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SIMULATION OF AIR FLOW PAST THE PARALLEL INCLINED FLAT PLATES IN A SQUARE DUCT

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ปรากฏการณ์การไหลของอากาศผ่านแผ่นแบนเรียบที่เอียงขนานกันในท่อรูปสี่เหลี่ยมจัตุรัสถูกศึกษาผ่านวิธีแก้ไขเชิงตัวเลขโดยใช้เทคนิคการคำนวณพลศาสตร์ของไหล (CFD) โปรแกรมคอมพิวเตอร์ที่ชื่อ ฟีนิกซ์ (PHOENICS) ถูกนำมาใช้เพื่อหาคำตอบสำหรับการไหลแบบปั่นป่วนที่สถานะคงตัวในสามมิติ ภายใต้หลักการของไฟไนต์โวลุ่ม สมการควบคุมคือ สมการนาเวียร์-สโตคส์ในรูปค่าเฉลี่ยของอิทธิพลทั้งหมดที่ไม่สามารถอัดตัวได้ ความเค้นเรย์โนลด์ถูกกำหนดด้วยแบบจำลองความปั่นป่วนเค-อัพซิลอน โดยใช้สมมุติฐานความหนืดที่หมุนวนของบูสซิเนสค

เพื่อตรวจสอบความถูกต้องเชิงตัวเลขและสภาพที่ใช้ได้ของแบบจำลองความปั่นป่วน ในขั้นแรกผลของการคำนวณถูกนำไปเปรียบเทียบกับข้อมูลของความเร็วซึ่งได้มาจากการทดลอง การเปรียบเทียบระหว่างผลที่ได้มาจากการวัดและผลที่ได้มาจากการคำนวณ โดยทั่วไปเป็นที่น่าพอใจถึงแม้จะพบความไม่ตรงกันบ้างในบางแห่ง ในตอนท้ายผลกระทบของจำนวนแผ่นแบนเรียบ ความเอียงของแผ่นแบนเรียบ และการไหลในท่อด้วยค่าตัวเลขเรย์โนลด์สูง ที่มีต่อระยะทางซึ่งใช้ในการปรับตัวเข้าสู่สภาวะการไหลคงรูป ตลอดจนการลดลงของความดันรวม ถูกตรวจสอบ

การทำนายแสดงให้เห็นว่าระยะทางสำหรับการพัฒนาเข้าสู่สภาวะการไหลคงรูปจะยืดออกไป เมื่อลดจำนวนของแผ่นแบนเรียบลง อย่างไรก็ตามระยะทางนี้จะถูกทำให้สั้นลง เมื่อความเอียงของแผ่นแบนเรียบลดลง ในกรณีของตัวเลขเรย์โนลด์ที่อยู่ภายในช่วงของการศึกษานั้น ผลลัพธ์เชิงตัวเลขทำนายว่าการไหลของอากาศที่ตัวเลขเรย์โนลด์มีค่าสูงกว่า จะต้องการระยะทางสำหรับการพัฒนาเข้าสู่สภาวะการไหลคงรูปยาวกว่ากรณีของตัวเลขเรย์โนลด์ที่มีค่าต่ำกว่า นอกจากนี้ยังพบว่า แดมเปอร์ชนิดแผ่นเดียวจะทำให้เกิดการลดลงของความดันรวมสูงกว่าแดมเปอร์ชนิดหลายแผ่นอย่างมีนัยสำคัญ

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THESIS CO-ADVISOR : ASI BUNYAJITRADULYA, Ph.D.
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The phenomena of air flow past the parallel inclined flat plates in a square duct is studied through the numerical solution by using computational fluid dynamics (CFD) technique. A computer program called PHOENICS , is adopted to solve for three-dimensional steady turbulent flow under the finite volume method. The governing equations are incompressible ensemble-averaged Navier-Stokes equations. The Reynolds stresses are modeled by the k - ε turbulence model with Boussinesq's eddy viscosity assumption.

To verify the numerical accuracy and validity of the turbulence model , the results are first compared with experimental velocity data. Comparisons between measured and calculated results are in general satisfactory , although some discrepancies are found. Finally , the effects of the number of flat plates , the inclination of flat plates and high Reynolds number in the duct flow , to the distance for fully developed flow , as well as total pressure drop , are investigated.

