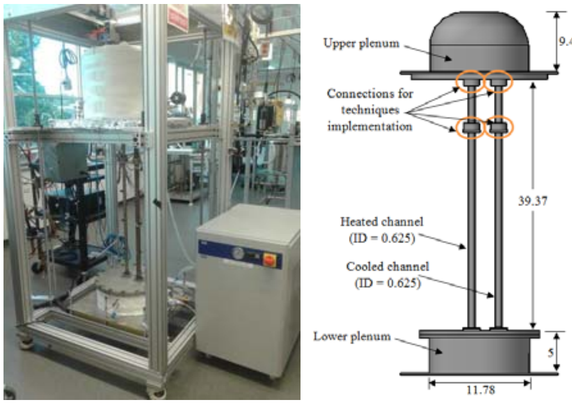

Figure 1. (a) picture of MSTF, (b) Schemtic diagram of MSFT

Discussion and Conclusions

Preliminary temperature and heat transfer coefficients distribution axially along the heated channel are shown in Figures 1 and 2.

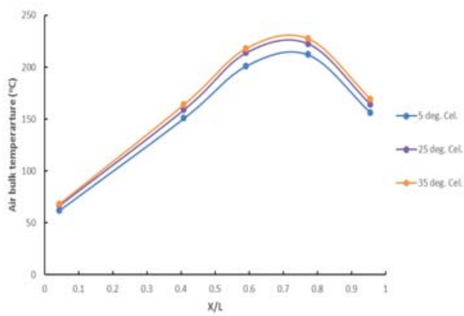

Figure 2. Axial distribution of air bulk temperature along the heated channel

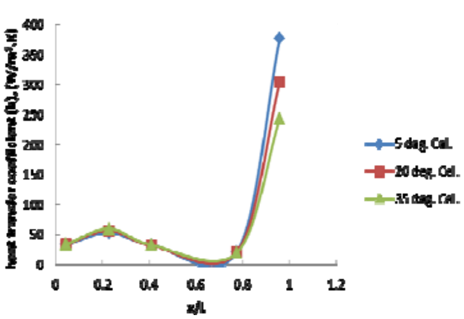

Figure 2. Distribution of local heat transfer copefficient values axially along the heated channel

As shown in Figure 1, air bulk temperature is increased axially along the channel. However, a sudden decrease in the temperature occurs at the top section of the channel. This decrease is attributed to sudden decrease in temperature due to applied cooling on the upper plenum. Also, air plumes mixing and vortices observed in the upper plenum contribute in this sudden temperature reduction (McVay et al., 2015).

The localized heat transfer coefficient values are dramatically varies along the length of the heated channel. It is found that, the value is decreased as gas is naturally flows upward along the channel. This reduction could be attributed to the increase in thermal boundary layer thickness. In addition increasing gas bulk temperature flow accelerates the gas movement through the channel. Thus, gas contact time with heated wall is reduced. This explanation needs more investigation of gas dynamics and velocity. This investigation will be carried out by using the hot wire anemometry technique. At the top of the channel, the heat transfer coefficient value is increase. This enhancement could be attributed to the turbulence and mixing occurs at the top of the channel due to plumes mixing in the upper plenum. Gas mixing phenomena will be investigated as a part of this study by implementing the gas tracer technique.

By completing the current and future proposed work, MSTF will advance the knowledge and understanding of natural circulation phenomena in PMRs. The novel sophisticated techniques that are implemented for the first time in such a study will provide benchmark available for CFD codes validation.

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References

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