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Optical fiber sensor temperature coded for concentration measurement of oil–biodiesel blends

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ABSTRACT

This work describes the operation of an optical fiber sensor employed in the determination of remaining oil concentration in oil–biodiesel blends. The sensor is based both on the sensitivity of a long period grating to changes in the surroundings refractive index and on the thermo-optical properties of oil–biodiesel blends. The sensor response is provided by a temperature coded interrogation unit that employs an auxiliary fiber Bragg grating. The standard metrological analysis of an optimized sensor showed that is possible to detect until 0.10% v/v of oil in oil–biodiesel blends.

1. Introduction

Nowadays, the environmental problems caused by the indiscriminate use of petroleum, the increasing pressure to reduce global emissions of greenhouse gases, the finite nature of fossil fuels and the growing of the eco-friendly market are leading researchers and industries to explore fuels derived from biomass conversion: the biofuels. In this scenario, biodiesel has been employed as a diesel additive to reduce levels of particulates, carbon monoxide and hydrocarbons from diesel-powered engines [1,2]. However, in order to achieve the biodiesel benefits, it is necessary to assure its quality in both manufacture and distribution networks. In general, the biodiesel is produced through a chemical process, the transesterefication, which converts triglycerides to alkyl esters [3–5]. This process results in methyl or ethyl esters (biodiesel) and glycerin as well as an incomplete reaction results in partial conversion of the triglycerides. In addition, oil can also be illegally added to biodiesel compromising the product quality [6,7].

The development of techniques to assess the quality of biodiesel has been a subject of some works in the last years [8,9]. Methods based on proton nuclear magnetic resonance [10,11], capillary gas chromatography [12,13], high-performance liquid chromatography [14] and direct infusion electro spray ionization mass spectrometry fingerprinting [15] have been reported in the literature. These techniques frequently require sample preparation, previous calibrations for analysis, long-time for analysis and high-cost equipments. Alternative and practical analytical methods have been proposed in order to allow field analysis along the biodiesel production, handling and storage processes. In a sense, near infrared spectroscopy [16], Fourier transform infrared [6,7] and Raman spectroscopy [6] present as possibilities for rapid, easy-to-handle, and cost effective monitoring of both transesterification reaction and biodiesel quality. However, accuracy and precision of these spectroscopy techniques typically depend on calibration models based on multivariate analysis such as principal component regression, partial least square regression or artificial neural network [6]. Refractive index measurements [17] and photothermal methods based on thermal lens spectrometry and open cell photoacoustic [18] have also been cited as alternative techniques for evaluating the biodiesel. Within this context, optical fiber grating sensors based on long period gratings (LPG) are useful and attractive tools for such purposes [19,20]. The main features of these devices are the small physical size, the immunity to electromagnetic interference, the electrical and chemical passivity, the low response time, the capability of integration with portable and automatic systems, and the high sensitivity to refractive index. Approaches proposed to interrogate LPG sensors can be classified into interferometric techniques and techniques based on intensity. Techniques based on intensity have a lower cost, which is an important factor for its field implementation.

In this work thermo-optical properties of oil–biodiesel blends and a sensor based on the refractometric properties of an LPG were used to identify the oil concentration in different oil–biodiesel blends. In the sensor set-up, interrogation is performed by an FBG connected in-series with the LPG. Despite the well known use of these devices for sensing, the new configuration presented in this work provides a sensor coded in temperature. The key for

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