FLOW INVESTIGATION IN A TWO-PASS COOLANT CHANNEL WITH/WITHOUT RIBBED WALLS

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ABSTRACT

The aero-engine industry and the power generation industry operate in a highly competitive market. Therefore high requirements in terms of high technology development as well as cost and development times reduction are constant major objectives. On the other hand, environmental and safety constraints are an increasingly stringent necessity, which enforces the demand for new technologies. Currently, the industry relies on expensive and time consuming rig test programs, whereas the existing numerical design tools have a number of deficiencies in accurately describing the complex multi-pass coolant channel flow. Under these conditions the Institute of Propulsion Technology at DLR is involved in national and European research programs aimed to provide the industry with high quality experimental data from the flow field for CFD validation.

In past projects the flow behaviour in rotating passages was analysed at DLR using wall pressure measurements to obtain the pressure drop. In addition, Laser-2-Focus velocimetry (L2F) was used to obtain flow velocity components and fluctuations. Although time-consuming, this non-intrusive, single-point measurement technique worked very well within straight and smooth duct flows, which generally have a moderate degree of turbulence. However, state of the art, serpentine shaped, multi-pass systems (Figure A) are equipped with ribbed walls, in order to improve heat exchange which is typical in realistic configurations. In this case L2F velocimetry was not able to measure accurate flow properties due to the increased turbulence intensities in the vicinity of the ribs as in the bend region and further downstream. The dividing wall separating the two passages forces the flow into a sharp turn which generally results in a flow separation. The flow within the separation bubble itself is very unsteady.

Modern planar measurement techniques such as particle image velocimetry (PIV) are capable of obtaining complete maps of flows even at high turbulence. As a first step toward applying this technique, a multi-pass cooling system is investigated in stationary (e.g. non-rotating) mode using two-component PIV. Two types of models were investigated: model (a) with smooth walls, model (b) with ribbed walls. The PIV

results are compared to some visualisation results of wall streamlines and throughflow as secondary flow development and 3D NS CFD results.

The high quality of the obtained results encourage the application of the two-component PIV to the rotating system. As a logical consequence, the application of three-component PIV will be necessary to obtain the complete flow field information within the complex flow passages.

