University College of Southeast Norway

Image analysis to measure settling characteristics of granular sludge

F.A.Tassew*, W.H.Bergland, C. Dinamarca, R.Bakke

Department of Process, Energy and Environmental Technology
University College of Southeast Norway
Kjølnes ring 56
3918 Porsgrunn
Norway
fasil.a.tassew@usn.no

Introduction

Granule characteristics may change with time and growth conditions. It is important to monitor such changes, especially settling behavior to avoid biomass loss. The objective of this paper is to establish a method that uses microscopic image analysis as a tool to monitor morphology and use this to estimate settling velocity of granules.

Material and Methods

Five samples were used: two from industries and three from lab reactors ('Top', 'Middle', 'Bottom'). Images of at least 200 granules were taken using a stereomicroscope. Image processing was used to generate data about perimeter (P), area and shape factor (SF) of granules (equations 1 - 4). Equivalent diameter (D_g) of granules were calculated and used to estimate theoretical settling velocity of granules (V_t). A high-speed camera (50 fps) and a settling column were used to measure experimental settling velocity.

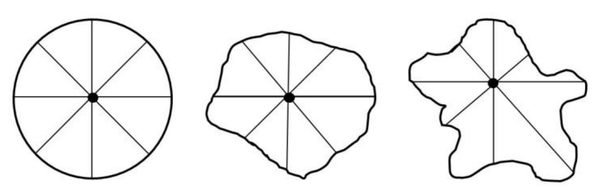

Figure 1. Shape factor measurement examples showing centroid and eight radii for each granule, with increasing shape factor left to right.

$$D_g = \frac{P}{\pi}\left[\frac{1}{1+\sqrt{\frac{2\pi SF}{P}}}\right] \quad (1) \qquad V_t = 0.781 f_w \left[\frac{D_g^{1.6}(\delta_g-\delta_f)}{\delta_g^{0.4}\mu_f^{0.6}}\right]^{0.714} \quad (2)$$

$$SF = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}|A_i - A_{mean}|^2} \quad (3) \qquad A_{mean} = \frac{1}{N}\sum_{i=1}^{N} A_i \quad (4)$$

A_{mean} average distance from centroid to perimeter
A_i distance from centroid to perimeter
f_w correction factor for wall effect
N number of distances measured
g notation for granule
f notation for fluid
μ viscosity
δ density

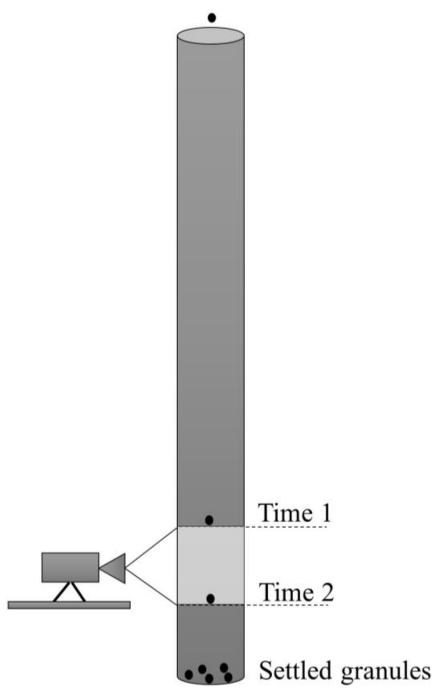

Figure 2. Settling column and camera setup

Result and discussions

All samples show different size distributions but similar pattern.

Industry-2 and Top (from the lab reactor) have the most similar size distributions, while Industry-1 has much larger granules than the other samples.

Granule size increased from top to bottom in the lab scale reactor.

Sample	δ (Kg/m³)	Value	Mean	Median	St.Dv
Industry-1	1015	Measured	62	62	12
		Calculated	59	59	19
Top	1075	Measured	45	43	12
		Calculated	46	44	13
Middle	1075	Measured	59	52	23
		Calculated	57	58	17
Bottom	1070	Measured	68	60	24
		Calculated	63	60	16
Industry-2	1070	Measured	63	58	19
		Calculated	67	58	29

Table 1. Theoretical and experimental settling velocities and densities of granules.

