AN EXPERIMENTAL INVESTIGATION OF THERMAL LOADING ON A PLATE FROM PARALLEL TRIPLE JET

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ABSTRACT

Temperature fluctuations are known to occur in the mixing region of non-isothermal flows, and can cause undesired thermal stresses. This is a concern in certain key components for next generation high temperature gas cooled reactors. One such reactor concept is the very high temperature gas reactor (VHTR), which uses helium as the primary coolant. In the lower plenum of such reactors, the coolant channels mix together and are collectively routed to a gas turbine or hydrogen production facility, and the potential for incomplete mixing is a concern. The objective of this study is to gain insight into the thermal loading conditions expected in the VHTR lower plenum. To analyze the lower plenum mixing behavior, an experimental study of the interactions of three non-isothermal parallel round jets is conducted. A cold jet is surrounded on either side by two hot jets with air as the working fluid. A flat polycarbonate plate is mounted parallel to the axial direction of the jets, with the top edge of the plate directly behind the outlets of the jets. In this configuration the downstream thermal mixing of the jets can be studied. Infrared temperature measurements of the plate surface enable characterization of the thermal forcing function. In general, the highest fluctuations occur in the plane common to the three jet axes. These fluctuations are also increased when the neighboring jets are at the same velocity. The research completed here represents the first step enabling confident predictions of the thermal loading in the VHTR lower plenum. These experiments are intended to serve as validation data for fundamental and applied thermal mixing simulations.

KEYWORDS
lower plenum; parallel triple jet; round jet; thermal loading; very high temperature reactor

1. INTRODUCTION

In both existing and next generation nuclear reactor designs, the mixing of hot and cold fluids at the outlet of the reactor core is of major concern due to the induced high thermal fluctuations in this area. These temperature fluctuations can cause severe high cycle thermal fatigue over the course of the nuclear reactor's operational lifetime and are known as thermal striping. Over the course of a reactor's lifespan, the effects of thermal striping can jeopardize the structural integrity of nuclear reactor cores and their adjacent coolant lines. Thermal striping is especially problematic in the Generation IV very high temperature gas reactors (VHTR), which employ helium as a coolant. Helium has several distinct advantages over water, of which include a higher heat capacity, which implies higher thermal fluctuations than modern pressurized water reactors (PWRs). Unlike modern PWRs which have water flow upward through the reactor, the helium coolant flows vertically downward through the VHTR core. The helium extracts heat throughout the core before mixing in the lower plenum, much like an array of impinging jets, and then exits the lower plenum through one single outlet. The mixing that takes place in the lower plenum is caused by the non-uniform heating of the helium in the reactor core and can have up to 300-400 K differences in jet outlet temperatures

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