INVESTIGATION OF MINIMUM FLOW CONDITIONS FOR MILK PRODUCTS IN FALLING-FILM EVAPORATORS

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SUMMARY

A daily nuisance in the processing of milk in evaporators is *fouling*, an undesirable deposit formed on the heating surface. Breakdown of the liquid film in the evaporator tubes is a major cause of this fouling, which can generally be avoided if the flow of milk is above the minimum peripheral flow. With knowledge of the minimum flow, the plant running time can be extended resulting in reduced cleaning time or frequency. Also, the plant efficiency can be increased without causing film break-up.

There are few models in the literature to estimate minimum peripheral flow (Chung & Bankoff, 1979; Hoke & Chen, 1992; Hartley & Murgatroyd, 1964; Zuber & Staub, 1966) most of which are strongly dependent on the physical properties of the liquid. For many milk products, however these physical properties are not available in the literature.

This thesis presents a standard force-balance theory to determine at what flow rate a stable dry patch will occur. Methods of estimating the required physical properties of milk products are then presented. These cover density, viscosity, contact angle and surface tension over a range of total solids content and temperatures encountered in milk evaporation. These are then used to estimate the minimum peripheral flow within an industrial falling-film evaporator set for given milk products at normal operating conditions. These values are used in testing the minimum flows after each pass in the Powder 3 Plant of Kiwi Co-op Dairies Ltd, at Hawera.

The current operating flows and total solids after each pass in the Powder 3 Plant were tested for minimum flow violation with different milk products and at different times during a run. The milk products are evaporated close to the advancing minimum flow and violate it in certain passes of the evaporation unit. The steady state model of the Powder 3 Plant was validated against these experimental results. The model predicted well the total solids and the outlet flows from passes (except for the first two passes) early in a run but showed deviation after several hours. The deviations were likely due to constant heat transfer coefficients in the model. Therefore, the steady state model was only used to find flows and total solids after each pass close to start-up.

The validity of the minimum peripheral flow estimation was judged by two different methods. The first involved analysis of the heat transfer coefficients within an industrial evaporator set. The second investigated past operational data from an industrial evaporator set to determine where fouling had occurred and what the peripheral flows were at the time.

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