The predictions show that the development length extends when the number of flat plates decreases , however , such length is shortened when the inclination of flat plates becomes smaller. In case of Reynolds number within the range of study , the numerical results predict that the air flow at higher Reynolds number requires the development length to be longer than the lower Reynolds number condition. Furthermore , it is found that the single blade damper causes total pressure drop to be significantly higher than the multi-blade damper.

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LIST OF SYMBOLS

ALPHABETICAL SYMBOLS

A	section area of body at right angles to motion direction
a	longitudinal spacing between two consecutive vortices in same row
B	test-section width
b	plate breadth
C_D	drag coefficient
C_L	lift coefficient
C_P	pressure coefficient
C_{Ps}	separation pressure coefficient
C_μ	empirical constant
C_1 , C_2	coefficients in approximated turbulent transport equation
D	drag force
D	duct diameter
D	diffusion conductance
D_h	hydraulic diameter
D_i	constants in tridiagonal system
E	roughness parameter
F	strength of convection

LIST OF SYMBOLS (continued)

f_x , f_y , f_z	body forces per unit mass in x , y , z directions
G	rate of production of turbulence from mean motion
I	turbulent intensity
J	integrated total fluxes over control-volume faces
J_x , J_y , J_z	convection plus diffusion fluxes in x , y , z directions
k	kinetic energy of turbulence
L	mixing length
L	lift force
L_e	development length
L_i , M_i , U_i	finite coefficients on lower- , main- , upper-diagonal
P	local static pressure
P_0	free-stream static pressure
P'	fluctuating component of pressure
P'	pressure correction
P^*	guessed pressure
$\overline{P}$	mean value of pressure
$\overline{P'}$	mean value of pressure fluctuation
R	resistance coefficient
Re	Reynolds number in duct flow (= $\rho V D_h / \mu$)

LIST OF SYMBOLS (continued)

S	source term
S_C	constant part of average value of S
S_P	coefficient of ϕ_P
T	time interval
t	time
U	mean velocity upstream of body
U_j	mean velocity at vena contracta
U_s	velocity at separation
u , v , w	velocity components in x , y , z directions
u' , v' , w'	fluctuating components of velocity in x , y , z directions
u' , v' , w'	velocity correction components in x , y , z directions
u^* , v^* , w^*	guessed velocity components in x , y , z directions
$\overline{u}$, $\overline{v}$, $\overline{w}$	mean velocity components in x , y , z directions
$\overline{u}_j$	mean velocity component in x_j direction
$\overline{u}_{j,nw}$	absolute value of resultant velocity parallel to a wall at first grid node in x_j direction
$\overline{u'}$, $\overline{v'}$, $\overline{w'}$	mean value of fluctuating velocity components in x , y , z directions
V	fluid mean velocity

LIST OF SYMBOLS (continued)

$\mathbf{V}$	vector velocity field in cartesian space
V_i , $\tilde{V}_i$	mean longitudinal velocity at same position of adjacent cross-section
V_0	undisturbed air velocity relative to plate
V_3	downstream velocity of individual vortices
$\overline{\mathbf{V}}$	vector mean velocity field in cartesian space
x , y , z	rectangular coordinates
x_j	coordinate direction
y^{+}_{nw}	normalized-coordinate near a wall

GREEK SYMBOLS

α	angle of attack
β	momentum coefficient
Γ	diffusion coefficient of ϕ
Δ	designates a difference when used as a prefix
δx , δy , δz	spaces of adjacent grid points in x , y , z directions
ε	dissipation of turbulent kinetic energy
κ	Von Karmann constant
λ	second viscosity coefficient
μ	molecular viscosity coefficient
μ_t	turbulent viscosity coefficient

LIST OF SYMBOLS (continued)

μ_{eff}	effective viscosity coefficient
ρ	fluid density
σ_k , σ_ε	effective turbulent Prandtl numbers for transport of k and ε
τ_{xx} , τ_{yy} , τ_{zz}	normal stresses on y-z , x-z , x-y planes
τ_{xy} , τ_{xz} , τ_{yz}	shear stresses on x-z , y-z , x-y planes
$\overline{\tau}_{xx}^{(t)}$	turbulent normal stress
$\overline{\tau}_{xy}^{(t)}$	turbulent shear stress
$\tau_{w,j}$	shear stress at a wall in x_j direction
ϕ	general dependent variable

SUBSCRIPTS

in	inlet value
nw	near wall value
nb	neighbor grid points or control-volume faces
P , E , W , N , S , L , H	grid points of a control volume and neighbors
e , w , n , s , l , h	control-volume faces

SUPERSCRIPTS

o	old value at beginning of time step