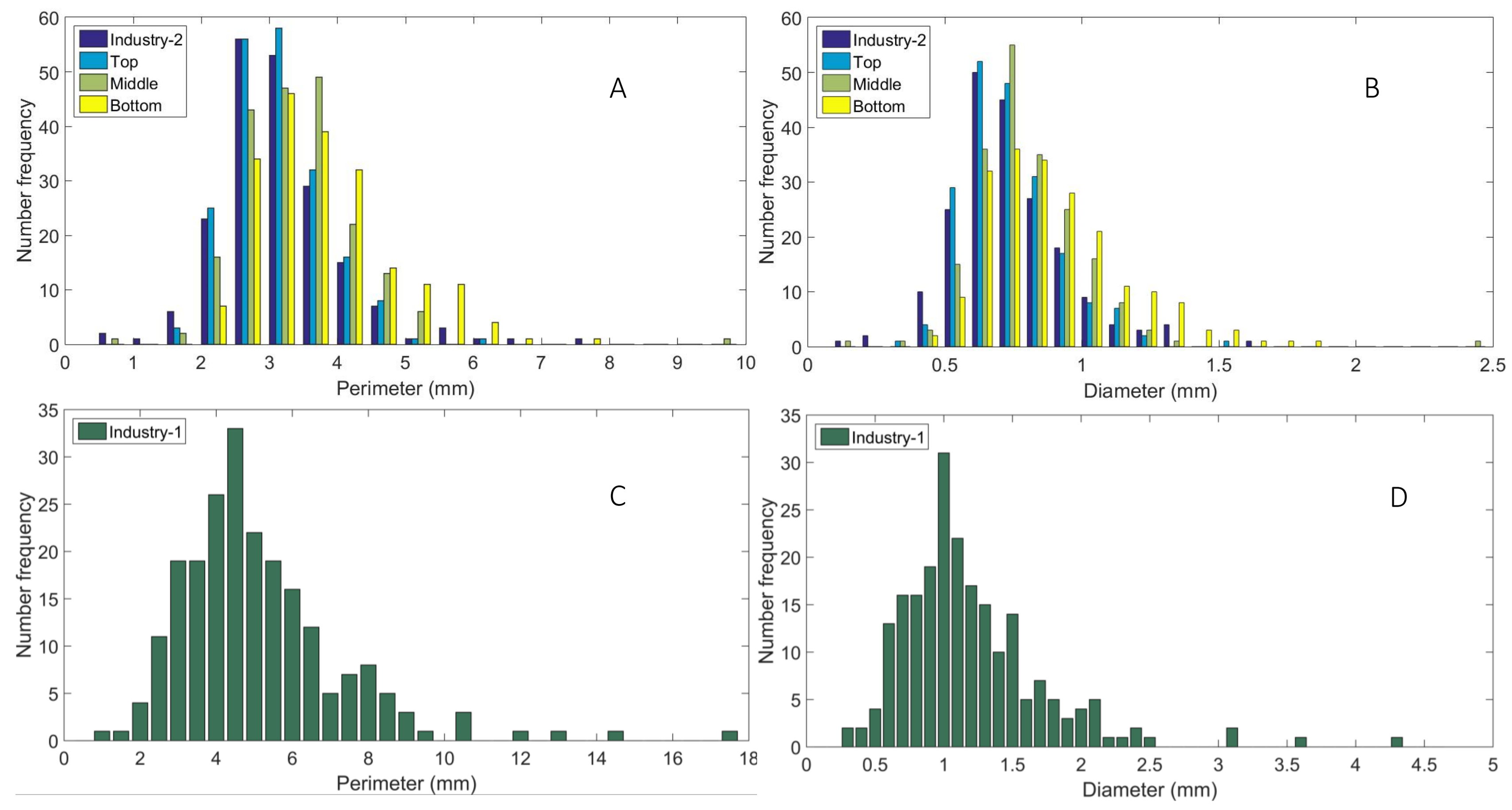

Figure 3. Size distribution of granules based on perimeter and diameter: A and B shows granules from lab reactor and Industry-2 while C and D shows Industry-1 granules.

- *The Top sample has the lowest calculated and measured settling velocity values. Both Industry samples and Bottom have settling velocities near 60 m/h.*
- *Settling velocity variations are best calculated for the Top sample while the calculations overestimate variations in the industry samples and underestimates in the Bottom and Middle samples.*
- *The relative errors between theoretical and experimental mean settling velocities are less than 8.5 % for all samples.*
- *Measured and calculated values increased with increasing Reynolds number.*
- *Agreement between the measured and calculated values are weaker at higher Re values*

