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MINOUFIYA UNIVERSITY
FACULTY OF ENGINEERING
SHEBIN EL-KOM, EGYPT

STUDY OF FLOW CHARACTERISTICS THROUGH ANNULAR DIFFUSERS

A Thesis

Submitted to Mechanical Power Engineering Department for the Award of M. Sc. Degree in Mechanical Power Engineering

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ABSTRACT

This thesis deals with the experimental investigation of air flow through annular diffusers. This investigation is mainly concerned with the aerodynamic characteristics of the annular diffuser. Other aim of this investigation is to study the internal performance of the annular diffuser in terms of the boundary layer growth. Therefore, velocity profiles and radial static pressure distributions are measured in the presence of struts with different cross-sections.

All the tested diffusers used in the present study have the same hub and casing radii at the inlet. Three straight walled annular diffusers were made with a constant half cone angle for the outer wall of 10 degrees, and half cone angle of 0, 5, and 10 degrees for the hub. All the measurements in the present experimental program were made in the incompressible flow regime at an average Reynolds number ranging from $1.3*10^5$ to $2.71*10^5$.

The experimental program consists of two parts. The first part considers naturally developed inlet conditions, and the second part examines the influence of inlet turbulence intensity, using wall spoiler at the inlet of the annular diffuser.

The objective of the present work is to obtain the effects of strut geometry and hub half cone angle on the performance of annular diffuser. The influence of increasing the level of inlet turbulence caused by flow spoilers of different thicknesses was also studied.

The variation of the performance and flow characteristics within the annular diffusers would be expected to result from corresponding changes in any or all of the inlet flow parameters, in addition to geometric parameters. The principal parameters are:

a- The inlet flow blockage.

b- The inlet turbulence intensity.

c- The inlet velocity distortion.

d- The diffuser cant angle.

Accordingly, the results indicate the best hub cant angle which yields a maxima of overall pressure recovery coefficient. It is also seen that, the boundary layer blockage along the diffuser decreases with increasing the hub cant angle. The results of the effects of increased inlet turbulence intensity using spoilers with different thicknesses show that, a marked gain in the overall pressure recovery coefficient and an improvement in the velocity profiles at exit are noticed. It is also seen that, the presence of wall spoiler near the diffuser entrance increases the rate of growth of the boundary layer parameters. The effects of strut geometries on the performance of tested annular diffusers are not deeply examined. However, some obtained results in this work show that, the overall performance of the annular diffusers is strongly dependent on the strut geometry.

CONTENTS

NOMENCLATURE

English Symbols:

A	Area, (m^2)
b	Width of the spoiler, (m)
D	Hydraulic diameter, (m)
L	Annular diffuser axial length, (m)
L_e	Length of approach pipe upstream of annular diffuser, (m)
L_s	Distance of spoiler from diffuser inlet, (m)
P	Static pressure, (Pa)
P_o	Total pressure, (Pa)
R	Diffuser radius, (m)
t	Spoiler thickness, (m)
u	local axial velocity, (m/s)
U_i	Mean velocity in the inlet cross section, = U / 1.2, (m/s)
U	Maximum velocity in the cross section, (m/s)
x	Axial distance measured from diffuser inlet, (m)
y	Radial distance normal to wall, (m)

Greek Symbols:

α	Annular diffuser divergence angle, = (Φ_c - Φ_h), (degrees)
δ	Boundary layer thickness, (m)
δ^*	Boundary layer displacement thickness, = $\int_0^{\delta}(1-u/U)dy$, (m)
θ	Boundary layer momentum thickness, = $\int_0^{\delta}(1-u/U)(u/U)dy$, (m)
$ø$	Swirl flow angle, (degrees)
γ	Stagger angle, (degrees)
Φ_c	Half cone angle of the casing, (degrees)
Φ_h	Half cone angle of the hub, (degrees)
μ	Dynamic viscosity, (N-s/m^2)
ρ_a	Air density, (Kg/m^3)
$\rho U_i^2/2$	Mean dynamic head at diffuser inlet, (N/m^2)
ΔP	Pressure difference at any distance along the diffuser, = (P_x-P_i), (Pa)
ΔP_o	pressure difference across the diffuser, = (P_2-P_i), (Pa)

ΔP_s	Radial static pressure difference, (Pa)
ΔR	Annulus height, = (R_c-R_h), (m)

Dimensionless Parameters:

A_r	Area ratio, = (A_2 / A_1)
B	Boundary layer blockage, = $(\delta^*_c+ \delta^*_h) / \Delta R_1$
C_P	Pressure recovery coefficient, = $\Delta p /0.5\ \rho U_i^2$
C_{Pi}	Ideal pressure recovery coefficient, = $1-1/(A_r)^2$
C_{Pm}	Mean pressure recovery coefficient, = $(C_{Pc} + C_{Ph})/2$
C_{Po}	Overall pressure recovery coefficient, = $\Delta p_o /0.5\ \rho U_i^2$
C_{Ps}	Radial static pressure recovery coefficient, $\Delta P_s / 0.5\rho U_i^2$
H	Boundary layer shape factor, = δ^* / θ
Kd	Total pressure loss coefficient, = $\Delta P_o /0.5\ \rho U_i^2$
M	Mach number
R_e	Reynolds number based on hydraulic diameter, = $\rho U_i D_h / \mu$
T	Dimensionless Spoiler thickness, = $t / \Delta R_1$
X	Non-dimensional axial distance measured from diffuser inlet, = $x/\Delta R_1$
Y	Non-dimensional radial distance, = $y / \Delta R$
$\bar{\delta}^*$	Dimensionless Boundary layer displacement thickness, = $\delta^* / \Delta R_1$
η	Overall efficiency, = C_p / C_{pi}

Subscripts:

1	Annular diffuser entrance
2	Annular diffuser exit
c	Casing
d	Diffuser
e	Approach pipe upstream of annular diffuser
h	Hub
i	Inlet conditions
m	Mean value
s	Spoiler
x	At any distance along the annular diffuser

LIST OF FIGURES