

Three-Dimensional CFD Validation of Hydrodynamic Behavior in Anaerobic Digester

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Abstract

An anaerobic digester is widely used for biogas production, however most existing studies assume homogeneous mixing conditions, which do not consider the complex hydrodynamic behavior in the reactor. In full scale operation, non-uniform flow distribution and low-velocity regions significantly affect mixing efficiency and biogas production. Previous studies mainly used two-dimensional (2D) simulation, which cannot show three-dimensional (3D) flow structures such as circulation loops, stagnant regions or dead zones, this issue used for scale-up applications. CFD validation against experimental data ensures that the model is accurate and reliable. This study aims to validate a three-dimensional (3D) CFD model of a gas-lift anaerobic digester against experimental data. The model simulated gas-liquid interactions using a multiphase Eulerian- Eulerian approach with the RNG $k-\epsilon$ turbulence model applying a structural hexahedral mesh with near-wall treatment. Grid independence study was performed using four different grid number of 106,180, 244,164, 301,384 and 460,480 to ensure that the simulation results do not affect by number of grids. Model validation was conducted by comparing predicted velocity profiles and flow patterns with experimental data. The results show that the 3D model successfully simulates key hydrodynamic behavior, including central upward two of circulation loops on both sides, and low velocity regions appear near the bottom and corner of digester, indicating possible dead zone areas. In particular, the model reveals the existence of low-velocity regions that cannot be clearly seen using a 2D model. This validated 3D model provides accurate simulation results. It is a useful tool to study mixing and improve the reactor in scale-up and real operations.

Keyword: CFD validation, anaerobic digester, 3D simulation, hydrodynamics, mixing