Computational Fluid Dynamics (CFD) Simulation of Multiphase Flow in Biogas Digester

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Introduction: Biogas has demonstrated a growing importance in recent years. Proper mixing of the sludge in the biogas digester is essential for providing an optimum performance. CFD software enables one to predict the effects that geometry, feed location, physical properties, and operating conditions. This paper developed a CFD model to simulate the hydrodynamic characteristics of multiphase flow in biogas digester. This work carried out by changing the internal geometry of digester.

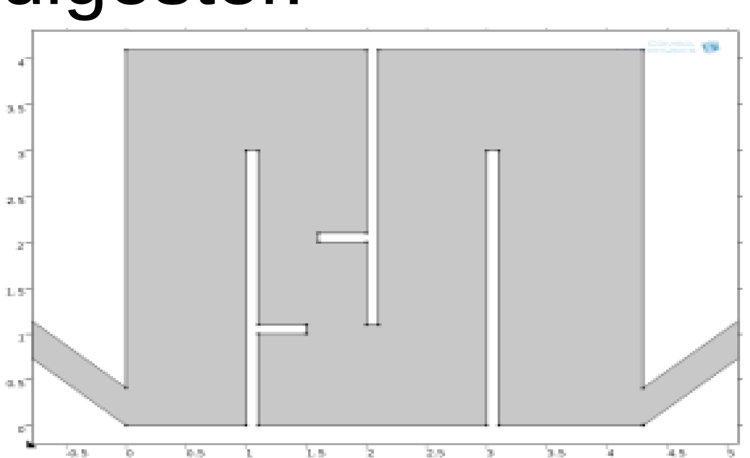

Figure 1. 2D Biogas digester geometry with an internal feature.

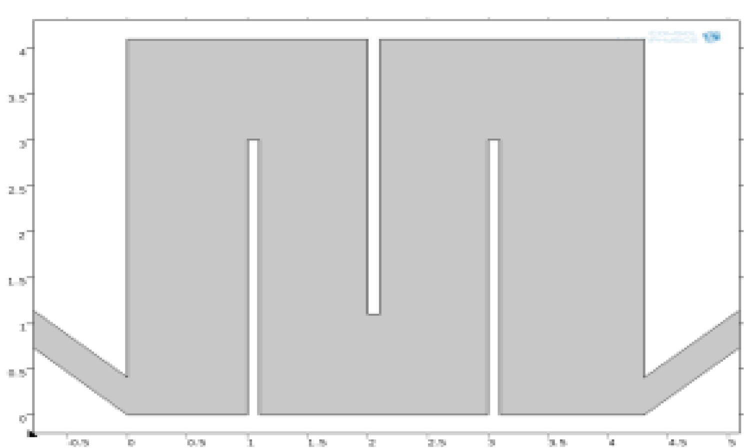

Figure 2. 2D Biogas digester geometry with an internal feature.

Computational Methods: A CFD-based simulation method was performed using COMSOL Multiphysics fluid flow software. A two-dimensional CFD model was developed in this work to simulate the characteristics of a gas–liquid two-phase tank. Liquid manure was described using the non-Newtonian Fluid Model:

$$\tau_{ij} = \eta \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}$$

Where η is non-Newtonian viscosity, which is only considered to be a function of the shear rate, γ.
The viscosity in the non-Newtonian power law is expressed as:

$$\eta = K\gamma^{n-1} e^{\frac{T_0}{T}}$$

Where K is the consistency coefficient (Pa s^n), γ is the shear rate (s^{-1}), n is the power-law index that determines the class of fluid, T_0 is the reference temperature (K), and T is the slurry temperature (K).

Results: Comparative results were carried out in the digester by changing the internal geometry of the digester. It is observed that the mixing is improved by the addition of two horizontal baffles in the first compartment of the biogas digester.

