XX Fluid Mechanics Conference KKMP2012,
Gliwice, 17-20 September 2012

SLOT INFLUENCE IN BOUNDARY LAYER SUCTION FOR SECONDARY FLOW CONTROL IN A HIGH SPEED COMPRESSOR CASCADE

Karsten Liesner[1], Robert Meyer[1], Christoph Gmelin[2], Frank Thiele[2]
[1]*German Aerospace Center DLR, Institute of Propulsion Technology, 10623 Berlin, Germany*
[2]*Berlin Institute of Technology, ISTA, Sekr. MB1, 10623 Berlin*
E-mail: karsten.liesner@dlr.de

Key words: compressor cascade, secondary flow, active flow control, boundary layer suction

A numerical and experimental study is presented in order to clarify more the influence of a suction slot design with respect to mass flow rate and slot area in a compressor with active flow control for secondary loss diminution. While the numerical simulations unveil no influence of the shape at constant mass flow rates, the experimental investigations show such a dependency of the suction efficiency.

In the past, aero engine developers have been very reserved using active flow control in their machines. Sufficiently low kerosene prices and non reliable technology have been reasons for the engine manufacturers' focus on conventional engine design. The latest developments in the oil prices as well as robust active flow control mechanisms may in the near future be a trigger for their implementation in an actual machine.
The German Research Foundation (DFG) funds a project in which active flow control (AFC) is examined regarding efficiency and robustness in a modern axial compressor. In this context, investigations in a high speed compressor cascade have been conducted at the German Aerospace Center (DLR), Berlin. The compressor cascade (see Table 1), consisting of five linear aligned NACA65 IPC stator vanes, has been equipped with steady boundary layer suction in order to enhance the flow quality and reduce pressure loss due to secondary flow and separation.

Ma_1	Re	chord	span	pitch	β_1	β_s
0.67	560.000	40mm	40mm	22mm	132°	112.5°

Table 1: Design conditions of the examined NACA65-K48 cascade

In a former study [1], two AFC boundary layer suction geometries have been found efficient for the compressor cascade. With suction rates of 2% and 5% for the different geometries, a total pressure loss reduction of 22% and 38%, respectively, has been achieved. The efficiency calculated with a reference rotor, showed an increase of up to 2% for the cases mentioned.
These suction geometries have now been subject to a parameter study, in order to learn more about the different mechanisms that help to enhance the flow through a compressor. Is the driving parameter the mass flow rate or does the speed of the suction have an effect on the result as well?
For the study, 2 different suction slots in side walls have been examined, the peacock slot in the junction between vane suction side and side wall at 50% to 100% chord, with a slot width of 0.6mm, 1mm and 2mm. The second one, a suction slot following the side wall flow detachment line from pressure side leading edge to the suction side along the wall, in a like manner with slot widths from 0.6mm and 1mm to 2mm. The parameter study has in part been

done numerically; the paper concentrates on the comparison with the experimental results. Both suction slot geometries have already been shown at this very conference [2] in 2010 with great success.

From the measurements it is obvious (and expected) that the measurements with more secondary flow suction show a better degree of efficiency than the one with lower suction mass flow rates. This trend is obvious throughout the measured and simulated variations.

This new experimental study shows the dependency of the efficiency of the cascade with the mass flow and the slot width, respectively. Both parameters can be varied independently. It is shown that the slot width has a remarkable influence on the efficiency. With larger slot widths, the mass flow rate can be increased. While a slot width of 0.6mm allows for only about 2% of the main mass flow to be sucked from the cascade, with a slot width of 2mm more than 5% of the main mass flow can be drawn off the compressor. An increased suction rate in combination with an appropriate slot design decreases the total pressure loss, as soon as the suction rate is high enough to guarantee a constant suction mass flow in the slot. Otherwise, a recirculation appears that destroys the effect of the flow suction.

As soon as the recirculation is diminished or disappears, an amount of detrimental secondary flow and separated boundary layer flow is drawn out of the cascade and the total pressure loss is decreased. This benefit is also visible in the efficiency, even if the energy consumption of the secondary air system and the mass flow loss is accounted for.

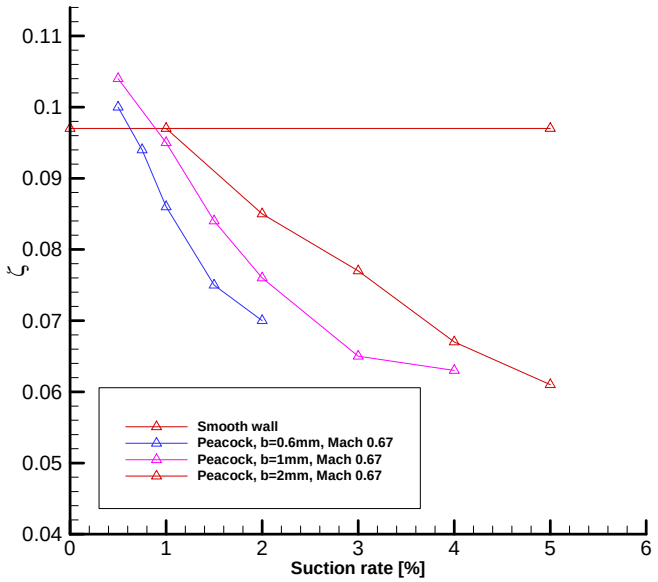

Fig.1: Experimental results: stator efficiency

The numerical simulation indicated that it is in theory not important how the suction slot is shaped, if the mass flow rate is kept constant. The experiments now show that there is a dependency on the slot width as well. With a narrower slot, the efficiency is enhanced already at smaller mass flow rates (see fig. 1). Some effects and a parameter study will be shown in the full paper.

References

[1] Liesner, K., Meyer, R., Lemke, M., Gmelin, C. and Thiele, F. (2010): "*On the efficiency of boundary layer suction in a compressor cascade*", ASME Turbo Expo 2010, Glasgow, UK. GT2010-22336

[2] Liesner, K. and Meyer, R. (2010): "*Non-symmetrical boundary layer suction in a compressor cascade*". Proceedings of the KKMP Conference 2010, Poznan, PL and Journal of Theoretical and Applied Mechanics, 2012, Vol. N.N.

[3] Gmelin, C., Thiele, F., Liesner, K. and Meyer, R. (2011): "*Investigations of secondary flow suction in a high speed compressor cascade*". ASME Turbo Expo 2011, Vancouver, Canada. GT2011-46479