UNSTEADY FLOW PATTERNS IN THE VICINITY OF A HEATED WALL MOUNTED TRANSVERSE RIBS

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The study deals with the experimental modeling of the unsteady junction flow features in the vicinity of an isoflux heated wall with mounted insulated rectangular ribs. This physical geometry is of great interest during transient free convection in industrial applications (surfaces of buildings, electronic equipment,..). Because roughness elements can induce transition to turbulence in the flow behaviour and modify the local heat transfer process, attention is focused on both dynamical and thermal aspects. The idea is to explore the thermal effects with the flow patterns deduced from flow visualizations.

EXPERIMENTAL

The experiments were performed in a plexiglass towing tank with water as the working fluid. The wall is a vertical plane thermofoil heater (4000 W/m²) on which are located three insulated transverse rectangular ribs. To get more details about the unsteady phenomena occuring in perturbated boundary layers, three complementary configurations have been tested according to the size of ribs. The array of ribs considered are either regularly increasing in size (I), constant (II) or regularly decreasing in size (III). The thermal data is obtained with thermocouples (chromel-alumel type) calibrated to ± 0.1 K. To examine the flow features, two kinds of flow visualization experiments have been conducted to get either streaklines or streamlines in the meridian section of the flow. For this purpose, the data are deduced from electrolytic precipitation as well as from suspended fine rilsan particles lighted with a laser sheet.

THERMAL ANALYSIS

First, we have studied the smooth case, considered as a reference one. The streamwise temperatures are shown in Fig.1 for different times. It appears that by increasing the time the temperature profiles reach, with a good agreement, the steady state solution of free convection, established in Polidori et al.(1). Then, each configuration has been thermally analyzed. For example, the temperature profiles in configuration (II) are presented in Fig. 2. One can see very interesting differences between these two cases. The ribs influence significantly the heat transfer rate by increasing the temperature, especially at the lower surface of each element. The configurations have in common that the size of the first rib has no effect on the temperature distribution downstream this rib. Moreover, each configuration shows a decrease of the temperature in the open cavities as well as past the last rib. Nevertheless, differences occur inside the open cavities. For example, the maximum temperature is observed down to the third rib for configuration (I), down to the second rib for (II) and down to the first rib for (III). To make this analysis more complete, we have used results of flow visualization (Fig. 3).

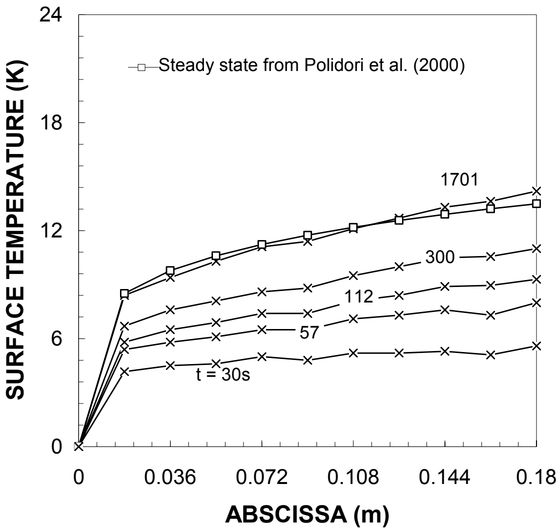


Figure 1 : Streamwise temperature distribution along the smooth wall (1)

