

Chapter 16

Intelligent Expert System to Optimize the Quartz Crystal Microbalance (QCM) Characterization Test: Intelligent System to Optimize the QCM Characterization Test

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ABSTRACT

This chapter describes an approach to reduce significantly the time in the frequency sweep test of a Quartz Crystal Microbalance (QCM) characterization method based on the resonance principle of passive components. On this test, the spent time was large, because it was necessary carry out a big frequency sweep due to the fact that the resonance frequency was unknown. Moreover, this frequency sweep has great steps and consequently low accuracy. Then, it was necessary to reduce the sweeps and its steps gradually with the aim to increase the accuracy and thereby being able to find the exact frequency. An intelligent expert system was created as a solution to the disadvantage described of the method. This model provides a much smaller frequency range than the initially employed with the original proposal. This frequency range depends of the circuit components of the method. Then, thanks to the new approach of the QCM characterization is achieved better accuracy and the test time is reduced significantly.

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INTRODUCTION

The Quartz Crystal Microbalances are used as sensors to determine mass variations due to its oscillation frequency changes. Some of their advantages include: their possible use either in gas or liquid medium, high sensitivity, detection capability for density-viscosity or viscoelastic changes in a solution in the bound interfacial material; the possibility of their coating surface with a selective layer to be able to detect a specific substance, etc. (Cooper & Singleton, 2007; Kimmel, LeBlanc, Meschievitz, & Cliffler, 2012; Lucklum & Hauptmann, 2006; Marx, 2003). So, the range of applications includes: detecting vapors, chemical analysis, environmental pollutants, biomolecules, cells, etc. (Hunter, 2009; Lec, 2001; Speight & Cooper, 2012).

In order to achieve an adequate interpretation of the results given by the sensor, a correct measurement of the resonator electrical parameters is needed. This fact includes the development of electronic instrumentation systems and the appropriate model of the pair resonator-load choosing according to a specific application (Torres-Villa, 2013). For most applications, there are two essential parameters which measure offers the information that the sensor gives about the load properties. These two parameters are the frequency shift and the change on the series resistance in the well-established Butterworth–Van Dyke model (BVD) (Schröder, Borngräber, Eichelbaum, & Hauptmann, 2002). But, for a more detailed QCM characterization, it is also necessary to know other crystal parameters such as the parallel capacitance (García-Martínez et al., 2011; Martin, Granstaff, & Frye, 1991).

The QCM electronic interface development has been gradually improved in order to obtain continuous monitoring systems. Then, it can be integrated easily into smaller electronic boards, optimized for fast data measuring and also provides, at least, the two mentioned parameters (frequency shift and series resistance). A comprehensive review of them can be found in (Arnau, 2008a). Systems that offer a complete sensor characterization, like impedance analysis based methods, require costly instrumentation and elaborate fitting procedures to extract the crystal parameters of interest (Calvo, Ethenique, Bartlett, Singhal, & Santamaria, 1997; Martin et al., 1991). Usually, oscillators have been used due to their low-cost circuitry, as well as, the integration capability and continuous monitoring (Arnau, 2008a). Its main drawback is the poor stability of high resonant frequency under high loading conditions (Montagut et al., 2011). New techniques, such as phase locked loop circuits, are being implemented to combine the accuracy of expensive instrumentation and the simplicity of oscillator (Arnau, 2008a; Ferrari, Ferrari, & Kanazawa, 2008).

Creating models based on Intelligent Systems is frequently nowadays, with the aim to settle problems that are difficult to solve in a traditional way. In this sense, it is possible to cite several previous works where different models were created to achieve new goals, or to improve many things. The next works are examples of this fact: (Simic & Dimitrijevic, 2013) proposes the tactical ASR recycling planning model which can be used to assist Japanese vehicle recyclers, improving their profitability and ASR recycling efficiency; in (Kułakowski, Matyasik, & Ernst, 2014) is described foundations for design of a robot to conduct regular and automated audits of lighting quality in office buildings, with emphasis on the modeling its behavior; (Calvo-Rolle, Casteleiro-Roca, Quintián, & Meizoso-López, 2013) shows a hybrid system, where it is modeled the existing knowledge of the PID controller tuning in open loop and, with Artificial Neural Network, it is completed the rule based model that allow to choose the optimal parameters for the controller; (Ferreiro Garcia, Calvo-Rolle, Pérez Castelo, & Romero Gómez, 2014) describes the implementation of a supervision strategy implemented with Artificial Neural Networks associated to recursive rule based techniques.

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