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Investigation of adhesion of $CaCO_3$ crystalline fouling on stainless steel surfaces with different roughness ☆

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ABSTRACT

Fouling adhering experiments on AISI 304 stainless steel surfaces with different roughness had been performed in boiling supersaturated calcium bicarbonate solution. The effect of surface roughness on adhesion of fouling is limited, and the adhesion of fouling does not have a simple linear relationship with the surface roughness of samples. The surface with roughness in middle is more easily induced to form "transitional interface" which connects the fouling and matrix surface. It is also found that the crystalline types of fouling are changed in the fouling process due to the variation of metallic ions in reaction solution.

1. Introduction

Calcium carbonate is the typical fouling adhered on the surface of heat exchangers in China. Its adhesion depends on two classes of parameters: physicochemical properties of water solution (types and concentration of metal ions) and heat transfer surface properties (the surface free energy, surface roughness and so on). Among the surface properties, the reports focused on the surface roughness are limited.

In the previous studies, the experimental conclusions are apparently contradictory. Keysar et al. [1] showed that the adhesion strength of the fouling layer on the mild steel surface was remarkably influenced by the degree of surface roughness. However, in recent literature, Al-Anezi et al. [2] showed the stainless steel sample with Ra = 0.33 μm had the lowest adhesion while sample with Ra = 0.038 μm was secondary. Surprisingly, sample Ra = 0.12 μm, whose roughness is in the middle, had the highest adhesion.

On the other hand, this problem confused the study of the fouling forming mechanism. The net force of interaction between fouling and the surface has been described predominantly by the sol particle interactions in terms of colloid chemistry [3]. Furthermore, studies on the fouling mass transfer modeling focus mainly on macroscopic particles, such as Kern–Seaton Model. In spite of few special cases [4], most studies have proved that the surfaces with higher surface free energy would prompt the adhesion of crystalline fouling. These conclusions have been widely used to further explore anti-fouling surface materials [5]. However, fouling modeling based on the above theories cannot predict the effect of surface roughness on the precipitate fouling precisely. Förster and Bohnet [6] argued that mechanical forces at the interface crystal/heat transfer surface are responsible for discrepancies between reality and theory which is described by current models. In fact, the idea of "mechanical adhesion" was put forward in 1925 by Mcbain and Hopkins [7] and has been substantiated unreasonable by empirical study by Packham and Johnston [8]. Besides the research on the $Ca_{1-x}Mg_xCO_3$ [9] solubilities formed in calcite growth in the presence of Mg^{2+}, few researchers noticed the application of quantum mechanical theory and lattice structure in the field of fouling. In the previous studies, one important problem is ignored, that is, whether the crystal type of fouling is changeless in the fouling process. In other words, it is not clear whether the type of crystalline fouling will be affected by the surface corrosion or oxidation. At least, no opening literatures reported this issue.

In our previous studies, we have reported "transitional interface" connecting fouling and matrix, and this "transitional interface" behaves selective absorption, that is, fouling tends to grow on it more easily if fouling has similar lattice structure and parameters as the "transitional interface" [10]. This "transitional interface" may be the corrosion or oxidation products of the metal matrix. In the present work, the adhesion behavior of $CaCO_3$ crystalline fouling on AISI 304 stainless steel samples with different roughness was studied by using fouling weight measurement. Furthermore, the change of crystalline type of fouling was tracked.

2. Experimental procedures

In order to minimize the effect of oxide layer on the fouling adhesion, the stainless steel AISI 304 samples with a size of 25 mm × 25 mm × 0.8 mm were employed as measured specimen. The samples were firstly prepared by wire-electrode cutting, and then

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