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Thermographic analysis of thin liquid films on a rotating disc: Approach and challenges

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ABSTRACT

This paper examines the temperature profiles and flow characteristics of thin liquid films on a rotating surface by means of an Infrared (IR) thermal imaging camera. The challenges of obtaining accurate temperature measurements using thermographic techniques, in particular for thin liquid films of varying thicknesses, are outlined in this study. The temperature profiles obtained by the Infrared camera are compared to those estimated by a theoretical model of disc/film heat transfer. It is found that the theoretical model based on the disc average film heat transfer coefficient, h, estimated by the Nusselt theory overestimates the exit process liquid temperature measured by the thermal imaging camera by up to 67% for water as the process fluid. Better agreement is generally obtained when Therminol SP oil is used as the process fluid. The reasons for the deviation between the theoretical and measured temperature profiles are attributed to a variety of factors such as significantly overestimated *h* values which affect the theoretical model and incorrect emissivity values which affect the IR temperature measurements. In spite of these limitations in the quantitative analysis, the use of the thermal imaging camera provides an excellent platform for qualitative analysis of liquid film flow in highly accelerated centrifugal fields whereby the flow path and wave characteristics on a rotating disc are visually observed to change significantly as the disc speed, fluid flowrate and viscosity are varied. The effects of increased disc speed and reduced feed flowrate on improving the heat transfer efficiency are also clearly visible on the thermograms.

1. Introduction

The spinning disc reactor (SDR) is a classical example of successful process intensification [1] which offers enhanced mixing and heat/mass transfer performances [2]. SDRs are particularly favoured for carrying out inherently fast, highly exothermic reactions, such as polymerisation [3,4], as well as reactions requiring rapid mixing, for instance, crystallisation [5,6]. SDRs can also offer benefits to processes involving heat sensitive materials, due to very short, controllable residence times, typically in the range of 0.1–5 s. Various SDR designs available at Newcastle University are capable of operating in a wide temperature range of 5–360 °C and disc rotational speeds of 200–4000 rpm Processing film and disc temperatures are typically measured by thermocouples inserted through the rotating shaft via a slip ring assembly. Measuring the film temperature by this invasive technique requires the thermocouple to protrude through the film which may disturb the continuous flow of fluid, especially in the presence of a very thin film at the measuring point on the disc. Further, due to certain design limitations in some SDRs, the only temperature measurements available are provided by thermocouples immersed in the heat transfer fluid whereby the film temperature has to be inferred from such indirect measurements. In this study an IR thermal imager, which is capable of producing temperature measurements in a non-contact mode, was used to shed light on the SDR heat transfer capability and processing film temperature profiles.

2. Apparatus

The general operating principle of SDRs is based on generating high acceleration environments by rotating a disc surface, which in this study is a smooth stainless steel horizontally mounted plate (16 cm diameter), as shown in Fig. 1. The liquid feed streams (water, water and glycerol or oil as outlined in Table 1) are pumped into a well in the centre of the top surface of the disc. As the disc rotates the well acts as a reservoir system to enable uniform distribution of

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