ISSN:0971-1260
Vol-22-Issue-37-December -2019

Influence of Turbulence Model on Predicting the Round Jet Flow Field

GopinathShanmugaraj, J. V. MurugaLal, Vijay Kumar Singh

School of Mechanical Engineering

Lovely Professional University, Phagwara, Punjab, India

Abstract:

In this study, the effects of different turbulence models on the decay characteristics of round jets were studied. The turbulence models considered for the current study is SST, k-ε, k-ω, RNG kε. For the entire turbulence model mesh density and boundary conditions were mentioned same. By comparing the simulated results with the experiments interesting results were obtained. SST predicts the flow better than the other models in this flow regime.

Introduction:

Round jets emerging from the round nozzles were long been employed in various industrial applications. It has been acted as an important flow phenomenon in the engineering research. It has been widely used in combustion, cooling process, chemical process, mixing and drying processes. The mixing of round jets was studied extensively by many researches in the past few decades [1, 2, 3]. Some studies were exclusively on the near field development of turbulent jets [4, 5]. Round jets were extremely sensitive to the initial conditions and boundary conditions. Nozzle geometry was important parameters that influence the initial conditions of the jet [6]. These effects were reported many researchers in the past decade.

Effect of Reynolds number is also studied and reported by few researchers [6]. Some studies suggest that the length of the potential core decreases with increase in Reynolds number [7]. Numerical modeling was extensively applied to predict the flow dynamics of jets. In these numerical simulations, turbulent models play a vital role. For a wall jet configuration, RNG kε gives the flow field of 10% error with the experiments. On the same case LES predicted with less error. If the flow is compressible and involves high temperature flow then this error may grow according to the turbulence model selected. In this study, the relative accuracy of a turbulence models such as SST, k-ε, k-ω and RNG kε were explored by using a round jet with a exit velocity of 50m/s as a testing model. Simulated results were compared with the experimental data.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Geometry and model:

Round jet emerging from a circular nozzle with the exit diameter of 10mm is designed. The typical layout of the domain is shown in figure1. Sufficient amount of length and breadth were fixed for the domain. At inlet, total pressure is specified and it's calculated using the Bernoulli's equation by fixing the exit velocity of set as 50 m/s. For all the configurations the mesh density and the inlet and outlet boundary conditions were kept constant. Only thing that varies across the model is the turbulence equation. The reference pressure is fixed a 1 atm pressure.

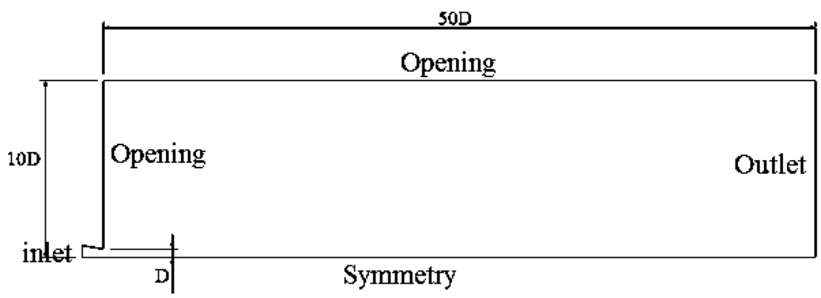

Fig 1 Domain dimensions and boundary conditions

k-ε Model:

In this model k is the turbulent kinetic energy. C_m is a function of mean velocity and turbulence. This equation is designed such that the unphysical solutions are not given. The ε is the dissipation rate. It performs poorly at pressure gradients. This model is proposed by Launder & Sharma [7,8].

k-ω Model:

It is one of the most common models. k is the turbulent kinetic energy and ω is the specific dissipation rate. k-ω has better performance in predicting the wall physics than the SST, k-ε. It is proposed by Wilcox [9].

SST k-ω model:

ISSN:0971-1260
Vol-22-Issue-37-December -2019

It is a combined model of k-ε and k-ω model. In near wall region k-ω is applied and in free shear stress flows k-ε is applied. This blending factor makes the SST kω a versatile model to go.

RNG kε:

It is called renormalization group theory k-ε model. It's derived by using different analytical technique than the standard k-ε model. so it has different constants and has additional terms in transport equations.

Results &Discussions:

A standard round jet model is used to predict the accuracy of turbulence models such as SST, k-ε, k-ω, RNG kε. The simulated centerline velocities were compared with the experimental data in figure 2. The curves with larger circular dots represent the experimental values. By observing the plot there is a huge difference in the centerline decay were observed. The length of the potential cone is also significantly different for each model. By comparing the figure RNG kε model is the least accurate model. It has the jet core length ofΔD_e =10 which is 2 times higher than the experimental values. k-ω performs poorly in the simulation. k-ε yields moderately good results and has predicted the core length almost accurately.

