Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 10 (24): 3384-3387, 2010
ISSN 1812-5654

This article was presented in International Conference on Process Engineering and Advanced Materials 24th Symposium of Malaysian Chemical Engineers (15th-17th June, 2010)

Numerical Studies of Fluid Flow Across a Cosmo Ball by Using CFD

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Abstract: Cosmo ball is a media used in wastewater treatment to increase the surface area of contact and provide longer contact time for biological activities. It is usually placed as a media or as packing in the aeration tank, BioFil tank or even in the activated sludge tank. It induces the growth of bacteria on its surface, which will serve as a contact area for the wastewater and the microbial. The objective of this simulation is to analyze the flow pattern around the Cosmo ball which is been packed in the wastewater treatment tank. By conducting this analysis, the overall insights on the interaction of the fluid flow with the Cosmo ball surface can be visualize. The velocity of the fluid flow across the ball is at a speed of 2 cm sec^{-1}. The velocity was obtained from the conventional wastewater treatment plant. During the simulation process, the model will undergo each section of program in ANSYS™ Computational Fluid Dynamics (CFD) such as Design Modeler, Meshing, Pre-Processing, Solver and Post-Processing. The flow distribution across the Cosmo ball was analyzed by varying the angle of attack of the flow. The rationale for this simulation arrangement is that the ball could take any orientation in the bulk media and the fluid flow across it would be at random angle. The result shows that the flow around the Cosmo ball was dispersing sideways thus inducing mixing in the wastewater system. Retention of flow has been observed to occur in the Cosmo ball. The retention of flow provides better microbial interaction with the wastewater.

Key words: Cosmo ball, computational fluid dynamics, wastewater, BioFil, flow, velocity

INTRODUCTION

Cosmo ball is made from plastic and the actual model is depicted as in Fig. 1. It has a proprietary design developed by UPM Waste Technology Centre (http://www.pakar.com.my/). The Cosmo ball mainly has its application as a filter media in an effluent treatment system. A very large surface area could be obtained for microbial attachment as the Cosmo ball has a design such that a surface for fluid interaction with the microbial is greatest. This will greatly improve the degradation of organic matter in wastewater trough the microbial activities.

Fig. 1: Actual Cosmo ball model (http://www.pakar.com.my/)

To be specific, the application of the Cosmo ball is in regards to the trickling process in wastewater treatment. The ball acting as the packing media will be located inside the tank where the wastewater flows across it. This will induce the microbial film growth and cling on the surface of the media (Lee and Shun, 1999). The microbial will oxidize the organic matter in the wastewater. By having a large population of microbial in the wastewater will directly translating to a better efficiency of the treatment plant (Ahmed *et al*., 2007). The specification of the Cosmo ball is shown as in Table 1.

According to experimental analysis, the bacterial developed on the Cosmo ball surfaces will be in excess of 5,000 to 10,000 mg L^{-1} (http://www.pakar.com.my/). This high value of bacteria growth on each of the Cosmo ball will yield a good efficiency in wastewater treatment and it is suitable in the anaerobic and aerobic conditions. The simulation of flow across the Cosmo ball will give full insights on the flow pattern around the ball.

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Table 1: Specification of Cosmo ball (http://www.pakar.com.my/)

Parameters	Values
Material	Polyethylene (PE)
Shape	Spherical
Specific gravity	0.9
Void fraction	85%
Outer diameter	85 mm
Inner diameter	75 mm
Wall thickness	>0.5 mm
Bulk density	75 kg m^{-3}
Specific surface area	> 160 m^2 m^{-2}
Number of Media/m^3	>2000
BOD loading factor	up to 5 kg/m^3.d
Hydraulic loading rate	0.06 m^3/m^2/h
Number required/PE	Varies with loading

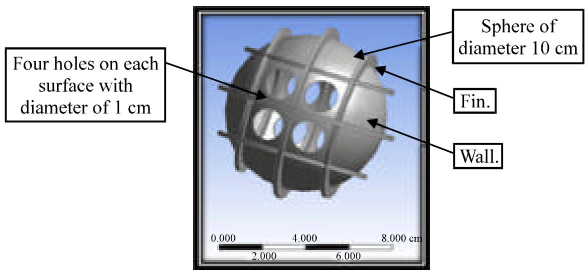


Fig. 2: Model of a Cosmo ball

MATERIALS AND METHODS

In modeling, the Cosmo ball was created with Design Modeler (DM) by ANSYS™. The Cosmo ball model was developed as shown in the Fig. 2.

