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단열판에 부착된 등온 사각비임에서의 자연대류 열전달에 관한 연구

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A Study on the Natural Convection from the Isothermal Square Beam Attached to an Adiabatic Plate

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요 약

본 연구는 장방형 발열체 주위에서의 열전달 특성을 고려하기 위하여 주위유체가 공기인 정상, 층류 상태하에서 수평단열판에 등온 사각비임이 부착된 경우 발열체 주위에서의 자연대류 열전달현상을 단열판의 경사각과 Rayleigh수를 변수로 하여 실험적으로 고찰하였다.

단열판의 경사각 θ를 변화시킴으로써 비임의 수평 및 수직표면에 의해 형성되는 열상승류의 영향에 따라 서로 다른 온도장과 유동장이 형성되었고 $\theta=45°$인 경우의 직각모서리를 제외한 나머지 직각모서리에서 가열된 상승류의 상호작용에 의해 국소 Nusselt수가 증가 하였다. Rayleigh수가 증가함에 따라 $\theta=90°$인 경우 X_2표면에서의 Thermal depression 현상이 가장 현저하였으며, $\theta=-45°$인 경우 X_1표면에서의 유동정체현상이 가장 심하였다.

단열판의 경사각을 변화시켜 실험 고찰한 결과 전평균 Nusselt수는 $\theta=45°$인 경우 최대, $\theta=-45°$인 경우 최소였다.

ABSTRACT

Steady laminar natural convection heat transfer from the isothermal square beam attached to an adiabatic plate has been studied for various inclination angles of the adiabatic plate and Rayleigh number by using Mach-Zehnder interferometer in air.

As the inclination angles change, the different temperature and fluid flow field were

obtained by the ascending heated fluid and the adiabatic plate.

In this study, the inclination angles were 0°(positive & negative), 45°(positive & negative), and 90°. The maximum total mean Nusselt number value was found at a positive inclination angle $\theta = 45°$.

1. INTRODUCTION

There are many studies about natural convection from the heated body of the complicated configurations, and these are practically, the problems of the free convection cooling of electronic elements and electrical systems which have been rapidly miniaturized in recent years and many of which are supersensitive for ambient temperature, becomes practically important.

Natural convection from the horizontal surface causes very complicated problems such as separation, stagnation, instability of the flow, etc. in the region of vertical plate, however, it is well known about similarity solution and can be easily formulated for flowing on the adjacent plate surface.

Yousef et al.[1] experimentally studied the free convection heat transfer from upward facing isothermal horizontal surface. They also investigated the separation of the inside boundary layer and the edge effect. Schulenberg[2] obtained the analytical solution of natural convection heat transfer below downward facing horizontal surface for various Prnadtl number and Rayleigh number.

Gryzagoridis[3] experimentally studied the leading edge geometry effect on natural convection from an isothermal vertical plate.

Numerical analysis of free convection heat transfer from vertical and horizontal short plates has been accomplished by Miyamoto et al.[4] Chang and Choi[5] found the vortices in the upper plume region from the numerical and experimental studies on natural convection above a horizontal isothermal square cylinder. But very few investigation has been accomplished about natural convection over the effect of the adiabatic plate.

In this work, the steady laminar natural convection heat transfer from the isothermal square beam attached to an adiabatic plate was undertaken experimentally by Mach–Zehnder interferometer for various inclination angles of the adiabatic plate and various Rayleigh number in air.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

A square beam and an adiabatic wall were designed for use in Mach–Zehnder interferometer. The copper square beam–height(and width) 20mm, and 100mm in length was machined from a solid copper bar. In order to fabricate the heating elements, the inside of the beam was grooved with 20mm in width by milling machine. Six holes of 1.2mm in diameter were drilled within 2mm of the beam surface by three at each end, and inserted copper–constantan thermocouple junctions. Three strip heaters were mounted inside wall of the beam. Glass wool was applied to the inside of the square beam for insulation, and attached asbestos–glass wool–plaster plate for an adiabatic wall.

Schematic diagram of the geometries and the drawing of the square beam are shown in Fig.1 and Fig.2, respectively.

To find out the insulation effect of the adiabatic wall, five equally spaced holes were drilled up and down from the square beam and then inserted thermocouples. A compensating chamber was made to calibrate the surface

