EFFECT OF TWO STAGGERED ROWS OF HOLES WITH ANTI-VORTEX HOLES ATTACHED TO THE UPSTREAM ROW ON FILM COOLING EFFECTIVENESS

By

Eng. Ahmed Fouad Abdel-Shafy Omar Sallam

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science

In

MECHANICAL POWER ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

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Key Words: Film Cooling; Staggered Rows; Anti-Vortex

Title of Thesis: "Effect of Two Staggered Rows of Holes with Anti-Vortex Holes Attached To the Upstream Row on Film Cooling Effectiveness"

Summary:

The present work focuses on the numerical investigation of Computational analysis of film cooling effectiveness from two rows of holes inclined with 30°, 60° and 90° on a flat surface with staggered arrangements. Three blowing ratios 0.45, 1 and 2, lateral and forward diffusion angles changing on the hole cooling from 0 to 15 degrees by step 5 degree are investigated. The upstream row is supplemented with anti-vortex holes. The addition of anti-vortex holes is presented as a new technique depends on adding two cylindrical holes branching out from the main holes. The results ensure that the staggered arrangement gives higher film cooling effectiveness than a single row for all studied velocity ratios. The use of anti-vortex holes increases the film cooling effectiveness.

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Dedication

To

MY BELOVED MOTHER, FATHER,

MY BROTHERS AND MY FIANCEE

For their Patience and Encouragement
That made this work possible

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List of symbols

C_{pc}	Specific heat of cold air
C_{ph}	Specific heat of hot air
D	Hole diameter
DR	Density Ratio
E	Total energy of a fluid particle constant
$\vec{F}$	External body forces
g	gravitational acceleration
G_b	Generation of Turbulent kinetic-Energy due to buoyancy
G_k	Turbulence kinetic energy production
h	Enthalpy
k	Turbulent kinetic energy
k_t	The turbulent thermal conductivity
k_{eff}	The effective conductivity
L	Hole length (m)
L_1	Hole metering section length
L_2	Hole diffused section length
M	Blowing ratio, $\rho_c v_c / \rho_h v_h$
p	Pressure
P	Hole spanwise spacing
Pr	Prandtl number, Pr = Cp μ /k
Pr_t	Turbulent Prandtl number
S	Source term
t	Time
T	Temperature
Tu	Turbulence level
u	Instantaneous velocity component in x direction
U	Bulk velocity
U*	Friction velocity
v	Instantaneous velocity component in y direction
W	Instantaneous velocity Component in z direction
y*	Dimensionless wall unit
Yj	Mass fraction of species j
x, y, z	Cartesian coordinate components

Greek Letters

α	Streamwise (simple) angle
β	Spanwise(compound) angle
γ	Lateral injection angle
δ	Forward injection angle
ε	Turbulence dissipation rate
η	Film-cooling effectiveness
μ	Dynamic viscosity
μ_t	Turbulent viscosity
ρ	Density