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A Review of Flow Maps to Validate and Develop Modelled Predictions

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PhD in Experimental Study of Counter-Current Two-Phase Flows in Annuli, School of Chemical Engineering

Project background and objectives

Flow regimes (Figure 1) are intrinsically linked to flow characteristics and pressure profiles. The objectives of this review are as follows:

1. **Collate existing experimental results**
2. **Review published experimental works**
3. **Validate previously developed models against a large data set**
4. **Develop a widely applicable prediction**

Figure 1. Flow regimes [1]

Methodology

1. A total of forty sets of experimentally determined results (flow maps) consisting of 4185 individual data points was collated
2. The most abundant and relevant data set was then evaluated in further detail using well known models published by Taitel et al. 1980 [2]

Results

The model developed by Taitel et al. 1980 was successfully validated using the data set (Figure 2). A confidence interval of 10% was added to the model to account for minor inaccuracies.

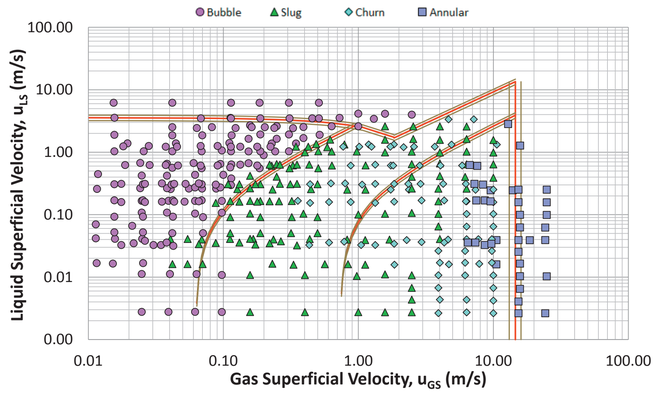

Figure 2. Collated flow map for co-current upward flow in a 51 mm I.D. vertical pipe

A non-dimensional solution was developed with the aim of accounting for variations in fluid properties within predictions (Figure 3).

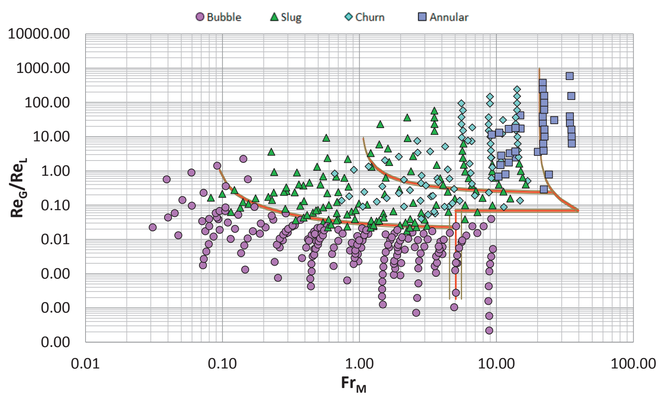

Figure 3. Non-dimensional solution flow map for co-current upward flow in vertical pipe

Discussion and Conclusion

The non-dimensional solution was found to perform similarly to the standard plot when considering air-water flows (Table1).

Table 1. Summary of air-water flow map accuracies including 10% confidence

Axis	Bubble	Slug	Churn	Annular	Overall
Superficial Velocity	96%	69%	63%	69%	79%
Fr_{SM} v Re_{SG}/Re_{SL}	96%	69%	63%	67%	79%
Data Points	223	153	120	48	544

When applied to air-silicone flows the flow maps provided differing accuracies (Table 2).

Table 2. Summary of air-silicone flow map accuracies including 10% confidence

Axis	Bubble	Slug	Churn	Annular	Overall
Superficial Velocity	60%	100%	57%	0%	64%
Fr_{SM} v Re_{SG}/Re_{SL}	0%	100%	100%	0%	75%
Data Points	5	7	14	2	28

Experimental results from non-air-water flows are limited and a conclusion cannot be drawn. Further investigation into this non-dimensional solution may be warranted.

References

1. Ghosh, S., Pratihar, D. K., Maiti, B., & Das, P. K. (2012). Identification of flow regimes using conductivity probe signals and neural networks for counter-current gas–liquid two-phase flow. *Chemical Engineering Science, 84*, 417-436. doi:10.1016/j.ces.2012.08.042
2. Taitel, Y., Bornea, D., & Dukler, A. E. (1980). Modelling flow pattern transitions for steady upward gas-liquid flow in vertical tubes. AIChE Journal, 26(3), 345-354. doi:10.1002/aic.690260304

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