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Developing a framework to model the primary drying step of a continuous freeze-drying process based on infrared radiation

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Abstract

The continuous freeze-drying concept based on spinning the vials during freezing and on non-contact energy transfer via infrared (IR) radiation during drying, improves process efficiency and product quality (uniformity) compared to conventional batch freeze-drying. Automated control of this process requires the fundamental mechanistic modelling of each individual process step. Therefore, a framework is presented for the modelling and control of the continuous primary drying step based on non-contact IR radiation. The IR radiation emitted by the radiator filaments passes through various materials before finally reaching the spin frozen vial. The energy transfer was computed by combining physical laws with Monte Carlo simulations and was verified with experimental data. The influence of the transmission properties of various materials on the emitted IR radiation profile was evaluated. These results assist in the selection of proper materials which could serve as IR window in the continuous freeze-drying prototype. The modelling framework presented in this paper fits the model-based design approach used for the development of this prototype and shows the potential benefits of this design strategy by establishing the desired engineering parameters and by enabling the engineer to assess mechanical tolerances and material options.

Keywords: Continuous freeze-drying, Infrared radiation, View factor, Monte Carlo simulation

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