**an alternative POST-PROCESSING of transient LIQUID CRYSTAL EXPERIMENTS using the wall temperature gradient time response**

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Abstract

In this study, an alternative method is presented for the fast evaluation of the experimental results of transient heat transfer measurements with thermochromic liquid crystals. The calibration of the liquid crystals has been considered essential to obtain accurate heat transfer coefficient measurements. Nevertheless, it remains a difficult and time-consuming procedure. Therefore, it is proposed to bypass it, by utilizing the evolution of the wall temperature gradient under the assumption of a semi-infinite solid. The calculation of the wall temperature gradient necessitates the use of the maximum color intensity of the red and green signals of the liquid crystals. Along with the determination of the time at which these colors reach their peak intensity, for narrow bandwidth liquid crystals, i.e. less than 1 K, the temperature difference between R and G max intensities is considered 0.3 K based on a wide range of open literature sources. Eventually, the calculation of the heat transfer coefficient is feasible. This approach was tested on a high-crossflow narrow impingement channel that consists of a double row of ten jets. The possession of the calibration curves of the liquid crystals, in advance, allows for the cross-evaluation of the method. Filtering and fitting on the obtained data have been applied. The results demonstrate that, despite evident differences locally, the suggested method is in sufficiently good agreement with the values of the temperature wall gradient, when it is compared with the values of the calibrated liquid crystals. This agreement further extends at the heat transfer coefficient calculations, too. In particular, in highly transient cases, where the time constant is very low, the average heat transfer coefficient of a surface though this approach is within 5% of the respective value, which would be obtained, if the calibration of the liquid crystals had preceded.

introduction

An established method for the calculation of the heat transfer coefficients in transient heat transfer experiments incorporates the use of thermochromic liquid crystals[1]. For the calculation of the heat transfer coefficient, on a surface subjected to a convective flow, the temperature distribution in the medium is described by the semi-infinite body approximation. When lateral conduction phenomena are considered negligible, the heat transfer within the medium can be described by Fourier’s 1-D conduction law:

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where Tg is the temperature of the gas flow, T0 is the initial surface temperature. TLC and tLC represent the optically monitored isotherm of the liquid crystal and the time of t detection, while ρw, cw and kw are the density, the specific heat and the thermal conductivity of the medium, respectively[2][3].

If Eqn. 1 is differentiated to form an expression for the temperature gradient as a function of time, it is derived:

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|  | (2) |

By applying a first-order finite expression, the gradient is selected to be quantified as the ratio of the temperature difference of green and red at their peak intensities, to the time difference between the time steps at which the peak intensities are detected by the camera.

In order to investigate the effectiveness of this alternative approach, data from experiments on a flat plate, which is cooled by impinging jets, are used[4]. The experimental apparatus is described in detail by Terzis et al[5]. The test rig is part of an open circuit wind tunnel. The air enters the rig through the flare. The necessary temperature step, for the liquid crystal experiments is measured with thermocouples and it is achieved via a mesh heater. On the top of the facility, there is the test section, where the jets impinge on the installed the models. The flow exits the facility through a vacuum pump.

RESULTS and DISCUSSION

Figure 1 illustrates the differences between the temperature wall gradient between calibrated liquid crystals, either with the use of the green color and the calibrationless approach. In Figure 1a, the temperature wall gradient field on the plate demonstrates a smooth transition from the lower to the highest values. The peaks are observed in the regions, where the jets impinge on the plate.

When the liquid crystals are not calibrated, as it is shown in Figure 1b, the post-processing of the experimental data results in a distorted temperature gradient field on the plate surface. The pixel resolution of the image is more pronounced, since the transition from lower to higher gradients is not gradual. It rather displays fluctuations, as it approaches the centers of the jets’ impingement. Furthermore, the peak values are significantly lower compared to the ones of the calibrated liquid crystals. Also, the high temperature gradient regions occupy a larger part of the plate.



**Figure 1: Wall temperature gradient distribution according to (a) Green color scheme, (b) Dichromatic approach**

References

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