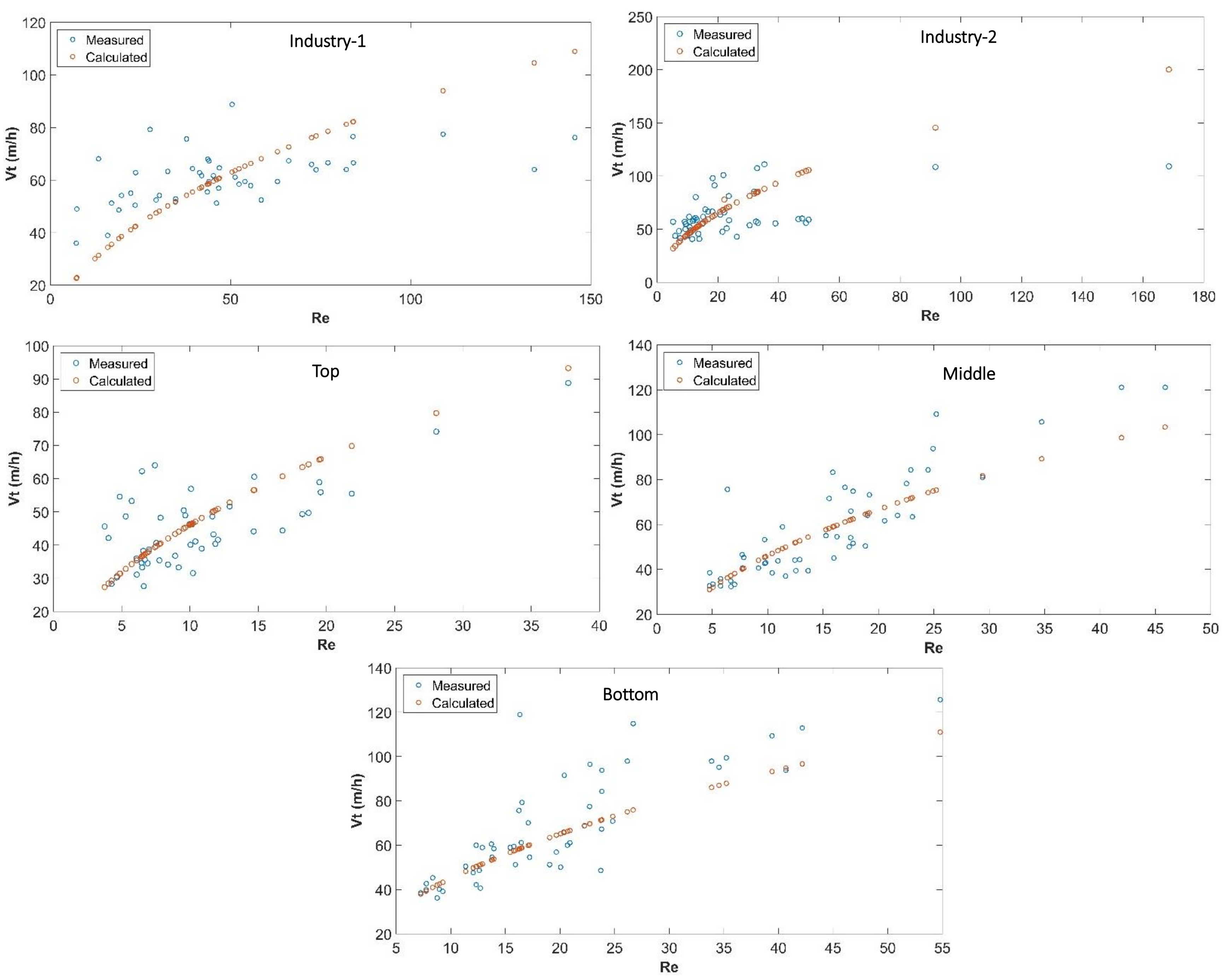

Figure 4. Comparison of theoretical and experimental settling velocities of granules with respect to Reynolds number.

Conclusions

Based on the above findings the following conclusions were made:

- Granules' settling velocity depends on shape, in addition to size and density.
- A shape factor and equivalent diameter, both measured by analysis of images from a stereomicroscope, can be used to calculate settling velocities of granule samples comparable to measured velocities.
- This method can be an efficient way to monitor settling velocity variations.

References

Ahn, Y.-H. and Speece, R. E. (2003). Settleability assessment protocol for anaerobic granular sludge and its application. Water SA, 29(4):419–426.

Alpenaar, A. and granular Sludge, A. (1994).

Characterization and Factors Affecting Its Functioning. PhD thesis, PhD Thesis, Wageningen University, The Netherlands.

Alves, M., Cavaleiro, A. J., Ferreira, E. C., Amaral, A. L., Mota, M., da Motta, M., Vivier, H., and Pons, M.-N. (2000). Characterisation by image analysis of anaerobic sludge under shock conditions. Water science and technology, 41(12):207–214.

Arsenijevi´c, Z. L., Grbavˇci´c, Ž., Gari´c-Grulovi´c, R., and Boškovi´c-Vragolovi´c, N. (2010). Wall effects on the velocities of a single sphere settling in a stagnant and counter-current fluid and rising in a co-current fluid. Powder Technology, 203(2):237–242.

Ataide, C., Pereira, F., and Barrozo, M. (1999). Wall effects on the terminal velocity of spherical particles in newtonian and nonnewtonian fluids. Brazilian Journal of Chemical Engineering, 16(4):387–394.

Bellouti, M., Alves, M., Novais, J., and Mota, M. (1997). Flocs vs granules: differentiation by fractal dimension. Water Research, 31(5):1227– 1231.

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