Mechanical Engineering Department Seminar

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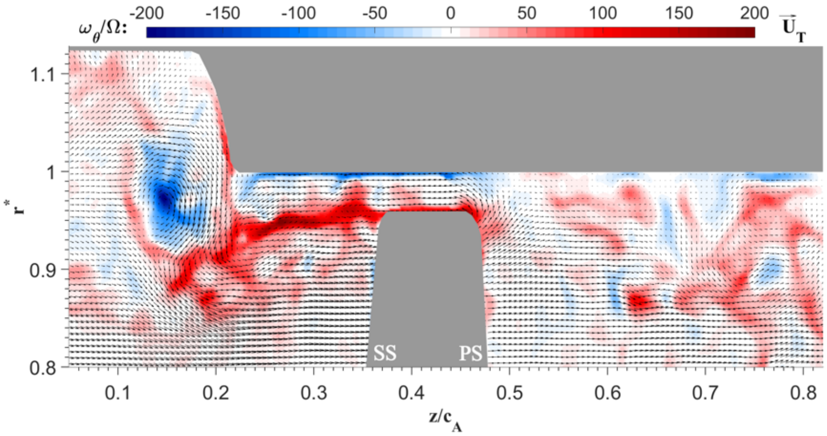
1130 Mechanical Engineering
111 Church Street SE, Minneapolis, MN 55455

Tip Leakage Flows and Stall Suppression In Taxial Turbomachines

Joseph Katz

William F. Ward Sr. Distinguished Professor of Engineering and co-founder of the Center for Environmental and Applied Fluid Mechanics – Johns Hopkins University

Tip leakage flows adversely affect the performance and contribute to the onset of stall in axial turbomachines. Stereo PIV measurements and flow visualization using cavitation performed in a refractive-index-matched facility examine the structure of tip leakage flows near the best efficiency point (BEP) and under pre-stall conditions. They follow the evolution the backward leakage flow, its rollup into a tip leakage vortex (TLV), the migration and breakup of this vortex, and the associated turbulence. In search for precursors to stall, flow features propagating from one blade passage to the next have been investigated. The most prominent process involves periodic formation of large-scale backflow vortices (BFVs) that extend diagonally upstream, from the suction side of one blade at mid-chord to the pressure side near the leading edge of the next blade. The BFVs originate form radial gradients in circumferential velocity occurring below the TLV, at the transition between the region affected by the tip leakage and the main passage flow. When the BFVs penetrate to the next passage across the tip gap or by circumventing the leading edge, they trigger a similar phenomenon there. In the stall regime, the number and size of these structures increase, and they regularly propagate to the next passage. Aiming to suppress the stall, we have installed skewed semicircular axial casing grooves, which partially overlap with the blade's leading edge and the rest extending upstream. They reduce the stall by as much as 40% and improve the pre-stall performance. However, they degrade the efficiency and pressure rise at high flowrates. The PIV data show that the inflow into the downstream end of the grooves and the outflow from their upstream side vary periodically, peaking when the inlet is aligned with the blade pressure side. They entrain the TLV, prevents the formation of BFVs, and cause periodic variations in the incidence angle near the blade leading edge. At high flow rates, near BEP, secondary flows generated in the grooves are entrained back into the passage by the TLV, affecting the tip region turbulence. To alleviate the associated performance degradation, a series of grooves with the same inlet, but different outlet angles have been evaluated. Aligning the outflow circumferentially against the blade rotation is extremely effective in suppressing the stall but degrades the BEP performance. Conversely, aligning the outflow with the blade rotation, achieves more moderate stall improvement (25%), but does not degrade the BEP performance.



Bio: Joseph Katz received his B.S. degree from Tel Aviv University, and his M.S. and Ph.D. from California Institute of Technology, all in mechanical engineering. He is the William F. Ward Sr. Distinguished Professor of Engineering, and the director and co-founder of the Center for Environmental and Applied Fluid Mechanics at Johns Hopkins University. He is Fellow of the American Society of Mechanical Engineers (ASME) and the American Physical Society. He has served as the Editor of the Journal of Fluids Engineering, and as the Chair of the board of journal Editors of ASME. He has co-authored more than 370 journal and conference papers. Dr. Katz research extends over a wide range of fields, with a common theme involving experimental fluid mechanics, and development of advanced optical diagnostics techniques for laboratory and field applications.