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CFD simulation and evaluation of the mixing performance of gas and non-Newtonian fluid during high solid anaerobic digestion

Lili Li[1], Kun Wang[1], Liangliang Wei[1], Qingliang Zhao[1], Huimin Zhou[1], Junqiu Jiang[1]*

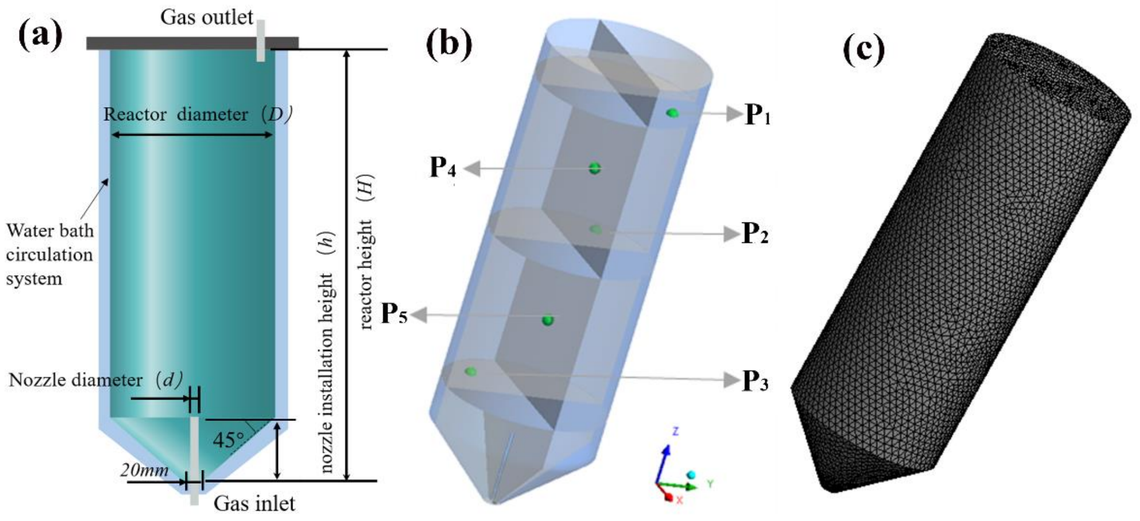
[1]Key Laboratory of Urban Water Resource and Environment, School of Environment, Harbin Institute of Technology, Harbin 150090, China

INTRODUCTION

High solid anaerobic digestion (HS-AD) (i.e., more than 10% total solids) has been considered as one of the most effective approaches for sustainable energy production during food waste management. The enhancement of mixing efficiency becomes critical rate-limiting factor in HS-AD systems operating at high organic loads and short residence time , however the flow characteristics of gas mixing in HS-AD reactors still remains unclear. The mixing efficiency varies widely depending on the equipment used and the geometry of the digester. Therefore, it is practically urgent to refine the design and operation of mixing in anaerobic digesters using CFD techniques to optimize the balance between the input mixing energy and the biogas output.

METHODS

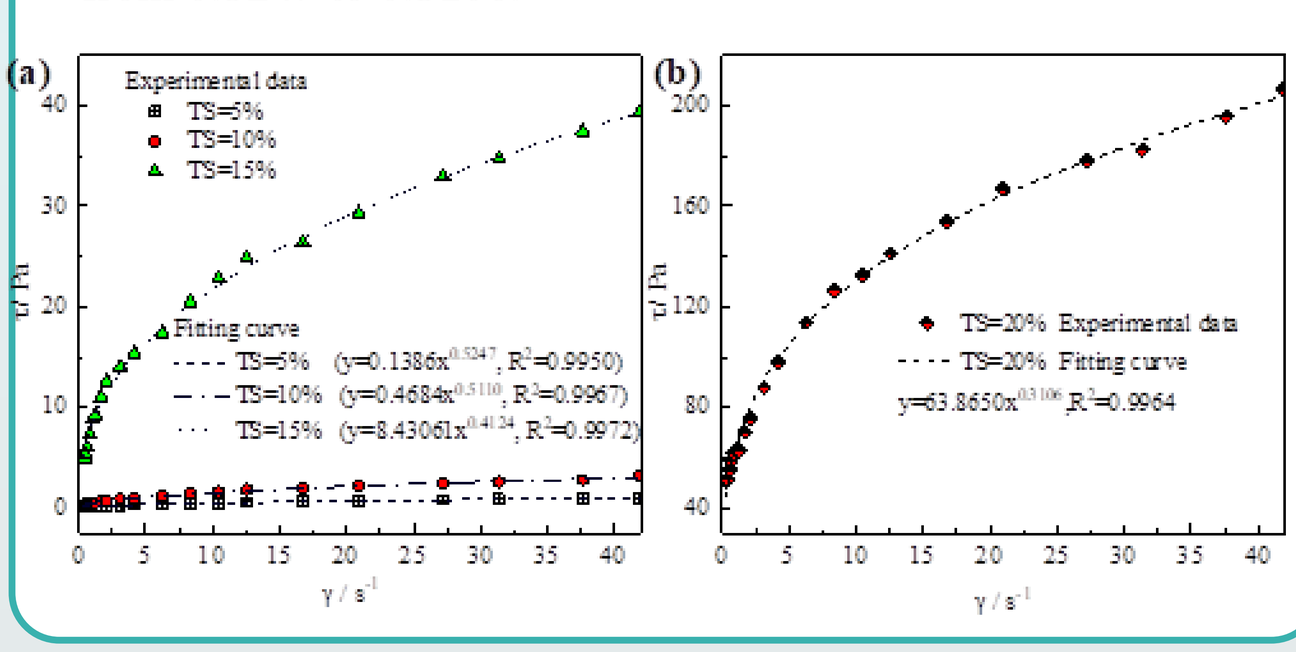
- A two-phase Euler-Euler model was applied to analyze the hydrodynamics of different geometric configurations and mixing energy . Furthermore, the effects of geometry and mixing efficiency on digester performance, including flow patterns, average velocity, energy consumption, dead volume, UI, and velocity gradient (G_L), were comprehensively analyzed.



