GRAPHITE-BASED HEAT EXCHANGERS FOR FOULING CONTROL IN DAIRY INDUSTRY

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Introduction

Fouling of heat exchangers is a major problem in the dairy industry. Deposits indeed produce a thermally insulating layer over the surface of the heat exchanger that decreases the heat transfer toward fluids and increases the pressure drop. Additionally, fouling can seriously affect the quality of food products by favoring the development of harmful bacteria, and thus increase the costs and environmental impacts because thorough cleaning procedures have to be used. In this context, fouling control solutions are thus required. The present work thus aimed at testing graphite-based materials to heat exchangers for the dairy industry. The fouling behavior was analyzed for four commercial graphite plates, submitted to pasteurization conditions in a pilot pasteurizer.

Materials and Methods

Four commercial graphite plates were kindly provided by Mersen (Pagny-sur-Moselle, France) and tested as surfaces for heat exchangers for the dairy industry. They were: (i) pure extruded graphite (EG); (ii) pure isostatic graphite (IG); (iii) extruded graphite impregnated with phenolic resin (IEG); and (iv) isostatic graphite impregnated with the same resin (IIG). A control material, presently used in true exchangers for milk pasteurization, was 316L 2B stainless steel (SS) (Sapim Inox: Lens, France).

The surface properties were characterized in terms of surface energy by using a drop shape analyzer and in terms of roughness by contact profilometry.

Industrial tests were carried out on a small plant (scale ~ 1/10), using two-plate heat exchangers (V7 model from Alfa-Laval-Vicarb, France) in a counter-current configuration. A model fluid mimicking milk was used, based on a 1% whey protein concentrate (Promilk 852 FB1, Ingredia: Arras, France) solution in reverse osmosis water, in which the calcium concentration was adjusted to 100 ppm by addition of $CaCl_2$ (Sigma Aldrich).

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Results and Discussion

The properties of the materials surfaces: water contact angle (WCA), surface energy (SFE), arithmetic mean roughness (Ra) and waviness (Wa) prior to any fouling test are given in Table 1.

Table 1. Surface parameters

Name	Grain size (µm)	WCA (°)	SFE ($mN.m^{-1}$)	Ra (µm)	Wa (µm)
SS	-	89.7 ± 4.8	32.1 ± 9.0	0.11 ± 0.01	0.05 ± 0.01
IG	20	*	*	0.18 ± 0.04	0.06 ± 0.02
EG	800	*	*	1.25 ± 0.67	0.77 ± 0.48
IIG	20	82.2 ± 3.6	44.7 ± 0.6	0.06 ± 0.01	0.02 ± 0.00
IEG	800	71.5 ± 5.3	44.2 ± 2.7	0.32 ± 0.15	0.19± 0.12

*The instant spreading / absorption of the liquid droplets prevented the measurement of the contact angle by using the drop shape analyzer.

Graphite is traditionally known to be hydrophobic with WCA within the 75 – 95° range[1]. The differences of SFE between SS and graphite plates were not that high. A similar result was reported elsewhere[2]. Ra and Wa were the lowest with the smallest grains, as well as in impregnated graphites. The Ra of the IG plate (1.25 µm) was found to be significantly higher than that of stainless steel (0.11 µm).

The coupons after fouling tests are shown in Fig.1. There was no obvious difference between the surfaces. The masses of deposit, expressed per unit area, are presented in Table 2.

Figure 1. Deposits before drying

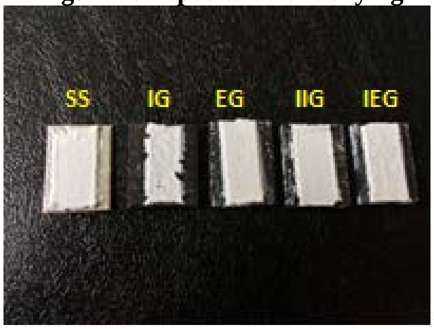

Table 2. Fouling density

Name	m_f (mg/cm^2)
SS	9.2 ± 0.2
IG	9.8 ± 0.3
EG	10.9 ± 0.3
IIG	12.1 ± 0.1
IEG	11.8 ± 0.3

The fouling densities of non-impregnated samples are similar and do not significantly differ from those of the stainless steel reference. Increasing Ra[3] and SFE[4] is known to favor fouling, and such a fact is consistent with the literature[2]. However, in the present case, the direct comparison of the data of Tables 1 and 2 did not allow establishing such trends.

Conclusion

In summary graphite-based materials, either in the form of extruded or isostatic graphite plates do not prevent fouling. Compared with SS, graphite-based composites do not show good anti-fouling performance. However, a comparison of these results with those published elsewhere[2], indicate that these surfaces have good performances in terms of reduced fouling adhesion upon rinsing. Such experiments are presently underway. Controlled surface modification of the graphite plates

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is also expected to give more insight into the relationships between surface texture and fouling and cleaning ability. This will be carried out in the near future.

References

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