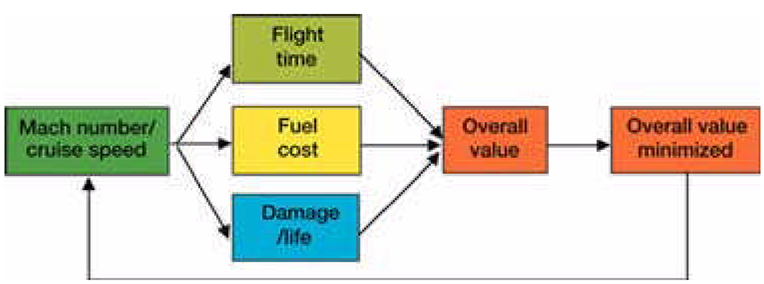
Life-Extending Control for Aircraft Engines Studied

Current aircraft engine controllers are designed and operated to provide both performance and stability margins. However, the standard method of operation results in significant wear and tear on the engine and negatively affects the on-wing life--the time between cycles when the engine must be physically removed from the aircraft for maintenance. The NASA Glenn Research Center and its industrial and academic partners have been working together toward a new control concept that will include engine life usage as part of the control function. The resulting controller will be able to significantly extend the engine's on-wing life with little or no impact on engine performance and operability. The new controller design will utilize damage models to estimate and mitigate the rate and overall accumulation of damage to critical engine parts. The control methods will also provide a means to assess tradeoffs between performance and structural durability on the basis of mission requirements and remaining engine life.

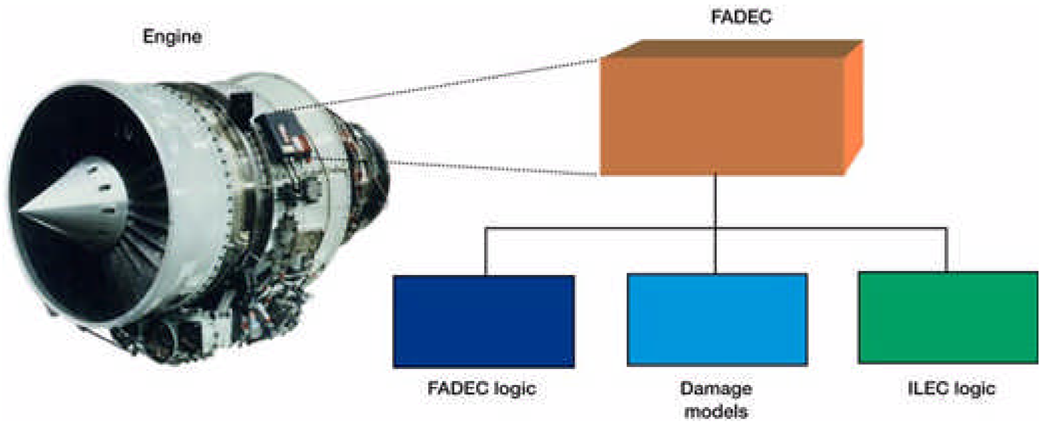
Two life-extending control methodologies were studied to reduce the overall life-cycle cost of aircraft engines. The first methodology is to modify the baseline control logic to reduce the thermomechanical fatigue (TMF) damage of cooled stators during acceleration. To accomplish this, an innovative algorithm limits the low-speed rotor acceleration command when the engine has reached a threshold close to the requested thrust. This algorithm allows a significant reduction in TMF damage with only a very small increase in the rise time to reach the commanded rotor speed.



Tradeoff optimization among flight time, fuel consumption, and component damages.
Long description: Flowchart showing how flight time, fuel usage, and engine damage are evaluated on the basis of the aircraft cruise condition. An optimization condition is reached that is based on the minimization of the overall assigned cost functions.

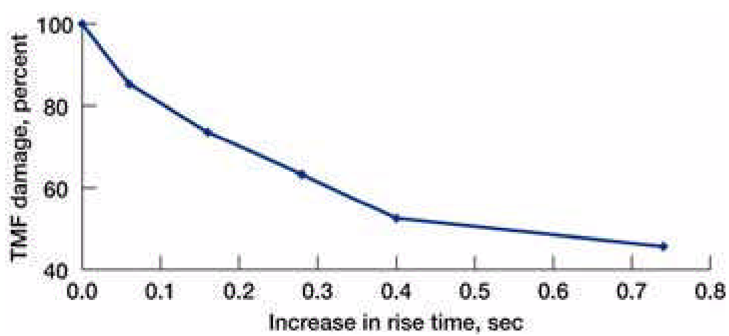
The second methodology is to reduce stress rupture/creep damage to turbine blades and uncooled stators by incorporating an engine damage model into the flight mission. Overall operation cost is reduced by an optimization among the flight time, fuel consumption, and component damages (see the preceding flowchart).

Recent efforts have focused on applying life-extending control technology to an existing commercial turbine engine, and doing so without modifying the hardware or adding sensors. This approach (see the following figure) makes it possible to retrofit existing engines with life-extending control technology by changing only the control software in the full-authority digital engine controller (FADEC).



Life-extending control approach. ILEC, Intelligent Life-Extending Control.
Long description: Flowchart showing how the engine damage model and life extending control logic are integrated into the current engine controller

The significant results include demonstrating a 20- to 30-percent reduction in TMF damage to the hot section by developing and implementing smart acceleration logic during takeoff. The tradeoff is an increase, from 5.0 to 5.2 sec, in the time required to reach maximum power from ground idle (see the graph).



Thermomechanical fatigue (TMF) damage versus rise time.
Long description: Thermomechanical fatigue damage decreases almost exponentially with the increase in rise time. An increase in rise time of 0.2 sec will reduce the damage by about 30 percent, and an increase in rise time of 0.4 sec will reduce the damage by 33 percent.

On a typical flight profile of a cruise at Mach 0.8 at an altitude of 41,000 ft, and cruise time of 104 min, the optimized system showed that a reduction in cruise speed from Mach 0.8 to 0.79 can achieve an estimated 25- to 35-percent creep/rupture damage reduction in the engine's hot section and a fuel savings of 2.1 percent. The tradeoff is an increase in flight time of 1.3 percent (1.4 min).

Bibliography

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