IJIRR

International Journal of Information Research and Review
Vol. 03, Issue, 06, pp. 2533-2537, June, 2016

Research Article

THE EXPERIMENTAL RESEARCH OF COAGULATION MIXING

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ARTICLE INFO

Article History:

Received 15th March 2016
Received in revised form
24th April 2016
Accepted 19th May 2016
Published online 30th June 2016

Keywords:

Coagulation Mixing,
Flocculant,
Wastewater Treatment,
Jar Test.

ABSTRACT

Coagulation mixing is an important process in water treatment technology, the research of coagulation mixing has engineering practice reference value. Through a series of coagulation jar test, the effects of changing the shape of containers and the geometric size on the settling efficiency of flocs and final turbidity removal rates were researched. The experimental results show that the hydraulic conditions of the square container were more favorable for the growth of the flocs, and the coagulation effect is better than the circular container.

INTRODUCTION

The experiment of coagulation mixing (Xu, 1992), which began in 1921, is one of the most widely used methods in the study and control of coagulation process. There are many factors that affect the mixing experiment, such as the mixing speed and time, the shape of the mixing vessel, the size and shape of the mixing paddle and so on (Zhuo, 2007). The circular container is commonly used in jar test, and produces smooth water without dead zone when mixing. But circular container does not have spoiler and will produce vortex in the center while mixing, and the water will rotate rapidly with the blades and that cause the same velocity and direction of particles which has bad influence on coagulation mixing. In order to prevent the water rotating with the blade, the domestic and foreign research data and practical experience show that the square container which D: H=1:1 (D is the length of the container; H is the effective water depth) has been used in jar test. The hydraulic conditions of the flow in the transparent square container is closer to the actual practice, the side wall collision and intense turbulent significantly improve the agglomeration effect of the particles. Compared with the large volume mixing tank, the results show that the coagulation results are similar, and that it is feasible to simulate coagulation process with lL square container.

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In this paper, 1Lsquare container was used to study its hydrodynamic characteristics and its effect of coagulation mixing.

- Flocculation kinetics mechanism
- Effects of hydraulic conditions on flocculation

Flocculation effect depend on two factors (Wang, 1998): the first factor is the absorption bridging ability of polymer complex which is generated after hydrolysis of flocculant, that ability is decided by the character of flocculant; The second factor is small particles collision probability and how to reasonably and effectively control their collision, that is determined by the dynamic conditions of the device. Coagulation effect depends on the size and density of the flocs. In the process of the formation of the flocs, there will be bonding interaction of particles and the effect of fluid turbulence on flocculation. It takes two basic preconditions for the particles to produce flocculation: contact impact and aggregation of particles. In order to make the contact impact of particles, there must be a velocity gradient in the flow layer, and there are 3 main ways to produce the velocity gradient in the water (Zhong, 1986): the Brown movement of particles and the settling velocity difference between the particles and the hydraulic action of the flowing water body. Only small particles can produce Brown movement, thus Brown movement will gradually weaken with the flocculation. In the flocculation period, the floc size increase from μm rank to mm rank, and the

Brown movement of the particles which size were more than 1 μm has disappeared (Wu et al., 2007). Therefore, the influence of Brown movement can be ignored; The settling velocity of particles is mainly caused by gravity, and in the flocculation process, due to the strong turbulence effect of water body, the particle contact impact caused by the settling velocity difference is very small, thus the influence of the settling velocity difference on the contact impact can be ignored too; The hydraulic action of the flowing water body is mainly composed of the inertia centrifugal force and the vortex shear force. In the radial movement of the particles under the inertial centrifugal force, large particles move fast and small particles moving slowly, this velocity difference provides the convenience for the contact impact of the particles, therefore, the inertia centrifugal force plays a significant role in the adhesion of different sizes of particles. The particle size increases with the inertia centrifugal force, and the density of the particles decreases correspondingly (John, 1978). At the same time, with the increase of particle size, the turbulent shear stress is also increasing. When the particle size is larger than the corresponding vortex size, the shear force will be destroyed. Therefore, under the effects of turbulence, the vortex shear force and inertial centrifugal force are the major dynamic factors in the flocculation process, and the vortex shear force is main power cause which decides the growth speed and the size of flocs (Wu et al., 2001).

