A Study on Dispersed Phases in a DCHX
for Solar Application

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태양열 응용을 위한 DCHX에 있어서 분산상에 관한 연구

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ABSTRACT

The present study has been carried out to examine the formation and movement of dispersed phases in DCHXs as this dictates the performance of any heat recovery systems including solar thermal energy systems. Different types of DCHXs are introduced and their operating principles are reviewed in view of fluid mechanical characteristics of dispersed phases. Different cases of DCHXs using two immiscible liquids are considered as these cases offer good examples in capturing and image processing of dispersed phases by using such a technique as electric tomography(ET) without undue difficulties. Also considered is the case of three-phase problem that needs further investigation to resolve the complicated physical phenomena involved with the operation of such DCHXs.

Key Words : electric tomography, DCHX, dispersed phase distribution

I. INTRODUCTION

There exist great opportunities for development of DCHXs (Direct Contact heat Exchangers) for the utilization of solar energy.[1-6] A DCHX is based on the direct contact heat transfer concept where one fluid is brought in intimate contact with another at applications a different temperature. Highly important

issue as it has diverse efficient heat transfer can result. The temperature driving force required for the conventional heat exchanger is greatly reduced in the direct contact heat exchanger system that operates with a negligibly small temperature driving force.

Direct contact processes are characterized by extremely efficient heat transfer with very small associated capital costs.[2] both comparisons being relative to conventional (closed) heat exchangers. A great deal of work has been done to develop more efficient and more reliable DCHX for many years. In solar energy applications, most of the work is related to the effective extraction of solar energy

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from the heat transfer medium which constantly circulates through the collection loop. Among them. the spray-column form has drawn more attention than others in solar applications because of its simple but highly efficient design. A diagram of this type of device with a solar collection loop is shown in Fig. 1. In this case. the lighter fluid is injected into the heat exchanger through a sparger (or distributor) at the bottom of the heat exchanger. The design also could be modified to disperse a heavier fluid from the top of the heat exchanger.
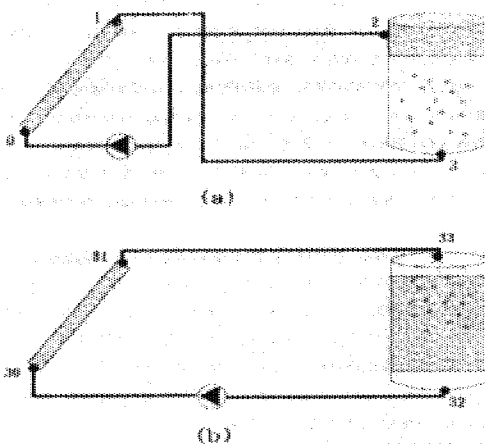
reduced in the direct contact heat exchanger system that operates with a negligibly small temperature driving force.

Direct contact heat transfer can take place between one stream of a solid and one stream of a solid. liquid or a gas. or between a liquid and a gas or another liquid. Most familiar applications of DCHXs are found in cooling towers (air and water). evaporative coolers(air and water). and open feed water exchangers(steam and water). The latter are found in most thermal power plants.

Fig. 1. Schematic diagram of a DCHX for the solar application

Fig. 2. Fluid lighter than water is dispersed in a spray column.

1.1. Operating principle of different types of DCHXs

There have been many research activities to develop better DCHXs as they offer great opportunities in exploiting solar energy more effectively and economically. A DCHX is based on the direct contact heat transfer concept where one fluid is brought in intimate contact with another at a different temperature. Highly efficient heat transfer can result. The temperature driving force required for the conventional heat exchanger is greatly

Direct contact processes are characterized by extremely efficient heat transfer with very small associated capital costs. both comparisons being relative to conventional (closed) heat exchangers. A great deal of work has been done to develop more efficient and more reliable DCHX for many years. Among them. the spray-column form has drawn more attention than others in solar applications because of its simple but highly efficient design. A picture of this type in operation is shown in Fig. 2. In this case. the lighter fluid is injected into the spray-column through distributor at the bottom of

the column. The design also could be modified to disperse a heavier fluid from the top of the column. Fig. 1. (b).

