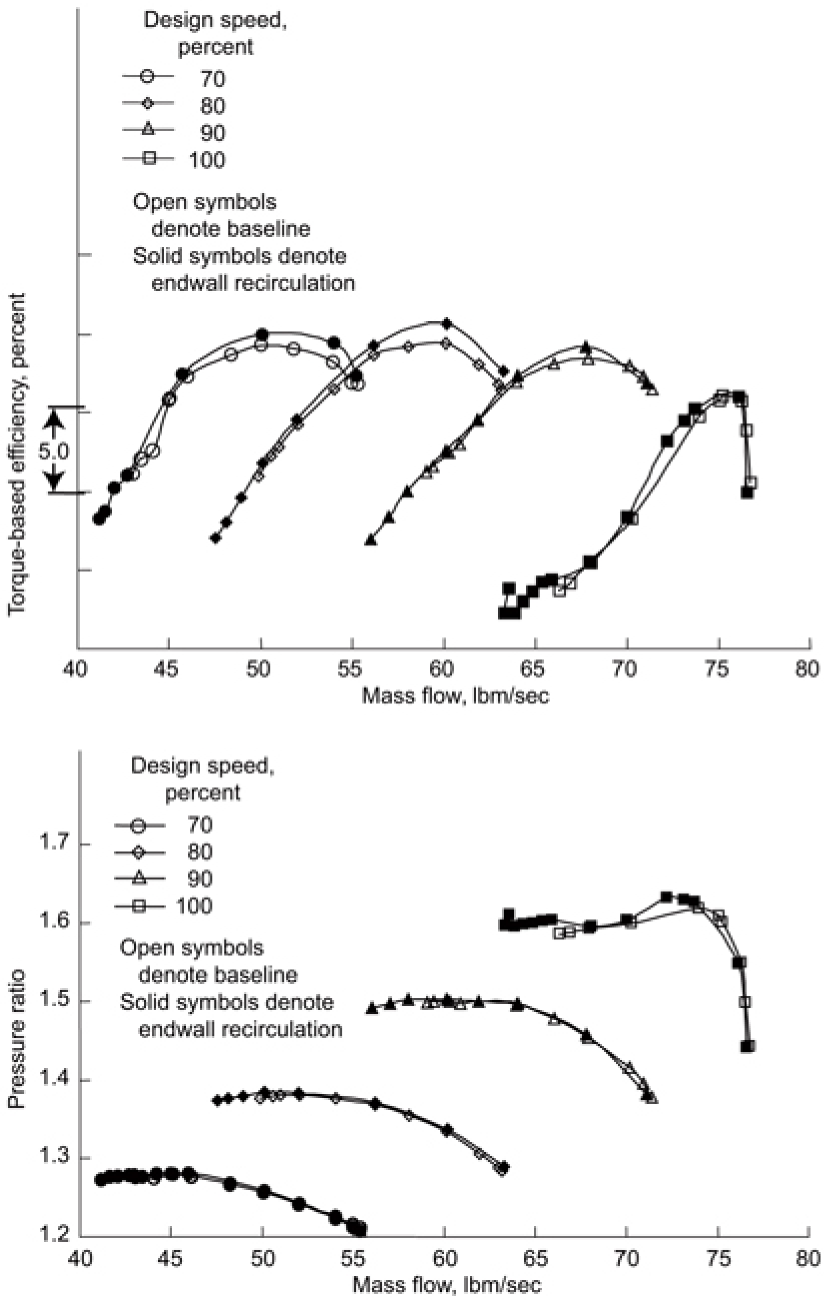
Adaptive Technologies Developed and Demonstrated for Extending the Stable Operating Range of Compressors

The operational envelope of gas turbine engines is constrained by the stability limit of the compression system. The dangers of exceeding this limit are severe, with the potential for engine failure and loss of the aircraft. To avoid such failures, compressor designers provide an adequate stability (stall) margin in the compressor design to account for inlet distortions, degradation due to wear, throttle transients, and other factors that reduce compressor stability from the original design intent. In some cases, the required stall margin results in the compressor operating line being below the maximum efficiency potential of the compression system. Current approaches to increasing stability tend to decrease the efficiency of the compressor. The focus of this work is to increase the stall margin of compressors without decreasing their efficiency.

Researchers at the NASA Glenn Research Center and the U.S. Army Research Laboratory, Vehicle Technology Directorate, have developed compressor stall-control technologies that have been demonstrated successfully in com-pressor component tests. These stall-control devices rely on the inherent energy rise that is imparted by a compressor rotor to recirculate higher energy fluid back to the front of the rotor, thus energizing the low-momentum flow in the rotor casing endwall region that typically sets the stability limits of the compressor. The new concepts have been developed through parametric experimental and computational studies. The technology requires no moving parts and is adaptive because the amount of recirculation depends on the pressure rise across the recirculation path, which is automatically regulated by the rotor work input. Thus, as the compressor is throttled toward stall, the pressure rise across the rotor increases, increasing the driving force across the recirculation path and, thus, the effectiveness of the recirculation in extending the stable operating range of the compressor. The figure compares the pressure-rise characteristics of a transonic fan stage with and without recirculation, showing that the compressor stage operates safely at lower mass flows when recirculation is used. This gain in stable operating range is achieved with no loss in efficiency and by recirculating less than 0.5 percent of the compressor throughflow.



Performance map of NASA Stage 67 showing the extended operating range provided by endwall recirculation stall-control technology.

Long description of figure. Graphs of pressure ratio and torque-based efficiency in percent versus mass flow in pound-mass per second for baseline and endwall recirculation data at design speeds of 70, 80, 90, and 100 percent.

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