Internal Flow Numerical Simulation Analysis of Coagulation Mixing

Pengzhi Liu, Yueqin Li, Xiaolong Luo, Ming Fan

Abstract—**The internal flow field of a square container and a circular container was simulated by finite element software. The mixing result of fluid in the container and the influence on growth of the flocs during coagulation mixing were analyzed from the following four aspects: average turbulent dissipation rate, average speed, average turbulent kinetic energy and the scale of micro vortex. The result shows that the distribution of velocity field, turbulent kinetic energy field and turbulent dissipation energy field is more balanced in square container and leads to the formation of more λ scale of micro vortex. The hydrodynamic conditions are more favorable for the growth of the flocs.**

***Index Terms*—coagulation mixing; flocculation; scale of micro vortex; numerical simulation**

I. Introduction

In the process of water treatment, the growth of the flocs will affect the efficiency of water treatment directly [1]. There are many factors such as the shape of the container, mixing time, mixing speed, the size and shape of the mixing paddle that affect the growth of the flocs [2, 3]. In this paper, the three-dimensional flow field in the container was calculated and simulated by FLUENT software. The effect of circular and square container on the growth of the flocs was studied while the mixing speed, mixing time, and mixing paddle shape remain unchanged. The calculated turbulent dissipation rate and scale of micro vortex were used as the evaluation index of the flocculation effect [4] and provide some theoretical guidance for the practical engineering

II. Numerical simulation research of mixing

Multi-reference system model（MRS）[5] was adopted in the numerical simulation. The specific research process is as follow: a fluid rotating reference frame which including the mixing paddle and the surrounding fluid was defined, and then a stationary coordinate system which was outside the area of the mixing paddle was defined in the container. The shape is shown in Fig 1 and Fig 2 (The dotted line means section of the two reference frame). Assuming that the section of the two reference frame is steady flow, that means the speed (absolute speed) of the section for each reference frame must be the same, and the grid does not move.

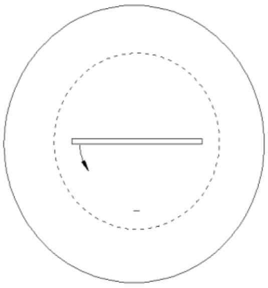


Fig.1 Sketch Map of mixing paddle in the circular container

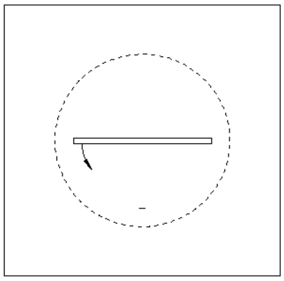


Fig.2 Sketch Map of mixing paddle in the square container

III. Establish mesh

The hexahedral mesh was chosen in the simulation model and the minimum interior angle of each mesh cell was above 50 DEG. All determinant (2 * 2 * 2) options in mesh cell were above 0.7. The mesh models are shown in Fig 3. The k-ε equation model was used in the calculation model, the boundary condition was the whole wall function.

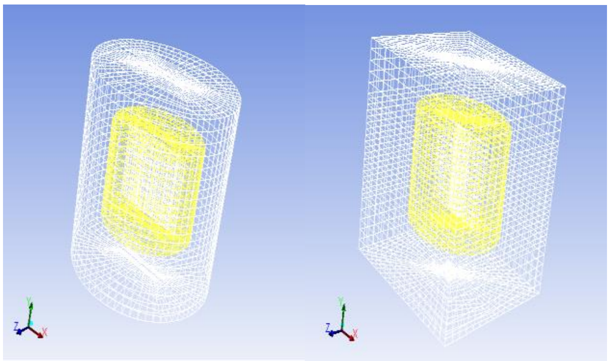


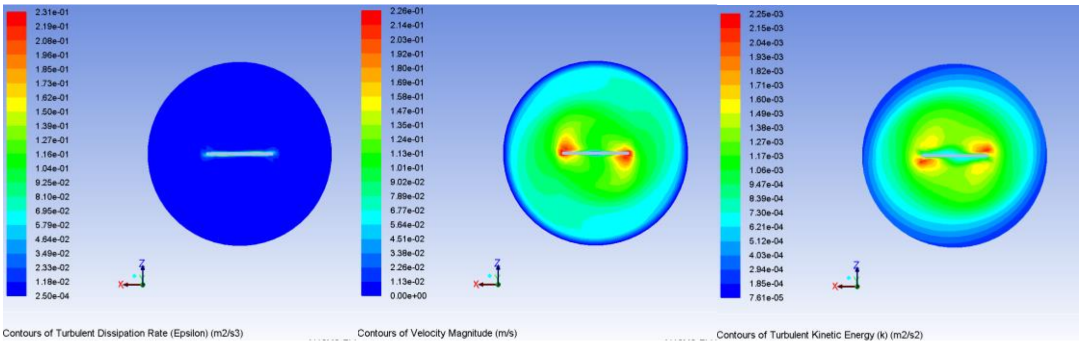
Fig.3 Mesh model of circular container and square container

IV. MIXING SIMULATION COMPARISON BETWEEN CIRCULAR AND SQUARE CONTAINER

The mixing speed was set to 65 rpm.