Biogas digesters with horizontal baffles and without horizontal baffles

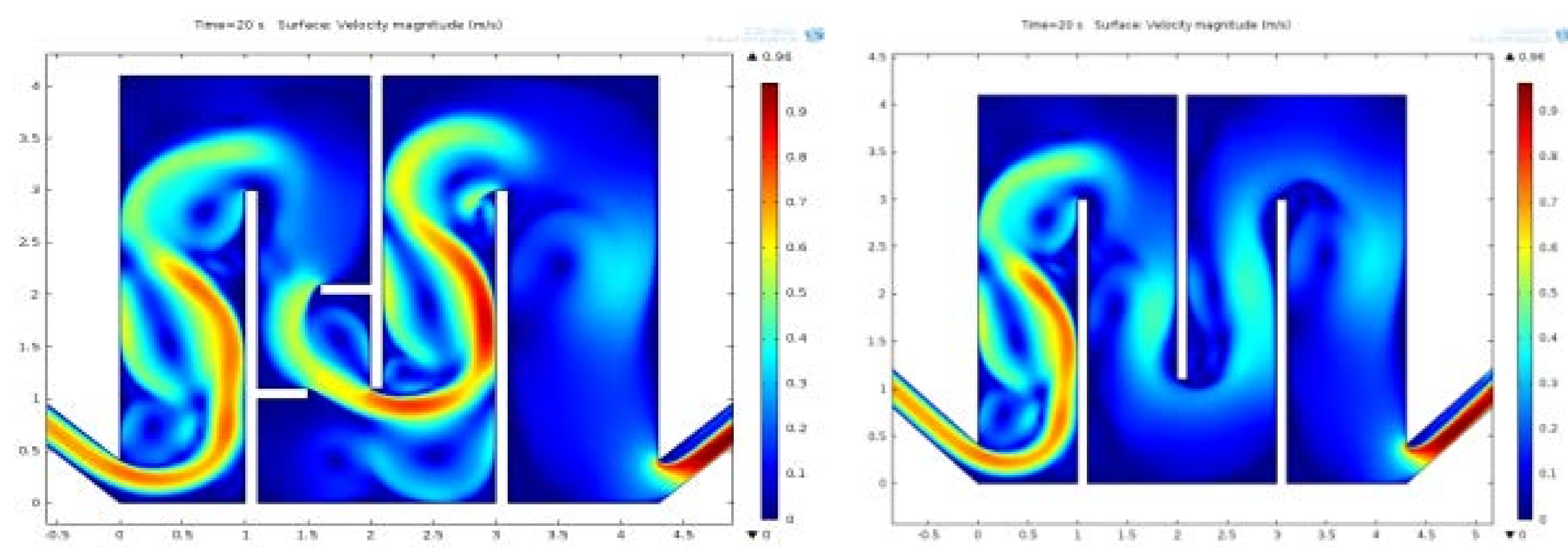

Figure 3. Total solids 2.5% and inlet Velocity 0.5

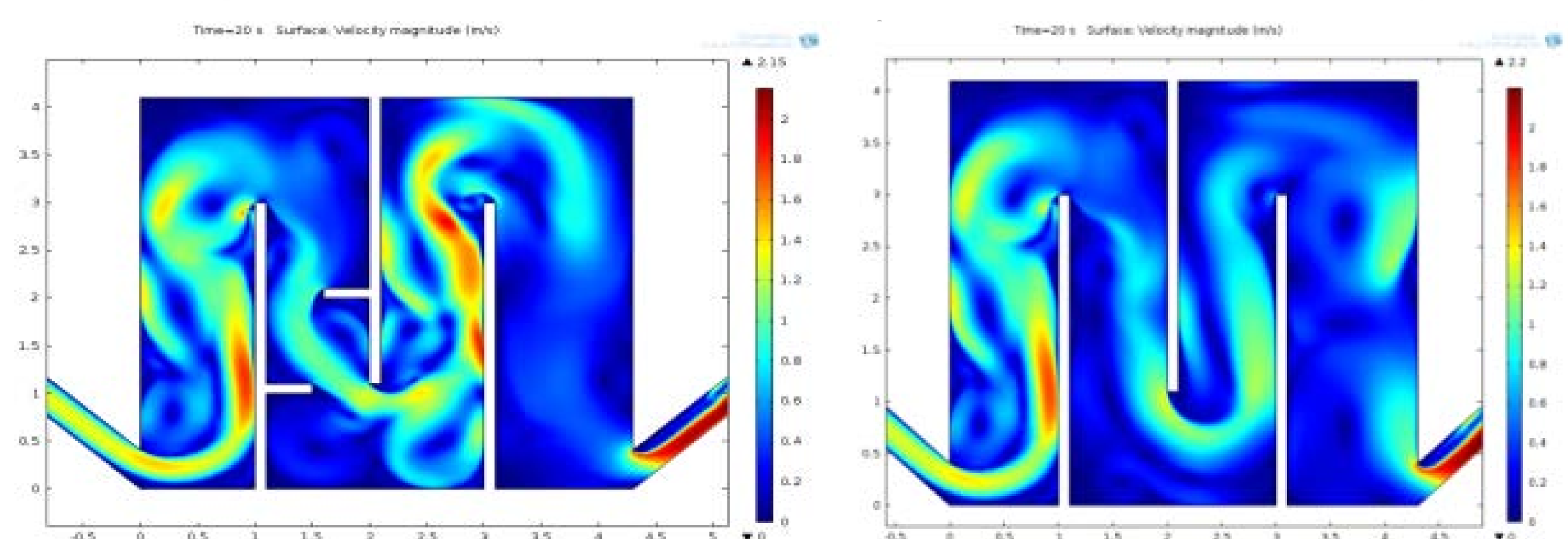

Figure 4. Total solids 7.5% and inlet Velocity 1 m/s

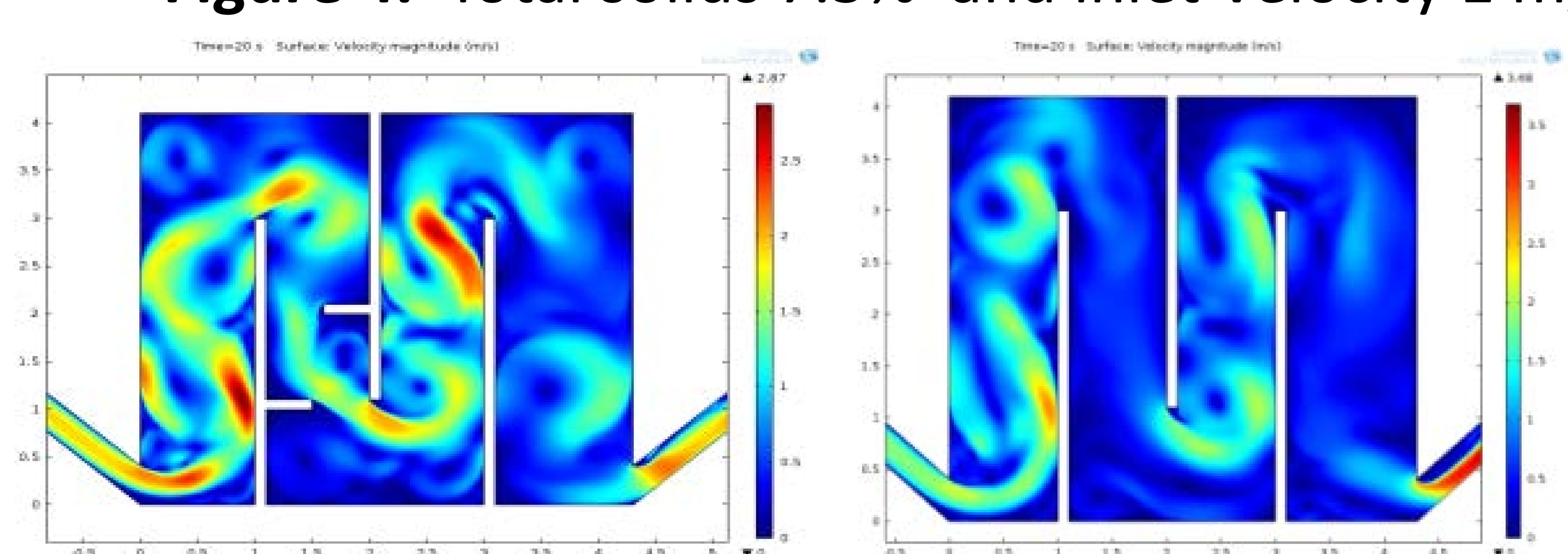

Figure 5. Total solids 12.1% and inlet Velocity 1.5m/s

Conclusions: To overcome the rheology problems in the biogas digester the internal geometry of the digester was changed. This will help to improve the biogas production rate and reduce the cost of energy required for the impeller.

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References:

1. Yu, L., Maa, J., Frear, C., Zhao, Q., Dillon, R., Li, X., Chen, S., 2013. "Multiphase modeling of settling and suspension in anaerobic digester", Applied Energy 111, pp. 28–39.
2. Kamarad, L. Pohn, S., Bochmann, G., Harasek, M., 2013 "Determination Of Mixing Quality In Biogas Plant Digesters Using Tracer Tests And Computational FluidDynamics",Acta Universitatis Agriculturae EtSilviculturae Mendelianae Brunensis, Volume LXI 140 Number 5.
3. Wu, B., 2013, "Advances in the use of CFD to characterize, design and optimize bioenergy systems", Computers and Electronics in Agriculture 93, pp. 195–208.

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