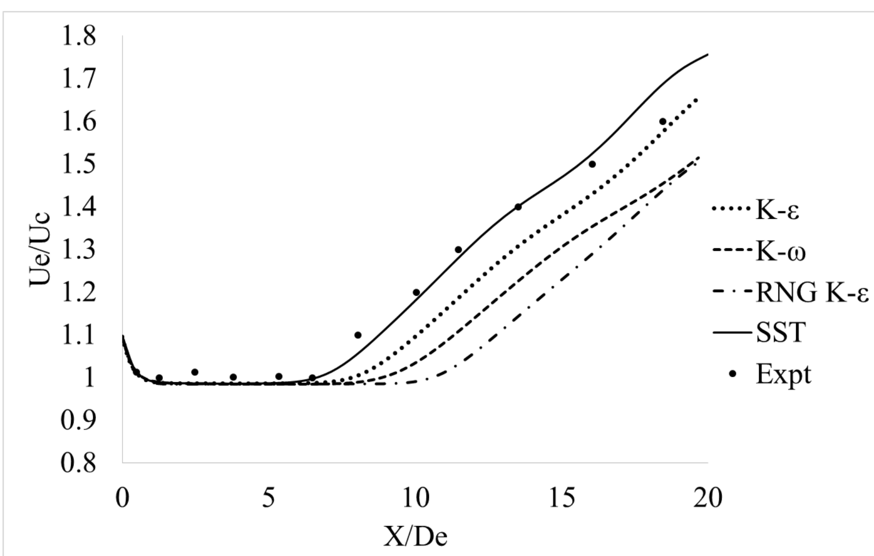

Fig 2 Centerline velocity distribution

ISSN:0971-1260
Vol-22-Issue-37-December -2019

SST model predicts the flow accurately than the other models. The length of the potential core length is also well in agreement with the experimental result. From the centerline plot it can be seen that the SST kω has good accuracy than the other models considered for the study. All the other models over predicts the values when compared with the experiments.

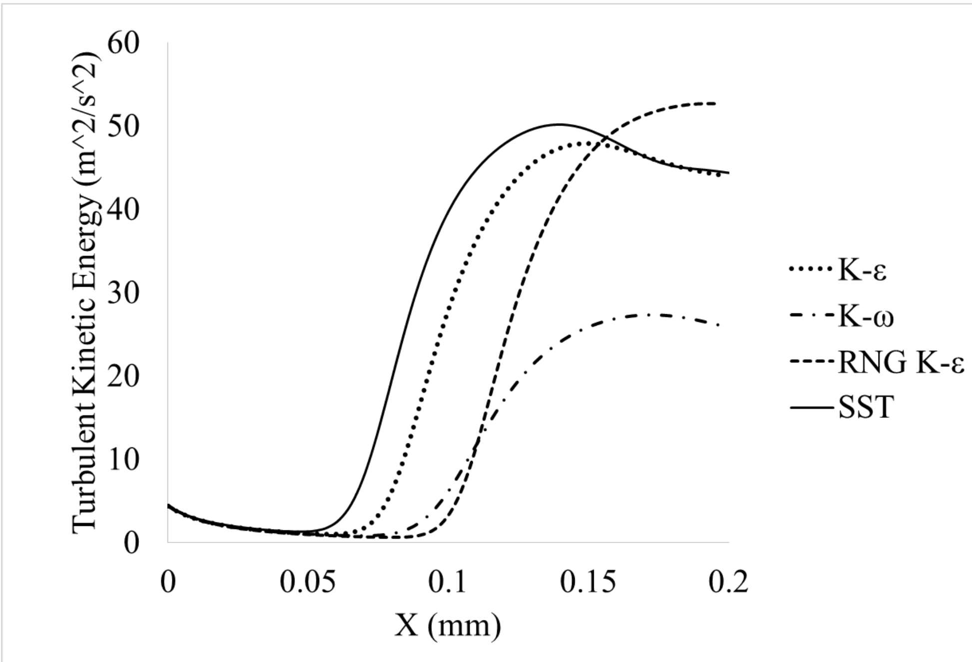

Fig 3 Centerline turbulent kinetic energy distribution

To explain further, the turbulent kinetic energy of different models was compared in figure 3. By observing the plots, the maximum turbulent kinetic energy is observed in the RNG kεwhich extremely over predicts the model. k-ω shows very low turbulent kinetic energy. A cross over between SST & k-ε were observed at X=0.15 which is not in the case of centerline velocity plot.

Conclusions:

In this study, different turbulent models were used to simulate the flow field of the jet emerging from the round nozzle. The results were compared with the experimentally derived results. The SST k-ω model predicts better than k-ε, k-ω, RNGkε.

References

ISSN:0971-1260
Vol-22-Issue-37-December -2019

[1]. Bejan, A., Ziaei, S. and Lorente, S., "Evolution: Why all plumes and jets evolve to round cross sections," Scientific Reports, vol. 04, no. 23, 2014.

[2]. C. Ball, H. Fellouah and A. Pollard, "The flow field in turbulent round free jets," Progress in Aerospace Sciences, vol. 50, pp. 1-26, 2012.

[3]. M. Kaushik, R. Kumar and G. Humrutha, "Review of Computational Fluid Dynamics Studies on Jets," American Journal of Fluid Dynamics, pp. 1-11, 2015.

[4]. Dewan, M. Pathak and A. K. Dass, "A survey of selected literature on important flow properties and computational fluid dynamics treatments of incompressible turbulent plane and round jets in quiescent ambient," Indian Journal of Engineering and Materials Sciences (IJEMS), vol. 13, pp. 180-194, 2006.

[5]. W. K. George, "The self-preservation of turbulent flows and its relation to initial conditions and coherent structures," Advances in turbulence, pp. 39-73, 1989.

[6]. MI, J., NOBES, D.S. and NATHAN, G.J., "Influence of jet exit conditions on the passive scalar field of an axisymmetric free jet," Journal of Fluid Mechanics, vol. 432, pp. 91-125, 2001.

[7]. F. R. Menter, "Two-Equation Eddy-Viscosity Turbulence Models for Engineering Applications," AIAA Journal, vol. 32, no. 8, pp. 1598-1605, 1994.

[8]. B. E. Launder and B. I. Sharma, "Application of the Energy Dissipation Model of Turbulence to the Calculation of Flow Near a Spinning Disc," Letters in Heat and Mass Transfer, vol. 1, no. 2, pp. 131-138, 1974.

[9]. D. Wilcox, "Re-assessment of the scale-determining equation for advanced turbulence models," AIAA Journal, vol. 26, no. 11, pp. 1299-1310, 1988.