- The reactor exhibited a working volume of 20 L, with a conical height of 90 mm, cylindrical height of 500 mm (H=590 mm, D=200 mm).

RHEOLOGICAL PARAMETERS

- With the increasing of the TS of the FW from 5% to 20 %, the corresponding consistency index increased from 0.1386 Pa·s^n to 63.8650 Pa·s^n, whereas the rheological index decreased from 0.5247 to 0.3106.



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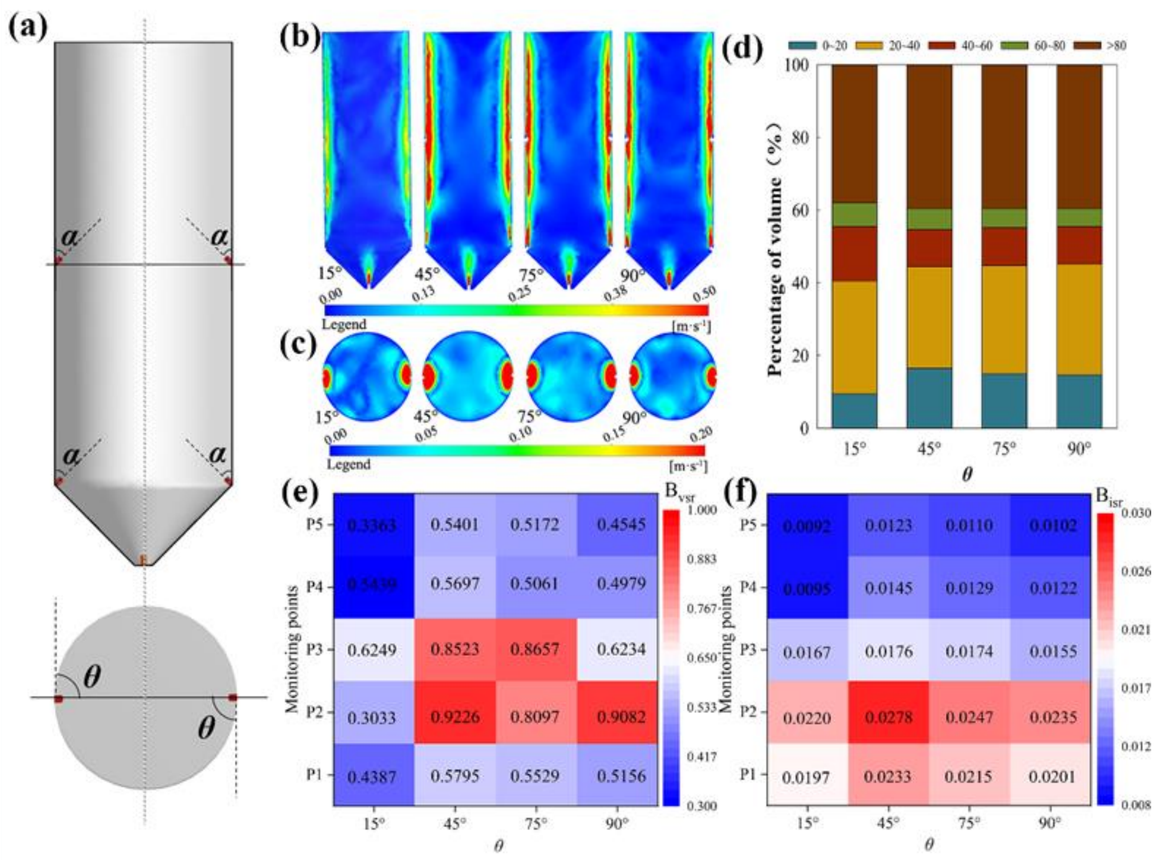
Results and Discussion



- The obtained velocity of substrates at θ=15° (0.034 m/s) were lower than those at θ=45°, 75°, and 90°, specifically the highest average velocity was obtained at 45° (0.045 m/s).
- The axial mixing was more homogeneous at θ= 45° , with UI = 0.487. The local G_L and dead zones with different θ changed insignificantly; LGZ, MGZ, and HGZ volume accounted for 9.5%~16.5%, 44%~52.5%, and 38%~39.5%, respectively, the sum of both LGZ and MGZ volumes exceeded 60%. B_{vsr} and B_{isr} were less than 1 for all monitoring points.

CONCLUTION

- The two-phase Euler-Euler model was verified to be valid for the simulation.
- Under such a condition that MEL was 64 W/m^3, the flow pattern, UI, and local GL distribution of *Nn*=5 was more homogeneous than *Nn*=1 and *Nn*=4, the gas decentralized entrance was more effective than the centralized entrance for mixing. Besides, the analysis of 180° spacing of each symmetric nozzle in the digester revealed that the highest mixing efficiency was achieved under the condition that the horizontal tangent of each nozzle formed 45° to the reactor wall.