Study on influence of initial wall temperature distribution on the transient measurement results of film cooling

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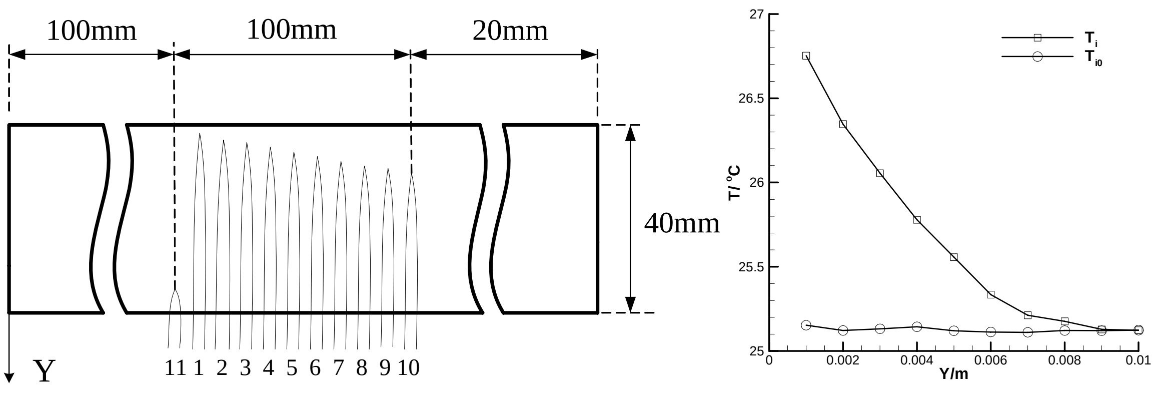
Transient heat transfer measurements are commonly employed by researchers nowadays because of very short experiment duration. One implicit assumptions in the traditional mathematical model of transient heat transfer measurement is that the initial wall temperature is uniform. Researchers tried many methods to achieve a uniform initial wall temperature, which made the test facilities very complicated and expensive. One of our papers, which is numbered as GT2009-59001 and will be presented in the coming ASME TURBO EXPO 2009, introduced a transient heat transfer measurement theory which can process the nonuniform initial temperature in the normal direction and a numerical validation method to exam the influence of nonuniform initial temperature. However, it is lack of experiment validation on the influence of nonuniform initial temperature. This paper tries to make up this shortage by calculating and comparing the film cooling effectiveness and heat transfer coefficient of cylindrical hole film cooling using different initial wall temperature distributions which were measured in the real experiment case.

The experiment apparatus and procedure are the same with those in paper GT2009-59002 which will also be presented in ASME TURBO EXPO 2009. The only difference between them is the film cooling hole. The initial wall temperature distribution $T_i(y)$ is measured by the thermal couples shown in Figure 1(a). The location of this cross-section is perpendicular to the mainstream. The test plate has been in the environment for long enough time to ensure a uniform temperature T_{i0} in the plate before installation. But the temperature difference between the test plate and the air in the duct produced nonuniform initial temperature distribution in the Y direction region [0, 10mm], which is shown in Figure 1(b), during the installation process. In every test case, the measured initial wall temperature distribution is similar with the curve in Figure 1(b), and the biggest temperature difference in the distribution is between $1^\circ C \sim 2^\circ C$.

Film cooling performance of cylindrical hole under two momentum ratios: 1 and 4, was measured. And three kinds of initial temperature distributions were used to calculate the film cooling effectiveness and the heat transfer coefficient: one is the real measured nonuniform initial wall temperature marked as “DISTRIBUTION”, one is the temperature measured by the 1# thermocouple marked as “CONSTANT1”, and one is the temperature measured by the 10# thermocouple marked as “CONSTANT2”. Relative to the results of “DISTRIBUTION”, the results of “CONSTANT1” is lower by about 10% under *I*=1 and about 20% under *I*=4 for cooling effectiveness and lower by about 10% for heat transfer coefficient under both momentum ratios; however, the results of “CONSTANT2” is higher by about 7% under *I*=1 and about 10% under *I*=4 for cooling effectiveness and higher by about 10% for heat transfer coefficient under both momentum ratios. The above deviations can be explained as the following. The temperature of “CONSTANT1” is higher than the real initial wall temperature. The liquid crystal color-change time should be shorter under “CONSTANT1”. Using the real but relatively long color-change time in the calculation makes the calculated convective heat flux smaller than the real, and the results of cooling effectiveness and heat transfer coefficient lower accordingly. Similar explanation can be drawn to the results of “CONSTANT2”. These results show that obtaining accurate initial temperature distribution is very important for transient heat transfer measurement of film cooling. Small overestimate or underestimate of the initial temperature can make the experiment results deviate from the true values badly. Moreover, the results show that the influence of inaccurate initial temperature on the experiment results is correlative with experiment time. In the region where experiment time is relatively long, the influence of inaccurate initial temperature is small relatively.



(a) (b)

Fig.1 Sketch of thermal couples’ distribution in the test plate and the measured initial temperature distribution