

***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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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	S	Source term
C_{ph}	Specific heat of hot air	t	Time
D	Hole diameter	T	Temperature
DR	Density Ratio	Tu	Turbulence level
E	Total energy of a fluid	u	Instantaneous velocity
	particle constant		component in x direction
$\bar{F}$	External body forces	U	Bulk velocity
g	gravitational acceleration	U*	Friction velocity
G_b	Generation of	v	Instantaneous velocity
	Turbulent kinetic-		component in y direction
	Energy due to buoyancy	W	Instantaneous velocity
G_k	Turbulence kinetic energy		Component in z direction
	production	y*	Dimensionless wall unit
h	Enthalpy	Yj	Mass fraction of species j
k	Turbulent kinetic energy	x, y, z	Cartesian coordinate
k_t	The turbulent thermal		components
	conductivity	Greek Letters	
k_{eff}	The effective conductivity	α	Streamwise (simple) angle
L	Hole length (m)	β	Spanwise(compound)
L_1	Hole metering section length		angle
L_2	Hole diffused section length	γ	Lateral injection angle
M	Blowing ratio, $\rho_c v_c / \rho_h v_h$	δ	Forward injection angle
P	Pressure	ε	Turbulence dissipation rate
P	Hole spanwise spacing	η	Film-cooling effectiveness
Pr	Prandtl number, $Pr = C_p \mu / k$	μ	Dynamic viscosity
Pr_t	Turbulent Prandtl number	μ_t	Turbulent viscosity
		ρ	Density