EVALUATION OF HEAT TRANSFER COEFFICIENTS FOR AN IMPINGEMENT COOLING CASCADE: EXPERIMENTAL CHALLENGES AND PRELIMINARY RESULTS

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ABSTRACT

Impingement channels are widely used for the cooling of gas turbine vanes and blades, due to the very high local heat transfer coefficients that can be achieved in the stagnation zones. In modern integrally cast turbine airfoils, narrow impingement cooling channels **[1]** can be created where the coolant is injected within the wall rather than the hollow of the airfoil. This generates a double-wall cooling arrangement **[2]**, as shown in the left part of Fig. 1. In-wall cooling technologies, which may also include small pre-film impingement chambers **[3],** are able to reduce metal temperatures by as much as 100K.

Narrow impingement cooling channels consist of single or double rows of several cooling jets (see right part of Fig. 1), while the small wall thickness of a typical airfoil (~2*mm*) dictates significant heat transfer for all the internal surfaces of the cavity. These integrally cast impingement channels are radially oriented in the turbine airfoil which can include a plurality of similar cavities ensuring homogeneous distribution of the material temperature. Therefore, crossflow effects are of great importance for the optimization of thermal designs because the spent air of the jets interferes with the other walls of the channel providing complex flow structures and a degradation of heat transfer performance for the downstream jets. Attempts to regulate the generated crossflow in narrow impingement channels include jet hole staggering positions **[4]**, varying jet diameters in the streamwise direction **[5]** as well as divergent channel geometries **[6]**.

In order to gain additional efficiency, the narrow channels can be used in a **cascade impingement scheme** where the air from one cavity could be used for impingement in the following channel through an intermediate plenum chamber, as shown in Figure 2.

Experimental tests on impingement channels are generally carried out using the **transient liquid crystal technique**: starting at ambient temperature, the flow is suddenly heated to a temperature, and the temperature evolution of the surface is determined by watching the color change of a thermochromic liquid crystal coating. The convective heat transfer coefficient is then derived by using the mono-dimensional heat conduction equation with a semi-infinite assumption.

In a cascade impingement scheme, however, the determination of T_{hot}, needed for the derivation of the heat transfer coefficient, is problematic: on one hand, the flow temperature can be non-uniform between the various jets of the downstream array; on the other hand complex schemes can include bypasses from one chamber to the other, so that the actual local hot gas temperature depends on the mixing of 2 or more flows, which can be at different temperatures.

This paper will present a new test facility built at EPFL for the evaluation of the heat transfer performance of an impingement cascade system. Detailed heat transfer coefficient distributions for the first impingement channel will be evaluated with the usual transient liquid crystal technique. For the subsequent impingement channels, however, a heater foil will be used and the thermal performance will be evaluated with both steady and transient heat transfer techniques.

With this technique the flow is kept at ambient temperature during the experiment and an electric current flows through a thin foil glued at the surface under consideration. Again, the heat equation is solved to derive the heat transfer coefficient, but the convective boundary condition is modified by adding a source term representing the electrical power dissipated in the foil. The paper will present the measurement challenges as well as preliminary results evaluating all measurement methods.

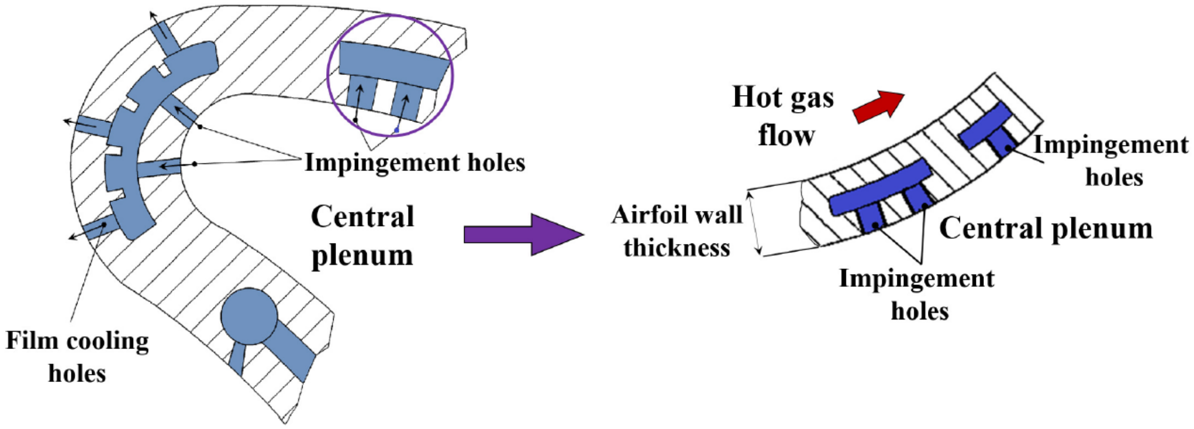

Figure 1 Narrow impingement channels in a double wall-cooling configuration.

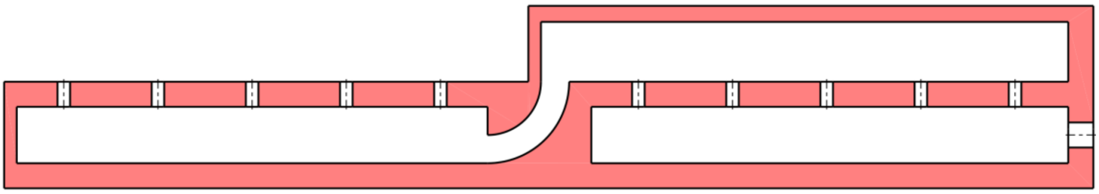

Figure 2 Cross-section of a cascade impingement channel.

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