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Design and Validation of Pressure Based Flow Rate Soft Sensor for Freeze-Drying

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ABSTRACT

Lyophilization or freeze drying is a process of removing water by sublimation. It is commonly used to extend the shelf life of drugs in the pharmaceutical industry. Because the process is costly and time consuming, precise and efficient pressure, temperature control and drying time estimation are required. It is the goal of freeze-drying to run at maximum capacity while staying within the safe zone by carefully controlling the sublimation rate. Currently, real time estimation of sublimation rate is still challenging. The technique available called Tunable diode laser absorption spectroscopy (TDLAS) is invasive, and requires major modifications. The current study focuses on exploring a new method of measuring the sublimation rate by using Computational Fluid Dynamics (CFD) and pressure sensors currently used. This involves both numerical analysis, using ANSYS FLUENT, and experiment of ice sublimation to find sublimation rate as a function of pressure drop across the pipe connecting the chamber and the condenser. The experiments were set up by increasing the shelf temperature in steps at certain pressure set points, and then the condenser pressure and sublimation rate were recorded. Using condenser pressure and chamber pressure as inputs for flow simulations, verification was done by comparing the simulated and experimental sublimation rates. The sublimation rates and pressure drops showed a positive nonlinear correlation, which was also dependent on the geometry of the freeze dryer. Each freeze dryer has different duct lengths and diameters. These parameters should be further investigated and included in the sublimation rate estimation in the future.

KEYWORDS

Freeze-drying, pressure based soft-sensor, in-process flow meter, fluid flow modeling, CFD