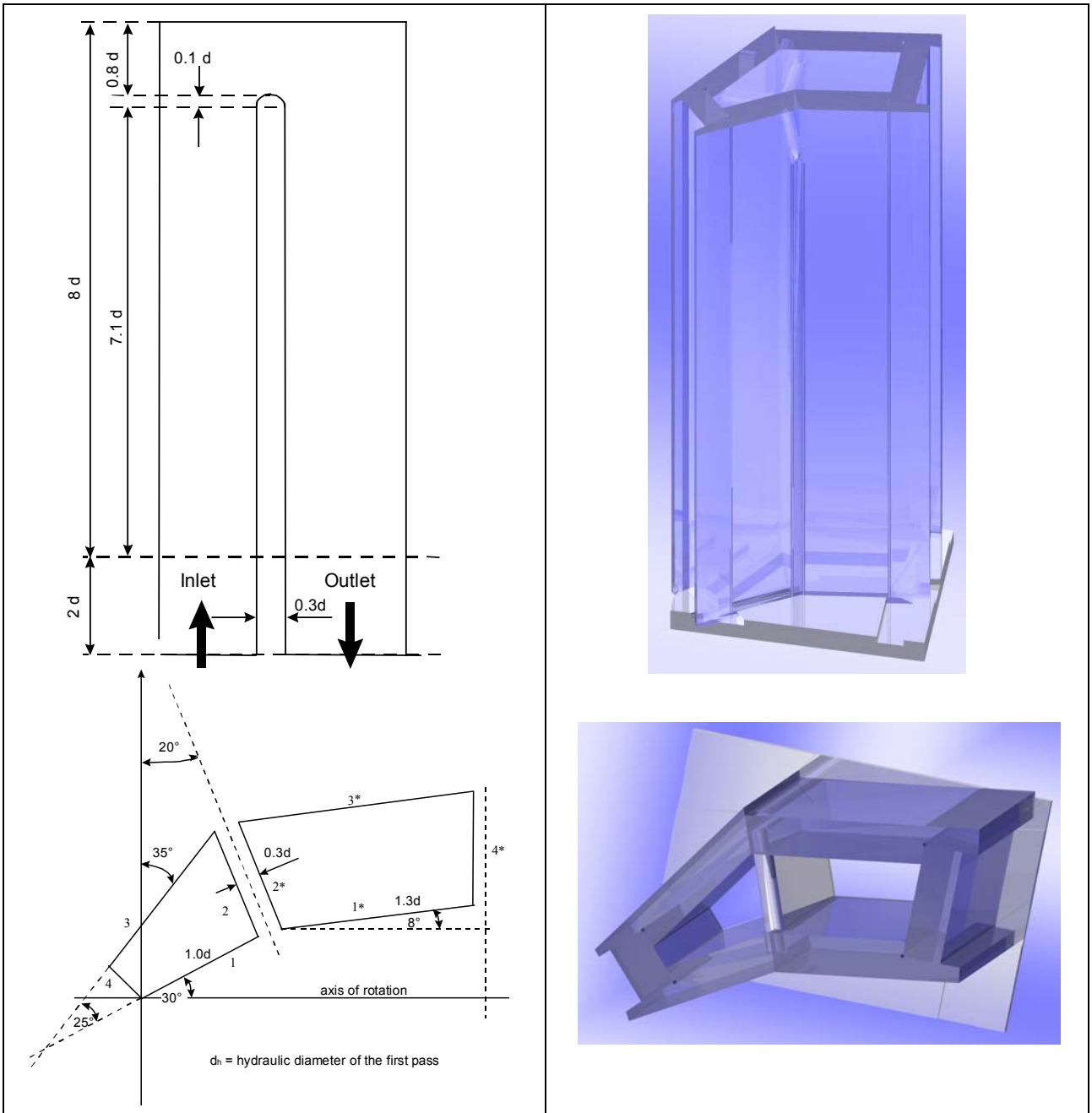

Figure A. Schematic and transparent view of the test model geometry without ribbed walls

RESULTS

With regard to PIV processing, standard cross correlation algorithms were used with an interrogation window size of 32 x 32 pixel and a 50 % overlap. The velocity of the intake flow into the first pass amounts to $v_0 = 30.5$ m/s, and consequently the REYNOLDS number is about 50.000 for the PIV measurements. The measured flow field of the secondary flow within the second pass in four cuts for a REYNOLDS number of 25.000 are shown in **Figure B**.

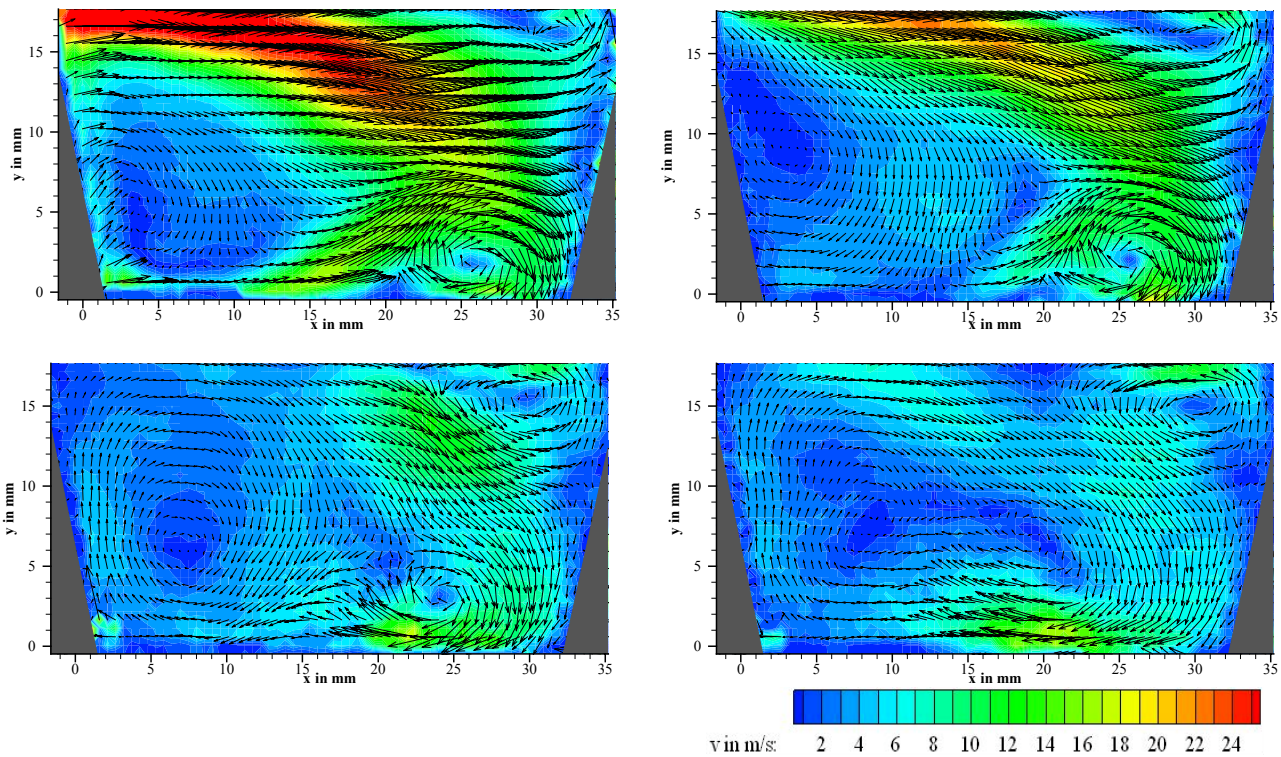

Figure B. Secondary flow velocity distribution in four cross cuts of the second pass measured with PIV (Re=25.000)

Figure C shows the streamline patterns and the velocity distribution on the leading wall of the duct, obtained from oil flow visualization experiments, in comparison with a numerical solution and a PIV measurement close to the wall.

