FORTRAN Functions for the Two Test Cases of the 2^{nd} Workshop on CFD Uncertainty Analysis

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1 Manufactured Solution

1.1 General

All the functions have been written in FORTRAN 90 with double precision (REAL*8) variables. The input arguments of all the functions are the Cartesian coordinates x and y. However, for the BSL $k-\omega$ model there is one function that includes an extra argument, which is an output parameter.

The function that computes the blending function, F_1 , of the BSL version of the $k-\omega$ model has an extra argument that contains the contribution to the cross-diffusion term,

$$\frac{1}{\omega}\nabla k \cdot \nabla \omega \ .$$

The argument of the damping functions of the one-equation models is the dependent variable of the model, $\tilde{\nu}$ or $\tilde{\nu}_t$.

1.2 Main flow variables

1.2.1 u velocity component

Name	Arguments	Output
UMS	x, y	Horizontal velocity component, u
DUDXMS	x, y	Derivative of u with respect to x, $\frac{\partial u}{\partial x}$
DUDYMS	x, y	Derivative of u with respect to y, $\frac{\partial u}{\partial y}$
DUDX2MS	x, y	Second derivative of u with respect to x, $\frac{\partial^2 u}{\partial x^2}$
DUDY2MS	x, y	Second derivative of u with respect to y, $\frac{\partial^2 u}{\partial y^2}$
DUDXYMS	x, y	Second-order cross-derivative of u, $\frac{\partial^2 u}{\partial x \partial y}$

1.2.2 v velocity component

Name	Arguments	Output
VMS	x, y	Vertical velocity component, v
DVDXMS	x, y	Derivative of v with respect to x, $\frac{\partial v}{\partial x}$
DVDYMS	x, y	Derivative of v with respect to y, $\frac{\partial v}{\partial y}$
DVDX2MS	x, y	Second derivative of v with respect to x, $\frac{\partial^2 v}{\partial x^2}$
DVDY2MS	x, y	Second derivative of v with respect to y, $\frac{\partial^2 v}{\partial y^2}$
DVDXYMS	x, y	Second-order cross-derivative of v, $\frac{\partial^2 v}{\partial x \partial y}$

1.2.3 Pressure, C_p

Name	Arguments	Output
PMS	x, y	Pressure coefficient, $C_p = \frac{p-p_{ref}}{\rho U_{ref}^2}$
DPDXMS	x, y	Derivative of C_p with respect to x, $\frac{\partial C_p}{\partial x}$
DPDYMS	x, y	Derivative of C_p with respect to y, $\frac{\partial C_p}{\partial y}$

1.2.4 Eddy-Viscosity, ν_t

- Two-equation Turbulence Models

Name	Arguments	Output
EDDYMS	x, y	Eddy-Viscosity, ν_t
DEDXMS	x, y	Derivative of ν_t with respect to x, $\frac{\partial \nu_t}{\partial x}$
DEDYMS	x, y	Derivative of ν_t with respect to y, $\frac{\partial \nu_t}{\partial y}$

- One-equation turbulence model
  - Spalart & Allmaras

Name	Arguments	Output
EDDYSAMS	x, y	Eddy-Viscosity, ν_t
DESADXMS	x, y	Derivative of ν_t with respect to x, $\frac{\partial \nu_t}{\partial x}$
DESADYMS	x, y	Derivative of ν_t with respect to y, $\frac{\partial \nu_t}{\partial y}$

  - Menter

Name	Arguments	Output
EDDYMTMS	x, y	Eddy-Viscosity, ν_t
DEMTDXMS	x, y	Derivative of ν_t with respect to x, $\frac{\partial \nu_t}{\partial x}$
DEMTDYMS	x, y	Derivative of ν_t with respect to y, $\frac{\partial \nu_t}{\partial y}$

1.2.5 Turbulence kinetic energy, k

Name	Arguments	Output
TKMS	x, y	Turbulence kinetic energy, k
DKDXMS	x, y	Derivative of k with respect to x, $\frac{\partial k}{\partial x}$
DKDYMS	x, y	Derivative of k with respect to y, $\frac{\partial k}{\partial y}$
DKDX2MS	x, y	Second derivative of k with respect to x, $\frac{\partial^2 k}{\partial x^2}$
DKDY2MS	x, y	Second derivative of k with respect to y, $\frac{\partial^2 k}{\partial y^2}$

1.2.6 Auxiliary variables

Name	Arg.	Output
VORTMS	x, y	Magnitude of Vorticity, $S_\Omega = \left\lvert \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} \right\rvert$
STRAINMS	x, y	Strain-rate, $\sqrt{S} = \sqrt{2\left(\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2\right) + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)^2}$

