392d Experimental and Theoretical Study of Flow and Sedimentation of Tubular Centrifuge for Bioseparation

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This paper presents a theoretical and experimental study on the flow and sedimentation of tubular centrifuge as widely used for many decades in bioseparation from separating E coli and yeast to separating presently mammalian cells. These types of centrifuges operate between 5000g to 20,000g, and manual to automatic solid-discharge mechanism are offered depending on the model and design.

The flow field to a high-speed tubular is essentially two-dimensional under strong influence of the rotating flow with feed suspension concentrating near the surface of the liquid annular pool in a thin "boundary" layer. A boundary layer model [1] was developed to scale-up the operating centrifuge. A key dimensionless Le (Leung) number embodies the flow condition (feed rate, pool depth), centrifuge geometry (length, bowl dimensions), and suspension properties (solid and liquid densities, liquid viscosity, hindered settling factor) are included.

In this paper, we present a rather striking experimental evidence visualizing this boundary layer flow using varies dye injection techniques. This was also confirmed earlier using CFD study. A biological suspension is introduced to a test tubular centrifuge of 175 mm diameter operating at rather lower G-force for test purposes. The solids capture is quantified for various feed rates and two different G-forces. The 1998 Leung model is further refined to include a uniform distribution of particles across the feed layer instead of concentrating at a fixed radius. This improved boundary layer model is then compared with experiments described in the foregoing with excellent agreement.

Furthermore, a new proprietary design on a tubular centrifuge has been developed altering the flow pattern to improve solid recovery and better centrate liquid with lower suspended solids. A new model was developed corresponding for this new design. Experiments carried out using this new design centrifuge indeed confirm that solid capture is higher at a given feed rate as compared with conventional tubular design. Also the new theoretical model also predicts this higher experimental capture rate extremely well.

Keywords:

Centrifugation, biopharmaceutical, tubular, centrifuges, biotechnology, bioseparation, numerical simulation, optimization, scale-up, mammalian cells, yeast, bacteria.

Reference: [1] Wallace W. Leung, Industrial Centrifugation Technology, McGraw-Hill, New York, NY 1998.