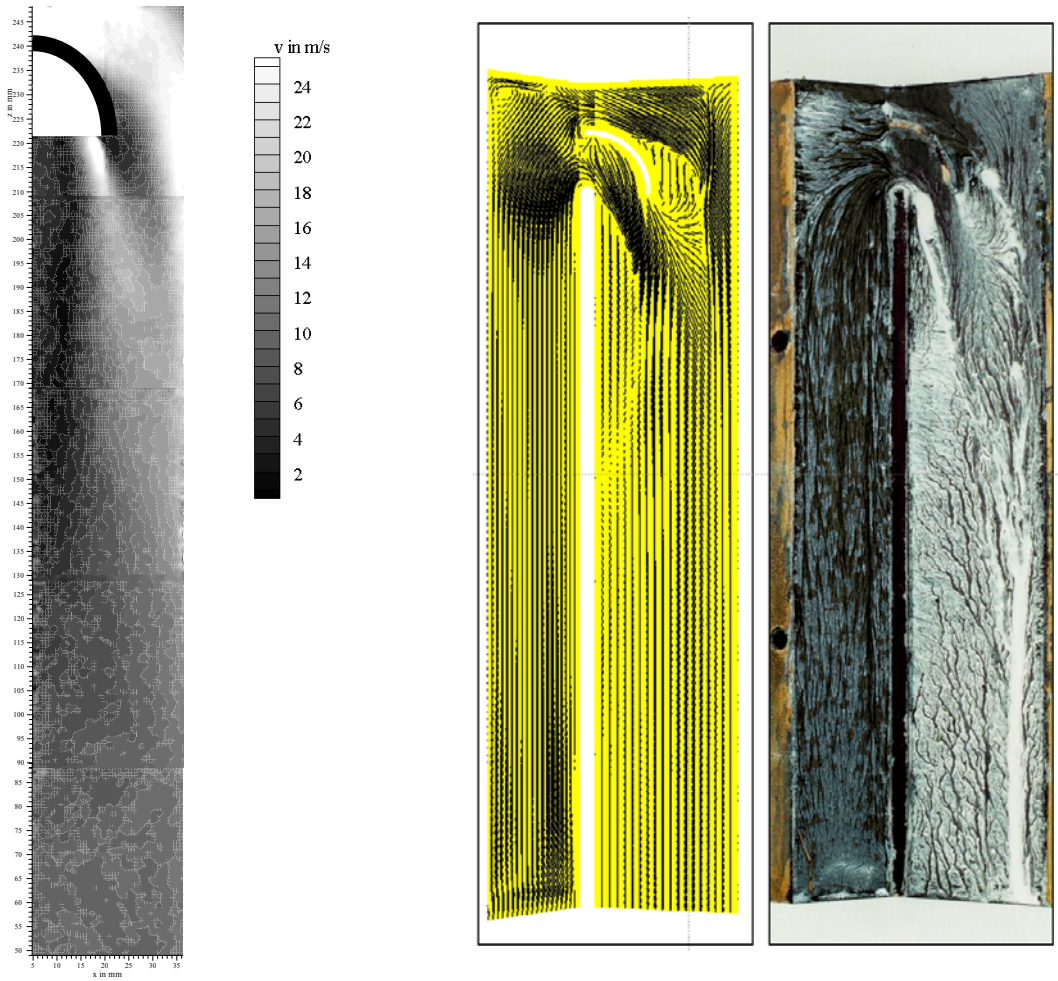

Figure C. Comparison between PIV, calculated and visualized wall velocities and streamlines on leading wall, non-rotating

SUMMARY

This paper describes experimental investigations of a typical two-pass cooling channel system of a turbine blade with and without ribbed walls with respect to fluid flow phenomena affected by geometry effects. A complex flow situation is present showing several kinds of separation and vortices. In order to give an accurate value of the turbulence level more than 2000 instantaneous PIV images will to be taken and evaluated. To collect such a relatively high number of images it requires relatively high storage capacity.

The performed flow visualization and simulation are very helpful in that case to understand the interaction of all apparent effects. The presented experiments were mainly intended to assess the feasibility of applying PIV in a multi-pass cooling channel used for applied cooling research. The results will show that it is possible to apply PIV at a multi-pass cooling channel also with ribs. The application of PIV is approved and will be adopted to the rotating system in the near future.