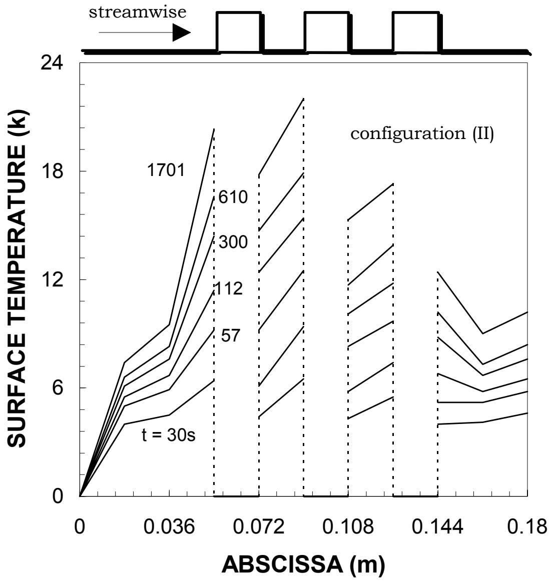


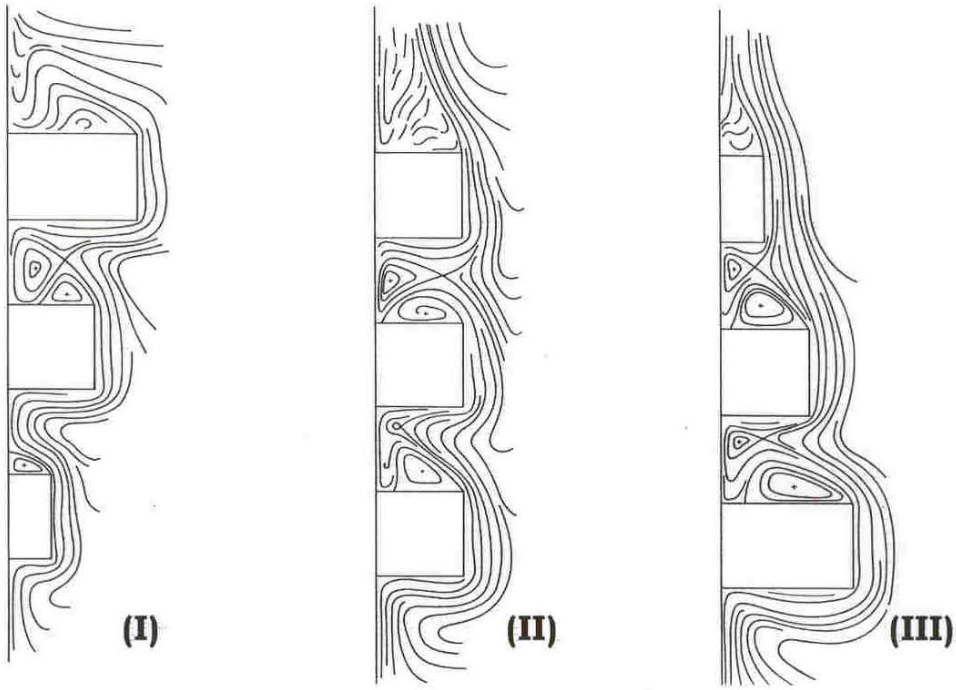
Figure 2 : Streamwise temperature distribution along the ribbed wall in the configuration (II).

FLOW PATTERNS

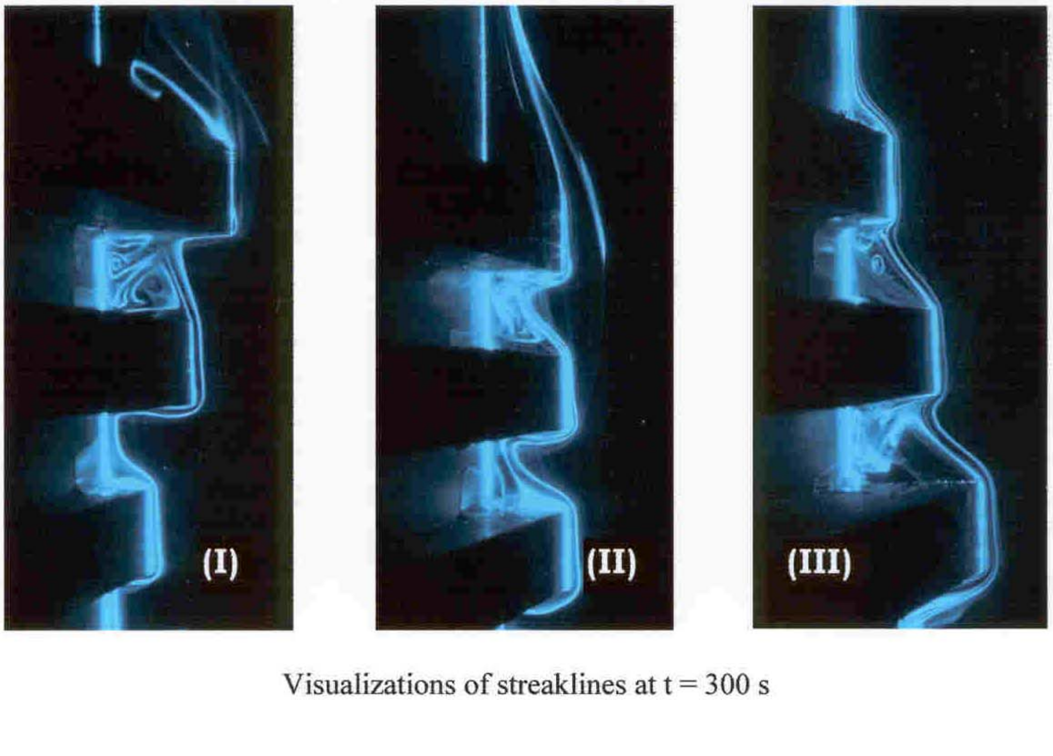
The analysis is based on both time-evolution of streaklines and streamlines (deduced from track visualizations) of the flow, as shown in Fig.3. It appears that the presence of an array of ribs causes separation of the dynamical boundary layer. For example, at t = 112s, in the first open cavity, one observes circulational flows consisting of two oppositely rotating vortices for the cases (II) and (III) while only a single cell is evidenced in the configuration (I). In the second cavity two vortices are present whatever the configuration at the first stage. Moreover, the study of the transient process shows that whatever the time, the vortex motion does not occupy the entire first cavity for the configuration (I). A detailed analysis shows that the rotational flow that appears in the cavities between the ribs intensifies the process of heat transfer.

REFERENCES

1. Polidori G., Mladin E.C., De Lorenzo T., Extension de la méthode de Karman-Pohlhausen aux régimes transitoires de convection libre, pour Pr > 0,6, *C. R. Acad. Sci. Paris*, t. 328, Série II b, p. 763-766, 2000.



Streamlines of the free convection flow at t = 112 s



Visualizations of streaklines at t = 300 s

Figure 3 : Flow patterns at different times