Why do Guinness bubbles sink?

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ABSTRACT

Anyone who has ever tried Guinness or another stout beer knows that the bubbles in the glass appear to sink. This suggests that they are driven by a downward flow, the velocity of which exceeds the upward velocity of the bubble due to the Archimedean force. The existence of such a flow near the wall of the glass implies that there must be an upward flow somewhere in the interior. The mechanism of such a circulation is, however, unclear. In this work, we demonstrate that the circulation in a glass of stout or any other container with a bubbly liquid is determined by the containers shape. If it narrows downwards (as the stout glass does), the circulation is directed downwards near the wall and upwards in the interior. If the container widens downwards, the circulation is opposite to that described above.

1 Introduction

Bubbles in liquids normally float up due to the Archimedean force yet those in so-called stout beers appear to go down. Such counter-intuitive phenomena rarely occur in our everyday life, challenging the curiosity of both scientists and lay people.

Interestingly, even though the effect of bubbles sinking in Guinness is widely known and that the bubbles/liquid interaction in stouts has been examined before [1], no explanation of this puzzling phenomenon has been put forward so far. In this work, we shall first describe the properties of Guinness as a two-phase medium and explain the basic mechanism which drives bubbles in Guinness downwards.

2 Mathematical Modelling

Since we attempt to explain the downflow of bubbles in Guinness by the geometry of the container and not by a physical effect, we shall use the standard model for bubbly flows included in the COMSOL Multiphysics package, based on the finite element method. We shall not discuss this models physical foundations, as they are described in detail in [2], but mention only that it assumes that the bubbles are all of the same size. In view of the problems axial symmetry, the axi-symmetric version of the model is used.

Two geometries were examined (see Figure. 1): a pint and an anti-pint, i.e. the pint turned upside-down. In both cases the initial distribution of bubbles was uniform. The results of typical simulations are shown in Figure. 1. One can see that an elongated vortex arises near the sloping part of the pint

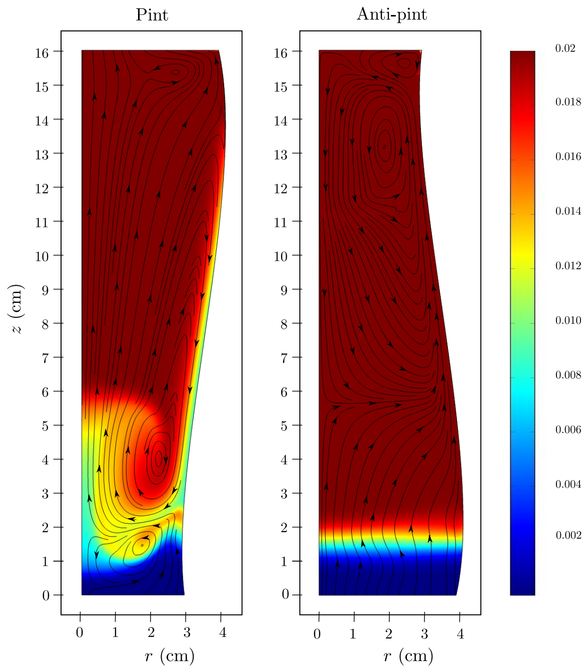

Figure 1: Streamline patterns at 4 seconds

container, resulting in a downflow of bubbles along the wall. A similar vortex also exists in the anti-pint, but it rotates in the opposite direction and, thus, causes an upward flow.

The latter results can be explained using the same kinematic argument as those for the pint geometry: if the container widens downwards, bubbles travel towards the wall (as illustrated in Figure. 1 (right)). This increases the near-wall density of bubbles and, thus, the upward drag applied to the liquid, resulting in an upward flow.The above argument, for both pint and anti-pint, is corroborated by the cross-sections of the bubble density and velocity shown in Figure. 2.

References

[1] M. Robinson, A. C. Fowler, A. J. Alexander and S. B. G. O'Brien, Waves in Guinness, Physics of Fluids 20 (6), 2008.

[2] M. Manninen, V. Taivassalo, On the mixture model for multiphase flow, Valtion teknillinen tutkimuskeskus, 1996.

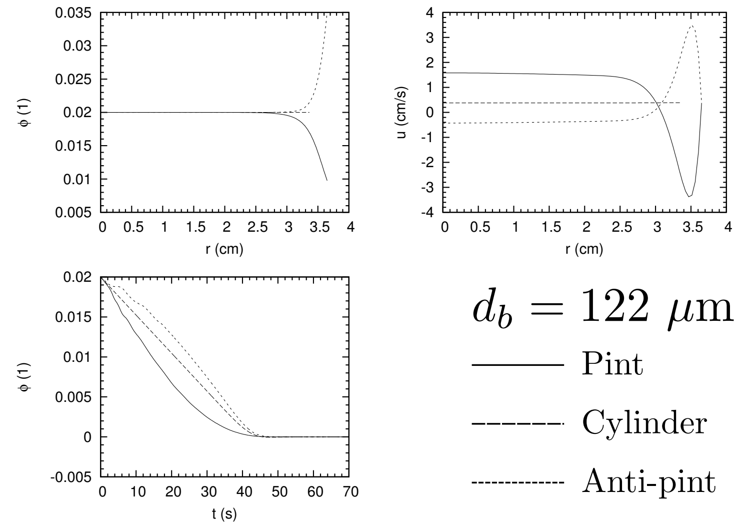

Figure 2: Velocity/voidage cross-sections and average void fraction