

ADVANCED THERMAL HPT CLEARANCE CONTROL

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**Advanced Thermal HPT Clearance
Control**

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Background and Introduction

NASA PROPULSION 21 DESIGN CRITERIA

•OBJECTIVE:

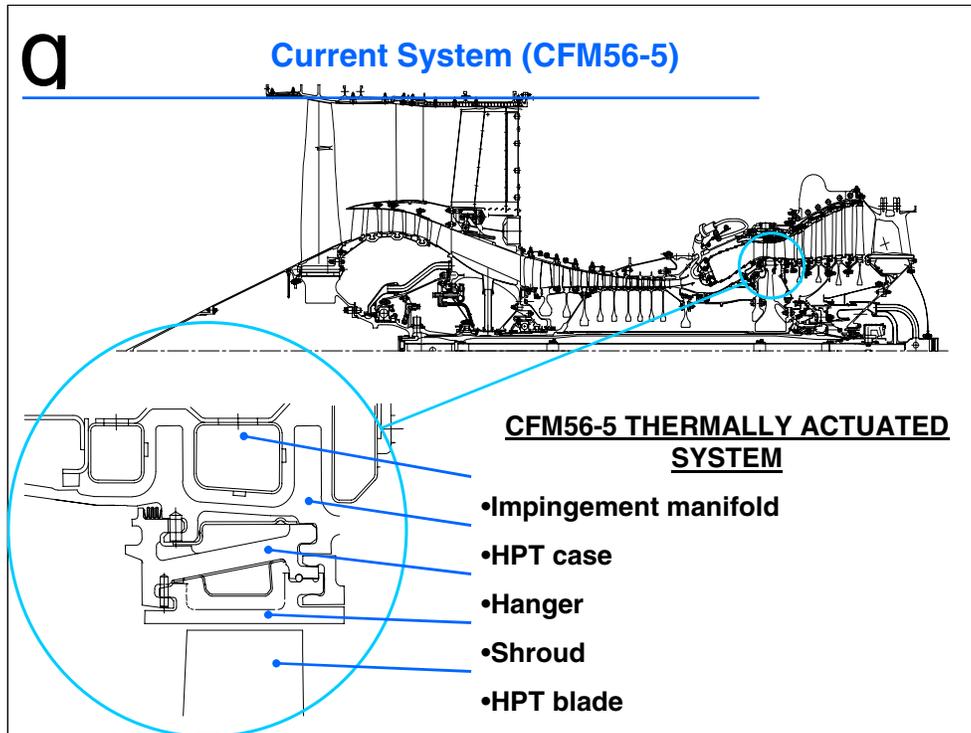
Develop a fast acting HPT Active Clearance Control System to improve engine efficiency and reduce emissions

•CHALLENGE:

Reduction of HPT blade clearance throughout engine operation

System complexity, reliability and cost must remain comparable or surpass today's engines

Reduced clearance may increase possibility of rubs



One of the currently used systems is presented on this slide. This is a CFM56-5 system targeted for improvement. The components of this system are the shroud, which is the closest part to the blade. Next is the hanger interconnecting the shroud and the HPT case. And finally, parts of the Active Clearance System are the HPT case and the impingement manifold. The impingement manifold distributes mid-compressor or compressor discharge air to the case which either expands or contracts depending on the temperature of the fluid. Mid-compressor discharge cools, while compressor discharge heats the case.

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Design Requirements

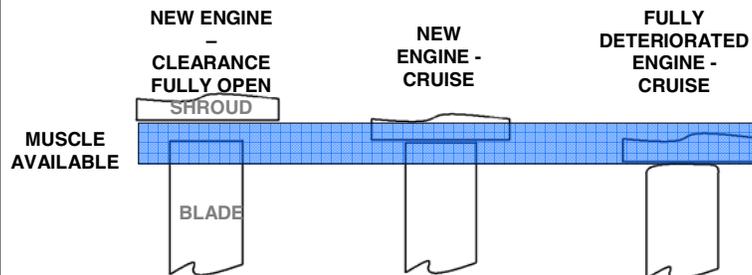
SYSTEM RANGE

•HPT CASE “MUSCLE”

$\delta_T = L\alpha T$ – deflection depends on temperature

•DETERIORATED ENGINE SYSTEM PERFORMANCE

Maintain new engine HPT clearance throughout engine life



The “Holy Grail” of clearances is a reliable system allowing for generous and nearly instantaneous control of HPT shroud diameter. Such a system would respond to blade tip position throughout an entire engine mission, as well as its entire life. The “muscle” of an HPT clearance control system is the difference between the smallest and largest shroud radius it can produce. A new engine may not need as much closure capability as a deteriorated one, but a good clearance control system should be able to compensate for the wear.

A thermally controlled system is contained within boundaries of the temperatures available for thermal control. In the case of the CFM56 this means the temperatures of the air at which compressor bleed is extracted.

