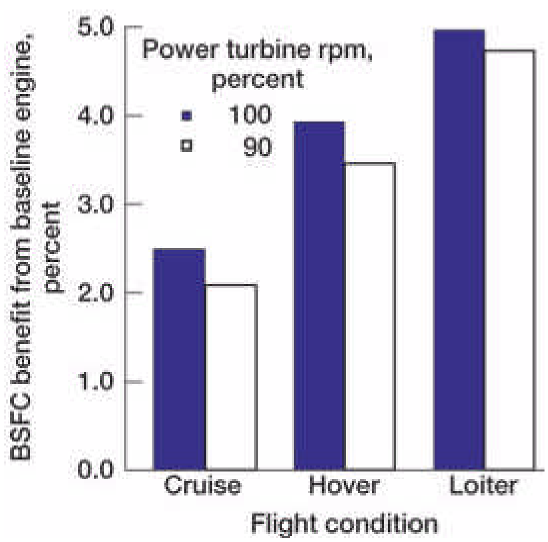
Performance Benefits for a Turboshaft Engine Using Nonlinear Engine Control Technology Investigated

The potential benefits of nonlinear engine control technology applied to a General Electric T700 helicopter engine were investigated. This technology is being developed by the U.S. Navy SPAWAR Systems Center for a variety of applications. When used as a means of active stability control, nonlinear engine control technology uses sensors and small amounts of injected air to allow compressors to operate with reduced stall margin, which can improve engine pressure ratio. The focus of this study was to determine the best achievable reduction in fuel consumption for the T700 turboshaft engine. A customer deck (computer code) was provided by General Electric to calculate the T700 engine performance, and the NASA Glenn Research Center used this code to perform the analysis. The results showed a 2- to 5-percent reduction in brake specific fuel consumption (BSFC) at the three Sikorsky H-60 helicopter operating points of cruise, loiter, and hover.

To simulate the technology, Glenn researchers varied the allowable flows into both the gas generator turbine and the power turbine to increase the compression system pressure ratio while maintaining gas generator revolutions per minute. In addition, the injected air could not be accurately modeled and thus was conservatively simulated by increasing the compressor bleed air extraction. Three engine operating conditions--cruise, loiter, and hover--were selected as being most relevant to the total fuel burn during a Sikorsky H-60 helicopter nominal mission. For these three operating points, the power turbine flow function was varied to maintain gas generator revolutions per minute at the baseline value as the stall margin changed. Shaft power output was also kept at the required (baseline) value for the flight condition.



Improvement in brake specific fuel consumption (BSFC) at cruise, loiter, and hover for the T700 turboshaft engine using nonlinear engine control technology.

Long description--When the power turbine is at 100-percent rpm, the technology improves the engine BSFC by 2.5 percent at cruise, 5.0 percent at loiter, and 3.9 percent at hover. When the power turbine is at 90-percent rpm, the technology improves the engine BSFC by 2.1 percent at cruise, 4.7 percent at loiter, and 3.5 percent at hover.

The results show that the increased axial compressor pressure ratio (and by assumption, the decreased stall margin) allows an improvement in BSFC. The amount of the benefit appears to be inversely proportional to the power level or engine compression ratio--approximately 2.3 percent for cruise, 3.7 percent for hover, and 4.8 percent for loiter--as shown in the bar chart. The white and black bars indicate the relative BSFC benefit from the baseline value for output shaft speeds of 90 and 100 percent, respectively. The benefits shown include a 1-percent compressor bleed air penalty, but they are relatively insensitive to this amount of bleed. The combustor exit temperature was tracked during the study to see if it increased: varying the turbine flow scalars ultimately causes T4 to increase about 25 °C. This would be a potential concern at the cruise condition since the temperature is near its maximum at that point, perhaps requiring the use of the technology only at other conditions, such as hover and loiter.

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