The fins around the ball serve to induce mixing in the bulk Cosmo balls wastewater system. The fluid flow is expected to divert outwards to the neighboring Cosmo ball. The flow strategy was implemented in 2 angles of attack. The direction of attack of the fluid on the ball was illustrated as Fig. 3. The 2 angles of fluid attack of 0° and 90° were analyzed. The dash line in the figure illustrates the symmetry axis of the ball.

The model of the Cosmo ball is then being brought into ANSYS™ Meshing to convert it to finite element model in order for it to be solved numerically. The physics and boundary condition is then applies. The wastewater inlet flow velocity of 2 cm sec^{-1} and its direction is defined. The surrounding is defined as an opening for the water to flow freely sideways. It is to be noted that this simulation will not cover all the possible direction of wastewater flow across the Cosmo ball. Instead, two extremes flow direction will only be considered which is depicted in Fig. 3. With the two flow direction extremes, the flow pattern could be forecasted for any possible angle as the ball is symmetry vertically and horizontally.

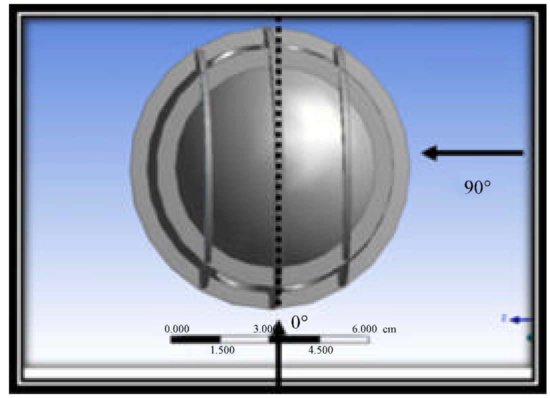


Fig. 3: Angle of fluid attack

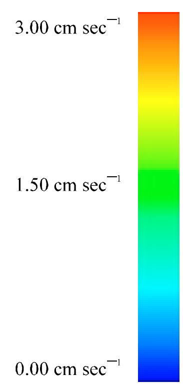


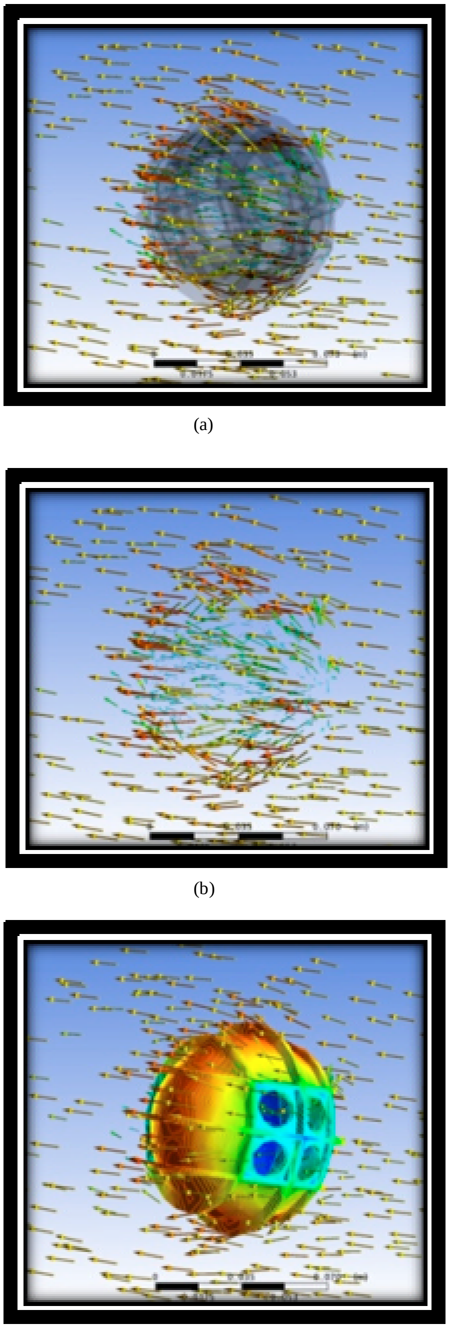
Fig. 4: Fluid flow velocity component scale

RESULTS AND DISCUSSION

Fluid flow system from a higher velocity to a lower velocity is shown in the scale as in Fig. 4 where it is represented by red color contour to blue color contour.