Mixing mechanism

Mixing process is that through the diffusion of the main diffusion, the vortex diffusion and the molecular diffusion, the molecular level uniform mixing is reached under the condition of the forced convection (John, 1978). In a mixing experiment, the rotating blades transfer the energy to the water by mechanical energy at first, and makes the water produce forced convection, then the high-speed rotation of the water flow is formed (Wu et al., 2001), which drives the circulation of all the internal water, this circulating flow which causes a wide range of water diffusion is called the main diffusion; While the blades are rotating fast in the water, there will be an instantaneous velocity gradient behind those blades and local shear flow, in this way, the larger scale vortex micro clusters in the water will be divided into scales of different size by turbulence shear force, meanwhile, the energy is also transferred from larger scale vortex to smaller scales until the vortex scale reaches the minimum which is the Kolmogoroff scale (Niu et al.,2012), this convection diffusion formed by the diffusion of different vortex scales in a local range is called the vortex diffusion (Shen et al., 2013). The mixing effect can only be achieved by molecular diffusion when the vortex scale reaches Kolmogoroff scale.

- Experimental conditions and methods
- Experimental conditions

Experimental equipments: MY3000-6M Coagulation experiment six joint stirring device (Wuhan Mei Yu Co., Ltd.), SGZ-1A Digital display turbidity meter(Shanghai Yue Feng Instrument Co., Ltd.), AMG EVOS series large screen digital inverted microscope (Particle size analysis instrument), and other instruments including 1L circular container and 1L square container and mixing blades with different sizes (Fig.1). Water sample and reagent: the water sample (Fig.2) is the oil well produced water which was simply treated by oil separation treatment of Jidong Oilfield in China.

Fig.1. Non-standard mixing blades

The turbidity of the water sample was 46.5, pH was 6.9, the experimental temperature was 20 DEG C. The flocculant was 10%PAC solution

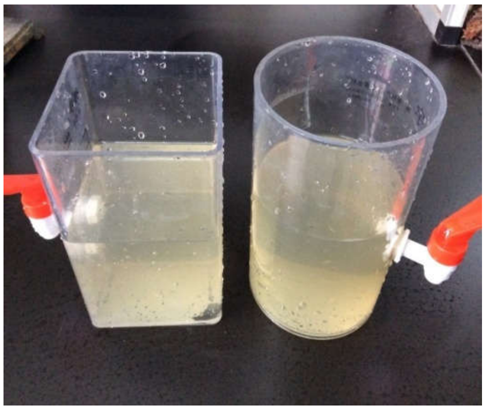

Fig. 2. Water sample for mixing experiment

Experimental methods

In order to explore the effects of different containers on coagulation mixing, circular container and square container were used to do the coagulation mixing experiment as the research objects, and the single-factor contrast experiment was conducted. The mixing parameter is determined by the empirical value. In order to eliminate the influence of the mixing blades on the mixing result, five different sizes of the mixing blades are taken as the interference elimination terms. The mixing baldes of MY3000-6M six joint stirring device have original size which is φ50×40×2mm, and 4 different sizes of mixing blades which sizes are φ40×40×2mm,φ50×50×2mm,φ50×60×2mm,φ60×40×2mm were made for the contrast experiment. The hydraulic mixing conditions were the same in each group, the mixing speed were 400rpm, the mixing time were 90s, the settling time were 30min; The dosage of PAC was 15ml (10% solution), PH was 8, the water temperature was 20.

The evaluation index of the experimental results were residual turbidity and average size of flocs from settling layer. In order to reduce the experimental error, each group of experiment repeat 5 times. The residual turbidity was measured after the end of the experiment, then the average turbidity was calculated after the outliers were truncated. In addition, after finish the experiments of each group and measurement of turbidity, use the colorant stain to soaking the flocs for 24 hours, then use the AMG EVOS series large screen digital inverted microscope to observe these size of the flocs, and select the representative sizes of flocs and take pictures of these flocs, then use ImageJ to analysis and calculate the average sizes. 5 pictures were taken for each effective experiment, that is to say, 25 pictures were taken for each group of experiment. At last calculate the average values.

