Electro-Thermally Active Seal for Fast Response Tip Clearance Control

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Purpose

To explore feasibility of thermally controllable variable geometry truss actuation as a means of turbine blade tip clearance control with a response time one order of magnitude faster than the current shroud contraction approach. To validate the approach at the system level and at the key components level.

Background

Actively maintaining a tighter blade tip clearance in aircraft turbine engine reduces hot gas leak and offers promise of significant benefits in engine performance and operation economy such as fuel burn, pollution, life cycle and service life. On a large transport engine, a tip clearance modulation of approximately 0.02 to 0.05 inch would prevent unnecessary gas path leakage during cruise and significantly improve overall engine efficiency. Research has showed that a reduction of 0.01-inch in turbine blade tip clearance achieves about 1 percent improvement in specific fuel consumption (SFC) and approximately a 10ºC reduction in exhaust gas temperature (EGT).

Modern large transport engines primarily employ an Active Case Cooling (ACC) system for real-time modulation of turbine clearances. The thermal expansion and contraction of the case takes something on the order of a minute to reach full modulation of clearances because of its enormous thermal mass. Due to the slow response, the steady-state clearances is mostly set to "more open" with respect to the possibility of snap throttle transients. The result is that the engine is not operating as efficiently as possible during long, steady-state flight segments, which dominates the overall commercial transport flight profile. In addition, the current engine case cooling system makes it difficult for asymmetric clearance control, and heating/cooling air management is cumbersome.

The hostile environment surrounding the turbine blades makes a very few approaches viable and practical for active tip clearance control. Many research efforts have looked at active clearance modulation using axial, radial hydraulic and pneumatics as primary movers, and more recently employment of solid state induced strain actuation as the actuation muscles, such as shape memory alloy (SMA) actuation and piezoelectric (PZT) actuation. Most of them have been proven impractical in terms of temperature compatibility, response time, integration into shroud head room and complexity of the mechanism. Recent researchers by NASA have conceptually demonstrated SMA is by far the most promising actuation muscles for the blade tip clearance modulation, especially

with rapid development of high temperature shape memory alloy (HTSMA) and the prospect of its availability in near future. Yet, a modulation device making full use of SMA as compact muscle power and fast response through thermal activation without moving parts, light in weight and integral to engine shroud environment, remains to be developed.

This research intends to explore a variable geometry structural actuation methodology that offers fast response in both directions and reliant on solid-state actuation technology for tip clearance control (free of kinematic and complex moving parts). The work will move SMA actuation to the next level, i.e., demonstration of feasibility and viability for high efficiency propulsion system.