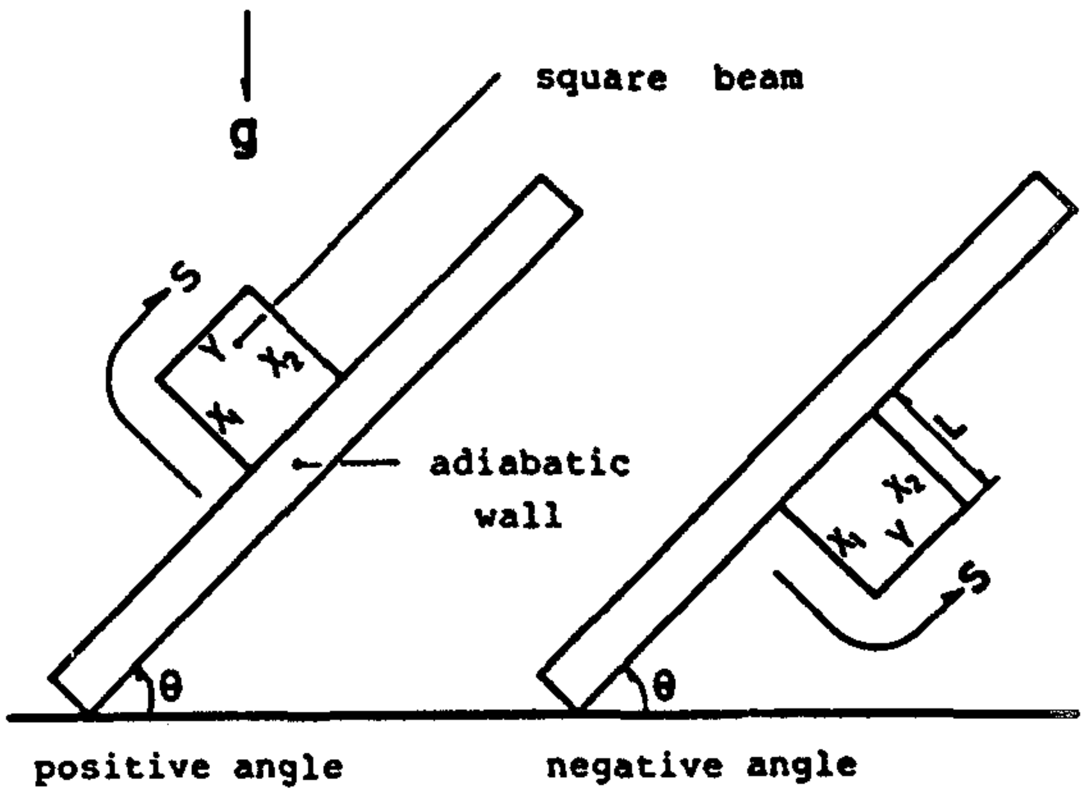

Fig. 1 Schematic diagram of the geometry

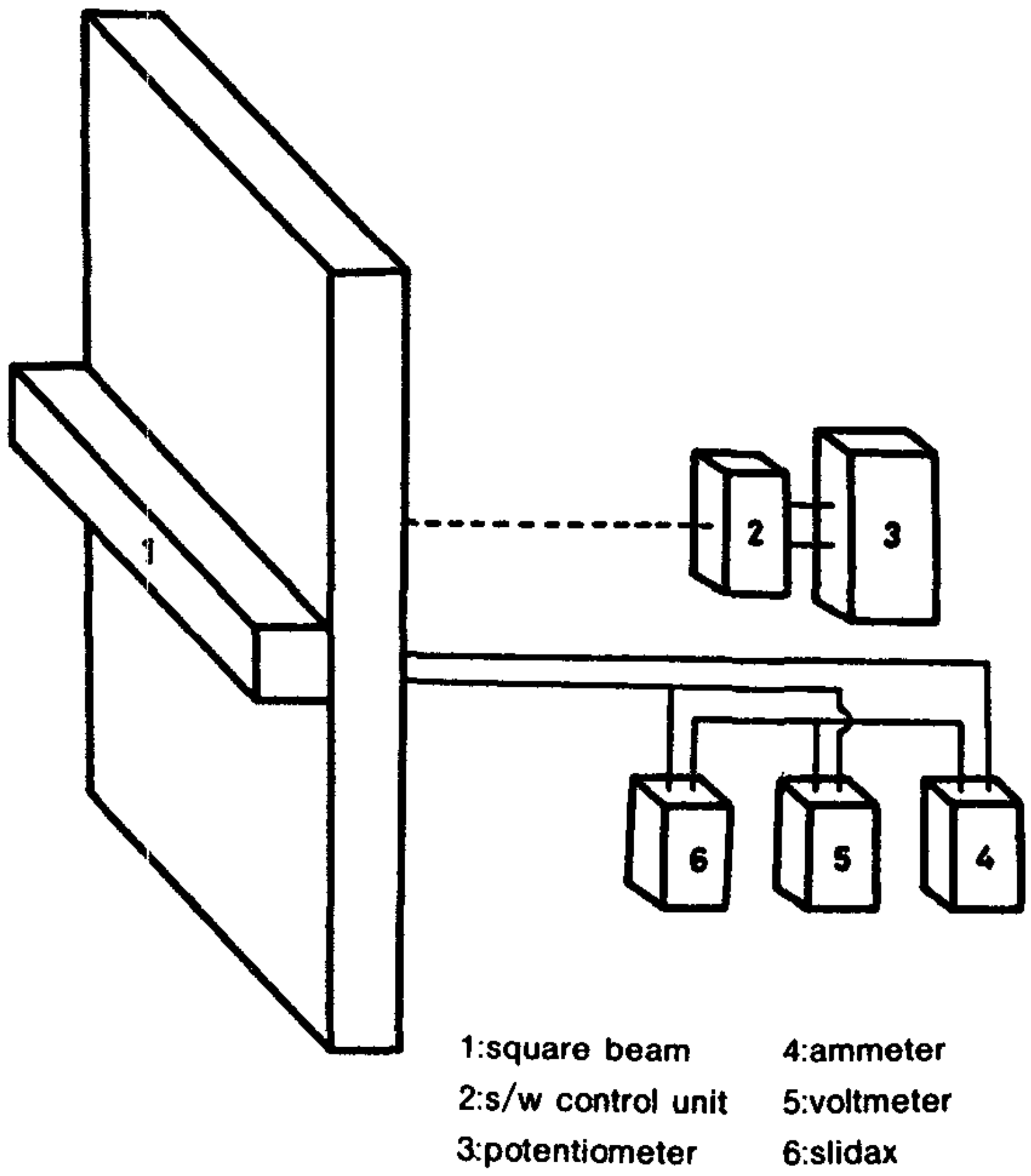

Fig. 3 Schematic diagram of experimental apparatus

temperature measuring errors from the thermocouples.

An 80mm lens Mach–Zehnder interferometer was used to obtain the temperature field over the heated surface. The inclination angles of the beam were also adjusted by the angle gage, which was attached to the supporting frame. With the interferometer adjusted for infinite fringe, a number of interferograms were taken pictures by 35mm camera. Fig.3 and 4 illustrate the schematic diagram of the experimental apparatus and the picture of the experimental apparatus, respectively.

Experiments were performed for the five inclination angles(90°, 45°, 0°, –45° and –0°) and the desired temperature of the heated surfae temperature distributions of the square beam are shown in table 1. For the evaluation of local Nusselt numbers over the whole surface of the square beam, the position of each fringe was

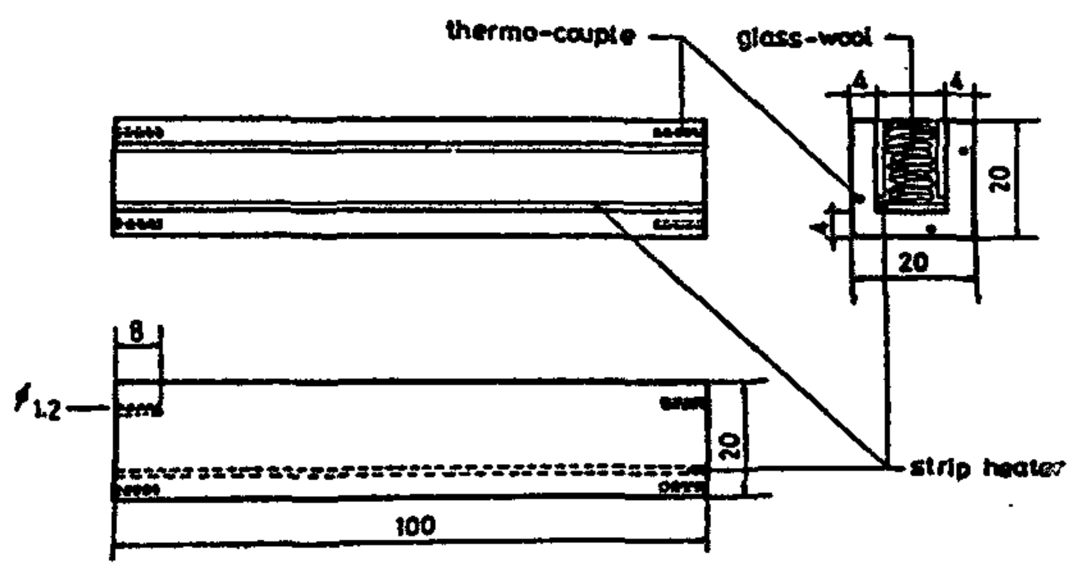

Fig. 2 Drawing of square beam

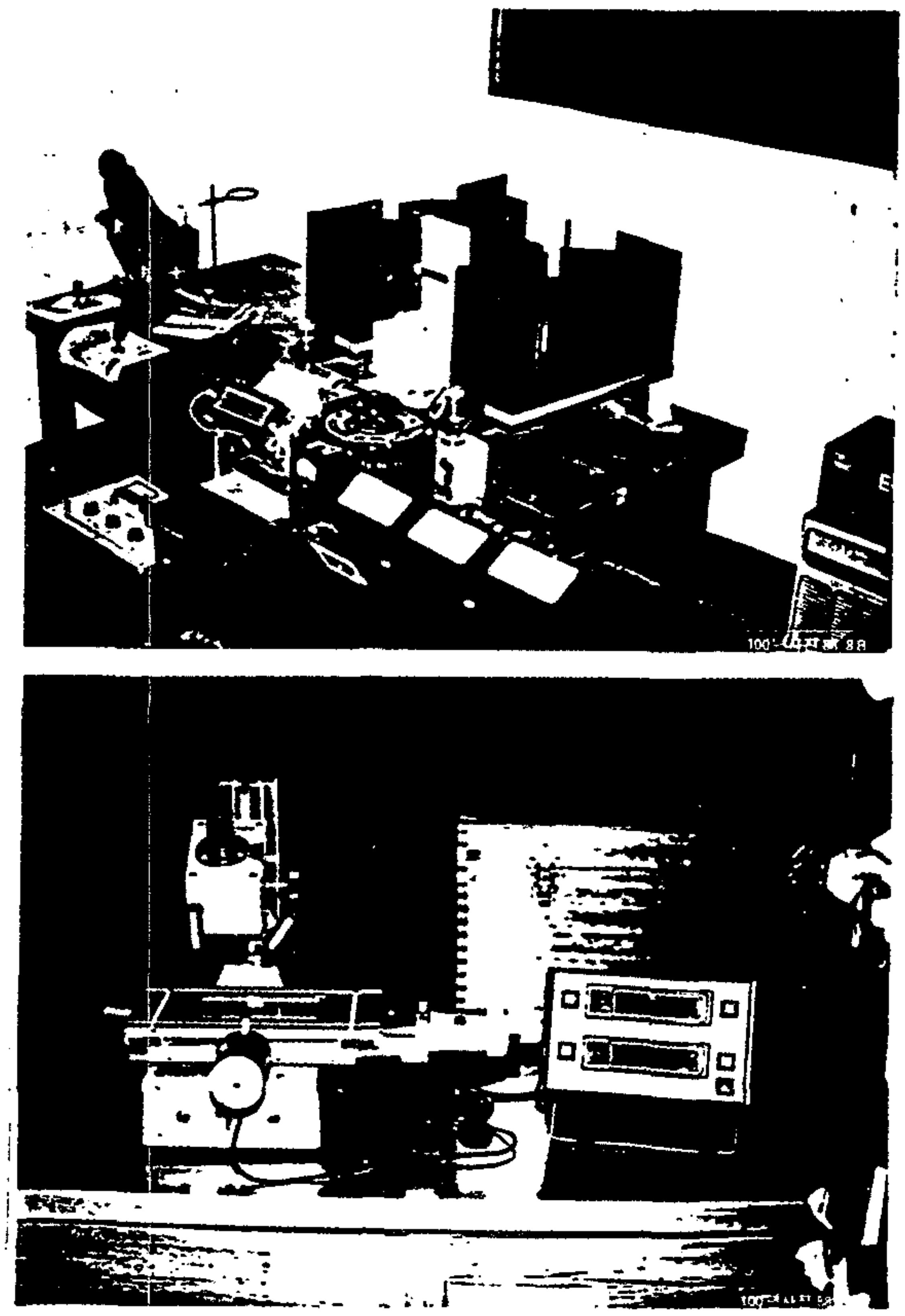

Fig. 4 The photos of the experimental apparatus

Table 1. The square beam surface temperature distribution
($T_\infty = 26.8$℃)