δ_T – deflection of member

L - length of member

α – coefficient of thermal expansion

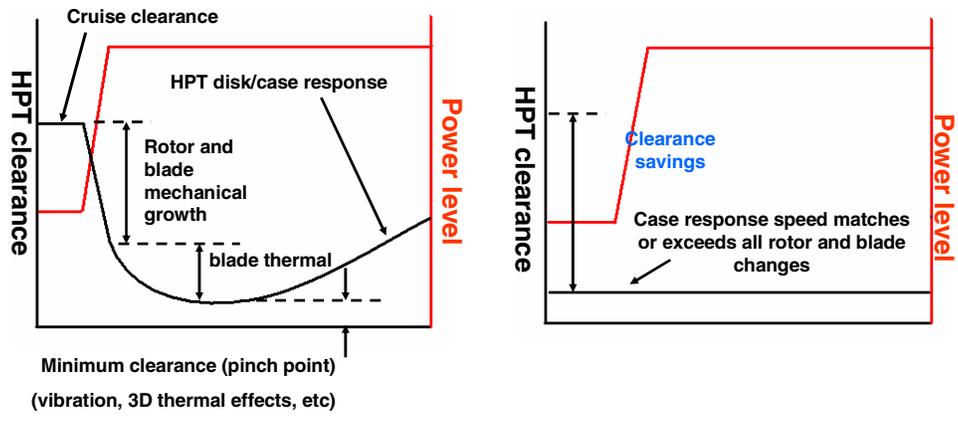
T – temperature difference

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Design Requirements

SPEED OF ACTUATION

- Deflection match throughout engine mission



For a system to be considered truly fast-acting the response of the shroud (or the case which carries it) needs to match or exceed that of the HPT blade tip. If this is achieved no extra clearance needs to be provided for the protection against rubs which would occur during engine acceleration.

This slide shows what happens to HPT clearance during a change in engine power level. An immediate effect is mechanical growth caused by increased rotational velocity. The second relatively fast effect is the thermal expansion of the blade due to increased flame temperature. Finally, change in pressures also causes instantaneous deflections on all parts – this is however, the smallest element of the change in clearance. All three of these cause closure of the HPT clearance. The much slower thermal growth of the rotor can easily be surpassed by the growth of the case, which is why clearances increase after the pinch point.

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Benefits of Improvement in ACC System

- **Increase in HPT efficiency**

0.01" HPT clearance = 1% HPT efficiency

1% HPT efficiency = 0.9% fuel burn

Emissions reduction for 1% of HPT efficiency:

10% NO_x

16% CO

- **Higher efficiency also means:**

Cooler temperatures – longer life

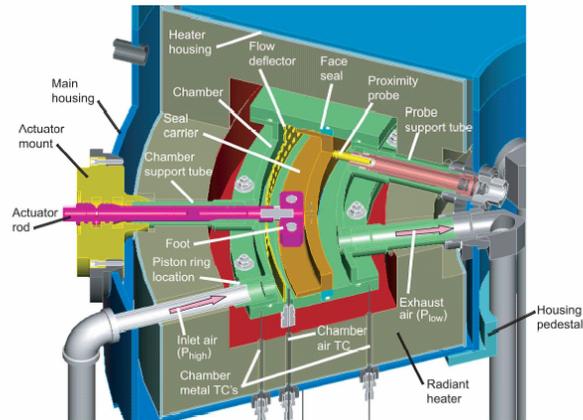
What is the benefit of reducing HPT clearance? Long-range engines can increase their HPT efficiency by as much as 1%. This translates into fuel savings as well as reduction in emissions and longer time on wing. Smaller engines on aircraft running shorter routes will see less increase in efficiency due to smaller core diameters (closer clearances) and shorter cruise periods.

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Propulsion 21 Solutions

•NASA GRC'S MECHANICALLY ACTUATED SYSTEM

•GE AE'S THERMALLY ACTUATED FAST ACTING SYSTEM



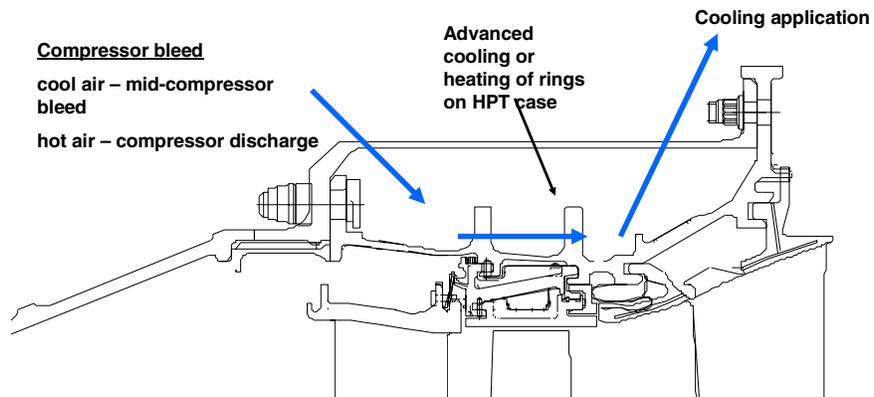
Under Prop 21 funding NASA GRC has been working on a rig which uses mechanical actuation of individual shroud segments. This system has the possibility of setting shroud radius locally based on the input from a clearance probe. Dr Bruce Steinetz will discuss the progress on this effort.