1.3 Source terms of the momentum equations

1.3.1 Two-equation turbulence models

Name	Arguments	Output
SMXMS	x, y	Source function of the x momentum equation, f_x
SMYMS	x, y	Source function of the y momentum equation, f_y

1.3.2 One-equation turbulence models

- Spalart & Allmaras

Name	Arguments	Output
SMXSAMS	x, y	Source function of the x momentum equation, f_x
SMYSAMS	x, y	Source function of the y momentum equation, f_y

- Menter

Name	Arguments	Output
SMXMTMS	x, y	Source function of the x momentum equation, f_x
SMYMTMS	x, y	Source function of the y momentum equation, f_y

1.4 Turbulence models

1.4.1 Spalart & Allmaras one-equation model

Name	Arguments	Output
SSAMS	x, y	Source function of the $\tilde{\nu}$ transport equation, f_{spal}
EDDYMS	x, y	Dependent variable of the turbulence model, $\tilde{\nu}$
DEDXMS	x, y	Derivative of $\tilde{\nu}$ with respect to x, $\frac{\partial \tilde{\nu}}{\partial x}$
DEDYMS	x, y	Derivative of $\tilde{\nu}$ with respect to y, $\frac{\partial \tilde{\nu}}{\partial y}$
DEDX2MS	x, y	Second derivative of $\tilde{\nu}$ with respect to x, $\frac{\partial^2 \tilde{\nu}}{\partial x^2}$
DEDY2MS	x, y	Second derivative of $\tilde{\nu}$ with respect to y, $\frac{\partial^2 \tilde{\nu}}{\partial y^2}$
FV1SAMS	$\tilde{\nu}$	Damping function of the model
DFV1SAMS	$\tilde{\nu}$	Derivative of the damping function with respect to $\tilde{\nu}$

1.4.2 Menter one-equation model

Name	Arguments	Output
SMTMS	x, y	Source function of the $\tilde{\nu}_t$ transport equation, f_{mnt}
EDDYMS	x, y	Dependent variable of the turbulence model, $\tilde{\nu}_t$
DEDXMS	x, y	Derivative of $\tilde{\nu}_t$ with respect to x, $\frac{\partial \tilde{\nu}_t}{\partial x}$
DEDYMS	x, y	Derivative of $\tilde{\nu}_t$ with respect to y, $\frac{\partial \tilde{\nu}_t}{\partial y}$
DEDX2MS	x, y	Second derivative of $\tilde{\nu}_t$ with respect to x, $\frac{\partial^2 \tilde{\nu}_t}{\partial x^2}$
DEDY2MS	x, y	Second derivative of $\tilde{\nu}_t$ with respect to y, $\frac{\partial^2 \tilde{\nu}_t}{\partial y^2}$
D2MTMS	$\tilde{\nu}_t$	Damping function of the model
DD2MTMS	$\tilde{\nu}_t$	Derivative of the damping function with respect to $\tilde{\nu}_t$

1.4.3 Standard $k-\varepsilon$ two-equation model

Name	Arguments	Output
SKSTMS	x, y	Source function of the k transport equation, f_{kst}
SESTMS	x, y	Source function of the ε transport equation, $f_{\varepsilon st}$
EPSSTMS	x, y	Second dependent variable of the turbulence model, ε
DESDXMS	x, y	First derivative of ε with respect to x, $\frac{\partial \varepsilon}{\partial x}$
DESDYMS	x, y	First derivative of ε with respect to y, $\frac{\partial \varepsilon}{\partial y}$
DESDX2MS	x, y	Second derivative of ε with respect to x, $\frac{\partial^2 \varepsilon}{\partial x^2}$
DESDY2MS	x, y	Second derivative of ε with respect to y, $\frac{\partial^2 \varepsilon}{\partial y^2}$

