

NUMERICAL INVESTIGATION OF THE EFFECT OF JET-FLAPS IN A TRANSONIC TURBINE CASCADE WITH SUPERSONIC OPERATING CONDITIONS

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Morden aero-engines are designed to suit for the different operating conditions, such as transonic speeding and manovering. In order to utilizing in the part-load or off-design conditions, the new named variable-cycle engine (VCE) is achieved with flexible cycle paramenters by changing some components' shape, size and position. As one of substantial methods, variable-geometry turbine (VGT) can vary the turbine mass flow by changing the throat aeras of HP turbines. The jet flap, one of the flow control techniques introduced into the inner flow by Stanley and John in 1971, now can be used as one of the adjustable variable-throat-area devices due to its ability to vary the main flow. So the study of the effect of jet-flaps in a transonic turbine cascade is usable to achieve a better turbine performance and thus a more advanced aero-engines.

However, the former studies are mainly on the low Reynolds number and subsonic conditions. For the transonic operating conditions or supersonic conditions, the state will be varied because of the complcated flow mechnism of the interaction of shock and boundary layer flow. With the utilization of the jet flaps, the flow mechnism should be even complex with the interactions between any two of them. To capture the internal flow mechanism well, numerical simulations of a linear transformed von Karman cascade, named "FKM cascade (consisting of 7 blades in the low-speed turbine cascade wind tunnel of the Northwestern Polytechnical University)"^[1-3], are carried out with jet-flap parameters variations under supersonic operating conditions in the present investigation.

The subsonic computations have been validated by the experiments, but the supersonic simulations cannot be verified due to the limitation of the low-speed wind tunnel. So the results are mainly discussed from the computational fluid perspective to demonstrate the interactions among shock, boundary layer and jet flow.

For the numerical simualtions, the commercial CFD software ANSYS CFX is used. Two-dimensional steady Reynolds-averaged Navier-Stokes equations are solved to simulate the flow in FKM cascade with jet-flaps. Considering the boundary layer separation bubble on the blade suction surface induced by the throat shock at transonic and supersonic operating conditions, Menter's SST two-equation turbulence model is used in the whole work. According to the demands of flow solver and turbulence model, a multiple O-H type mesh is used. The block structured computational domain is generated for the flow field. The O-grid is used around the

blade with 25 nodes in the wall-normal direction leading to the dimensionless wall distance of y^+ equal to about 0.5. the total number of grids nodes for the whole computational-domain is up to 0.2 million.

The jet flaps used to vary the turbine throat area with supersonic operating conditions are located upstream of the passage throat shock on the blade pressure side near the trailing edge. With variations of jet slot width and jet mass flow rate, the changes of turbine aerodynamic performance and the structure of shock-boundary layer interaction are studied.

With the discussions in this paper, the PS jet-flap seems to be quite effective to change the pattern of shock-boundary layer interaction under supersonic inflow in this numerical simulation. As a result, the separation bubble induced by the shock-boundary layer interaction is diminished owing to the change of shock location. Like a wing of jet, the shock was reduced, which will then contribute to the reduction of throat area and a different transonic turbine performance.

With two-dimensionally steady simulations, the PS jet-flap can slightly change the deflection of the mainstream, which can be concluded from the velocity distribution at the measurement line 1 in the wake with PS jet-flap. Consequently, the passage mass flow rate is decreased by jet-flap as a result of the throat velocity distribution. Referring to the flow loss, with jet flap, the width and depth of wake are augmented significantly. As a result, the profile loss is larger than the original case. Compared to the subsonic inflow, the influence of design parameters of PS jet-flap is not so significant as the subsonic conditions^[4]. Separately, the thinner jet slot decreases the velocity of mainstream more than the wider one; and the bigger jet mass flow ratio can have a much significant influence on the reduction of mainstream velocity.

Using a $C_m=2\%$ PS jet-flap with 1.025mm slot width and counter-axial (-x) jet blowing direction, the income mass flow rate is diminished by 4.2%, the turning angle augmented by 0.48 degree, but with an extended total-pressure loss coefficient of 0.01.

In the full paper we will show mostly numerical simulations, some of which are highlighted with detailed flow mechanism analysis. The distributions of the velocities with flaps in the throat and the wake will be compared with the reference no-jet case.

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