# Low-Pressure Turbine Cooling Systems

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Modern low-pressure turbine engines are equipped with casings impingement cooling systems. Those systems (called Active Clearance Control) are composed of an array of air nozzles, which are directed to strike turbine casing to absorb generated heat. As a result, the casing starts to shrink, reducing the radial gap between the sealing and rotating tip of the blade. Cooling air is delivered to the nozzles through distribution channels and collector boxes, which are connected to the main air supply duct. The application of low-pressure turbine cooling systems increases its efficiency and reduces engine fuel consumption.

cooling systems turbine casings Active Clearance Control

Gas path sealing is a challenging problem of aircraft gas turbine engine design. It is caused because the clearance between the blade tip (rotating structure) and casing with sealing (static structure) tends to vary during engine operation due to various mechanical and thermal loads. What is more, inertial (maneuver) and aerodynamic (pressure) loads during flight have to be taken into consideration. More factors, which also have a negative influence on tip clearance control, are manufacturing and assembly limitations such as case ovalization effects, tolerance stack-ups, shaft deflections, etc. Additionally, the clearances between blade tip and sealing vary along the lifespan of the whole engine as well as the part itself, as the wear and thermal erosion on all of the parts occur.

Despite the large number of limitations that have to be considered, low-pressure turbines are commonly equipped with impingement cooling systems, called Active Clearance Control (ACC), which help to control gas path sealing and therefore reduce gas path leakages. The main role of the impingement cooling system (to provide efficient gap control) is gap reduction between the tip of the blades and sealing during engine operation in the cruise phase. The benefits of active clearance control are, among others, increased engine efficiency, reduced specific fuel consumption (SFC), and reduced NOx and CO emissions.

An impingement cooling system comprises an array of nozzles, which direct jets of high-velocity fluid at a target surface, thus securing proper operating conditions of attached hardware (e.g., the blade tip and sealing surface) through convective heat transfer between fluid and target surfaces.

Lowering air leakage in the area of blade tips boosts turbine efficiency, making it possible for the engine to fulfill thrust and performance targets utilizing less fuel and with the lower temperature at the rotor inlet. The lifecycle of the hot section components may be increased by operating the turbine at lower temperatures, which consequently will increase the engine’s service life as a result of the greater interval between overhauls. Lattime and Steinetz [1] give overviews of multiple advantages of advanced active clearance control systems. Taking fuel savings into consideration, a reduction of tip clearance by 0.010 in. decreases specific fuel consumption by ~0.8% to 1%. A significant cut down in NOx, CO, and CO2 emissions are also achievable by reduction of fuel consumption. Exhaust gas temperature (EGT) may be lowered by ~10 °C through the reduction of tip clearances by 0.010 in. The main reason for the removal of an aircraft engine from service is the deterioration of the EGT margin. Up to 1000 extra cycles of engine on-wing time may be achieved by operating it at lower temperatures, thus increasing the life of hot sections parts. Other advantages are an increase in payload and mission range.

A certain amount of technical issues has to be focused on to field an efficient active clearance control system. Two main challenges encompass the high-temperature environment and the necessity for precise control.

## References

1. Lattime, S.B.; Steinetz, B.M. Turbine Engine Clearance Control System: Current Practices and Future Directions. NASA/TM-2002-211794. 2002. Available online: http://ntrs.nasa.gov/archive/nasa/c-asi.ntrs.nasa.gov/20030003697.pdf (accessed on 19 July 2021).