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Experimental investigation of effective parameters and correlation of geyser boiling in a two-phase closed thermosyphon

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ABSTRACT

In this study, the geyser boiling in a two-phase closed thermosyphon was investigated experimentally. Parameters such as filling ratio (FR), aspect ratio (AR), heat input (Q) and the coolant mass flow rate ($\dot{m}$) affect the geyser boiling in thermosyphon. A series of experiments were carried out to investigate the influence of the above parameters on the period and intensity of geyser boiling under the normal conditions. Two copper pipes of 1000 mm length with 15 and 25 mm inside diameter and methanol as the working fluid were employed. An experimental equation was offered to correlate the data for the period of geyser boiling. The results showed that the period of geyser boiling decreased by increasing the heat load and aspect ratio and increased by increasing the filling ratio. The results were compared with the results found in the literature.

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1. Introduction

A two-phase closed thermosyphon is a heat pipe needing no wicks to return the condensate working fluid from the condenser section to the evaporator due to gravity. However, the evaporator must be positioned at the lower part of the gravitation field (compared to the condenser). The operation of a thermosyphon is sensitive to the fill volume of the working fluid. For thermosyphons, it has experimentally been shown that the maximum rate of the heat transfer increases with the amount of the working fluid up to a certain value. Because of its simple structure, stable operating conditions during steady state, the characteristic of a thermal diode and its wide operating temperature range, it has been applied to many industrial fields. Applications such as: heat exchangers, cooling of electronic components, solar energy systems, deicing and snow melting [1].

Thermal performance of the thermosyphon is affected by several factors, such as the type of working fluid, filling ratio (defined as the ratio of working fluid volume to evaporator section volume), aspect ratio (defined as the ratio of evaporator section length to inside diameter of the pipe), operating pressure, and length of various sections of the pipe.

Geyser boiling is an unstable phenomenon inside thermosyphon which generates and expands suddenly throughout and can vibrate and damage the pipes. Griffith [2] was the first to investigate geysering in thermosyphons. Geyser boiling occurs where liquid in a vertical column with a closed end is heated near the bottom. The superheated liquid suddenly vaporizes and leads to a large slug bubble which grows as it moves toward the top end due to a decrease in its static pressure. Then, the vapor is mixed with sub-cooled liquid in an upper plenum and is condensed there. The effect of this phenomenon is decreasing the pressure and returning the sub-cooled liquid to the evaporator section. This phenomenon is a process repeated periodically.

Fig. 1 shows the geyser boiling phenomena in a two-phase closed thermosyphon where at first, small bubbles are produced that subsequently grow to the size of the inside diameter of the tube which can be recognized by vibration and a special sound.

2. Previous works

Andros and Florschuetz [3] used an annular thermosyphon with a glass outer cylinder that visualized the flow patterns in the device at the operating conditions. For small and intermediate fills, basic flow regimes were observed in the evaporator section for increasing heat load: (1) a smooth continuous film with surface evaporation, (2) breakdown of the smooth continuous film into a series of stable rivulets, (3) a wavy film with unstable rivulets, and (4) a wavy film with bubble nucleation occurring in the unstable rivulets.

Negishi and Sawada [4] made an experimental study on the heat transfer performance of an inclined two-phase closed thermosyphon. They used water and ethanol as working fluids. A cop-

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