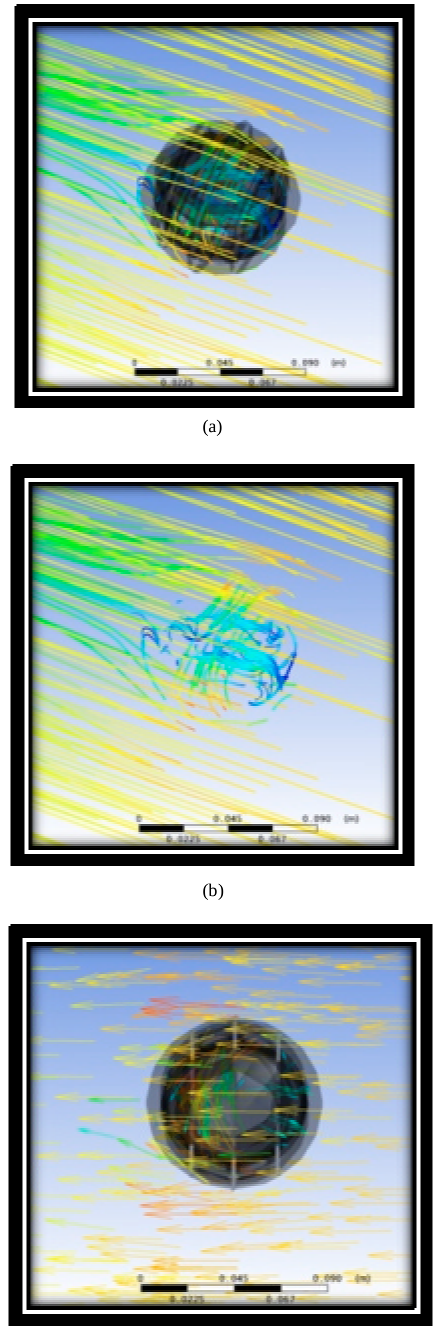
An overall exterior and interior fluid flow across the Cosmo ball was depicted in Fig. 5a and b, respectively. It is seen that the velocity distributed uniform namely intermediate flow region across the Cosmo ball whereas the velocity is higher at the edge namely turbulence flow region of the fluid flow direction. Figure 5b shows the interior observation where the fluid flows slowly in the hollow region causing a lag of flow for the internal zone of the ball. The fins across the Cosmo ball caused dispersion to the fluids streamline. The overall contour plot of uniform vector streamlines at 0° flow angle was depicted in Fig. 5c.

The angle of flow at 90° was shown in Fig. 6a and b. It is observed that the water is still able to enter the hollow region. There is an extremely chaotic region observed inside the Cosmo ball. The blue regions indicate that the flow was retarded due to collision of the fluid to



(a) (b) (c)

Fig. 5: Fluid flow across at 0° (a) exterior, (b) interior and (c) vector direction at fixed Cosmo ball position (side view) 0°



(a) (b) (c)

Fig. 6: Fluid flow across at 90° (a) exterior (iso-view), (b) interior (iso-view) and (c) vector direction (top view) at fixed Cosmo ball position 0°

the wall. In order to show the fluid direction across the Cosmo ball, vector plot was shown in Fig. 6c. It was observed that most of the wastewater traps in the hollow region of the Cosmo ball. This phenomena retards the wastewater flow, thus prolong the interaction time between the bacteria and the wastewater.

CONCLUSION

The objective of this simulation is to analyze the flow pattern of wastewater across the Cosmo ball in the wastewater tank. It is found that the lag of flow in the individual Cosmo ball indicates that the hollow region in the ball can induce higher retention time for wastewater treatment. This will greatly improve the efficiency of the wastewater treatment plant as well as to reduce the area needed for the treatment due to sufficient time for the microbial in the wastewater to obtain oxygen for oxidation process.

ACKNOWLEDGMENTS

First and foremost, I would like to express my deepest gratitude, appreciation and support to the staffs of Pakar Management Technology their valuable information, advice and comments trough the achievement of this project.

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