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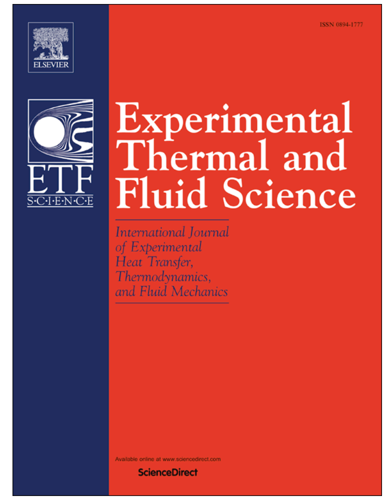

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Aerodynamic impact of finned heat exchangers on transonic flows

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ABSTRACT

Ongoing engine developments require advanced thermal management technologies to handle the increasing demand of refrigeration and lubrication. As the thermal capacity of the oil lubricant and coolant circuits becomes saturated, conventional fuel-based oil cooling systems need to be supplemented with additional cooling sources. Finned heat exchangers integrated in the core/bypass-flow splitter surface of a turbofan provide enhanced oil heat removal capabilities. For a positive impact in the overall engine efficiency, the surface heat exchangers need to be designed to maximize heat transfer while minimizing the impact in the propulsive efficiency. This work focuses on the sensitivity of the complex transonic and three-dimensional turbofan bypass-flow to arrays of fins embedded on the splitter, which determines the aerodynamic penalty that can be incurred at the benefit of increased oil heat capacity. We present an experimental study of a turbofan bypass-flow and asses the flow modifications introduced by two different fin heat exchanger designs, with “continuous” and “interrupted” fins, both aligned with the mean flow direction. Experiments were performed in a ground test facility that reproduces the flow in the bypass duct of turbofan at the design point characterized by cruise velocities and take-off atmospheric conditions. Different measurement techniques were adapted to the flow and wind tunnel requirements to provide an accurate characterization of the flow developing over the splitter surface. Results are reported in terms of flow velocity and orientation, turbulence intensity and temperature with and without the arrays if fins present in the flow. This work demonstrates the importance of aerodynamically optimized designs to minimize detrimental effects on propulsive efficiencies, and provides estimate values of flow disturbances in realistic engine conditions that can be incorporated into simplified engine performance models.

KEYWORDS: Transonic flow fins interaction; Air surface cooler; Aero-engine bypass flow; Fin heat exchangers; Multi-hole probes.

1. INTRODUCTION

High bypass ratio turbofan engines are the preferred solution for future, medium- to long- range civil aircrafts. Reducing aero-engine specific fuel consumption (SFC) requires upgrades of thermal and propulsive efficiencies, along with advanced thermal management solutions and system developments. Efforts to increase thermal efficiencies are directed to reduce the cooling air bled from the compressor and to advanced materials. Minor improvements can be obtained by further increasing pressure ratios and burner exit temperatures, or subcomponent efficiencies, without modifying the thermodynamic cycle [1, 2]. Recuperators or/and intercoolers, commonly integrated in land based gas turbines, are under development for their efficient use in aircraft applications [3–6]. The improvement of SFC through propulsive efficiency is linked to the increase of bypass ratio and simultaneous reduction of the outer fan pressure ratio. This trend rises difficulties associated with the implicit increase of engine diameter, drag, and weight. Geared turbofans are attractive for bypass ratios larger than 11, allowing to reduce the number of low pressure turbine stages, while un-ducted engine architectures with counter-rotating propellers are considered for bypass ratios larger than 16/18. Most of these efforts to rise engine efficiencies call for an enhancement of the thermal capabilities of current oil systems. The raise in mechanical complexity of higher bypass ratio architectures, as well as the increase of electronic devices