

# Similarities in the Hydrodynamic Operation of a Bubble Column with Aqueous Solutions of Alcohols and Salts

Stoyan Nedeltchev\*

*Institute of Chemical Engineering, Polish Academy of Sciences*

*Baltycka Str. 5, 44-100 Gliwice, Poland*

*\*Corresponding author: sned@iich.gliwice.pl*

## **Highlights**

- Flow regime identification in a BC based on new parameters
- Detailed statistical analysis of the gauge pressure fluctuations
- Distinction of the onset of a complete foaming state in aqueous solutions of alcohols
- Distinction of the onset of a slug flow regime in aqueous solutions of salts

## **1. Introduction**

Bubble column (BC) reactors are frequently used in the performance of oxidations, chlorinations, absorptions (with and without chemical reaction), methanol and Fischer-Tropsch syntheses, etc. A gas is passed through a distributor (porous plate or perforated plate), which forms bubbles in a pool of liquid. The BC performance is usually characterized by the gas holdup, mixing time, mass transfer time, heat transfer coefficient, etc. All these parameters depend on the prevailing flow regime (FR) in the bubble bed. That is why the development of reliable methods for FR identification is very important since it would help further in the establishment of accurate empirical correlations for predictions of the main transition velocities  $U_{trans}$ . The ultimate goal is to develop reliable FR maps.

## **2. Methods**

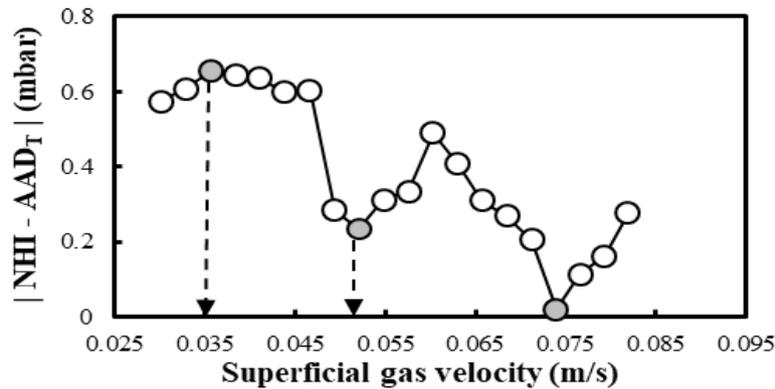
Gauge pressure (GP) fluctuations (10 000 points) were measured in a BC (0.1 m in ID) equipped with a perforated plate (96 orifices  $\times$   $\varnothing$  1 mm). The column operated at ambient conditions with aqueous solutions of alcohols and salt (NaCl). The GP sensor was positioned at an axial height of 0.65 m.

For the sake of FR identification two new and innovative parameters were developed. For this purpose, the GP fluctuations were subdivided into 10 intervals consisting of 1000 points. The average absolute deviation (AAD) in every interval was calculated. Then the summed AAD was defined as a sum of all 10 local AAD. In addition, the local probability that the individual AAD will be close to the summed AAD was calculated. The local information amount (IA) was defined as a negative logarithmic function from this local probability. The summed IA was defined as a sum of all local IA. Then the novel hybrid index (NHI) was expressed as the absolute difference between the summed IA and total AAD divided by the total IA. The NHI algorithm is clearly explained in [1].

In the second approach, the same idea of division of the GP signal into 10 intervals was applied. However, an error analysis was also performed. The average relative error (ARE) in each interval was calculated. Then the summed ARE was defined as a sum of all local ARE. In this alternative approach, the first difference is in the formulation of the probability. The dimensionless summed AAD was divided by the dimensionless summed ARE. Finally, again following the information entropy theory [2] the IA was calculated as a negative logarithmic function of the probability. It varied between 0 and 1 bit.

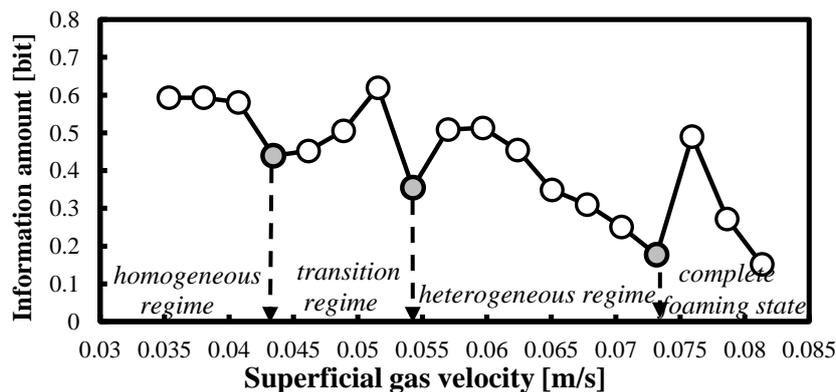
## **3. Results and discussion**

It was found that the results about the main  $U_{trans}$  in several aqueous alcohol solutions and one salt are very similar. **Figure 1** shows that in case of mixture of deionized water (DW) and 1-butanol (0.5 vol. %) the first well-pronounced local minimum occurred at  $U_g = 0.052$  m/s and it identified the end of the homogeneous FR. This critical  $U_g$  value is predictable by the correlation [3], which yields 0.046 m/s (13.2 % relative error). Since beyond 0.052 m/s a macro-circulation was observed, these operating conditions belonged to the heterogeneous FR. At  $U_g = 0.074$  m/s the end of the heterogeneous FR is distinguishable (see the second local minimum). Beyond this  $U_g$  value the complete foaming state prevails.



**Figure 1.** Identification of the main FR boundaries in 1-butanol (0.5 vol. %) mixed with DW and aerated by air

In case of low concentration (0.5 vol. %) of 2-pentanol in DW the IA profile (see **Fig. 2**) was capable of identifying the three main  $U_{trans}$  values based on well-pronounced local minima at  $U_g = 0.043$ ,  $0.054$  and  $0.073$  m/s, respectively. In Fig. 2 the first critical  $U_g$  value identified the end of the homogeneous FR, the second critical  $U_g$  value distinguished the end of the transition FR and the third one identified the onset of the complete foaming state in the bubble bed. Under that condition, it was visually observed that numerous small bubbles occupied completely the column's upper zone. No gross circulations were observed. In addition, the overall gas holdups were higher than 0.35.



**Figure 2.** Identification of the main FR boundaries in 2-pentanol (0.5 vol. %) mixed with DW and aerated by air

When the concentration of 2-pentanol in DW was doubled (1.0 vol. %), then the three  $U_{trans}$  values were identified at  $0.049$ ,  $0.063$  and  $0.073$  m/s, respectively. In case of aqueous solution of NaCl (1.0 vol. %) the two  $U_{trans}$  values were distinguished at  $0.047$  and  $0.074$  m/s, respectively.

#### 4. Conclusions

Based on two similar FR identifiers was demonstrated that the two main transition velocities in a BC operated with aqueous solutions of alcohols (1-butanol, 2-pentanol, etc.) and salt (NaCl) are comparable and predictable by an empirical correlation. By means of the second approach could be also identified the boundaries of the transition FR, i.e. it is a more sensitive parameter.

#### References

- [1] S. Nedeltchev, J. Katerla, E. Basiak, J. Chem. Eng. Japan 55 (2022) 201–216
- [2] H. Im, J. Park, J. W. Lee, ACS Omega 4 (2019) 1329–1343
- [3] S. Nedeltchev, S. Ookawara, K. Ogawa, J. Chem. Eng. Japan 32 (1999) 431–439

#### Keywords

Bubble column ; Gauge pressure fluctuations ; New regime identifiers ; Alcohols and salts