1.2. Image reconstruction of dispersed phases in a DCHX

There are currently many measurement schemes such as LDV (Laser Doppler Velocimetry), PIV (Particle Image Velocimetry) and other optical methods to investigate the thermal hydraulic behavior of the dispersed phase in a flow field of any DCHXs. Dispersed phase droplets can be effectively studied by applying Electric Impedance Tomography (ET) technique.7, 8) The EIT (Electric Impedance Tomography) technique, which was originally invented to obtain the tomographic image of human organ, is introduced in the present analysis to investigate the dynamic motion of dispersed phases in multiphase flows. The major difficulty in EIT technique lies in image reconstruction problem. The Hessian matrix occurred in iterative image reconstruction problem based on Newton-Raphson method is usually ill conditioned. Furthermore, the contrast which is the ratio of impedance of continuous phase (usually water) to that of dispersed phase (usually water or vapor) is very high in two-phase flows. To cope with these predicaments in the solution procedure, some modifications to the well-known methods are proposed and tested in the present study. Reconstructed images of fictitious masses as well as real ones are examined to assess the validity of the present scheme in extending its scope to the dynamic realm of multiphase flows.

II. EXPERIMENTAL INVESTIGATION

2.1. Thermal hydraulic behavior

Depending on the distributing mechanism of the dispersed working fluid, drop sizes vary quite comparatively which could have no small effect on the thermal performance of a direct contact heat exchanger (DCHX).

According to previous findings, the drop sizes most effective to maximize heat transfer rates are in the range of 1mm to 2mm in diameter. Fig. 3 shows the formation of small droplets as the working fluid is dispersed from the bottom of a spray column type DCHX. Its thermal performance is also given in terms of temperature variation of the continuous phase.
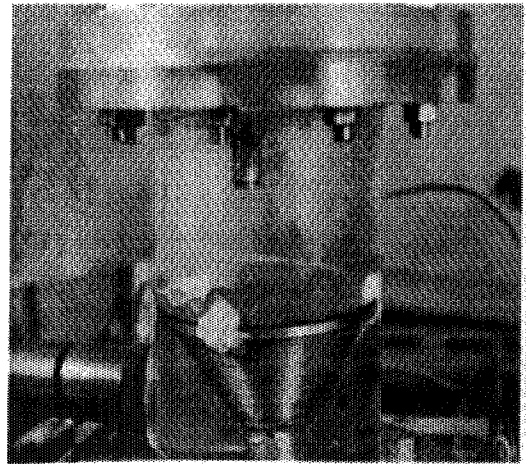

Fig. 3. Droplets of Dowtherm J formed on the surface of a distribution plate.

Apart from the above configuration, dispersed phases could be heavier than the continuous phase and streams downward. The case of Phthalate consists one of such examples as shown in this figure. The Phthalate masses (droplets) are moving downward as they sink in a column of water. Fig. 4 shows a result of such a case.

2.2. Image processing of dispersed phases

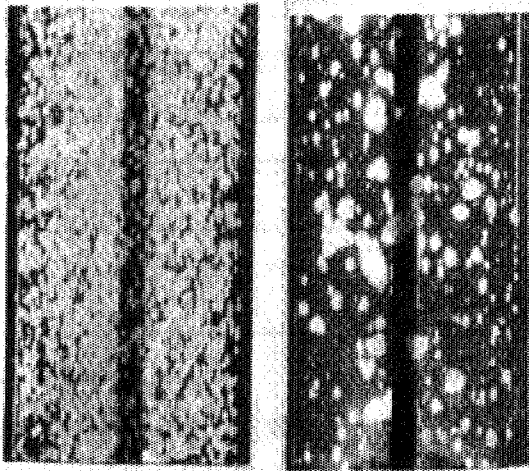If there exists a great difference in its conductivity

Fig. 4. Presence of dispersed phase in a DCHX:
(a) uniform size masses (droplets), (b)
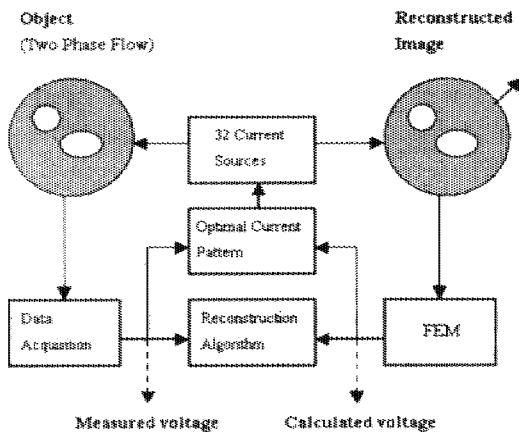small and large masses are mingled

Fig. 5. Schematic diagram of the experimental
apparatus.

