IMPROVEMENT OF THE MIXING LENGTH MODEL AND NUMERICAL CALCULATION OF THE FLOW OVER A BACKWARD-FACING STEP

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INTRODUCTION

In this paper, based on the comparative study of the two models, an improved mixed turbulence model is firstly proposed by means of dimensional analysis, in which the calculation formula of eddy viscosity coefficient includes not only turbulent kinetic energy k and its dissipation rate ε, but also the velocity gradient of the mean field. Then the model is applied to the numerical simulation of the flow over a backward-facing step. And the calculated longitudinal velocity profile, turbulent kinetic energy k and dissipation rate ε distribution of separation zone are analyzed. Meanwhile, by comparing with some measured data and the calculation results under the standard k-ε model, it is fortunately found that in the range of Reynolds number (Re) from 5×10^3–1×10^5, the improved mixed turbulence model with velocity gradient can predict this type of turbulent flow more accurately.

IMPROVED MIXED TURBULENCE MODEL

☛ k Equation

$$\frac{\partial k}{\partial t}+\bar{u}_l\frac{\partial k}{\partial x_l}=\frac{\partial}{\partial x_l}\left(C_k\frac{k^2}{\varepsilon}\frac{\partial k}{\partial x_l}\right)-\varepsilon+P$$

☛ ε Equation

$$\frac{\partial \varepsilon}{\partial t}+\bar{u}_l\frac{\partial \varepsilon}{\partial x_l}=\frac{\partial}{\partial x_l}\left(C_\varepsilon\frac{k^2}{\varepsilon}\frac{\partial \varepsilon}{\partial x_l}\right)+C_{\varepsilon1}\frac{\varepsilon}{k}P-C_{\varepsilon2}\frac{\varepsilon^2}{k}$$

☛ Turbulent Eddy Viscosity Coefficient (Obtained by Dimensional Analysis)

$$\nu_t=f\left(k,\varepsilon,\frac{du}{dy}\right)=C\frac{k^3}{\varepsilon^2}\left|\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right|=C_\mu\frac{k^2}{\varepsilon}$$

CALCULATION AREA

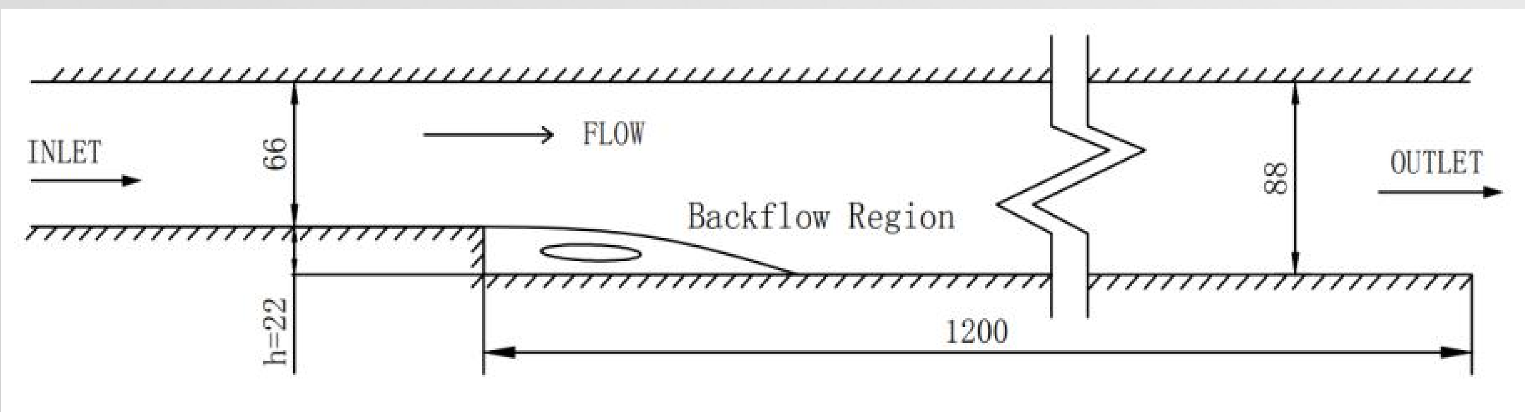

Figure 1. Schematic diagram of calculation area (unit: mm)

