



Experimental observation of surface morphology effect on crystallization fouling in plate heat exchangers[☆]

Chengwang Lei^{a,*}, Zhongxiao Peng^b, Thomas Day^b, Xinping Yan^c, Xiuqin Bai^c, Chengqing Yuan^c

^a School of Civil Engineering, The University of Sydney, Sydney, NSW 2006, Australia

^b School of Engineering and Physical Sciences, James Cook University, Australia

^c Reliability Engineering Institute, Wuhan University of Technology, China

ARTICLE INFO

Available online 18 November 2010

Keywords:

Crystallization fouling

Surface texture

Antifouling

Heat exchanger

ABSTRACT

In this study, stainless steel test plates with different surface roughness and textures, which are used as the heat transfer surface of a plate heat exchanger, are tested individually in calcium carbonate fouling experiments. The present experimental results clearly indicate a strong correlation between the surface roughness and the amount of crystallization fouling deposit. Through detailed image analysis, four stages of the formation of crystallization fouling are identified, and the impact of the surface morphology on the extent of crystallization fouling is described qualitatively.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Fouling is the accumulation of an unwanted layer of scale on a surface submerging in a fluid medium. Six different forms of fouling may occur in industrial applications, which include crystallization, particulate, chemical, corrosion, biological and solidification fouling [1–3]. Fouling is a highly detrimental process which has a significant negative impact on the performance of industrial systems. In industrialized countries, fouling costs have been estimated to be as large as 0.25% of the country's gross national product [3]. Therefore, significant effort has been devoted to fouling prevention and mitigation as well as the development of antifouling techniques.

Among the six different forms of fouling, crystallization fouling, which is common in industrial heat exchangers, is responsible for approximately 25% of the scale related issues. Inversely soluble salts such as calcium sulphate and calcium carbonate have been recognized as the most prolific forms of crystalline scale deposit in heat exchangers [1]. Crystallization fouling involves three basic fouling phases [2,3]. The first of the three phases of crystallization is called 'attainment of supersaturation'. Following supersaturation, nanometre scale clusters of dissolved salts then begin to form as nuclei, which become stable once they mature to a critical size. This phase is referred to as the 'formation of nuclei'. The final phase of crystallization is called 'growth of crystals', which involves subsequent development of a variety of larger, variably sized crystal shapes. Bansal et al. [3] revealed five circumstances under which supersaturation, and hence crystallization fouling can occur. In addition,

crystallization fouling is affected by factors such as flow velocity, heat and mass transfer, chemical composition of the fluid medium, and material properties of the surface, etc. [4].

The occurrence of crystallization fouling may dramatically reduce the performance of industrial heat exchangers. On one hand, the poor thermal conductivity of the scale deposit slows down the heat transfer rate through the fouled surface. On the other hand, the presence of the unwanted layer of scale deposit in flow channels produces an additional resistance to the flow and increases the pressure drop across the heat exchangers and thus the pumping power of the industrial processes. Accordingly, industrial heat exchangers are commonly overdesigned in order to compensate the loss of efficiency due to crystallization fouling [2]. This method of dealing with fouling is inefficient and uneconomical, and expensive cleaning and removal procedures are desirable at routine intervals.

Plate heat exchangers are among the most cost-effective types of heat transfer devices. They are comprised of flat, corrugated or finned plate-like heat transfer surfaces, which separate hot and cold process fluids, and they can be designed with single or multi-pass configurations in parallel or counter flow arrangements. The plates are generally designed as large as possible to maximize the heat transfer area. Plate heat exchangers are used for a wide range of applications, including food processing, space heating, refrigeration, central cooling systems, automotive applications, power plants, chemical plants, petrochemical plants, petroleum refineries and natural gas processing [5]. However, once fouled, plate heat exchangers become highly unreliable compared to alternative designs. This highlights the need for further study into the fouling of plate heat exchangers.

In the field of biofouling, extensive studies have explored the effects of various microtopographic surface parameters in marine environments, and green and biomimetic antifouling techniques

[☆] Communicated by W.J. Minkowycz.

* Corresponding author.

E-mail address: Chengwang.Lei@sydney.edu.au (C. Lei).