EFFECT OF SURFACE ROUGHNESS ON PERFORMANCE OF LP TURBINE BLADES AT LOW REYNOLDS NUMBERS

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The recent trend in LP turbine design aims at reducing the number of blades and thereby the weight and costs of aero-engines. Reducing the blade number leads to higher pitch-to-chord ratios and therewith to higher blade loading. Such blades are characterized by relative high suction side velocity peaks followed by strong decelerations on the rear blade surface which may induce laminar boundary layer separation at low Reynolds number conditions as encountered in high altitude flights. The use of controlled surface roughness elements as mean to induce boundary transition and thereby avoid laminar separation is considered a promising approach for maintaining high blade performance at low Reynolds numbers. Compared to present day design philosophy it is expected that artificial roughness could lead to 20% increase of blade loading and an equivalent reduction in blade numbers.

The aim of this project is the use of variable roughness elements on the suction side of LP turbine blades to achieve minimum losses over a Reynolds number range of 30,000 to 150,000. The variable roughness is realized using balloon actuators. The experimental facility is the C1 cascade facility.

The first part of the project was a feasibility study for the technical applicability of balloon actuators on turbine blades. A model test piece with cylindrical internal cavity and narrow slots connecting the cavity to the outer surface was manufactured. The slots were covered with a 100µm thick rubber foil and glued to the surface with a 20 µm thick tape. Tests were performed investigating the deflection of the rubber at different inflation pressures with emphasis on a regular balloon shape.

In the second part of the project the effect of balloon actuators was tested on the turbine blades. Loss measurements were carried out at mid-span and along the blade span (for secondary flow investigations) over a wide range of Reynolds numbers. The effect of the balloon actuators on the blade pressure distribution was also investigated.

The experiments demonstrate a positive effect of the balloon actuators on the mid-span losses for RE ≤ 120,000 reducing the losses by 25% respectively 60 % at RE = $7x10^4$ and $4 x10^4$. Moreover, at high RE number the detrimental effect of the balloon actuators is less than that of a trip wire of equivalent thickness. Secondary losses are little effected.