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Propulsion 21 Solutions

•NASA GRC'S MECHANICALLY ACTUATED SYSTEM

•GE AE'S THERMALLY ACTUATED FAST ACTING SYSTEM



GE Aircraft Engines is working, under Prop 21, on a thermally actuated system which promises to provide fast response. This system uses hot and cool air as heat sinks for a convection cooled or heated case. In order quickly change the temperature of the case, and thereby its diameter, a significant temperature difference as well as mass of air are needed. This flow is “borrowed” from rotor cooling for Active Clearance Control purposes.

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Propulsion 21 Solutions

- NASA GRC'S MECHANICALLY ACTUATED SYSTEM

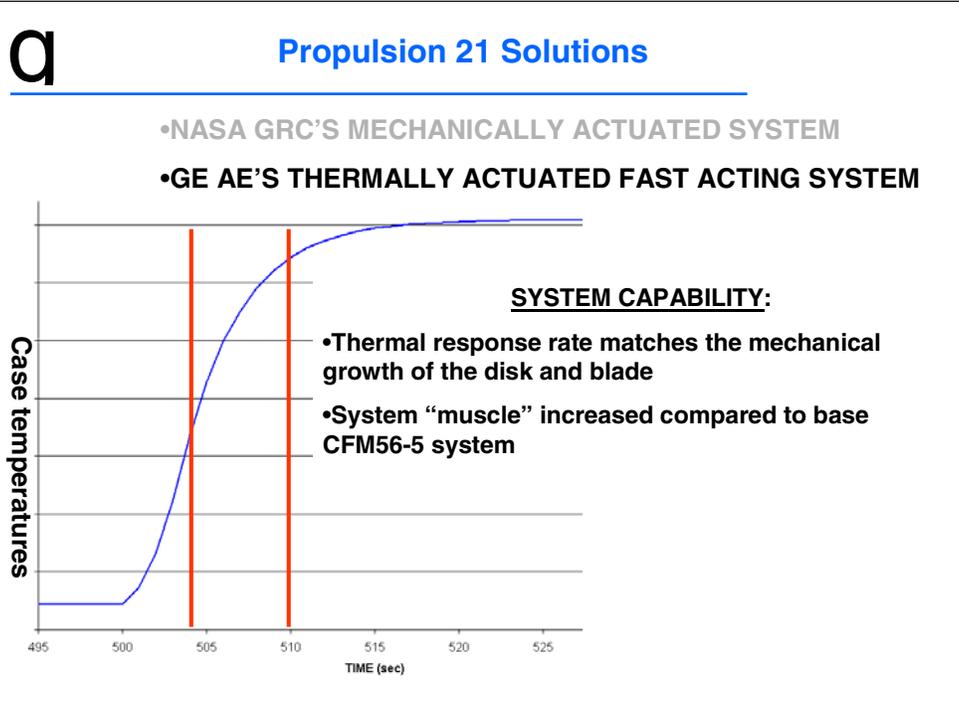
- GE AE'S THERMALLY ACTUATED FAST ACTING SYSTEM

 - Advanced thermal design increases heat convection beyond current system's capability

 - Air used in ACC reused in rotor cooling

 - HPT case time constants allow for elimination of rub protection (analysis)

Increased flow through the HPT case, as well as improved heat transfer method allows for faster case response. The flow through the ACC system would be labeled as “non-chargeable”, meaning it would return to core flowpath.



This is a result of analysis of a flight maneuver where speed was increased from cruise to climb. This type of change typically is executed to bring aircraft to a higher altitude. The reason for this change may be to make the flight more efficient as the aircraft burns off fuel, or to increase passenger comfort during excessive air turbulence.

It is assumed that this acceleration is linear over 4 sec. This is the time allowed for the system to react and respond to the clearance change associated with the acceleration. The system allows for rub protection to be excluded from cruise clearance setting. Also, the amount of “muscle” provides for clearance changes associated with normal deterioration of an engine.

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Summary of Fast Thermally Controlled ACC

- ADVANTAGE:**

 - HPT ACC system fast enough to reduce cruise clearance

- CHALLENGES:**

 - Minimize cost, weight and complexity of proposed system

- WORK AHEAD:**

 - Rig test system

 - Develop best FADEC schedule for system

 - Clearance Probe development – May provide best benefit with this Prop21 program

 - Control logic

 - Engine test