1.4.4 Chien's $k-\varepsilon$ two-equation model

Name	Arguments	Output
SKCHMS	x, y	Source function of the k transport equation, f_{kch}
SECHMS	x, y	Source function of the $\tilde{\varepsilon}$ transport equation, $f_{\tilde{\varepsilon} ch}$
EPSCHMS	x, y	Second dependent variable of the turbulence model, $\tilde{\varepsilon}$
DECDXMS	x, y	First derivative of $\tilde{\varepsilon}$ with respect to x, $\frac{\partial \tilde{\varepsilon}}{\partial x}$
DECDYMS	x, y	First derivative of $\tilde{\varepsilon}$ with respect to y, $\frac{\partial \tilde{\varepsilon}}{\partial y}$
DECDX2MS	x, y	Second derivative of $\tilde{\varepsilon}$ with respect to x, $\frac{\partial^2 \tilde{\varepsilon}}{\partial x^2}$
DECDY2MS	x, y	Second derivative of $\tilde{\varepsilon}$ with respect to y, $\frac{\partial^2 \tilde{\varepsilon}}{\partial y^2}$
FUCHMS	x, y	Damping function of the turbulence model, f_μ
DFUDXMS	x, y	First derivative of f_μ with respect to x, $\frac{\partial f_\mu}{\partial x}$
DFUDYMS	x, y	First derivative of f_μ with respect to y, $\frac{\partial f_\mu}{\partial y}$

1.4.5 TNT $k-\omega$ two-equation model

Name	Arguments	Output
SKWTMS	x, y	Source function of the k transport equation, $f_{k\omega t}$
SWTMS	x, y	Source function of the ω transport equation, $f_{\omega t}$
WSTMS	x, y	Second dependent variable of the turbulence model, ω
DWSDXMS	x, y	First derivative of ω with respect to x, $\frac{\partial\omega}{\partial x}$
DWSDYMS	x, y	First derivative of ω with respect to y, $\frac{\partial\omega}{\partial y}$
DWSDX2MS	x, y	Second derivative of ω with respect to x, $\frac{\partial^2\omega}{\partial x^2}$
DWSDY2MS	x, y	Second derivative of ω with respect to y, $\frac{\partial^2\omega}{\partial y^2}$

1.4.6 BSL $k-\omega$ two-equation model

Name	Arguments	Output
SKWBMS	x, y	Source function of the k transport equation, $f_{k\omega t}$
SWBMS	x, y	Source function of the ω transport equation, $f_{\omega t}$
WSTMS	x, y	Second dependent variable of the turbulence model, ω
F1KWMS	$x, y, \frac{1}{\omega}\nabla k \cdot \nabla\omega$	Blending function of the model, F_1
DWSDXMS	x, y	First derivative of ω with respect to x, $\frac{\partial\omega}{\partial x}$
DWSDYMS	x, y	First derivative of ω with respect to y, $\frac{\partial\omega}{\partial y}$
DWSDX2MS	x, y	Second derivative of ω with respect to x, $\frac{\partial^2\omega}{\partial x^2}$
DWSDY2MS	x, y	Second derivative of ω with respect to y, $\frac{\partial^2\omega}{\partial y^2}$

2 Backward Facing Step

2.1 General

For the second test case, case C-30 of the ERCOFTAC Classic Database, the inlet profiles of the two velocity components and all the turbulent quantities must be specified from the provided functions. All the functions have been written in FORTRAN 90 with double precision (REAL*8) variables.

The input arguments of all the functions is the vertical Cartesian coordinate, y, which must vary between $h \leq y \leq 9h$, where h is the height step. The inlet station must be located at $x = -4h$. The origin of the (x,y) coordinate system is the bottom corner of the step.

2.2 Main flow variables

2.2.1 u velocity component

Name	Arguments	Output
UBSINLET	y	Horizontal velocity component, u

2.2.2 v velocity component

Name	Arguments	Output
VBSINLET	y	Vertical velocity component, v

2.2.3 Eddy-Viscosity, ν_t

Name	Arguments	Output
EDDYBSINLET	y	Eddy-Viscosity, ν_t

2.3 Turbulence models

2.3.1 Spalart & Allmaras one-equation model

Name	Arguments	Output
EMSABSINLET	y	Dependent variable of the turbulence model, $\tilde{\nu}$

2.3.2 Menter one-equation model

Name	Arguments	Output
EMMTBSINLET	y	Dependent variable of the turbulence model, $\tilde{\nu}_t$

2.3.3 Two-layer $k-\varepsilon$ two-equation model

Name	Arguments	Output
TKBSINLET	y	Turbulence kinetic energy, k
EPSBSINLET	y	Second dependent variable of the turbulence model, ε

2.3.4 Chien's $k-\varepsilon$ two-equation model

Name	Arguments	Output
TKBSINLET	y	Turbulence kinetic energy, k
EPSCHBSINLET	y	Second dependent variable of the turbulence model, $\tilde{\varepsilon}$

2.3.5 TNT and BSL $k-\omega$ two-equation models

Name	Arguments	Output
TKBSINLET	y	Turbulence kinetic energy, k
OMBSINLET	y	Second dependent variable of the turbulence model, ω