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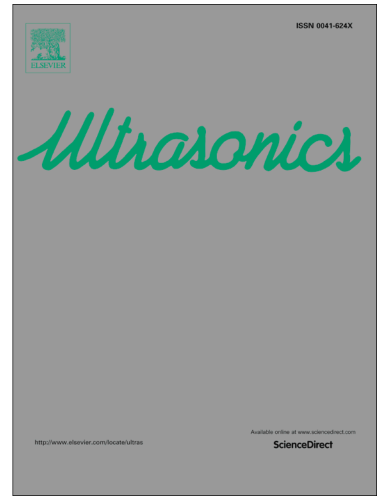

Contribution of the shear wave ultrasonic reflectometry to the stickiness measurements

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Contribution of the shear wave ultrasonic reflectometry to the stickiness measurements

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Today, non-invasive quantification of the adhesion of a deposit to a surface is always a challenge and, unfortunately, few tools are available in this area. This is an obstacle, in several industrial processes, to the identification of conditions limiting the fouling and to the establishment of eco-efficient cleaning strategies.

In this paper, a non-invasive ultrasonic technique was developed in the aim of characterizing the adhesion of viscoelastic fluids or solid deposited on a substrate. We adopted the idea that the more a deposit is difficult to clean the more adherent it is. From this point of view the value of the reflection coefficient of an ultrasonic shear wave informs us about the adhesion of the deposit on a surface.

A large bibliography on the adhesion measurement is given. Then the principle of ultrasonic test is presented and cares required for the measurement of the reflection coefficient are widely discussed. The ultrasonic reflection coefficients obtained with different controlled samples covering a wide range of interfaces (liquid / substrate, solid / substrate) are presented and compared with other indicators of adhesion. All the data on various samples showed that the ultrasonic test is a tool to discriminate non-destructively a large range of interface quality, allowing ranking according to the adhesive strength.

Keywords: Fouling/Cleaning, Ultrasonic Shear waves, Adhesion, Reflectometry

I. INTRODUCTION

Numerous practical applications in various industrial sectors require knowledge of the adhesive strength of soft materials on solid surfaces (paint, gluing, microfluidics, tribology, prosthetic implants, cleaning ...). In many industries, such as the food industry, knowledge of the adhesion of fouling deposits is a prerequisite for defining innovative treatment conditions and cleaning strategies.

Unfortunately, this quantification can seldom be predicted by simplistic theoretical considerations based on the direct molecular forces of attraction between the fouling deposit and the substrate.

Moreover, in the event of theoretical considerations, the energy associated with the detachment (or fracture energy) of these soft materials can be up to several orders of magnitude greater than the thermodynamic value. This dispersion could be mainly attributed to the energy dissipated in viscoelastic and plastic deformation, which is rarely taken into account in the molecular forces equilibrium, Zhao et al. [34].

Predicting the adhesive strength is not an easy task. Indeed, it has been demonstrated in several studies that mechanisms governing the bonding between soft materials and substrates depend on a large number and/or often unknown physico-chemical parameters (chemical composition of the soft material and the substrate, distribution of the roughness and energy properties of the surface ...), Akhtar et al. [1]. Consequently, measuring adhesion is often the preferred and only way to assess the adhesive strength.

Several approaches have been developed to measure adhesion of soft materials on a solid surface. These methods are intimately linked to the nature of the interactions which have to be characterized and consequently are very specific to the industry for which they were initially developed, Baldan [3]. Among the methods used to measure adhesion of soil and biofilms on substrates in the food sector, one may mention the dynamic gauging method which consists in sucking the deposit from the surface using a fluid jet and deducing the applied shear stress (N/m^2), Chew et al. [7], Hooper et al. [14], Saikhwan et al. [28], Gu et al. [12]. One can also cite the micro-manipulation technique which was developed in Birmingham to monitor micron or mm-scale forces during deposit removal in order to deduce the associated adhesive strength (J/m^2), Liu et al. [17], Liu et al. [18], Liu et al. [19], Akhtar et al. [1].

More recent papers attempt to quantify the adhesion interaction using AFM, Akhtar et al. [1], Shen et al. [29], Bonaccurso et al. [6], Fang et al. [10], Bohen et al. [5]. Data are presented in terms of the ratio between the force and the tip radius (N/m), which standardizes the results from different tips.

The major drawbacks of these methods are their invasiveness and the lack of possibilities of using them online. Moreover, for some of them (such as AFM for example), the scale of observation is so small that the local quantification obtained does not correspond to mean value which can be very different from the macroscopic value by several orders of magnitude.

Many studies have therefore attempted to overcome