INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

SHORT ABSTRACT OF THESIS

Name of Student	: **Ashutosh Kumar Singh**
Roll Number	: 186103109
Programme of Study	: PhD

Title of Theis: Film cooling analysis of injection configurations for afterburner aero-engine applications.

Name of Supervisors (s)	: Prof. Niranjan Sahoo (IIT Guwahati) : Dr. Dushyant Singh (NIT Manipur)
Thesis Submitted to the Department/Centre	: Mechanical Engineering
Date of Completion of Thesis Viva-Voice Exam	: 08 September 2023
Keywords for the description of Thesis Work	: Film cooling, Heat Transfer, Turbulent flow, Afterburner, Injection location, Shaped hole, Slot injection, Reverse injection, and Corrugated surface.

SHORT ABSTRACT

There is a significant need for thrust augmentation in aircraft for several specific operations, such as combat or take-off from short runways. The additional thrust requirement is achieved by burning extra fuel in the afterburner, which further raises the temperature to 2200K. In order to increase thermal efficiency and power output, the turbine entry temperature of modern gas turbine engines has to be increased considerably. Furthermore, the exposed components in the pathway of the exhaust stream experience a very high temperature. Therefore, to maintain the permissible metal temperature for safe operation, the component under such high thermal loads requires a sophisticated cooling technique. “Film cooling” is one of the most adopted to protect the component which is subjected to hot flue gases.

The main objective of the present work is to design an efficient film cooling configuration for aero-engine afterburner applications, with a primary focus on corrugated surfaces. Corrugated surfaces are the most adopted surface configuration for afterburners of aero-engine liners, due to its effectiveness in terms of coolant attachment, high stiffness, and structural rigidity. The scope of the work involves the following: (a) film cooling assessment of cylindrical and laidback fan-shaped holes with reverse injection; (b) study of the effect of various injection locations film cooling performance of a corrugated surface; (c) study of the effect of double-row slot injection locations on film cooling performance of a corrugated surface; (d) study of the effect of reverse injection on film cooling and thermal stress of a corrugated surface. The methodological approach involves experimental study as well as numerical. Experiments were mainly performed for corrugated surfaces with different injection locations and cooling hole configurations to validate the computational methodology.

To develop an effective injection configuration, as an initial step the numerical studies on a flat plate are conducted using forward and reverse configurations. In the case of reverse/backward injection, the secondary flow is injected in such a way that its axial velocity component is in the direction opposite to the mainstream flow. The formation of a counter-rotating vortex pair (CRVP) is one of the major issues in film cooling. This study revealed that the CRVP found in the case of the forward cylindrical hole which promotes coolant jet "lift-off" is completely mitigated in the case of the reverse-shaped hole. The coolant coverage for reverse cylindrical and reverse-shaped holes is uniform and higher. After developing the numerical model for flat plates using reverse configurations, the focus has been given to the corrugated surface. The numerical studies have been to identify the suitable injection locations and amplitude to wavelength ratio for film cooling performance on corrugation. First of all, the effort has been done by using single injection locations, on a corrugated liner to identify suitable injection locations. The present study reveals that the film cooling on the corrugated surface is strongly influenced by the secondary stream injection locations and corrugation amplitude to wave-length ratio. This study also shows that the film cooling behaviour on a corrugated surface is inherently different from that of a flat surface; the effectiveness plots show improvements even at a higher blowing ratio. Thereafter, focus has been given to double-row secondary injection locations on a corrugated surface. Various double-row injection location combinations have been used. After identifying the suitable injection location, experimental and numerical studies have been conducted using forward and reverse injection configurations on a corrugated surface. This study includes three rows of cylindrical holes per wavelength at 45°, and the outcome of the parametric study demonstrates that reverse holes are more effective as compared to the forward hole. Apart from that coolant coverage is also uniform for reverse injection, as compared to forward injection. Moreover, thermal stress is also reduced in the case of reverse injection.