TECHNOLOGY

Relative Cooling with Liquid for Gas Turbine Rotors and Blades

OVERVIEW

Due to the power and fuel conservation needs of society, more powerful and efficient gas turbine engines are required. For this reason, the design of turbines has been continuously perfected. Nevertheless, during the last twenty years engine designers have become frustrated by diminishing results.

A key requirement for increasing the power and thermal efficiency of gas turbine engines is to raise the gas temperature at turbine inlet. Until now, the ability to increase the inlet temperature was limited by the lack of efficient cooling systems for turbine blades. State of the art cooling systems use air, which has a low heat transfer capacity and therefore is a poor choice for coolant. As a consequence, these systems limit the temperature and pressure at turbine inlet (optimum pressure being correlated with peak temperature) to about 1750 K and 26 bars, respectively. This means the ideal thermal efficiency of current engines is limited to about 60%. In addition, such systems need to remove a large amount of air from the main flow (i.e., 10% to 15%). This air bypasses the combustor, thereby reducing gross engine power by 10%-15% (net power is reduced far more) and the overall efficiency is further degraded.

Most of the heat extracted from turbines by cooling is wasted, because such systems allow only one method of heat recovery, i.e., the expansion of cooling air within turbine. Furthermore, the pressure limitation means current gas turbines are far bulkier and heavier than necessary. Liquids have a far greater heat transfer capacity than air. Cooling systems with liquid allow IC and Diesel engines to operate at temperatures and pressures of more than 2200 K and 40 bars, respectively. The only reason gas turbine engines cannot achieve similar values is the reliance on cooling systems with air.

Cooling systems with liquid for gas turbines have also been tested. Basically, three designs were investigated. The first used a closed-loop coolant circuit straddling both the engine rotor and stator, because the heat exchanger and coolant pump were placed on the stator. Forced re-circulation and efficient cooling were effortlessly achieved, nevertheless the design failed because reliable seals for stator/rotor interfaces proved impossible to manufacture and the losses of coolant were unacceptably high. To circumvent the sealing problem, the second design eliminated the pump in order to encapsulate the entire system within the rotor. For re-circulation, the system relied on the thermosyphon effect. Primarily, this design failed because density gradients provide a negligible amount of power, therefore re-circulation cannot be established. The third approach was to spray coolant on the surface of turbine blades and discs. The amount of liquid consumed in such an open-loop design is prohibitive, except for close-cycle plants.

Researchers at University of Maryland and SC Turbomecanica have proposed a design that solves all problems causing the failure of previous systems of cooling with liquid. The relative system of cooling with liquid for gas turbines is expected to be highly reliable and highly effective at the same time. This design eliminates stator/rotor seals and at the same time assures virtually unlimited power for re-circulation. Unlike the thermosyphon design, the relative cooling system includes a re-circulation pump. The system can raise the temperature and pressure at turbine inlet to match the maximum values attained in Diesel and IC engines, thereby boosting the ideal thermal efficiency of gas turbine engines by 8%-11% compared to most advanced air-cooling techniques. In addition, the system recuperates virtually all heat extracted from turbine for cooling, does not remove any air from the flow entering the combustor and drastically reduces the size (including frontal area) and weight of gas turbines.

The expected high reliability of the new technology will permit a large applicability in aerospace propulsion and power turbines.

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Additional Information

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PATENT STATUS

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CATEGORIES

- Industrial Processing

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- US Patent 6,672,075

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