℃ No	T_1	T_2	T_3	T_4	T_5	T_6	T
1	60.04	60.02	59.97	60.01	60.03	59.99	60.01
2	70.05	70.03	69.98	70.02	70.04	70.00	70.02
3	80.07	80.05	79.97	80.03	80.06	79.98	80.02
4	90.06	90.03	89.96	90.05	89.97	90.01	90.02

measured by a tool maker's microscope. And the local temperature gradients were calculated from the method described by Hauf and Grigull.[6]

3. DISCUSSION

Series of experiments were carried out for various Rayeigh number and inclination angles of the adiabatic plate. Figs. 5, 6, 7 and 8 illustrate the selected interferograms for the square beam with an adiabatic plate in air whose Rayleigh number were $Ra_L = 1.74 \times 10^4$, 2.13×10^4, 2.48×10^4 and 2.78×10^4 based on the characteristic length L and $Pr = 0.71$.

The general trends in the interferograms are shown that the isotherms are more densed as the Rayleigh number increasesat the vicinity of the beam surface. In case of positive adiabatic plate inclination angles, the inflow boundary layers are somewhat expanded by the imperfection and interference of the adiabatic plate. But, the isotherms at the edges excepted trailing edges for $\theta = 45°$ are fairly attached to the beam surface due to the interaction of the ascending heated fluid. They show the increased temperature gradients at the edges, which are the increased local Nusselt number.

For negative inclination angles($\theta = -0°$ and $\theta = -45°$), however, the isotherm expansion was developed near the corner between beam surface and adiabatic wall because of the interception of the fluid flow by the adiabatic plate.

