EXPERIMENTAL DETERMINATION OF AVERAGE TURBULENT HEAT TRANSFER AND FRICTION FACTOR IN STATOR INTERNAL RIB- ROUGHENED COOLING CHANNELS

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EXTENDED ABSTRACT

Component durability is of prime importance for advanced HP gas turbine stages. Current combustor outlet temperatures and pressures levels require efficient cooling systems for blade and disks to ensure the design lifetime. Focusing on blade internal cooling mechanism, turbulators have been widely used because they are easy to manufacture and give a good heat transfer augmentation effect.

Such an augmentation is mainly due to two contributions:

(a) fluid dynamics: high turbulence level is promoted in the core flow due to periodic stream acceleration ad deceleration induced from the ribs; maximum heat transfer occurs at stream separation and reattachment, and, between these, high heat transfer regions are established whose extension has been found to be a function of geometrical features as rib height, aspect ratio, pitch and angle of attack. (b)geometrical: heat transfer area increase due to the presence of ribs

Obviously, increased complexity of geometrical features lead to a better heat transfer performance but also to increased friction losses. As a consequence, internal heat transfer cannot be considered separately from coolant flow rate consumption and channel chocking. Geometry optimisation is therefore always necessary. Pitch over rib height ratio from 8.5 to 10, and blockage ratios from 10% to 20% are currently used in HPT design.

Transient state facilities are used to simulate, according to similarity parameters, flow and heat transfer characteristics of internal cooling channels. Local heat transfer coefficient have to be independently averaged on each channel wall and then composed to get information on the average heat transfer coefficient [1,2,3]. The main limitation of this kind of approach is the computation of the surface averaged heat transfer coefficient of the single wall. its actual distribution is not easily predicted because of the strong three dimensional patterns of the flow on the surface. Large variations arise moving for instance from the centre line to lateral sides.

A large body of literature is available about turbulator equipped channels covering local thermohydraulic performance of different shapes and flow regimes.

An alternative approach is to evaluate the mean adductive heat transfer coefficient in a significant portion of the channel wall in stationary conditions.

The present work proposes a simple approach to obtain information on average heat transfer for ribbed channels which has not already appeared on the acknowledged literature.

This method allows not only to carry out accurate measurements of the average heat transfer flow rate on selected regions of ribbed channels without resorting to "artificial" compositions of local data, but also, when coupled with techniques giving local heat transfer data, to obtain information about the actual contribution to the total heat transfer given by different areas of the channel walls.

The averaged heat transfer coefficient of the test section is evaluated in steady state conditions. The sketch and the picture of the test section are given in figure 1.

This is divided in three parts of approximately equal length, two of them having four plexiglass walls, and one having a wall made of copper which sections can be exchanged from downstream to upstream. The heat source is an electrical resistance squeezed in a copper sandwich inserted between the two copper walls. Such test section wall is roughened with 20 ribs. Wall temperature for each heat transfer plate has been measured

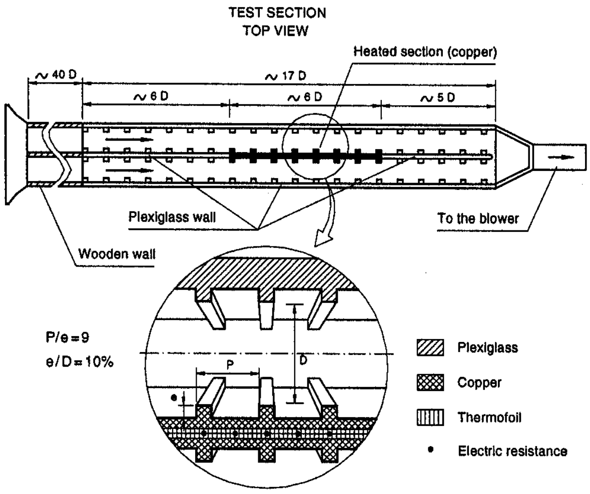

Fig.1 - Sketch of the test section

The averaged heat transfer coefficient was determined from bulk air flow rate and supplied electrical power measurements. Results are presented as heat transfer enhancement factor : Nu/Nu_0 versus Reynolds number in Fig2 And 3.. As preliminary tests, smooth copper foil walls have been installed and the enhancement factor computed for Re = $3 \cdot 10^4$, $4.5 \cdot 10^4$ and $6 \cdot 10^4$. Electrical power has been adjusted in the range between 60 and 300 W. Temperature of the copper plate ranged from 30 to 80 °C. Negligible variation of the heat transfer coefficient was observed by varying the copper surface temperature. For the ribbed configuration, the geometrical configuration- 90° double side square ribs was considered. The spacing of the ribs was kept at 9 times the ribs height (p/e=9), and the blockage ratio (e/D) equal to 10%. Levels of electrical power and plate temperature are the same as for the smooth tests. The results have been compared with published data [4,5,6,7,8].

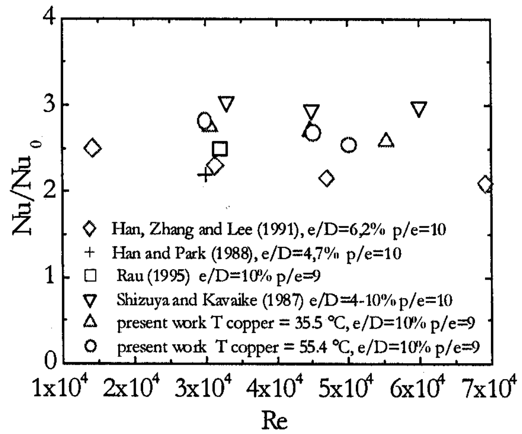

Fig. 2 – Enhancement factor versus Re

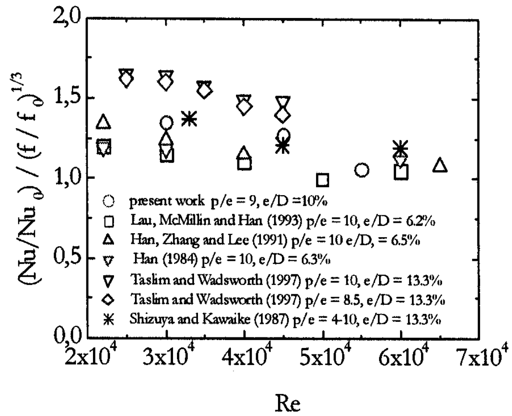

Fig. 3 – Thermal performance versus Re

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