A. Mixing paddle 1（40×40mm）

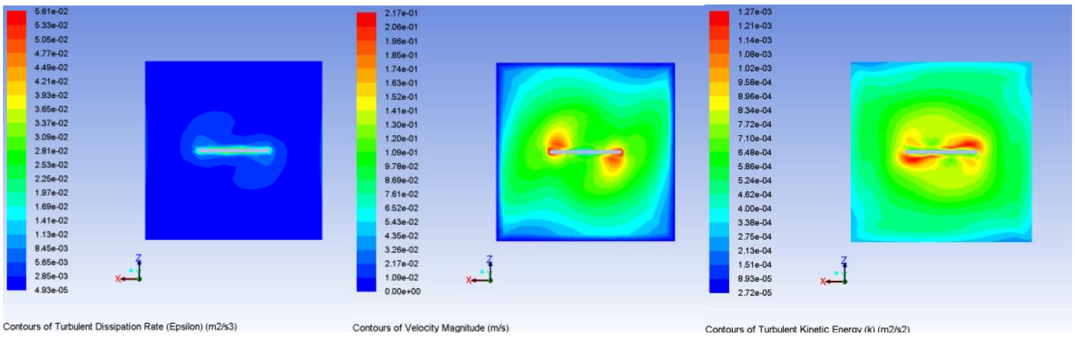
Simulation cloud image of mixing in the circular container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.4 The distribution of three indexes in circular container

Simulation cloud image of mixing in the square container：

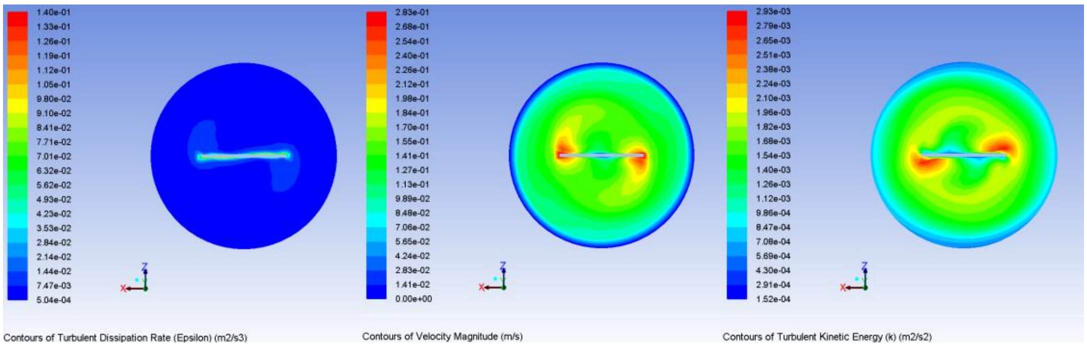


a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.5 The distribution of three indexes in square container

B. Mixing paddle 2（50×40mm）

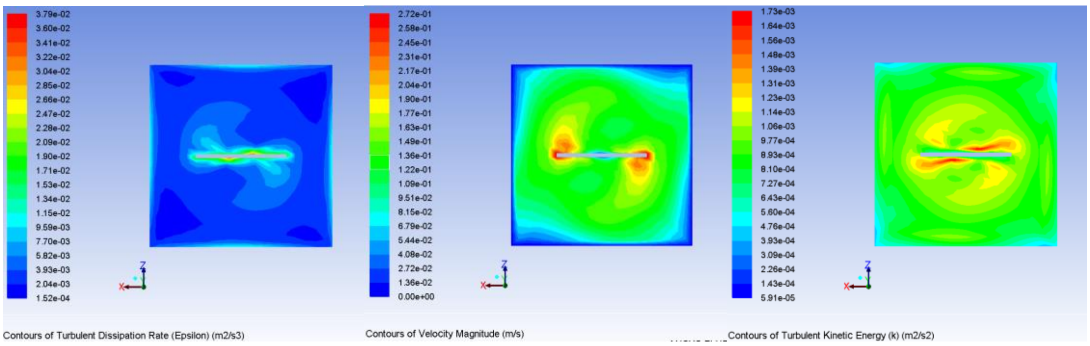
Simulation cloud image of mixing in the circular container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.6 The distribution of three indexes in circular container