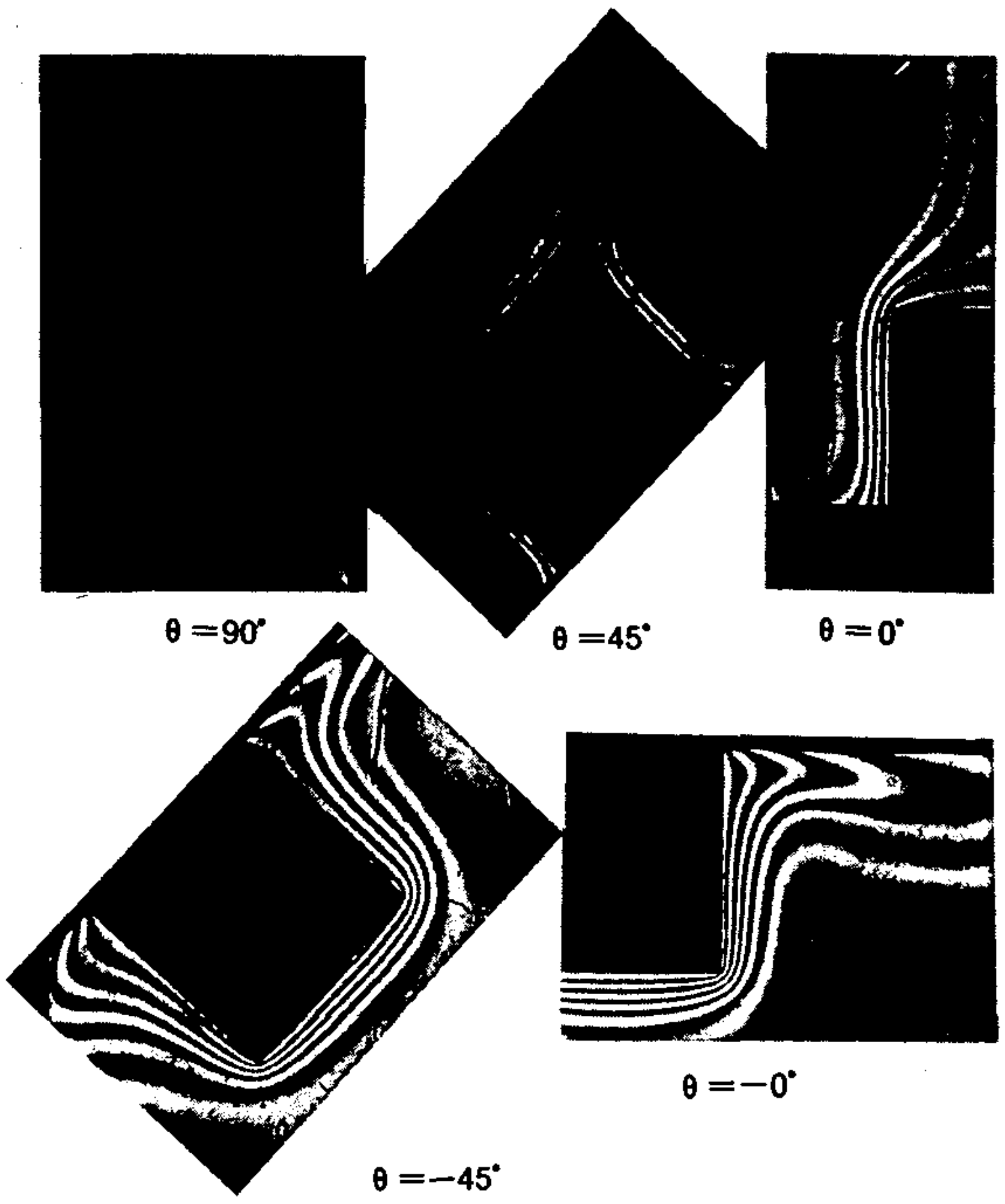

Fig. 5 Interferograms from the experimental run at $Ra_L = 1.74 \times 10^4$

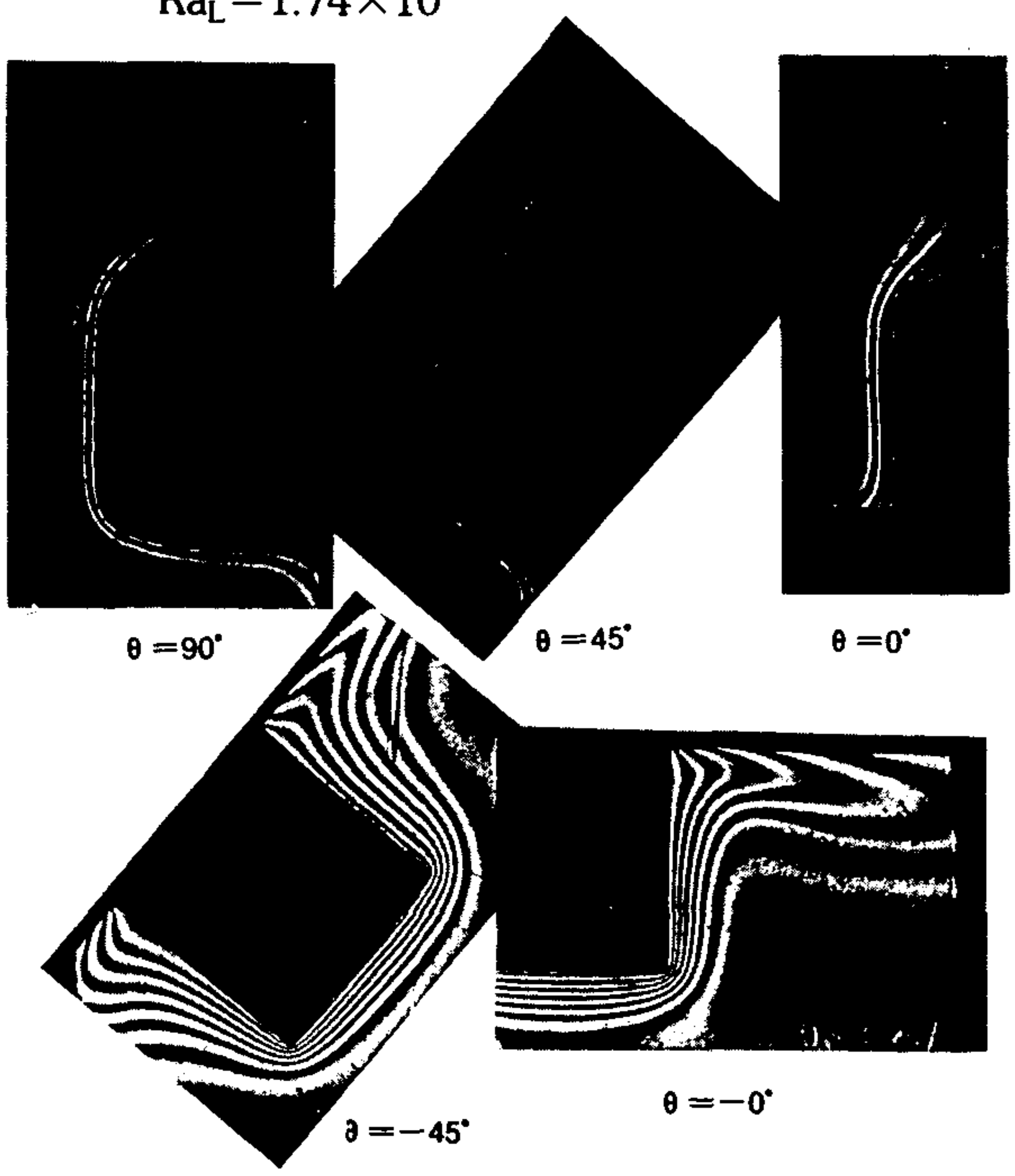

Fig. 6 Interferograms from the experimental run at $Ra_L = 2.13 \times 10^4$

In case of the X_2 surface of $\theta = 90°$, the

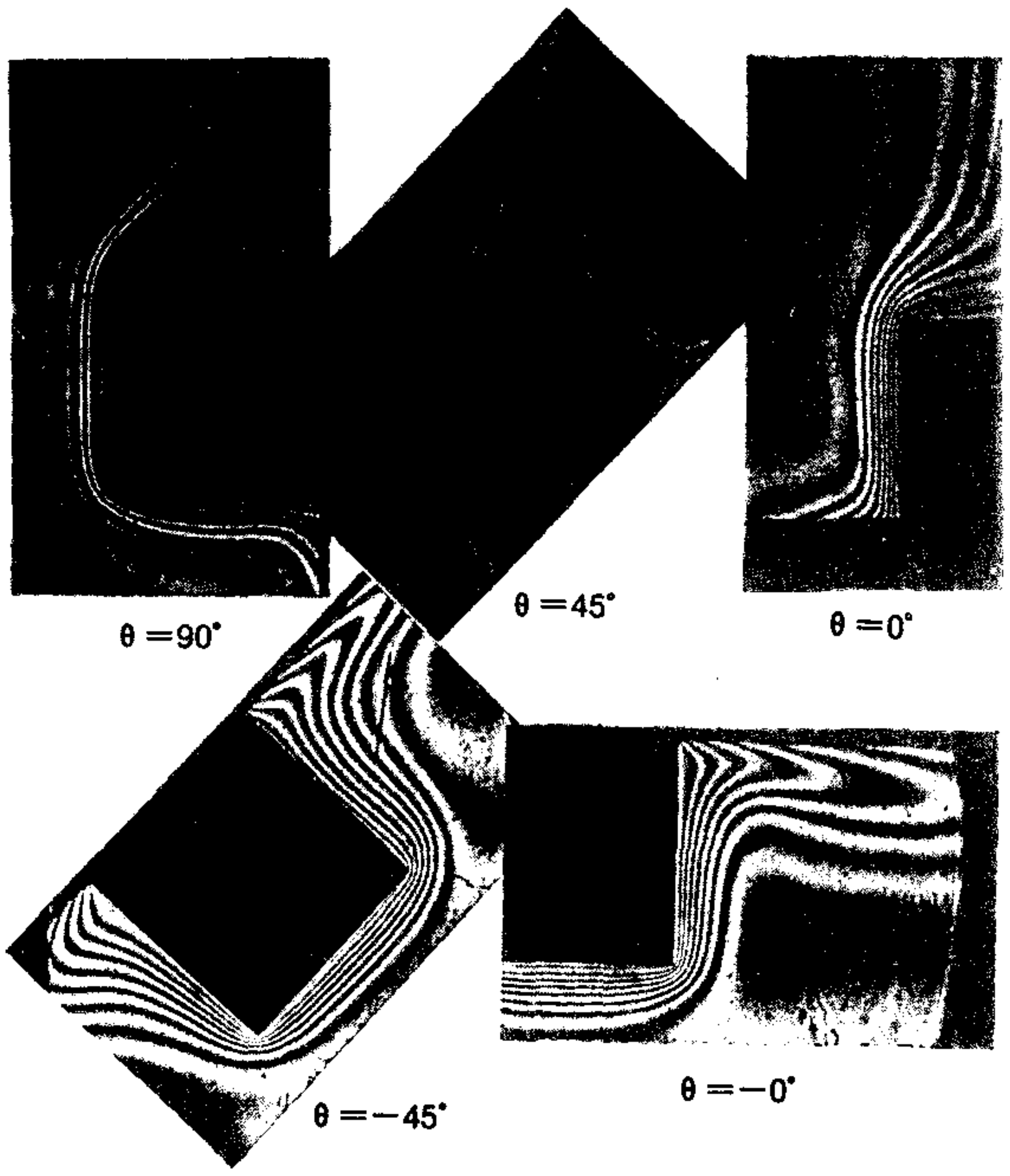

Fig. 7 Interferograms from the experimental run at $Ra_L=2.48\times10^4$

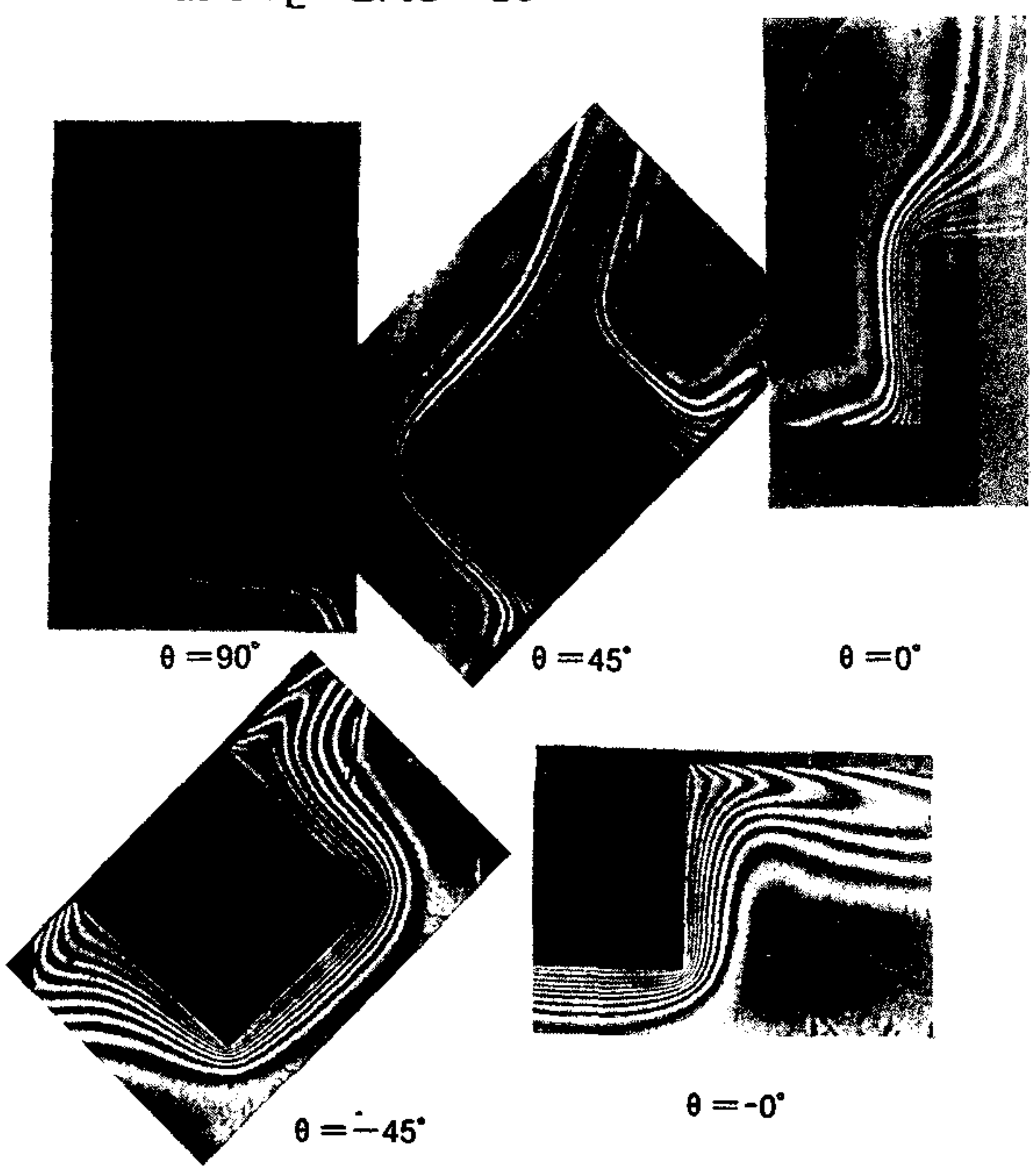

Fig. 8 Interferograms from the experimental run at $Ra_L=2.78\times10^4$.

isotherm depression was developed above the beam surface, and there was flow separation near the edge by Chang and Choi.[5] This irregular flowing is generated by the ascending heated fluid and the adiabatic plate interferencing. However, there was no the isotherm depression at the positive inclination angles $\theta=45°$ and $\theta=0°$ by reducing the acceleration of the heated fluid and the interference of adiabatic plate.

