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An experimental investigation into the operation of a direct contact heat exchanger for solar exploitation☆

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Abstract

The use of a direct contact heat exchanger (DCHX), if properly applied, will allow several benefits. Primarily these include the elimination of the cost of a closed heat exchanger and the ability to operate with much lower temperature differences. This paper examines the operation of a liquid–liquid type DCHX in harnessing the solar energy. Heat is delivered to the working fluid (heat transfer fluid) in the collection loop composed of solar collectors and a circulation pump. Two different kinds of working fluid were tested for their thermal characteristics that are immiscible with water. Texatherm 46 and diethyl phthalate ($C_6H_4(CO_2C_2H_5)_2$) and those that are experimented in the present analysis. Different schemes were used to introduce these fluids into the DCHX as they are either lighter (Texatherm 46) or heavier (diethyl phthalate) than water. A series of outdoor tests were conducted to determine the overall performance of DCHX as well as transient behaviors as the sun's energy is exploited. It is worthwhile to note that no thermal stratification was observed throughout the DCHX when in operation regardless of the working fluid. Stability and thermal performance, however, appear to improve when the working fluid is dispersed from the top of a DCHX. A difference of 8% is measured in the heat exchanger effectiveness, which gives a measure of the heat exchanger's overall ability in heat transfer.

Keywords: Solar energy; Direct contact heat exchanges (DCHX); Experimental investigation

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1. Introduction

The use of a direct contact heat exchanger (DCHX), if properly applied, could give a good solution to the freezing problem in wintry seasons, which has long been a major hurdle in harnessing the solar energy. It will not merely allow a technical solution to the problem but also several benefits. Primarily these include the elimination of the cost of a closed heat exchanger and the ability to operate with much lower temperature differences [1]. The temperature driving force required for the conventional heat exchanger is greatly reduced because of the direct contact between the two fluids without any intervening solid surfaces. Systems using DCHXs, however, are quite similar to systems using indirect heat exchangers in many respects. In these systems, the DCHX unit can be combined with the thermal storage unit, or alternatively, it can be used separately from the storage unit, much like an external (to storage) closed heat exchanger system. Hence either the DCHX system or the closed heat exchanger system can operate with the same number of pumps/loops.

A DCHX generally relies upon the gravitational force to accomplish the fluid flow within the device. In most direct contact liquid–liquid heat exchangers, oil or hydrocarbon with a density less than water is normally used as the dispersed working fluid—the working fluid that is dispersed in a DCHX. In this case, the lighter fluid is injected into the DCHX (so-called, “spray column”) through a perforated device (or a sparger) at the bottom of the DCHX [2,3]. This arrangement sometimes requires the control of the interface at the top of the DCHX which is formed by the coalescence of the dispersed working fluid. The interface must remain fixed as water is introduced into the DCHX immediately below the interface. In addition, the rate of coalescence of the dispersed working fluid (arising as small droplets) has to be controlled appropriately as it influences the location of the interface. The rate of coalescence can be catalyzed by introducing a honeycomb structure (easily become wet by the dispersed phase) at the desired interface location.

Apart from the arrangement above, a consideration could be made to use a liquid that is heavier and immiscible with water. Of course, the liquid should have higher boiling and lower freezing temperatures [4]. In such arrangement, it is possible to eliminate the internal structures to enhance the coalescence of the dispersed working fluid mentioned above. The perforated plate at the top of the DCHX evenly breaks the working fluid into small particles and uniformly distributes them before they start their journey through the water body contained in the DCHX. There is no need for a device to catalyze the coalescence of droplets or to adjust the interface with the water as in the case of the light working fluids. However, this does not mean

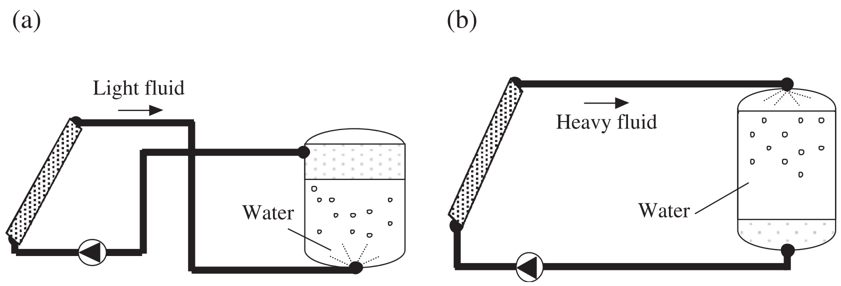

Fig. 1. Schematic diagram of the experimental setup. (a) A working fluid injected into a lighter fluid. (b) A working fluid dispersed in a heavier fluid.