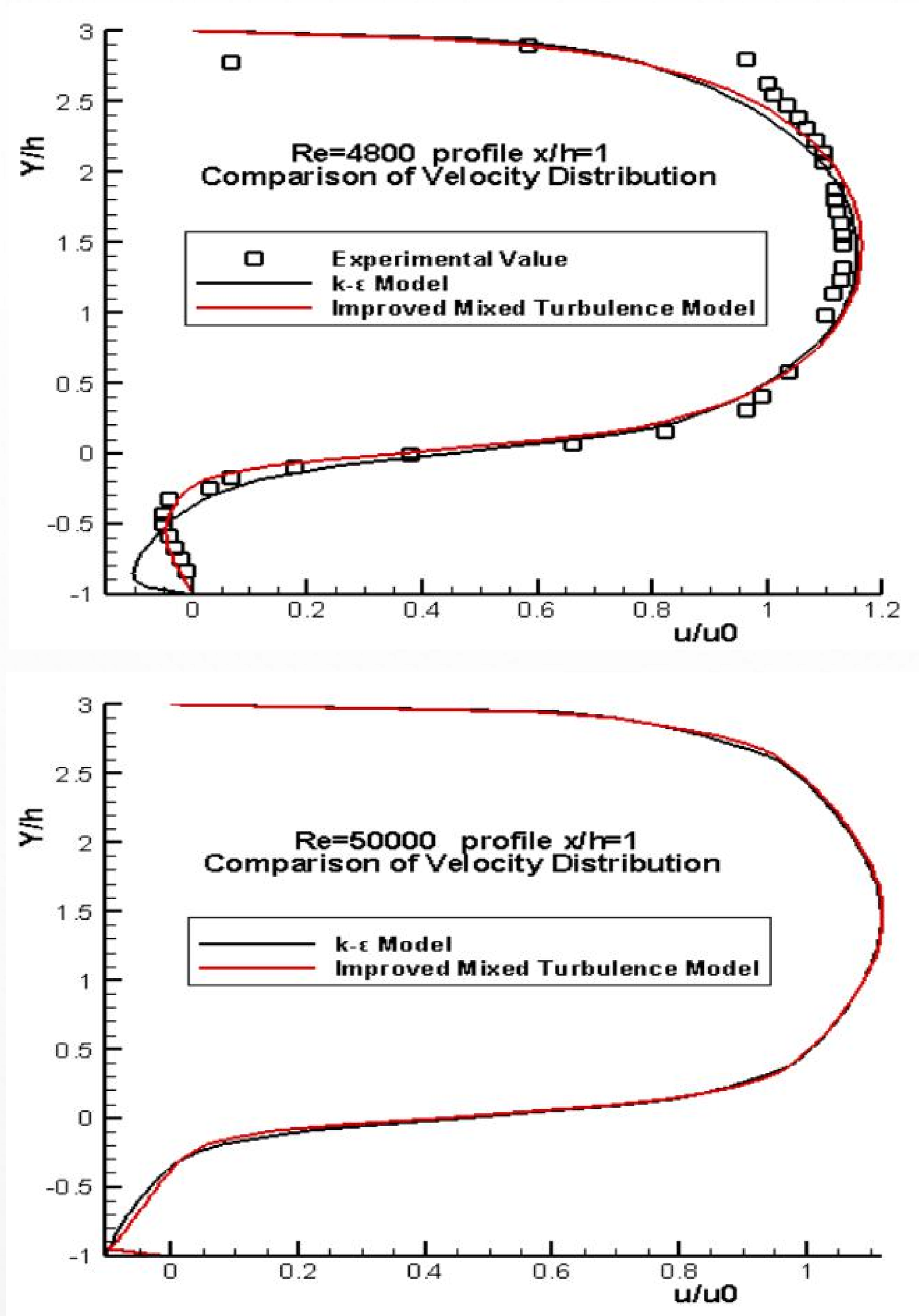

Figure 2. Longitudinal velocity distribution of x/h=1 section

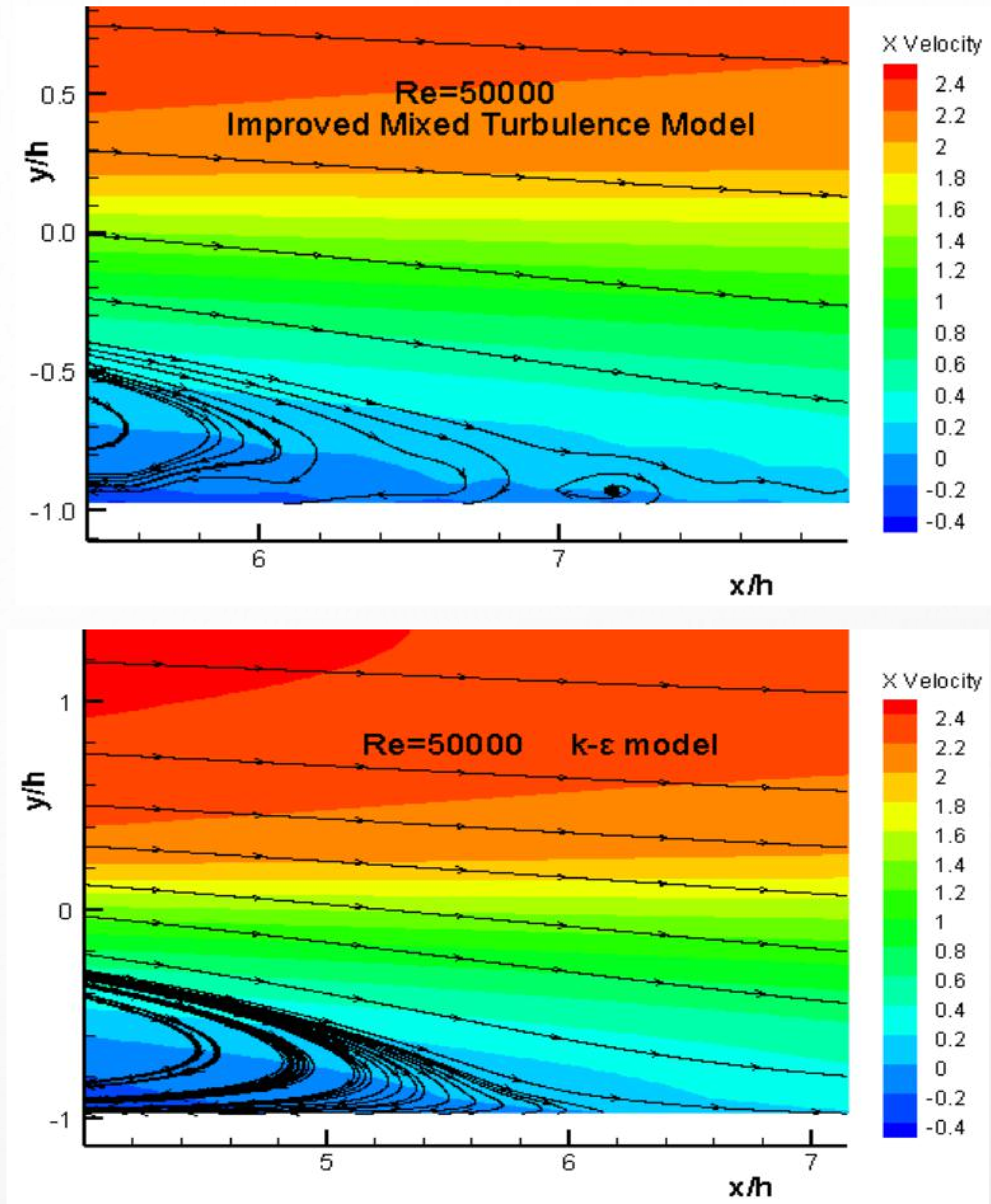

Figure 3. Local magnification of additional separated-flow regions.

ANALYSIS AND COMPARISON OF CALCULATION RESULTS

☛ The improved model can obtain the velocity profile closer to the experimental data as figure 2 shows.

☛ The improved model can successfully simulate this separated-flow region as figure 3 shows.

☛ The improved model is superior in the simulation of the turbulent kinetic energy near the boundary, and can credibly calculated the the turbulent kinetic energy dissipation rate as figure 4 shows.

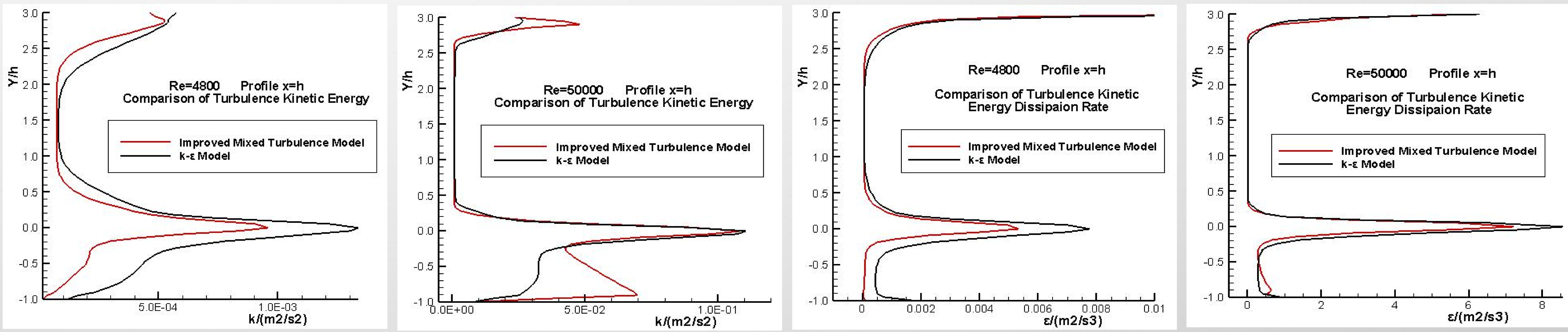

Figure 4. Distribution of turbulent kinetic energy and turbulent kinetic energy dissipation rate at the profile x/h=1.

CONCLUSION

☛ For the uncertainty of the mixed length l in complex flow, we consider expressing l as a function of the turbulent kinetic energy k and its dissipation rate ε. And an improved mixed turbulence model considering the turbulent kinetic energy k, dissipation rate ε and mean field velocity gradient is proposed.

☛ The improved mixed turbulence model can not only better simulate the distribution of turbulent energy k near the wall under the condition of large Reynolds number, but also successfully simulate the additional separation vortex downstream the main separation zone.

☛ the improved model can better simulate the distribution of kinetic energy dissipation rate ε.