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Active Separation Control on Highly Loaded LPT Blades using Microjets

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The efficacy of separation control on an LPT using microjets was determined through the use of pressure and velocity field measurements over a wide range of Reynolds numbers. The AFRL designed L1A low pressure turbine blade, which was used in this study, is a highly aft-loaded profile which experiences a non-reattaching separation at approximately 62%C_x for low Reynolds Numbers. Microjet actuators have been shown to be very effective for separation control in subsonic conditions and a microjet array has been implemented to the L1A LPT at 60%C_x. Baseline blade pressure distributions as well as wake loss coefficient traverses show that the blade's non-reattaching separation is present for Re<50000 for a freestream turbulence intensity of 1%. Microjets were activated at various blowing ratios for each Reynolds number of interest and were shown to eliminate the boundary layer separation. At Re≈20000, the minimum effective blowing ratio was B=3 whereas at Re≈40000, the minimum effective blowing ratio was B=1. By utilizing microjet control, the integrated loss coefficient dropped 500% from the no-control case at Re≈20000 and the Re≈40000 case had a drop of 700% from the no-control case. Lower blowing ratios were required as the experimental Reynolds number approached that of the blade's transition Reynolds number which was found to be between Re≈50000 and Re≈60000. PIV velocity fields show a complete elimination of all reverse flow on the blade's suction surface when the microjets were steadily actuated during low Reynolds number conditions. Turbulence statistics found through PIV also showed a dramatic reduction in u_{rms} and v_{rms} unsteady quantities when the microjets were actuated. These results were achieved with low mass flux and compare favorably with other flow control methods for LPT separation reduction.

Nomenclature

C_x	=	LPT blade axial chord (0.216m)
S	=	Blade spacing (0.218m)
d	=	microjet diameter (400µm)
Re	=	Reynolds Number based on axial chord
C_p	=	pressure coefficient $(P_{T,\,inlet} - P_{S,\,local})/(P_{T,\,inlet} - P_{S,\,inlet})$
P_T	=	total pressure
P_S	=	static pressure
U_{jet}	=	microjet exit velocity
U_{local}	=	local free stream velocity at 53%C_x
B	=	Blowing Ratio $(U_{jet}/U_{local@53\%Cx})$
A_{jets}	=	total microjet array exit area
$\dot{V}$	=	volumetric flow rate of microjet array (SLPM)
λ	=	wake loss coefficient $(P_{T,\,inlet} - P_{T,\,exit})/(P_{T,\,inlet} - P_{S,\,inlet})$
TE	=	trailing edge
CB	=	blade with microjet actuators
u	=	velocity component in the x direction
v	=	velocity component in the y direction
U	=	velocity magnitude

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