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# Thermo rheology of highly viscous products processed in a scraped surface heat exchanger

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## ABSTRACT

A novel type of a scraped surface heat exchanger has been developed specially for efficient heating, cooling and evaporation of highly viscous products like liquorice mass, concentrated fruit pastes. The overall heat transfer coefficient is found to depend on the rheological properties of the product.

## INTRODUCTION

A scraped surface heat exchanger is developed by Delta Process Engineering, Denmark to fill out a gap in processing equipment suitable for quasi stationary processing of highly viscous food products. The heat exchanger is paced in a system with a mixer and an evaporation unit which is called Push-Pull. The Push-Pull system is believed to replace conventional batch systems for production of concentrated fruit products, liquorices mass and the like which becomes stiffer during production. The paper demonstrates the Push-Pull systems performance and ability to process a highly viscous model fluid.

## MATERIAL AND METHODS

The novel type of a scraped surface heat exchanger is unique in the design and has been developed specially for heating, cooling and evaporation to improve efficiency of production of highly viscous products like liquorice mass, concentrated fruit pastes or any mass which experience a significant increase in viscosity level trough the production process.

The concept is build as a batch system working on a confined volume. The product is forced to pass the scraped surface heat exchanger using hydraulic pressure to overcome the pressure drop when the product becomes highly viscous. The heat exchanger is conical and heat is transferred to the product from two sides. The inner part can oscillate at slow pace to ensure the scraping of the surfaces and mixing.

The heat exchanger system has been tested in the heating mode only using starch slurry for a simplified liquorice product. The ingredients are mixed and heated through several passes through the scraped surface heat exchanger. The end temperature of the product is past the gelatinisation point for the starch in the slurry. The performance of the heat exchanger is recorded through calculation of the overall heat transfer coefficient.

The rheology of the product has been investigated of-line using a StressTech rheometer, Rheologica, Sweden equipped with air heating in order to produce a heating profile similar to that observed in the scraped surface heat exchanger. The investigation comprises shear viscometry at fixed temperatures and both viscometry and fixed frequency oscillation measurements through tests runs where the temperature is increased during the measurement.

## RESULTS

The results show that the heat transfer performance drops as would expected when the viscosity of the product increases through gelatinisation. This can be seen in Fig. 1 where the overall heat transfer is at the level of 400 W/($m^2$ K) until 80 °C where it drops below 180 W/($m^2$ K) before it increases again to around 280 W/($m^2$ K).

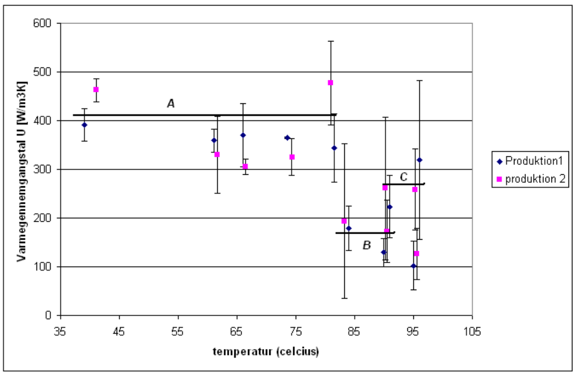


Figure 1. Over all heat transfer coefficient in the Push-Pull system depending on the temperature of the product

The decrease in the heat transfer performance is found to coincide with the gelatinisation of the product where the viscosity level increases significantly as seen in Fig. 2. Through the gelatinisation the heat transfer coefficient is small, however following some mixing the performance improves as the product becomes more homogeneous again.

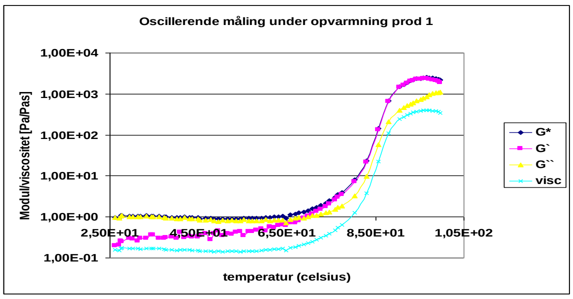


Figure 2. Temperature depended oscillatory measurement on the model fluid. Showing G', G'' and the viscosity.

The rheological results shown are from oscillation measurement. The corresponding measurement in shear viscometry mode shows a similar result. The oscillatory measurement is chosen to show that there is no change in the relation between viscous and elastic properties in the model fluid during heating.

A good correlation is found between the viscosity profile and the heat transfer performance. Thus a thermo rheology model can be constructed to describe the relation between the heat transfer performance and the product behaviour. The model (not shown) incorporates the parameters from the power law model into the equations for calculation of the heat transfer performance i.e. the Nusselt number. The model is validated to give good correlation to the experimental results.

## CONCLUSION AND FUTURE WORK

In conclusion the heat exchanger is found to yield good performance through the entire heat process and handles the viscosity increase in an excellent manner. Of cause the heat transfer performance drops as a result of the increased viscosity but not more than the process is still efficient. Overall heat transfer coefficients in the range of 180 to 400 W/($m^2$ K) are highly satisfactory when processing high viscous fluids. The heat transfer performance only drops to a very low level for a temperature range of 10 °C. Thus the new system is found applicable for heat processing of highly viscous products.

The future work will concentrate on applying the evaporation unit during processing and especially ways to describe the rheology of the product during this.


## ACKNOWLEDGMENTS

Thanks to Einar Dyhr, owner of Delta Process Engineering for letting us try out the prototype of the Push-Pull system. This indeed is a novelty to processing of highly viscous food products.