Experimental phenomena

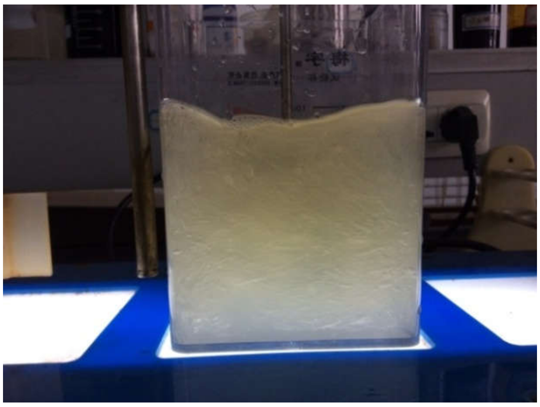

Fig. 3. Square container mixing

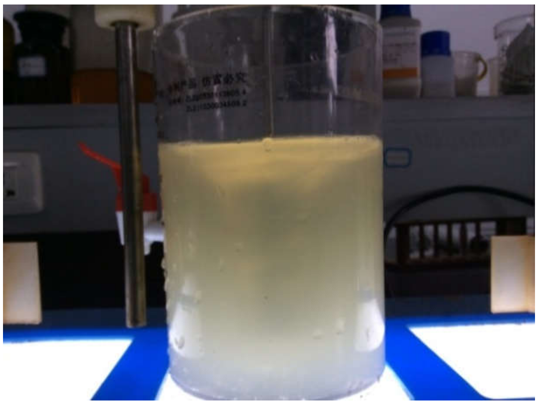

Fig. 4. Circular container mixing

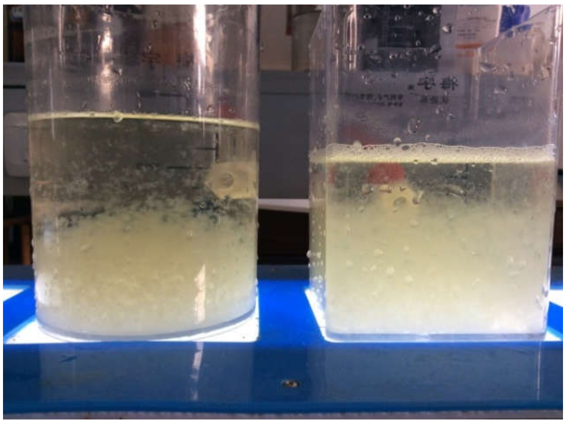

Fig. 5. One minute after the mixing

Fig.3 and Fig.4 are square and circular container when mixing. The turbulent flow in square container appeared to be more dissipative, and accompanied by obvious bubbles when mixing, and there were back-flow vortex which had a certain rhythm in each corner of the container at the bottom; But the turbulence level was more clear and stable. After mixing, the floc precipitation could be observed immediately, and its settling speed was much faster than the square container. As shown in Fig.5, one minute after the mixing, the stratification of flocs and water was basically achieved in circular container while flocs and water were still evenly mixed together in the square container. Thus we could preliminary conclude that the flocs produced in circular container settling faster than the flocs of square container.