Simulation cloud image of mixing in the square container：

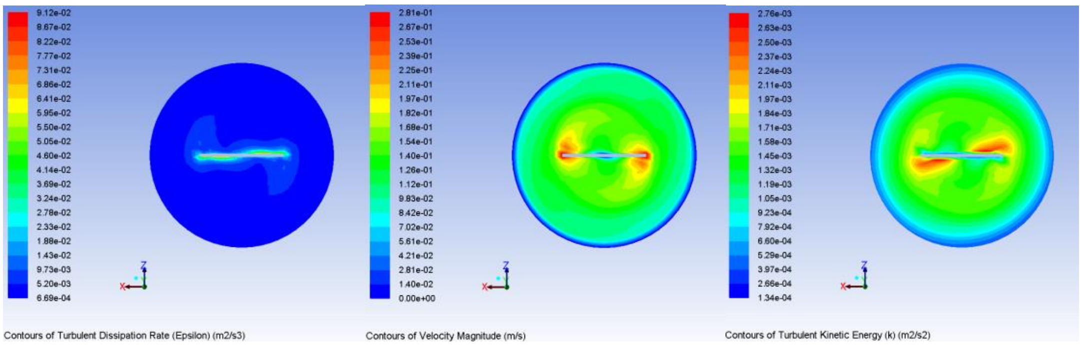


a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.7 The distribution of three indexes in square container

C. Mixing paddle 3（50×50mm）

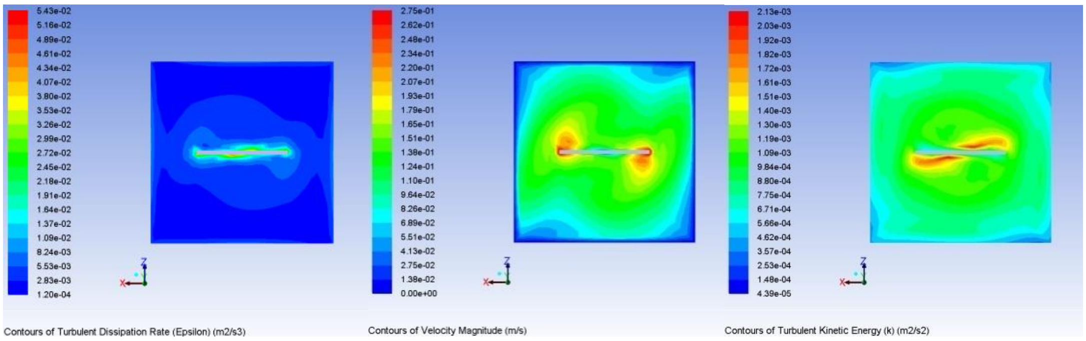
Simulation cloud image of mixing in the circular container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.8 The distribution of three indexes in circular container

Simulation cloud image of mixing in the square container：

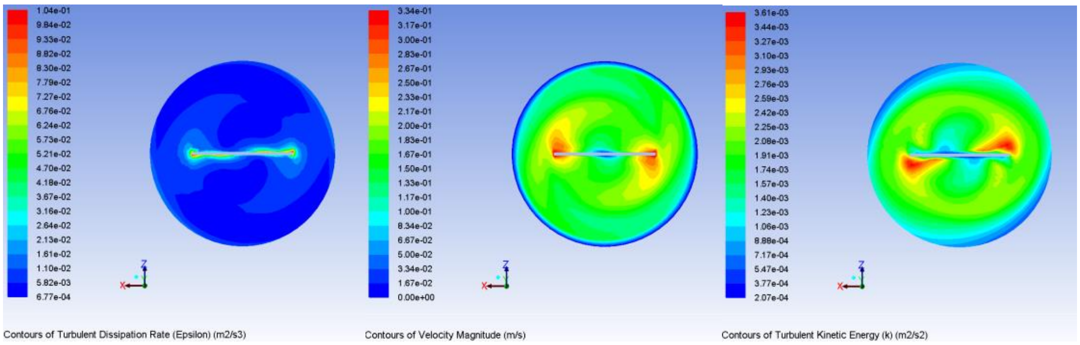


a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.9 The distribution of three indexes in square container