The distribution of local Nusselt number above the beam surface at $Ra=1.74\times10^4$, 2.13×10^4, 2.48×10^4 and 2.78×10^4 are shown in Fig. 9, 10, 11, 12 respectively. The distributions of the local Nusselt number for X_1 surface were increased by the following orders in case of $\theta=-45°$, $\theta=-0°$, $\theta=90°$, $\theta=45°$ and $\theta=0°$.

Fig. 13 illustrates the distributions of mean Nusselt number from the X_1 surface of the square beam. The distributions of mean Nusselt number for X_1 surface were maximum at $\theta=0°$ and minimum at $\theta=-45°$. In case of negative 45°, much flowing stagnation phenomena of the X_1 surface was effected on the heat transfer compare to other cases. The distributions of mean Nusselt number from the heated beam surface of Y and X_2 are shown in Figs. 14 and 15. For Y surface, the distributions of mean Nusselt number were increased by the following orders $\theta=-0°$, 0°, −45°, 45° and 90°. In case of the X_2 surface, It was recorded by the order of $\theta=-45°$, −0°, 90°, 45° and 0°.

The total mean Nusselt number above the beam surface vs. Rayleigh number is shown in Fig. 16. In this study, the total mean Nusselt number distributions of the positive inclination angles were greater than those of the negative inclination angles. It should be considered that the instability and stagnation are increased in X_1 and X_2 surface for negative inclination angles, besides the convection heat transfer is interrupted because of the buoyancy opposing flow. And the total mean Nusselt number distributions were maximum at $\theta=45°$ and minimum at $\theta=-45°$.

