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INFLUENCE OF COOLING AND VORTEX GENERATORS ON SHOCK INDUCED SEPARATION REGION ON TURBINE BLADE

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Nowadays a lot of efforts have been made to reduce mass and size of the new designed airplane engines. It is achieved by the reduction of blades number in the particular turbine cascades. This leads to increase of blades load and as a consequence the local supersonic region terminated by the shock wave appears in the blade passages. Mach number on the suction side of a blade upstream of the shock reaches up to 1.55. The interaction of shock wave with a boundary layer at such high Mach number leads to a strong separation. The process of separation usually becomes unsteady and is connected with buffeting at airfoils and shock oscillations in the internal flows. Shock oscillation causes the pulsation of pressure thus the change of the blade load.

Application of the streamwise vortices generated by air-jets (AJVG) for the separation control appears very effective (Szwaba 2009) and the AJVG's can be applied with success in a turbine blades. In the case of internal flows, as in gas turbines, very often an injection of coolant through holes and slots is applied. Therefore an introduction of flow control in form of AJVG's should not be a problem. The method is treated as passive, what means that the stagnation parameters of the jets are equal to the stagnation parameters of the main stream. Therefore the air can be supplied from the leading edge and there is no need to install any additional devices.

The jets have to be given appropriate angle of injection in relation to the main stream. There have been analysed (Doerffer, Flaszynski 2007) the jet inclination affects and the intensity of the generated vortices. These results have been taken into account in the experimental investigations.

The results of experimental investigations concerned the influence of cooling and vortex generators on shock induced separation region on turbine blade is presented in this paper. The investigations were carried out in generic linear cascade shown in Fig. 1. The channel was designed to obtain in the investigated region the same velocity distribution and boundary layer thickness as in real reference turbine profile on the suction side. Thus the flow pattern in interaction area is very similar to flow on suction side of turbine blade.
AJVG's are designed as a one row of holes across the width of the test section. They are located in channel upstream of the shock wave and downstream of the coolant injection.
The main measurements consist of:

- static pressure distribution along the centre line of the blade
- schlieren visualization of the shock wave structure
- oil flow visualization at the test wall to display separation size and structure
- boundary layer velocity profiles upstream and downstream of the interaction area
- velocity profiles in the wake of the blade
- shock wave oscillations

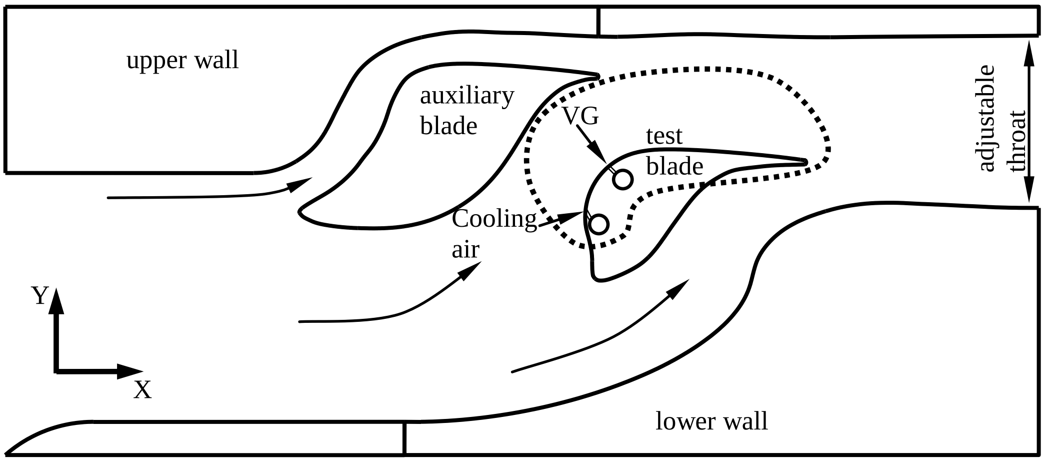

Fig. 1. Layout of the test section

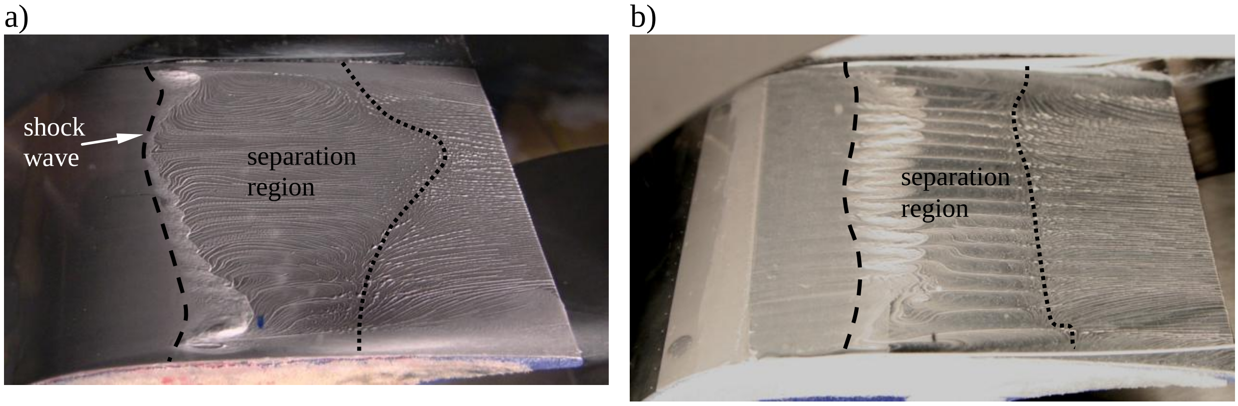

Fig. 2. Oil visualization, a) flow without AJVG, b) flow with AJVG

The effect of cooling and the AJVG's application is presented in the Fig. 2. They show surface oil flow visualisation on the wall in the interaction area. The flow only with cooling is shown in the Fig. 2a and the flow with cooling and AJVG in the Fig. 2b. The end of separation is marked by dotted line. Streamwise vortices penetrate the whole region downstream of the shock. The Fig. 2 proves that application of the AJVG causes the considerable reduction of separation size.

Very promising results were obtained from these experimental investigations in the context of shock wave induced separation control by streamwise vortices. Additionally reduction of the shock wave unsteadiness has been obtained.

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