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Research of the influence of several constants of the quadratic turbulence model on the results of pulsated separated flow simulation

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Abstract

Offered in this article modification variant of quadratic High-Reynolds number k-ε turbulence model is intended for more accurate prediction of the local characteristics of pulsated separated turbulent flow of compressible gas in channel behind diaphragm at rather high values of Strouhal number. Correction functions C_1 and κ values are determined at Sh = 0..0.5, Re = 17000 and Re = 33000 regimes. Thus, the mathematical model of the flow is represented by the Reynolds-averaged Navier-Stokes equations, continuity equation, energy equation, equation of the ideal gas, equations of the original and modified turbulence model. The dimensions of the computational region, regime parameters and experimental data of the flow characteristics are taken from the dissertation of I.A. Davletshin. Generation of the pulsation in numerical experiments is achieved by periodic fluctuation of the outlet area in the channel during the time. Verifying calculations were carried out. Simulation results (skin-friction and pressure coefficients, reattachment length, turbulent characteristics) were compared with experimental data. Shear stress and axial velocity varying along the channel during the pulsation period was analyzed. It was established that original turbulence model permits necessary calculation accuracy only at Sh < 0.07, moreover, applying of the correction function allows to predict behavior of observed flow parameters at a higher pulsation frequency.

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Keywords: pulsated flow; separated flow; turbulent flow; numerical simulation; turbulence model; reattachment length

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Nomenclature

ρ	density
V	velocity vector
t	time
x	coordinate
μ	dynamic viscosity
ν	kinematic viscosity
$\dot{S}$	strain rate tensor
p	static pressure
δ	identity tensor
P_{turb}	turbulent stress tensor
E	total energy
λ	thermal conductivity
q_{turb}	turbulent heat flux vector
T	temperature
R	specific gas constant
k	turbulent kinetic energy
μ_t	turbulent dynamic viscosity
G_k	turbulent production
ε	turbulent dissipation rate
Ψ_M	dilation dissipation
C_T	time scale coefficient
$\dot{W}$	vorticity tensor
K	local rotation number
y	normal distance from the wall
C_1	correction function
Sh	Strouhal number
Re	Reynolds number
κ	von Karman constant
U_{CP}	average flow velocity in channel
Q_{CP}	average volume flow rate
U	axial velocity
β	relative amplitude of axial velocity pulsations
f	pulsation frequency
F	area
r	radius
C_f	skin-friction coefficient
C_P	pressure coefficient
X_R	reattachment length
τ_{wx}	wall shear stress
Δp	pressure difference
σ_U	root-mean-square axial velocity pulsations

1. Introduction

Many technical devices, functionality of which implies liquids or gases flow, have inherent pulsations of flow parameters. Oscillations are generated by turbulent fluctuations, equipment vibration, transitional and unstable regimes of aggregates operation, periodic actuation of valves and could result in hydraulic resistance change,