II-215 The Simulation of Confluence Flow By Using K–ε and SGS Turbulence Model

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1. INTRODUCTION

The understanding of the confluence flow structure is of great fundamental and practical importance. Several numerical studies have been made by using K–ε turbulence model. A typical simulation of these is that of S.B. Weerakoon[1] (1990). In his studies,some three-dimensional and depth averaged models for confluence flow were developed by using standard K–ε model and applied to laboratory and engineering flows. Fairly good results were reported. But it seems to be that smaller recirculating region behind downstream corner was predicted. The reason for that was not mentioned.

The flow in a 90° confluence is simulated by solving time averaged Navier–stokes equation and cell averaged Navier–Stokes equation. The computational results for discharge ratio 0.6 and width ratio 2/3 of branch to main channel , Reynold's number $Re=9\times10^4$ are presented and compared with experimental results. It is obviously observed that smaller recirculating region was predicted by K–ε model, and that the fair good recirculating region and large vortex structures were simulated by SGS model.

2. MATHEMATICAL MODELS

1). The set of equations using standard k–ε model are as follows:

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial U_i}{\partial t} + U_j\frac{\partial U_i}{\partial x_j} + \frac{1}{\rho}\frac{\partial P}{\partial x_i} = \nu\frac{\partial}{\partial x_j}(\frac{\partial U_i}{\partial x_j}) + \frac{\partial}{\partial x_j}(-\overline{u_iu_j}) \tag{2}$$

$$\frac{\partial k}{\partial t} + U_j\frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}[(\nu + \frac{\nu_t}{\partial x_j})\frac{\partial k}{\partial x_j}] + P_k - \epsilon \tag{3}$$

$$\frac{\partial \epsilon}{\partial t} + U_j\frac{\partial \epsilon}{\partial x_j} = C_{\epsilon 1}\frac{\epsilon}{k}P_k - C_{\epsilon 2} + \frac{\partial}{\partial x_j}(\nu + \frac{\nu_t}{\sigma_\epsilon})\frac{\partial \epsilon}{\partial x_j} \tag{4}$$

where $P_k = -\overline{u_iu_j}\,(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i})$; $\nu_t = C_\mu k^2/\epsilon$; $-\overline{u_iu_j} = \nu_t\,(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}) - \frac{2}{3}\delta_{ij}\,k$;

C_μ, $C_{\epsilon1}$, $C_{\epsilon2}$, σ_k, and σ_ϵ are the model constants.

2). The set of equations using SGS model are as follows:

$$\frac{\partial u_i}{\partial x_i} = 0 \tag{5}$$

$$\frac{\partial u_i}{\partial t} + u_j\frac{\partial u_i}{\partial x_j} + \frac{1}{\rho}\frac{\partial p}{\partial x_i} = \nu\frac{\partial}{\partial x_j}[\frac{\partial u_i}{\partial x_j}] + \frac{1}{\rho}\frac{\partial}{\partial x_j}(-\tau_{ij}) \tag{6}$$

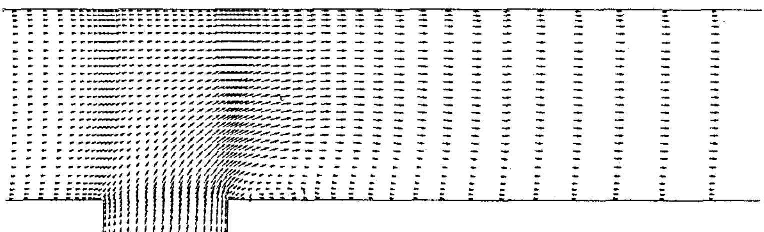
where $\tau_{i,j} = -\nu_t\,[\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}]$; $\nu_t = (C_s\Delta)^2|\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_j}|$;

Cs is the model constant and Δ is the representative grid interval.

The finite difference scheme used is that of VOF method. Wall function and no–slip boundary condition are used in k–ε model and SGS model calculations,respectively.

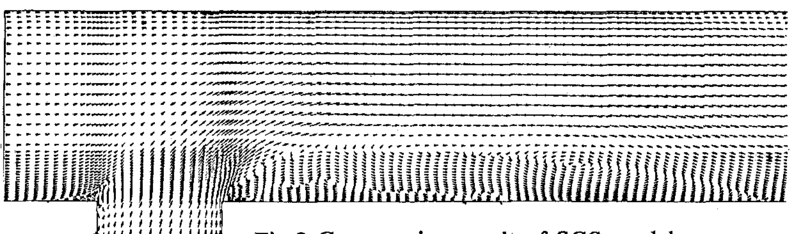
3. RESULTS AND DISCUSSIONS

The computational velocity vector distribution obtained by using k−ε and averaged velocity vector distribution by SGS model are shown in Fig.1 and Fig.2 . The experiment result of Fujita[4] (1990) is shown in Fig.3. It is easy to see that k−ε model predicted very small recirculating region and SGS model predicted fair good flow structures. The reason for the poor prediction of k−ε model may be due to the strong adverse pressure gradient distribution behind the downstream corner of confluence. According to Hanjalic[2] (1980) and Rodi's[3] (1986) studies,the standard k−ε model can not predict the adverse pressure gradient flow very well because the coefficient used in ε−equation,which have been determined by reference to zero pressure gradient boundary layers, are not compatible with the experimental observations in decelerated flows,especially for the irrotational straining term which plays the special role in the spectral transport from the large, energy−containing to the small dissipating eddies. This point is proved by author's computational results. Finally it is concluded that standard k−ε model is not appropriate for confluence flow with recirculating regions, but on the other hand, SGS model can simulate such flows fairly good. The further work that incorporated the suggestions of Hanjalic being undertook by authors and the results will be presented later on.



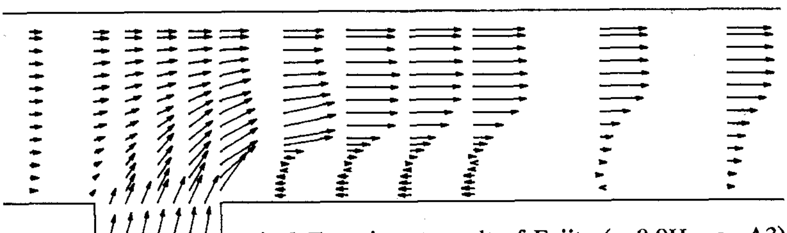
Computation Conditions:
$Re=9\times10^4$, Qr=0.6
time step : 0.005
minimum mesh: 0.02×0.02

Fig.1 Computation result of k−ε model



Computation Conditions:
$Re=9\times10^4$, Qr=0.6
time step : 0.001
minimum mesh:0.005×0.005

Fig.2 Computation result of SGS model



Experiment Conditions:
$Re=9\times10^4$, Qr=0.6
Three Dimensional

Fig.3 Experiment result of Fujita (z=0.9H,case A3)

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