Bubble Rise Velocity and Trajectory in Xanthan Gum Crystal Suspension

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Abstract:
An experimental set-up was used to visually observe the characteristics of bubbles as they moved up a column holding xanthan gum crystal suspensions. The bubble rise characteristics in xanthan gum solutions with crystal suspension are presented in this paper. The suspensions were made by using different concentrations of xanthan gum solutions with 0.23 mm mean diameter polystyrene crystal particles. The influence of the dimensionless quantities; namely the Reynolds number, *Re*, the Weber number, *We*, and the drag co-efficient, c_d, are identified for the determination of the bubble rise velocity. The effect of these dimensionless groups together with the Eötvös number, *Eo*, the Froude number, *Fr*, and the bubble deformation parameter, *D*, on the bubble rise velocity and bubble trajectory are analysed. The experimental results show that the average bubble velocity increases with the increase in bubble volume for xanthan gum crystal suspensions. At high *We*, *Eo* and *Re*, bubbles are spherical-capped and their velocities are found to be very high. At low *We* and *Eo*, the surface tension force is significant compared to the inertia force. The viscous forces were shown to have no substantial effect on the bubble rise velocity for $45 < Re < 299$. The results show that the drag co-efficient decreases with the increase in bubble velocity and *Re*. The trajectory analysis showed that small bubbles followed a zigzag motion while larger bubbles followed a spiral motion. The smaller bubbles experienced less horizontal motion in crystal suspended xanthan gum solutions while larger bubbles exhibited a greater degree of spiral motion than those seen in the previous studies on the bubble rise in xanthan gum solutions without crystal.

Zusammenfassung:
Ein experimenteller Aufbau wurde verwendet, um die Eigenschaften von Blasen bei ihrer Strömung durch eine Kolonne mit einer Suspension aus Xanthangummi und Kristallen visuell zu beobachten. Die Eigenschaften der aufsteigenden Blasen in der Xanthangummilösung mit suspendierten Kristallen werden in diesem Artikel vorgestellt. Die Suspensionen von Xanthangummilösungen mit Polystyrolkristallen, die einen mittleren Durchmesser von 0.23 mm besitzen, wurden mit unterschiedlichen Konzentrationen hergestellt. Der Einfluss dimensionsloser Größen, d. h. der Reynoldszahl *Re*, der Weberzahl *We* und des Drag-Koeffizienten c_d wird bei der Bestimmung der Aufstiegsgeschwindigkeit der Bläschen erläutert. Der Einfluss dieser dimensionslosen Gruppe zusammen mit der Eötvös-Zahl *Eo* der Froude-Zahl *Fr* und des Blasendeformationsparameters *D* auf die Aufstiegsgeschwindigkeit der Blasen und die Trajektorien der Blasen wird analysiert. Die experimentellen Resultate zeigen, dass die mittlere Blasengeschwindigkeit mit dem Blasenvolumen für Xanthangummikristallsuspensionen zunimmt. Bei hohen Werten von *We*, *Eo* und *Re* besitzen die Blasen eine kugelfömige Gestalt und eine hohe Geschwindigkeit. Bei niedrigen *We*, *Eo* und *Re* ist die Oberflächenspannung groß im Vergleich zu den Trägheitskräften. Die viskosen Kräfte haben keinen signifikanten Einfluss auf die Aufstiegsgeschwindigkeit der Blasen für $45 < Re < 299$. Die Ergebnisse zeigen, dass der Drag-Koeffizient mit der Blasengeschwindigkeit und mit *Re* abnimmt. Die Analyse der Trajektorien belegt, dass kleine Blasen eine Zigzag-Bewegung durchführen, während sich größere Blasen spiralförmig bewegen. Die kleineren Blasen führen eine geringere horizontale Bewegung in mit Kristallen supendierten Xanthangummilösungen durch, während größere Blasen eine stärkere spiralförmige Bewegung aufweisen als sie in vorherigen Studien mit Xanthangummilösungen ohne Kristalle beobachtet worden ist.

Résumé:
Un dispositif expérimental a été utilisé pour observer visuellement les caractéristiques des bulles en se déplaçant d'une colonne contenant la gomme de xanthane suspensions de cristal. Les caractéristiques de montée des bulles dans les solutions de gomme xanthane avec la suspension de cristal sont présentés dans le présent document.

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inertia forces had a strong influence on the bubble rise velocity. However, for the larger bubbles investigated (high *We* and *Re*), inertia forces governed the bubble rise velocity, and surface tension and viscous forces were shown to be less important. The effect of *Fr* on bubble rise velocity was found to be insignificant for the range of conditions studied. The results also showed that, as the *Re* increased, the drag co-efficient decreased resulting in increases in bubble rise velocity.

The trajectory results were able to demonstrate common trends for the different bubble sizes. The trajectory analysis showed small bubbles experienced less horizontal motion in crystal suspended xanthan gum solutions in comparison with the bubble rise in xanthan gum solution without crystal. This is due to the presence of crystal in xanthan gum solution which increased the solution viscosity. Larger bubbles produced more spiral motion in crystal suspended xanthan gum solutions as larger bubble experience more resistance on top and deform as their size increases. At low *We* and *Re* for smaller bubbles, the rising bubbles showed a zigzag trajectory, while larger bubbles at high *We* and *Re* exhibited spiral motion. The zigzag motion occurs due to an interaction between the instability of the straight trajectory and that of the wake produced by vortices. The results of this study have given important information and data of the entire flow characteristics of bubbles which could be used to develop a CFD model. This innovative predicted model can be used to gain a sound knowledge of mass and heat transfer operations in vacuum pans used in sugar mills.

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