Assessment of biodiesel-diesel blends with an optical fiber grating sensor

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***Abstract* — This work shows a method based on intrinsic optical fiber sensor for evaluating biodiesel-diesel blends. A long-period grating refractometric sensor was used to detect the biodiesel volumetric concentration in biodiesel-diesel blends. For this, all biodiesel-diesel samples were diluted in cyclohexane in both 1:1 and 1:2 proportions. The following metrological characteristics were obtained: calibration curve, sensibility curve, resolution curve, conformity, repeatability, reproducibility, combined standard uncertainty and expanded uncertainty. The expanded uncertainties obtained for confidence level of 95.45 % were 3.66 % v/v and 5.94% v/v for 1:1 and 1:2 proportions, respectively.**

Keywords* – *Optical fiber sensor, long-period grating refractometric sensor, biodiesel-diesel blends.

I. Introduction

Biodiesel is a fuel typically produced from renewable sources such as vegetable oils, animal fats and/or frying oils, which accounts for its classification as biofuel. Technically, biodiesel is defined as a mixture of mono-alkyl esters derived from long fatty acids chains, which is usually obtained by a transesterification reaction. In this reaction, the fatty acids, in the presence of a catalyst, react with an alcohol, as methanol, obtaining glycerin as a by-product, which is removed from the final product [1,2,3].

In the past few years, the search for an energy source that is environmentally appropriated stimulated the scientific interest and motivated the biodiesel production, mainly because its combustion reduces atmospherics emissions such as carbon monoxide, particulate matter and aromatic hydrocarbons [4]. Besides the environmental advantages, the biodiesel production and use add value to the raw materials, promote industry development and employment expansion [5].

The chemical-physical properties of biodiesel allow the total or partial replacement of diesel, a non-renewable fuel derived from petroleum. The biodiesel-diesel blend is called BX, where X is the biodiesel volumetric concentration in the blend [6].

The biodiesel quality analysis and concentration determination in BX blends is usually made by means of gas-liquid chromatography (GLC), high resolution gas chromatography coupled to mass spectrometry (GC-MS), high performance liquid chromatography (HPLC), near-infrared spectroscopy (NIR) and nuclear magnetic resonance spectroscopy (^{1}H NMR) [7]. However, these techniques are expensive, present low portability and require a skilled operator, making it necessary to develop faster and more efficient methods [7]. The wide applicability of optical fiber intrinsic devices and their particular characteristics such as fast response time, electromagnetic immunity, reduced weight/volume and low chemical reactivity, have motivated the scientific community and its interests, particularly with regard to sensors capable of analyze and distinguish liquid substances properties [8]. Among these devices are LPGs (long period gratings), transducers which enable analysis of such substances due to its sensitivity to the surrounding medium refractive index [9].

Long-period gratings are fiber gratings which couples light from the fundamental core propagating mode to co-propagating cladding modes due to the induced periodic modulation of the refractive index of the fiber core, with periods ranging from 50 µm to 1 mm [9]. In the LPG, part of the optical power previously confined in the core is transferred to the cladding, which is scattered on the interface cladding/surrounding medium [9,10]. Due to power attenuation and cladding modes losses, there are attenuation bands in the grating transmission spectrum, centered at wavelengths that satisfy the following phase matching condition [9,10]:

$$\lambda_m = \left(n_{eff} - n_{cl}^m\right)\Lambda \qquad (1)$$

where λ_m is the dip resonance wavelength of the m-th cladding mode, n_{eff} is the effective refractive index of the core mode, n_{cl}^m is the effective refractive index of the m-th cladding mode and Λ is the grating period [9,10].

The effective refractive indices of cladding modes depend on the fiber cladding and core effective indices, and the resonance wavelengths change as the external medium changes. So, modifications in the fiber surrounding medium refractive index may be detected by means of resonance wavelengths shifts, making possible the LPG application in liquid substances refractive indices evaluation [11]. However, LPG refractive index sensitivity depends on the refractive index of the substance under evaluation, as well as on the cladding refractive index of fiber. When the surrounding

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