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Free convection enhancement between inclined wall and air in presence of expired jets at temperature difference of 40 K

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ABSTRACT

This paper aims to determine the heat transfer enhancement in natural convection between a downward-facing inclined wall, heated by Joule effect, and air in the presence of small air pulsating expired jets, in conditions of medium temperature difference between wall and air, namely 40 K. Experimental measurements have been taken both with and without pulsating expired jets. The wall is kept in condition of uniform temperature. The expired jets blow out perpendicularly from the wall surface. An infrared thermo-camera was used to check the wall temperature uniformity. Hot-wire anemometer and visualization with smoke were used to find information on the air velocity field.

The wall inclination angle which maximizes the convective heat exchange near the leading edge has been investigated too.

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1. Introduction

Free convection heat transfer from vertical walls to air has been studied theoretically and experimentally by many researchers [1–3] since 1921; successively some investigations have evidenced the possibility of a considerable enhancement of heat transfer by means of fins and pins, namely by passive devices [4–8]. The enhancement by means of devices which require energy consumption were studied many years ago by Schlichting [9], who investigated the influence of the aspiration and recently by Ligrani [10–12] and Alì [13], who evidenced the influence of transpiration.

All these studies, specifically the theoretical ones, which are based on the boundary layer theory, refer to moderate temperature differences between the fluid and the plate, i.e. a few degrees or 20 K at the most.

On the contrary, the current literature does not offer references about the use of jets for destabilizing the boundary layer on a vertical or inclined wall in natural convection. The present work is the continuation of an experimental activity performed at the Department of Energetics "L. Poggi" of the University of Pisa [14–18], during the last four years, that was aimed at the investigation of vertical wall both in free and mixed convection modified by aspiration and expiration, in conditions of medium temperature differences between wall and air, namely from 25 to 70 K.

In this paper, we have measured the heat transfer enhancement due to the influence of the expired jets in conditions of a temperature difference of 40 K between an inclined aluminum wall, and air. The expired jets are performed intermittently through small holes.

The vertical aluminum wall size is $1200 \times 660 \times 8$ mm^3 and it is heated by the Joule effect. The circular jets have a diameter of 1.5 mm.

Besides, an interesting phenomenon has been observed during the experimental tests: the heat transfer coefficient trend versus inclination angle until 25°, in the case of wall without jets, can't be described by anyone correlations present in literature [19]: in fact it may not be simply correlated with the cosine of the downward inclination angle.

Finally, interesting practical applications could be there in the fields of expired walls in the buildings and aspired surfaces in aeronautics.

2. Experimental apparatus

The experimental apparatus consists of an aluminum wall (L, 600-mm; W, 6-mm; H, 1.200-mm), fixed to a support in order to remain in vertical or inclined position (Figs. 1 and 2). To reduce the radiant heat transfer from the front surface, this one had polished as a mirror. Instead, in the back side of the wall, there are two insulating layers, 40-mm. in thickness, with conductivity $k = 0.04$ W/mK.

Forty-eight adhesive electrical resistances (100×150 mm^2) are applied to the wall inner side and regulated by voltage variators. Each voltage variator is connected to a horizontal couple of electrical resistances, in the central part of the wall.

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