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EXPERIMENTAL SETUP FOR HEAT TRANSFER MEASUREMENTS IN PULSATING IMPINGING JET FLOW

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INTRODUCTION

In impinging jets in its standard configuration a fluid exits from a nozzle and flows perpendiculary onto a flat plate. Due to its different characteristics in the flow field three regions can be distinguished: Free jet region below the nozzle, stagnation region near the stagnation point, where the flow is decelerated towards the plate and accelerated parallel to the plate and the wall jet region, where the fluid flows parallel to the plate. Depending on Reynolds number and nozzle-to-plate-spacing laminar-turbulent-transition may occur within the boundary layer.
While impinging jets with steady mean flow are well understood, only few studies exist on the effect of pulsation in the mean flow on heat transfer. Real flows in technical applications are often transient. Therefore knowledge about the effects of unsteady flow on heat transfer is required.
In practical applications correlations for heat transfer as a function of system parameters like Reynolds number, Prandlt number and geometry parameters are very useful. For heat transfer in steady impinging jets new correlations have been developed for a better description of local and space-averaged heat flux. A publication is in preparation. The correlations will be extended for transient effects.
Besides using correlations of experimental data, CFD modelling is commonly applied. Due to the occurrence of laminar-turbulent transition in many parameter settings heat transfer in impinging jets is still a challenge for turbulence modelling. A first assessment of the ability of commonly used turbulence models has already been published[1]. An extension of this work is in preparation. Future work will include an assessment for transient flows as well as parameter variations in order to obtain additional information on flow field and heat transfer.
In order to validate these numerical studies on the effect of transients on heat transfer in impinging jets an experimental database of pulsating impinging jets is required. This paper presents an experimental setup for examining the effect of pulsation on local heat transfer in an impinging axisymmetric air jet.
The measurement technique, based on thermography, will be described. A finite difference technique is used for taking conduction in the plate into account. Then, it will be shown how a well-defined pulsating flow can be generated in the equipment. The final paper will include experimental results performed in the installation described in this abstract.

MEASUREMENT PRINCIPLES

A round glass plate of 8 mm thickness and 300 mm diameter is placed on a copper vessel. A thin film of heat-conductive paste between them ensures good thermal contact. The copper vessel is heated by steam at low pressure. With this setup nearly constant temperature can be realized on the lower face of the glass plate. This is controlled by 4 resistance thermometers. The impinging jet is cooling the upper face of the glass plate, where the local temperature is measured by thermography.
The thermal resistance of the plate is of the same magnitude as the resistance from the fluid to the plate. This enables a maximum resolution of the temperature signal.

If no heat flux in radial direction was taken into account, heat flux through the plate which equals in stationary or quasistationary conditions heat flux from the plate to the fluid, could directly be calculated from local temperature difference, thickness and thermal conductivity of the plate.
By relating heat flux to the temperature difference between exit of the nozzle and local position on the plate surface, local heat transfer coefficients can be determined.
Although this method works in large parts of the examined installation, it dampens the extreme values, where large gradients in heat transfer result in large gradients in surface temperature, which in turn lead to larger heat flux in radial direction. Additionally, for obtaining time-resolved heat transfer coefficients, heating and cooling of the glass plate itself has to be taken into account. This was done by a finite difference method, which considers heat flux in radial direction in steady and time-averaged heat transfer measurements. It will be extended for time-resolved periodic measurements.
The main problem using the finite difference method is that small deviations in the surface temperature will be amplified during the calculation and result in large oscillations in the resulting heat flux. Therefore the temperature curve has to be very smooth. In this work, this is realized by superposing 200 single temperature curves followed by a smoothing algorithm.

GENERATION OF PULSATING FLOW

Büchner[2] developped a pulsation facility to superimpose a pulsation on a steady flow. With some modifications this principle was used in this project, too. The pulsation facility consists of a rotor with 8 equidistant disruptions. When it is in rotation, it openes and closes an outlet in the cage of the pulsator. One side of the outlet orfice is shaped like a sine. Therefore the space of the outlet changes sinusoidally in time and a nearly sinusoidal velocity variation can be obtained. The rotor is driven by a servo motor. The pulsation facility has a bypass-valve for steady flow. Therefore amplitude and frequency of the pulsating flow combined with an independently adjustable steady flow can be set up.

TIME-RESOLVED MEASUREMENTS

Apart from the determination of time-averaged Nusselt numbers within a large range of frequencies, the aim of future experiments will be to determine local, time-resolved Nusselt numbers for lower frequencies. The data acquisition system is extended by a synchronization facility, which consists of a light barrier, which gives trigger signals at defined phase angles. The data acquisition at the infrared camera, the conventional data acquisition board and a laser doppler anemoneter for flow measurements starts with the trigger signal. The second step is to take into account transient effects in the finite difference method.

REFERENCES

1. Hofmann, H.; Martin, H.; Kind, M.: CFD calculations of heat transfer in impinging jet flow, Proceedings of the 12th International Heat Transfer Conference 2002, 363-367
2. Büchner, H.; Experimentelle und theoretische Untersuchungen der Entstehungsmechanismen selbsterregter Druckschwingungen in technischen Vormisch-Verbrennungssystemen. Dissertation Universität Karlsruhe 1992

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