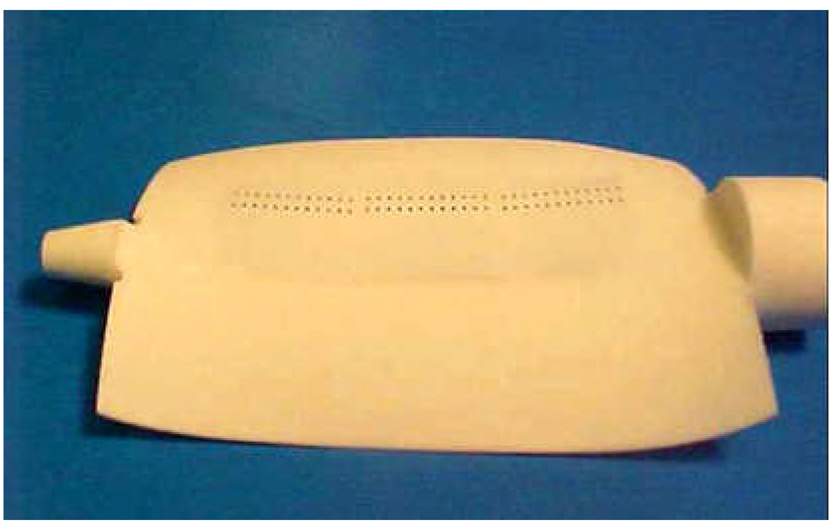
# Compressor Performance Enhanced by Active Flow Control Over Stator Vanes

The application of active flow control technology to enhance turbomachinery system performance is being investigated at the NASA Glenn Research Center through experimental studies. Active flow control involves the use of sensors and actuators embedded within engine components to dynamically alter the internal flow path during off-nominal operation in order to optimize engine performance and maintain stable operation.

Modern compressors are already highly optimized components that must be designed to accommodate a broad range of operating conditions in a safe and efficient manner. Since overall engine performance is driven by compressor performance, advances in compressor technology that reduce weight and parts count, reduce fuel consumption, and lower maintenance costs will have a significant impact on the cost of aircraft ownership. Active flow control holds the promise of delivering such technology advances.

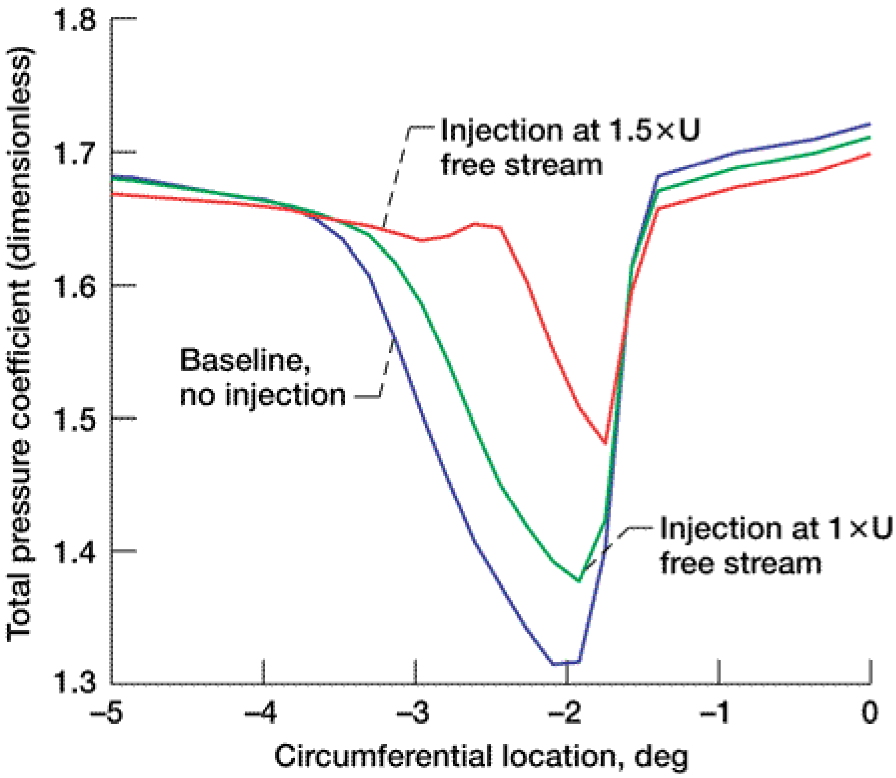
In highly loaded modern compressors, the flow tends to separate from stator airfoils under conditions of low mass flow. These conditions are often encountered during critical periods such as takeoff and landing and, for military aircraft, the extreme maneuvers encountered during combat operations. Flow separation acts as a blockage in the flow path which limits pressure recovery and may trigger severe mechanical stress conditions such as stall or even surge. Flow control delays the onset of separation with the use of injected air ahead of the separation line. The low momentum fluid creating the blockage at the airfoil surface is energized by the injected air, and the blockage is eliminated, or at least minimized, to the point that it does not adversely affect engine performance. The following photograph shows one example of a flow control vane using an array of holes on the vane surface.



*An example of a rapid prototype flow control vane using an array of angled holes to inject fluid ahead of separated flow on the suction surface.*

Long description of figure 1. One example of a flow control vane produced with a rapid prototyping process. An array of holes is shown along the span at one chord location on the suction surface side.

Flow control is being applied at the surface of stator vanes in Glenn’s Low-Speed Axial Compressor facility. This facility provides a flow field that accurately duplicates the aerodynamics of modern highly loaded compressors. Emphasis is being placed on the development of efficient actuators, effective injection schemes, robust sensors, and control methodologies for a practical system for a new generation of aircraft. The following graph shows measurements of the circumferential total pressure distribution acquired at midspan downstream of a flow-controlled vane. The vane is operating beyond its design loading with a separated suction surface boundary layer. Injection through slots in the vane suction surface reduces the severity of separation, which is manifested as a reduction in the area of low total pressure downstream of the vane.




*A plot of total pressure distribution in the blade wake at midspan with varying velocity levels of injected fluid. The air injected from the vane surface (for the two curves with injection) has a velocity of 1.5 times the free stream or power stream velocity through the machine.*

Long description of figure 2 Plot of total pressure coefficient versus circumferential position at the midspan of a flow control vane. Low momentum fluid along the vane suction surface induces flow separation in the baseline condition. Injection along the vane surface energizes the stalled fluid and reattaches the separated flow, thus minimizing the total pressure loss in the downstream wake. The effect of two levels of injection, as measured by injected velocity, is shown..

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