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AEROTHERMAL INVESTIGATION OF GAS TURBINE COMPONENTS

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Fuel efficiency of a gas turbine used for aircraft propulsion depends on the performance of many key engine components. One of the most important is both the HP and the LP turbine whose efficiency has a large influence on the engine fuel consumption and hence its carbon dioxide emissions. The turbine airfoils and all of the gas swept parts are subject to the engine's most aggressive heat loads. The last evidence is exacerbated by the increase of gas path temperatures as requirement for even more efficient gas turbine engine and, nowadays, the design of turbine cooling systems consists in one of the most challenging processes in engine development. The cooling flows are bled from combustor or during compression stages and reduce the engine efficiency as they can represent around 20% of the total main gas path flow. These performance penalties manifest themselves in two ways, i.e. having a direct impact on thermodynamic cycle performance, resulting from imperfect work extraction in the turbines, and in the spoiling effect of the efflux at the point where it re-enters the turbine main annulus flow, causing a reduction in stage efficiency. These penalty sources may become quite relevant especially considering stator-rotor cavities. As a matter of fact up to 1/3 of the cooling air bled from the compressor (7% of the main annulus flow) is injected within the stator wells for sealing purposes.

It is desirable therefore to minimize these cooling flows, to levels consistent with maintaining the optimum components life and the mechanical integrity of the engine.

The Department of Industrial Engineering of Florence DIEF (formerly known as DE) has been for many years active in the gas turbine cooling area, devoting significant research efforts on both experimental and numerical analyses and in the development of procedures for the gas turbine components design. DIEF has been involved in several European Community research programs. These programs cover different aspects of the entire secondary air system design, ranging from combustor cooling to the characterization of turbine stator-rotor cavities.

Present contribution describes the main findings obtained by DIEF in the framework of two EU programs.

The first one is the MAGPI (Main Annulus Gas Path Interaction) project that deals with gas turbine stator-rotor cavities. The project was focused on the optimization of the interactions between primary and secondary air systems and, at the time of the project, this was a novel approach as these systems have hitherto only been considered separately. In particular the focus of DIEF activities was on numerical analysis of turbine stator well heat transfer. A coupled CFD/FEM procedure has been established for convective heat transfer in the complex flow fields of turbine stator wells, and this methodology has been adequately validated for a representative geometry and a range of flow cases. The validated CFD was used to draw out optimized cavity cooling schemes that proved their reliability leading to patent application.

The second contribution comes from the EU project ERICKA (Engine Representative Internal Cooling Knowledge and Application). When LP blades cooling is concerned, complex buoyancy and forced convection interactions makes cooling flow prediction and system design highly challenging. Focusing on LP blades, the main goals of ERICKA project is to enable the aero-engine companies to develop and validate their design methods, using results gathered from a combination of rotating and stationary experiments, and to provide data to optimize cooling designs.

DIEF has been involved from both experimental and numerical point of view in the framework of leading edge impingement engine geometries. An innovative test-rig has been designed and operated delivering useful data for numerical tools validation. The study produced very encouraging results identifying optimized geometries which are nowadays under consideration by industrial partners.