D. Mixing paddle 4（50×60mm）

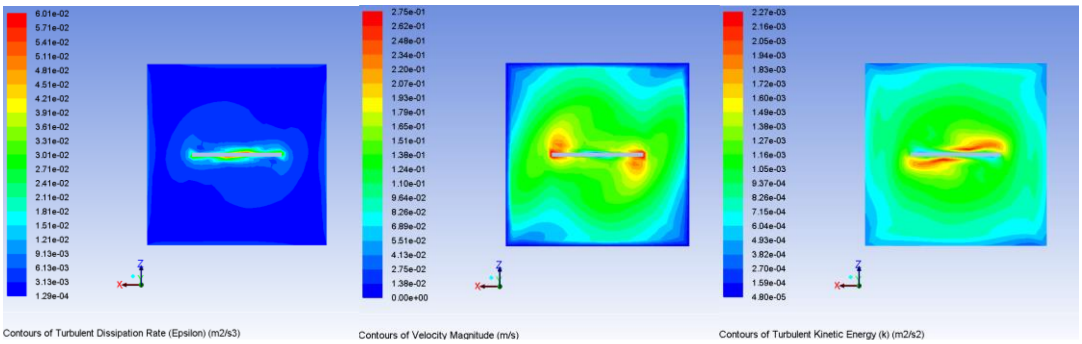
Simulation cloud image of mixing in the circular container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.10 The distribution of three indexes in circular container

Simulation cloud image of mixing in the square container：

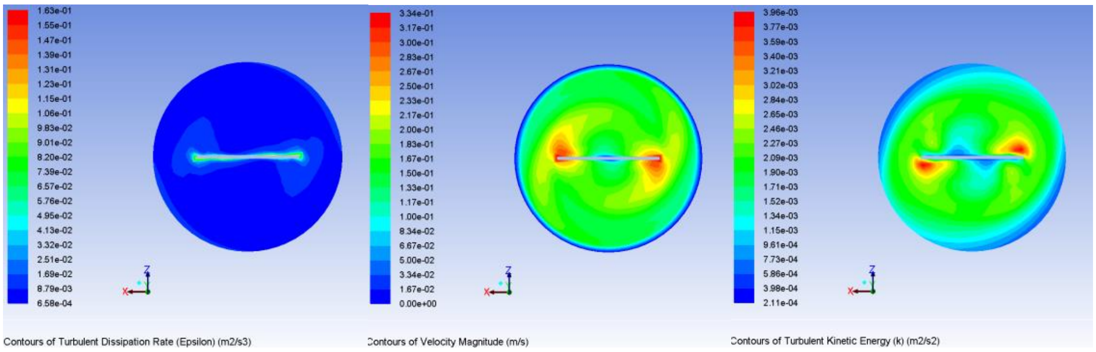


a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.11 The distribution of three indexes in square container

E. Mixing paddle 5 (60×40mm)

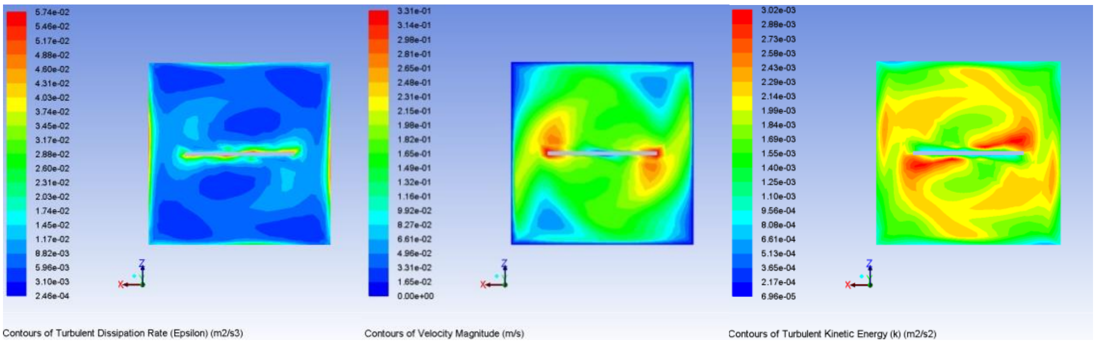
Simulation cloud image of mixing in the circular container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.12 The distribution of three indexes in circular container

Simulation cloud image of mixing in the square container：



a. the turbulent dissipation rate b. the turbulent velocity c. the turbulent kinetic energy

Fig.13 The distribution of three indexes in square container

Notice: the above cloud images are the cross section which is on Y axis of the container and 50mm from the bottom.

Comparing with the cloud images above, it can be found whether mixing in circular or square container, the turbulent dissipation rate field, turbulent velocity field and the turbulent kinetic energy field are concentrated around the mixing paddle, and gradually expand outward, but there is a large difference between the two containers in expansion degree. Comparing with each set of simulation one by one, the index distribution is more balanced in the square container under the same mixing conditions, the most obvious difference exist in the turbulent dissipation rate.