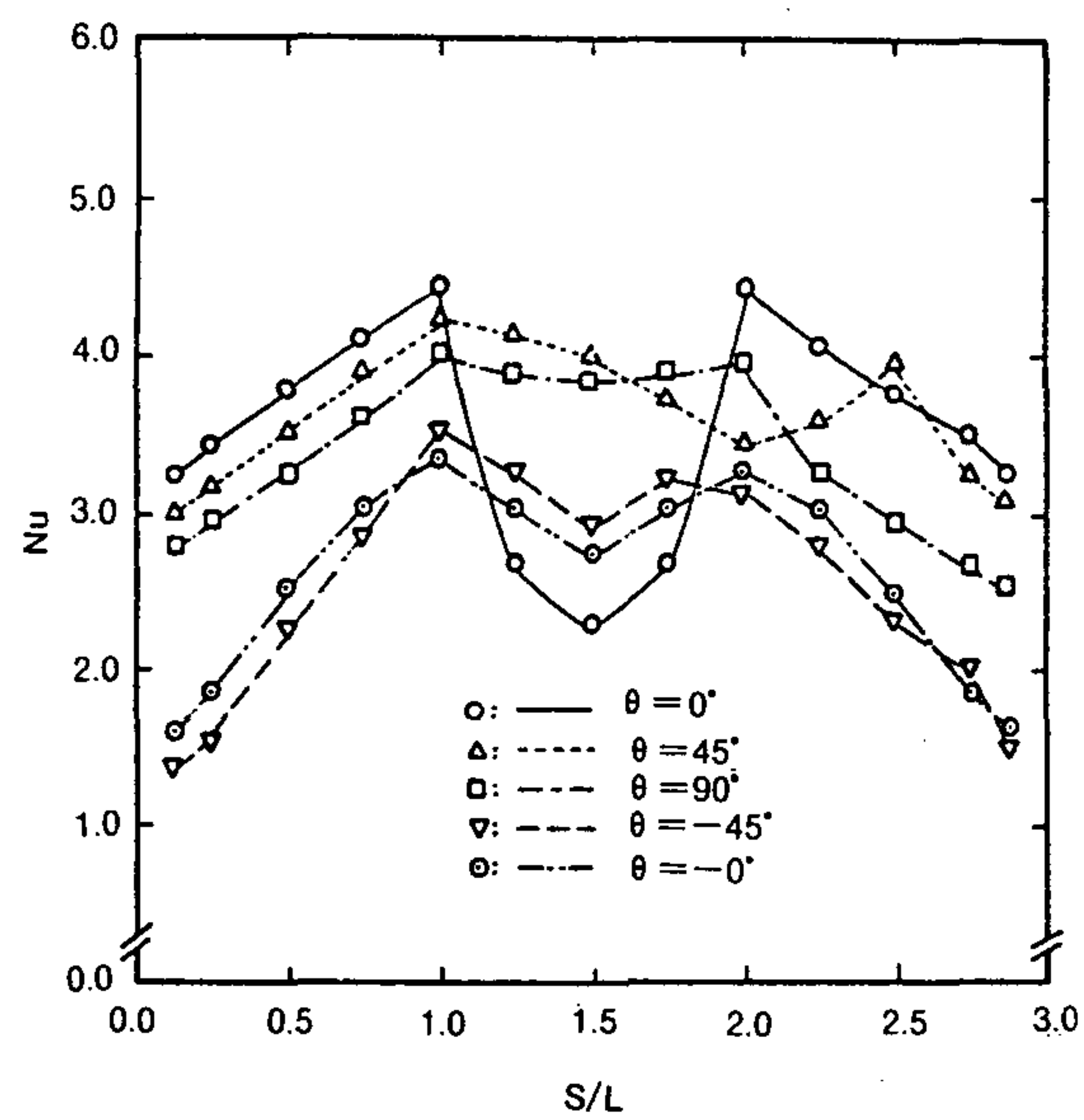

Fig. 9 Local Nusselt number from the heated surface at $Ra_L = 1.74 \times 10^4$

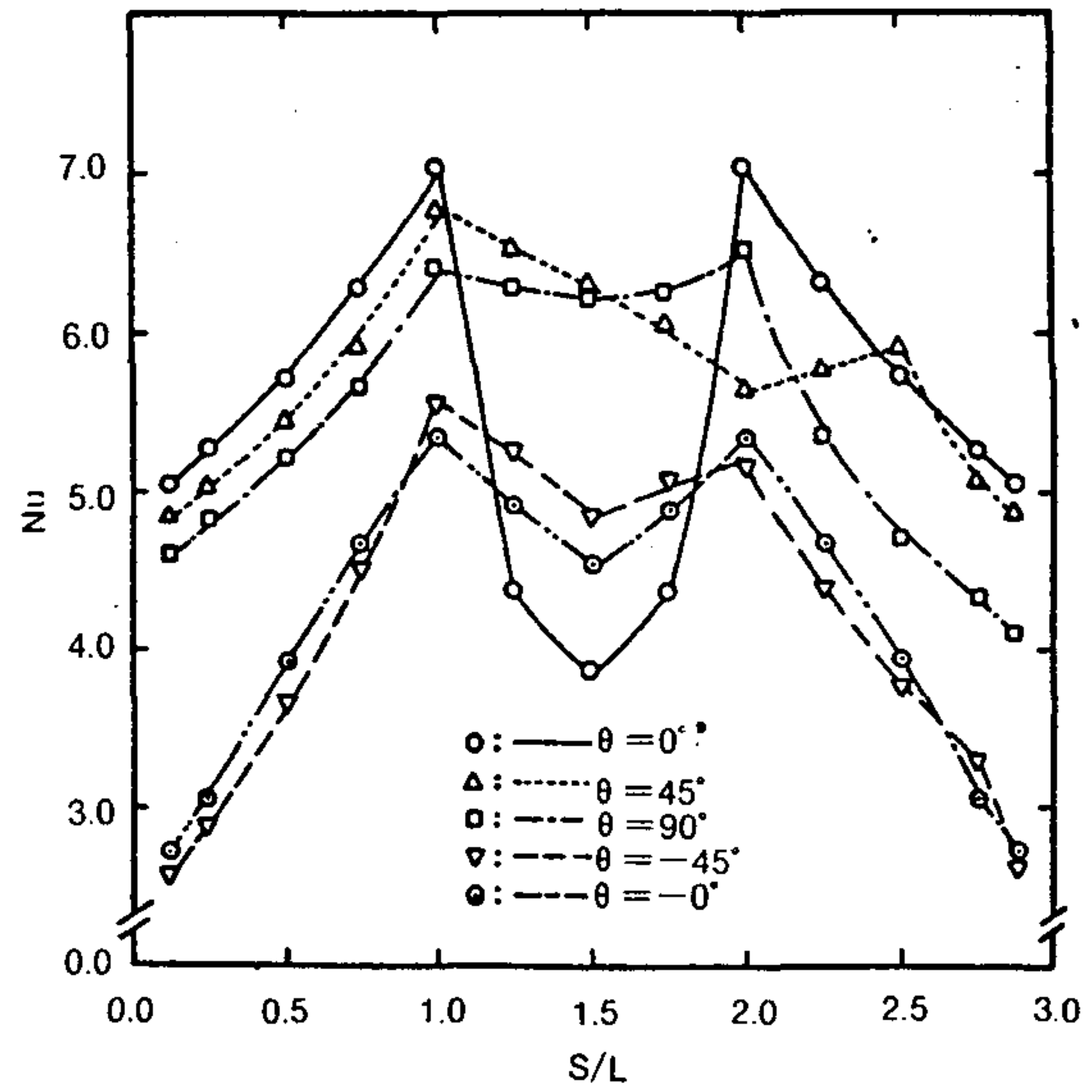

Fig. 11 Local Nusselt number from the heated surface at $Ra_L = 2.48 \times 10^4$

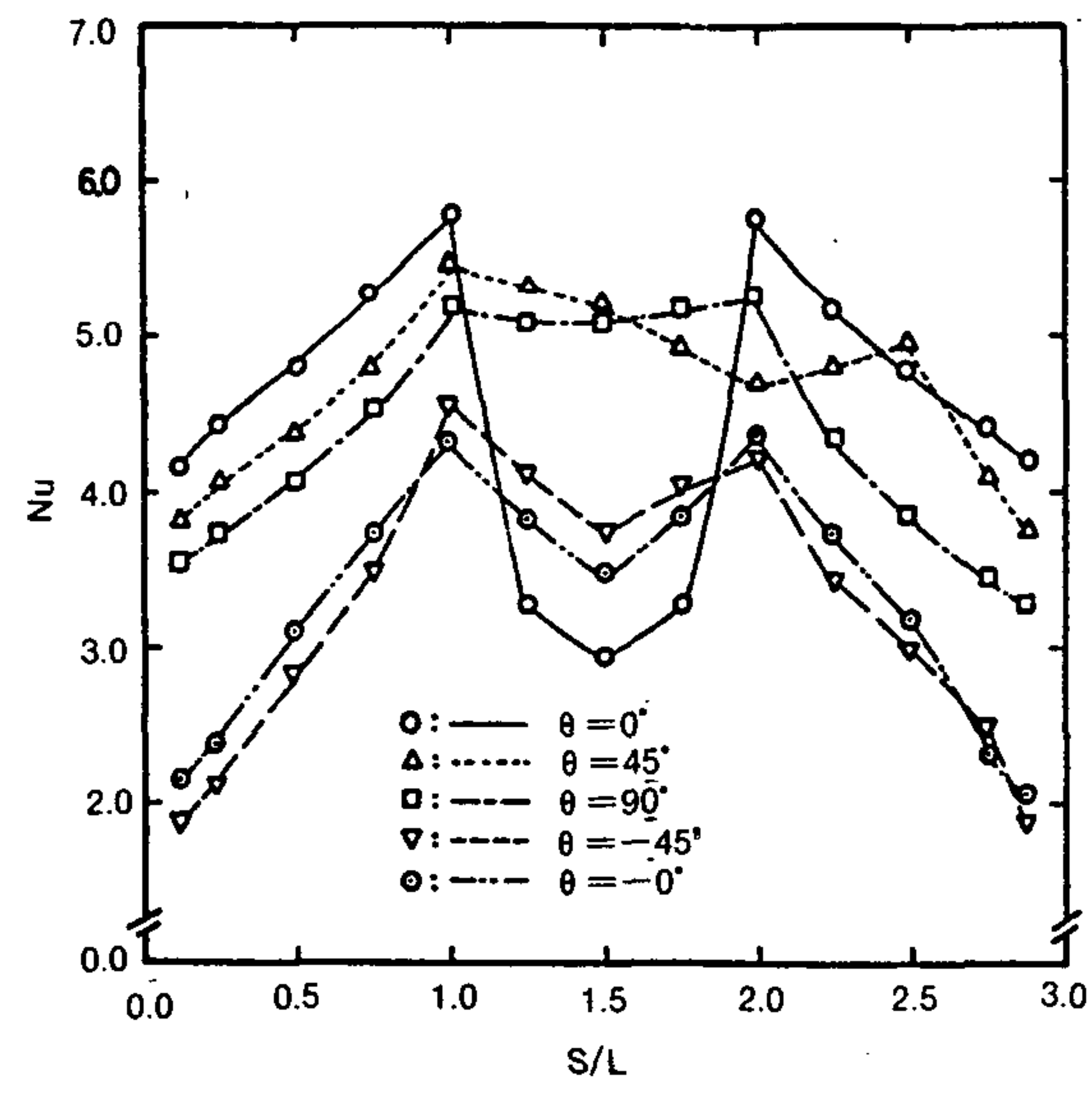

Fig. 10 Local Nusselt number from the heated surface at $Ra_L = 2.13 \times 10^4$

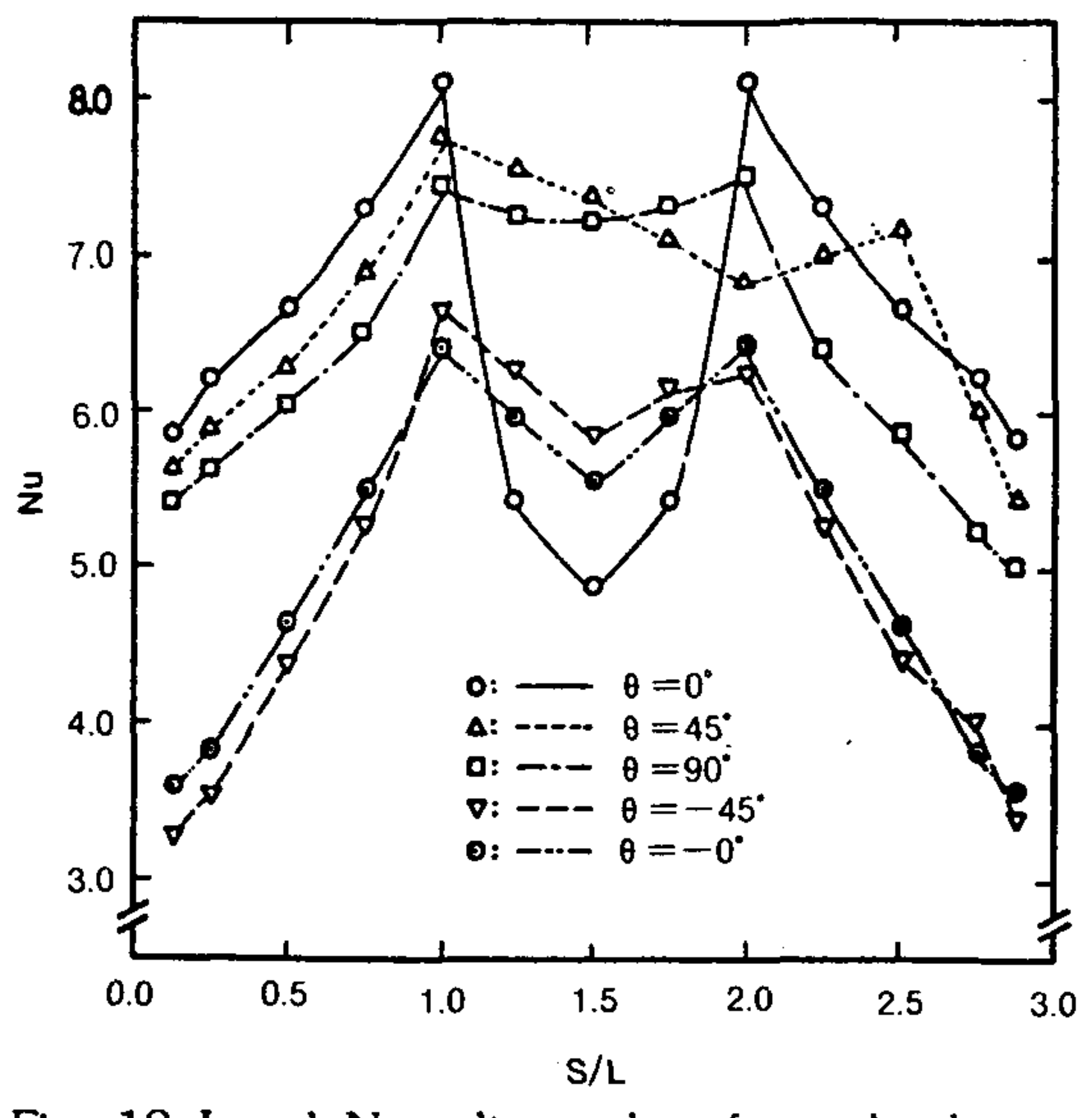

Fig. 12 Local Nusselt number from the heated surface at $Ra_L = 2.78 \times 10^4$