Experimental results and analysis

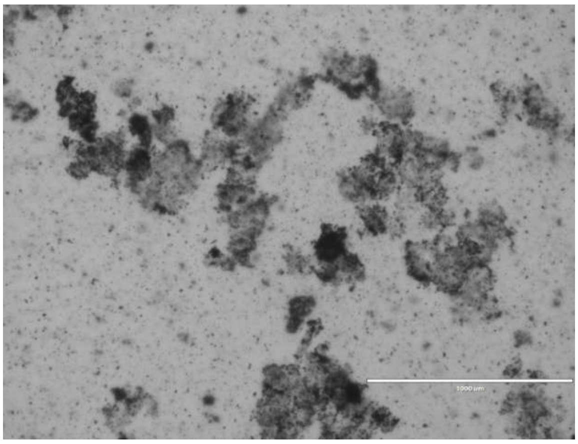

Fig. 6. Flocs image in square container

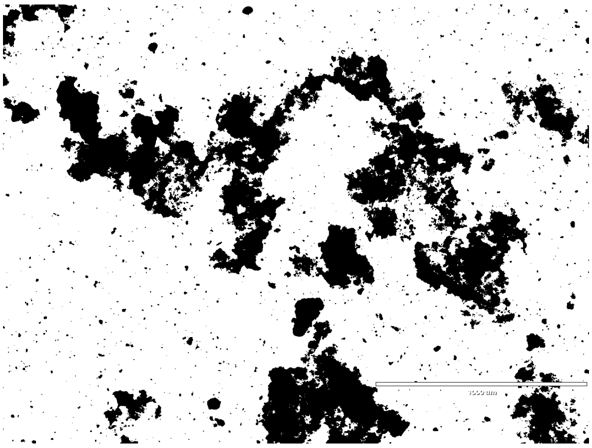

Fig. 7. Flocs image in square container after treatment by Image J

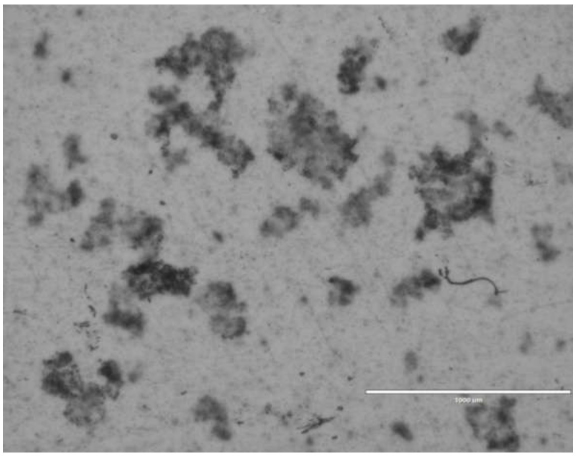

Fig. 8. Flocs image in circular container

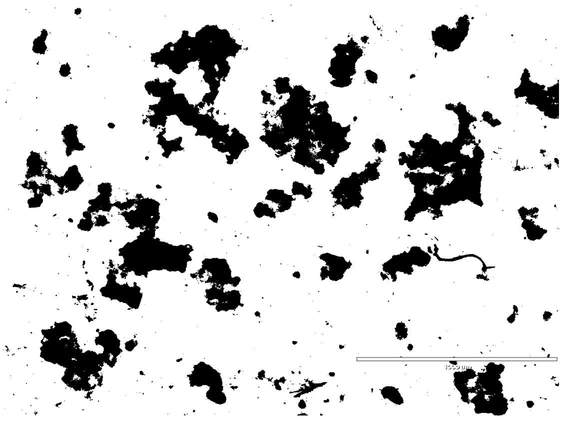

Fig. 9. Flocs image in circular container after treatment by ImageJ

Fig.6 and Fig.8 are the pictures of flocs in the square container and circular container, and Fig.7 and Fig.9 are the treated pictures by the software of ImageJ. The average particle size was calculated by ImageJ then.

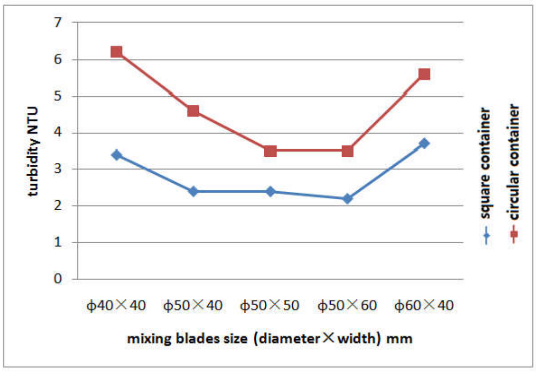

Fig.10. Comparison of turbidity results of different sizes of mixing blades in different containers

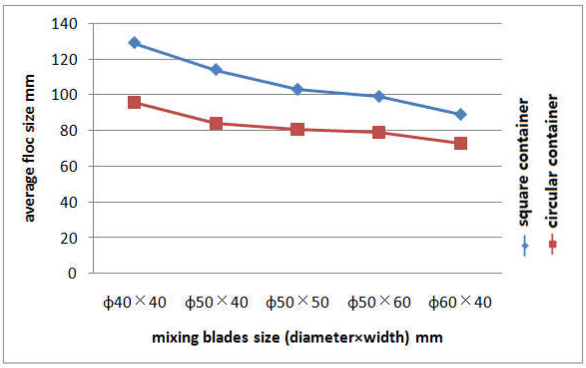

Fig. 11. Comparison of F of different sizes of mixing blades in different containers

As shown in Fig.10 and Fig.11, under the same mixing conditions, the differences of mixing effect between two kinds of containers are significant, the turbidity value of square container is always lower than the circular container, but the particle size is just the opposite. In addition, the variation trends of mixing effect of two different containers with the change of the mixing blades are similar.

This result shows that the influence of mixing blades on the effect of interference can be eliminated, therefore, it can be confirmed that the mixing effect of the square container is better than the mixing effect of the circular container. The reason for this is that a strong oscillation occurs at the four right angles in the square container, resulting in a more axial shear flow and more turbulent vortex; But the flow in the circular container is more smooth and stable, and the direction of the turbulent flow concentrates in radial flow, its turbulent vortex mainly develops in the radial direction, in a certain extent the turbulence intensity of the circular container is greater than the square container, and the turbulent vortex shear force is greater, the viscous dissipation of the large vortex in the process of generating the small vortex is also greater.

The turbulence intensity and turbulent shear stress of the circular container is greater than the square container for comprehensive comparison, the shear stress of the flocs in the circular container in mixing process is also larger than the shear stress in the square container. So the floc size in the circular container is obviously smaller than the square container; On the other hand, when the flocs are shear fractured, it will produce some small scale floc particles, and unable to collision and flocculation for small particles to become large particles with the coagulation process, so the shear fracture is greater and more frequent, the turbidity value is larger. Therefore, the coagulation residual turbidity value of the circular container is higher than the residual turbidity value of the square container. Based on the above analysis and experimental results, it is shown that the coagulation effect of the square container is better than that of the circular container.

Conclusion

In this paper, through a series of coagulation jar test, the effects of changing the shape of containers and the geometric size on the settling efficiency of flocs and final turbidity removal rates were researched. The experimental results show that the hydraulic conditions of the square container were more favorable for the growth of the flocs, and the coagulation effect is better than the circular container.

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