(a)   (b)

Fig. 6. Reconstructed results for a cylindrical object.
which has nearly the same electric
resistivity($>10^{\wedge}12\,\Omega$ cm) as Dowtherm J.
immersed in a saline solution($300\,\Omega$ cm):
(a) actual image (b) reconstructed image

(or resistivity) between the dispersed and the
continuous phase. the EIT technique is quite
efficient in finding the location and geometric shape
of the dispersed phase. This case has been studied
for the case when one cylindrical object of nearly
the same impedance as Dowtherm J is placed in a
column of saline solution(0.15%) whose electric
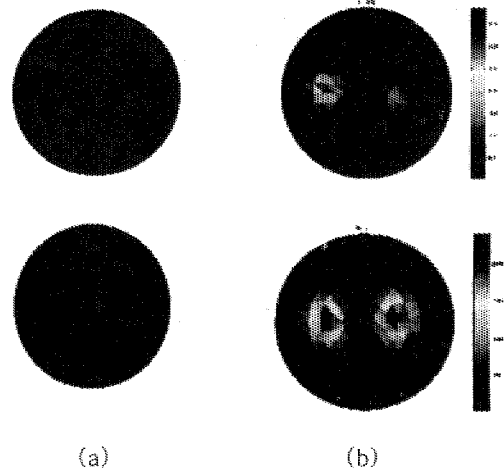resistivity is $330\,\Omega$ cm. For Dowtherm J. the electrical

resistivity is measured to be over $1012\,\Omega$ cm. which
is practically infinite when compared to the saline
solution. The actual measurements are made by
embedding 32 stainless steel electrodes around the
cylindrical vessel which holds the saline solution.
Currents are injected through these electrodes and
the resulting voltages are measured to electrically
analyze the domain of interest. A schematic diagram
of the experimental setup is given in Fig. 5. Fig. 6
is the result of the aforementioned case are actual
and reconstructed images of the immersed object are
given for different locations. The size of the object is
also examined as it deems to influence the clarity of
the reconstructed image. It is quite obvious that the
present technique is fairly accurate in locating the
targeted mass (object). even though more work is
needed to obtain clear images. The clarity of the
reconstructed image appears to be dependent on the
size of the targeted mass as well as the removal of

Table 1. Physical properties of Phathalate(Dimethyl)

Molecular Formula	Specific Density	Viscosity, Poise	Specific Heat, J/g°C	Thermal Conductivity, W/cm°C	Freezing Point, °C	Boiling Point, °C
C8H6O4	1.052	0.024	1.57	1.29 x 10-3	-40.5	297.7

Table 2. Physical properties of Dowtherm J

Molecular Formula	Specific Density	Viscosity, Poise	Specific Heat, J/g°C	Thermal Conductivity, W/cm°C	Heat Capacity, J/cm3°C	Freezing Point, °C	Boiling Point, °C
alkylated aromatic	0.8067	0.0036	2.07	1.26 x 10-3	1.67	-73.3	181.1

noises in measured data. Subsequent research is currently underway to improve its image and interactive dynamic processing of dispersed phases for various cases.

III. CONCLUSIONS

This work has been carried out to study the physical phenomena involved in Direct Contact Heat Exchangers (DCHXs) in connection with the utilization of solar energy. A study has been carried out to examine the formation and movement of dispersed phases in DCHXs. Also investigated are the possibilities of applying of EIT (Electrical Impedance Tomography) Technique for capturing the images of dispersed phases as they stream through a stagnant body of water. In most direct contact liquid-liquid heat exchangers. oil or hydrocarbon with a density different (lighter or heavier) from water is normally used as dispersed working fluid. This work has studied a number of cases using different types of heat transfer medium that are dispersed in a spray column type DCHX. For image processing. simple cases are considered

where two dimensional cross-sectional static images are given for fictitious and actual masses present in a column of water (saline solution). It shows static images of dispersed phases where dynamic images could be obtained by simply extending the algorithms and strategies employed in the present analysis.

요 약

DHCX는 태양에너지를 포함한 열회수 시스템의 일종으로. 본 연구는 DCHX에서 DCHX의 성능을 평가하는데 중요한 분산상의 형성과 거동을 살펴보기 위한 연구이다. 여러 형태의 DHCX와 그들의 작동 원리를 분산상의 유체역학적 특성 관점에서 조사하였다. 두개의 불혼합 유체를 사용하는 여러 형태의 DCHX에 대해 전기임피던스 단층촬영 기법이 분산 상의 분포를 영상화하는데 좋은 방안이 될 수 있음을 보았다. 또한 3상 문제를 야기하는 DCHX에 대해서도 살펴보았다.

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