4. RESULTS

1. By the interaction effect of the heated fluid, the local Nusselt number was increased at the rectangular edges except trailing edge for the positive inclination angle $\theta = 45°$.
2. In case of $\theta = 90°$, the heat transfer of Y surface was maximum because of the least interruption of the adiabatic plate and the favourable buoyancy force.
3. The isotherm depression was strongly developed above the X_2 surface of $\theta = 90°$ as the Rayleigh number was increased, and the flow stagnation was severed at X_1 surface of $\theta = -45°$.

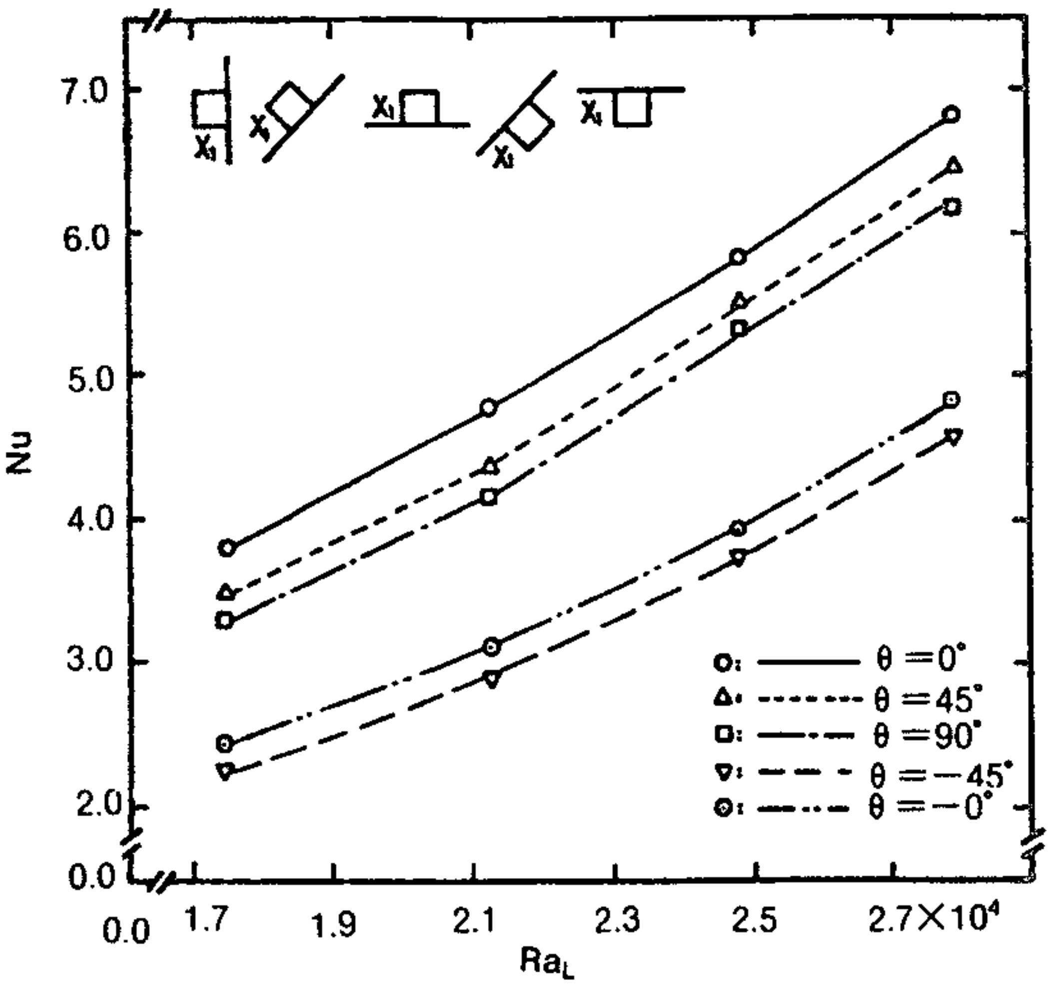

Fig. 13 Mean Nusselt number from the heated surface X_1

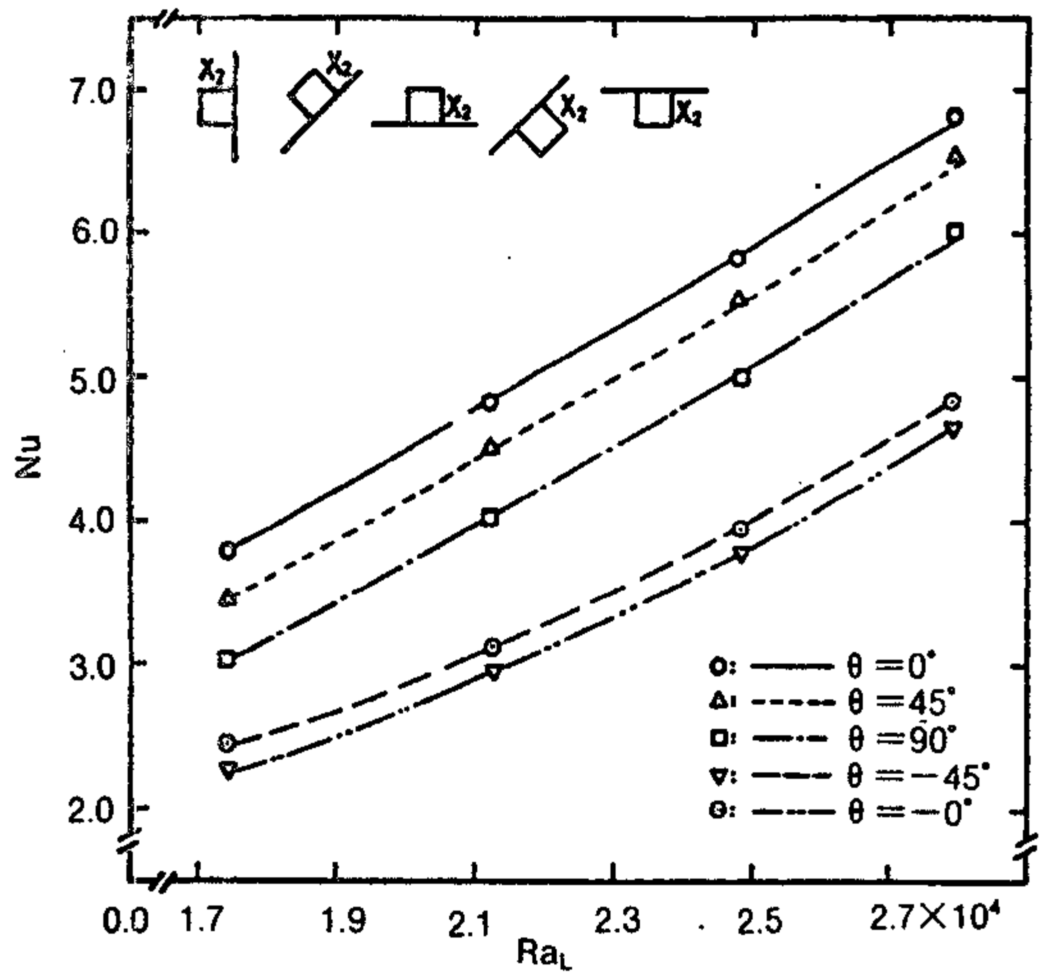

Fig. 15 Mean Nusselt number from the heated surface X_2

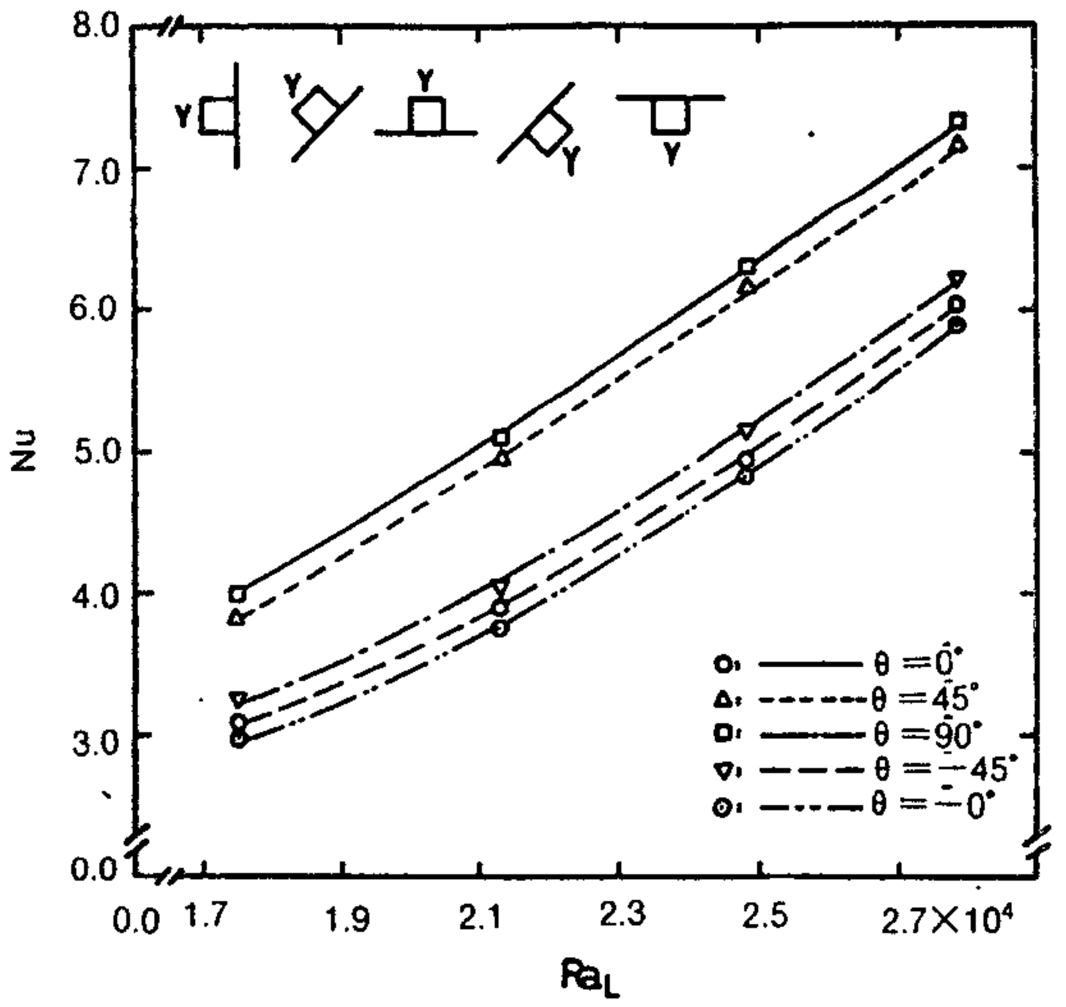

Fig. 14 Mean Nusselt number from the heated surface Y

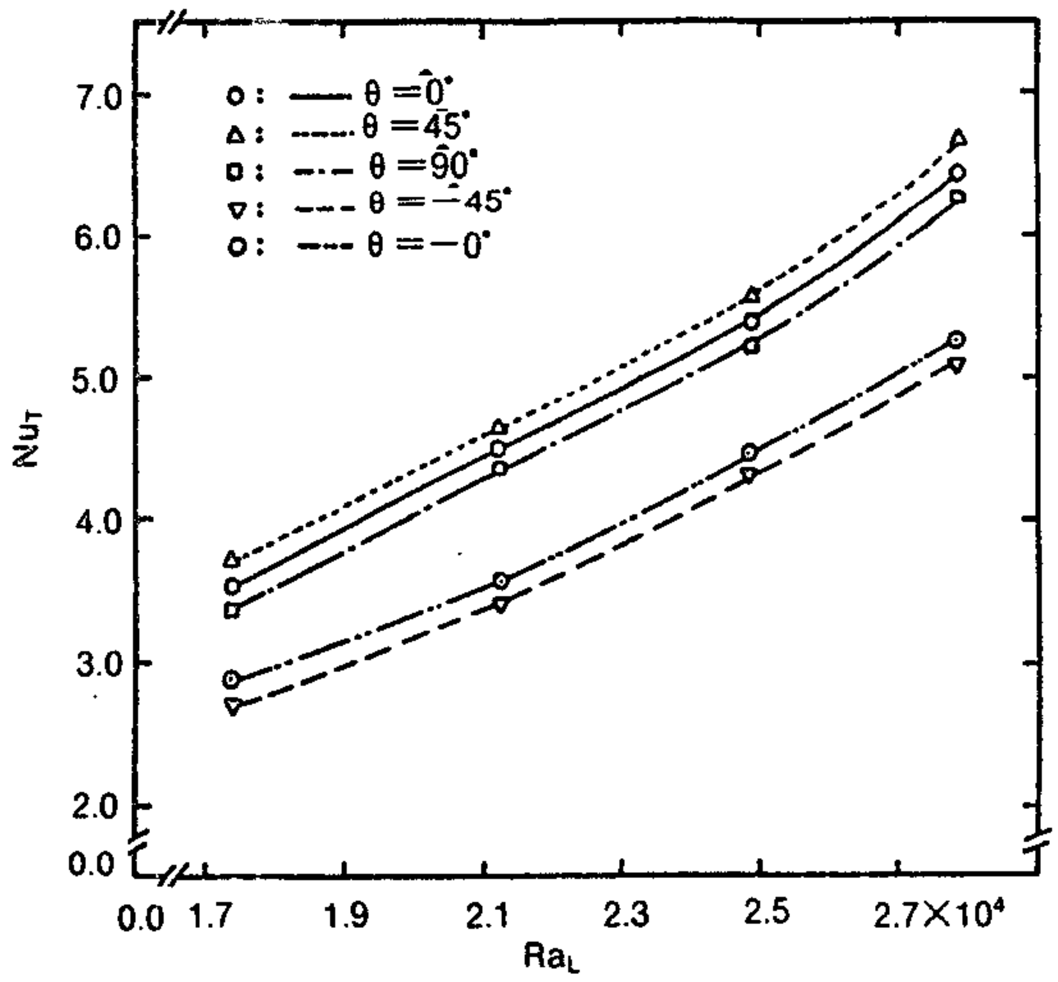

Fig. 16 Total mean Nusselt number above the beam surface vs. Rayleigh number.

4. The total mean Nusselt number was maximum at the positive inclination angle $\theta =$ 45° and minimum at the negative inclination angle $\theta = -45°$.

NOMENCLATUE

g : acceleration of gravity
h : heat transfer coefficient
k · thermal conductivity of the fluid
L : height(and width) of the beam
Nu : local Nusselt number, hL/k
$\overline{Nu}$: mean Nusselt number, $\bar{h}L_{x1}/k$, $\bar{h}L_Y/k$, $\bar{h}L_{x2}/k$
Nu_T: total mean Nusselt number
Pr : Prandtl number
Ra : Rayleigh number
T : temperature
α : thermal diffusivity
β : thermal expansion coefficient
ν : kinematic viscosity
θ : inclination angle of the adiabatic plate
S : distance along the beam sides

Subscripts

s :square beam surface

T :total

∞ :ambient

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efficiency. The characteristics of solar cells are improved by the annealing. The optimum annealing temperature and duration are 420[℃] and 12[min], respectively it is shown that the peak values of spectral response are shifted to the long wavelength region with increasing the annealing temperature. The X-ray diffraction patterns and the scanning electron micrographs show the grain growth in SiC film as the annealing temperature and time is increased. The best conversion efficiency is 11.7[%] for a 2.5×1[㎠] cell.

The Development of Software for Design of Centrifugal Pumps

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ABSTRACT

A centrifugal pump was selected as a basic study, for it was utilized widely at the industry among various types of pumps. The purpose of this study was to develop the software for design of centrifugal pump. The step of this design was divided into two stages. First, the impeller was designed by the experiences and theory of A.J.Stepanoff, and the head was checked whether the design of impeller was acceptable. Second, the volute chamber was designed by the Archimedes spiral. Then, These procedures of impeller and volute chamber were developed into the software in C-language.

Checked the validity of the developed software, the results were consistent with the actual pump produced domestically.

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In this study, the inclination angles were 0°(positive & negative), 45°(positive & negative), and 90°. The maximum total mean Nusselt number value was found at a positive inclination angle $\theta = 45°$.