For a more intuitive analysis of the various indexes, line charts of the turbulent dissipation rate, average speed and the turbulent kinetic energy which were solved under the mixing conditions by the FLUENT software were drew for comparison. The results are shown in the following three figures.

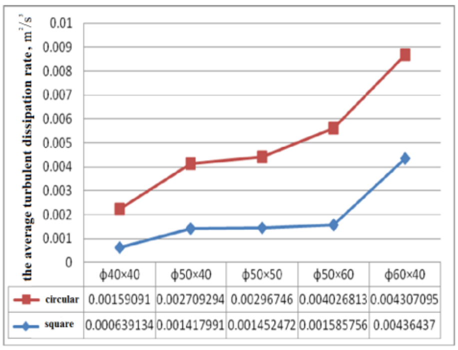


Fig.14 Comparison of average turbulent dissipation rate between circular and square containers

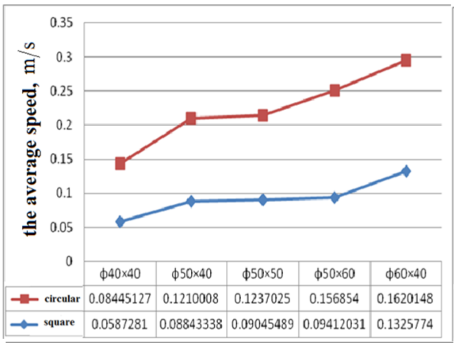


Fig.15 Comparison of average speed between circular and square containers

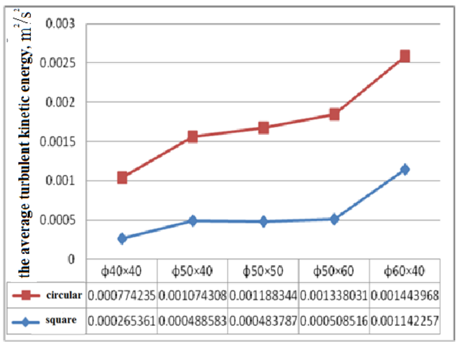


Fig.16 Comparison of average turbulent kinetic energy between circular and square containers

It can be seen from the chart above, the average turbulent dissipation rate, average speed and average turbulent kinetic energy in circular containers are larger than the average values in square container under the same mixing condition. It can be seen obviously that the turbulence intensity in the circular container is larger than the turbulence intensity in the square container, from the perspective of the floc collision theory [6], the floc collision will dissipate more energy in the circular container than the square container, and it also generate greater shear force which will break flocs; from the perspective of the scale of micro vortex theory [7], the range of the vortex scale is wider in circular container, but when the ratio of scale of micro vortex which is similar to the flocs gets smaller, the growth of flocs gets more difficult.

V. COMPARISON OF THE SCALE OF MICRO VORTEX

By the formula $\lambda = \left(\nu^3/\varepsilon\right)^{1/4}$, the data which were obtained by numerical simulation are used to draw a line chart of the scale of micro vortex in two different containers. As shown in Fig 17.

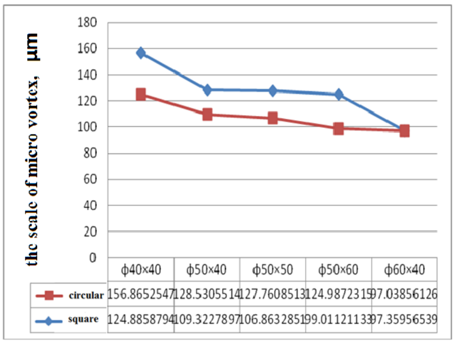


Fig.17 The line chart of the scale of micro vortex in different containers and by different mixing paddle

It can be seen from the chart, whether in a circular container or a square container, the tendency of the scale of micro vortex which changes with the mixing paddle is same as the tendency of floc changing (Fig 17). In addition, under the same condition, the scale of micro vortex in a circular container is smaller than the square container. Thus, the distribution of the turbulent dissipation rate is more balanced in the square container, the scale of micro vortex in the fluid is bigger than the circular container. The conclusion can be reached that the effect of coagulation mixing in the square container is better than the circular container by the scale of micro vortex collision theory [8].

VI. CONCLUSION

The internal flow field of a square container and a circular container were simulated by the finite element software. The result shows that the distribution of velocity field, turbulent kinetic energy field and turbulent dissipation energy field is more balanced in square container under the same condition. The hydrodynamic conditions are more favorable to the formation of the flocculation. Meanwhile the square container generates more λ scale micro vortex which will lead to the formation of the coagulation and make a contribution to water treatment.

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