Refractometric optical fiber sensor for measurement of ethanol concentration in ethanol-gasoline blend

Gustavo Rafael Collere Possetti, Marcia Muller, José Luís Fabris[1]
Programa de Pós-Graduação em Engenharia Elétrica e Informática Industrial - CPGEI
Universidade Tecnológica Federal do Paraná - UTFPR
Curitiba, Brazil
[1]fabris@utfpr.edu.br

Abstract — **In this paper, an optical fiber device based on long period grating is applied as refractive index transducer to measure the ethanol concentration in ethanol–gasoline blends. The device metrological characteristics - response curve, sensitivity, resolution, conformity, repeatability, combined uncertainty and expanded uncertainty - were determined and compared with characteristics associated with an Abbe refractometer. For ethanol concentration ranging from 20 % to 40 %, the LPG combined uncertainty was 0.70 % and the expanded uncertainty was 1.70 %.**

Keywords - optical fiber sensor; refractive index measurement; long period grating; ethanol-gasoline mixture

I. INTRODUCTION

Gasoline is a complex mixture of liquid hydrocarbons, volatile and flammable, with physical and chemical properties that accounts for its high applicability in the field of fuels, especially as a source of energy for motor vehicles. The chemical structure of gasoline contains a variable number of carbon atoms associated with the formation of paraffins, isoparaffins, naphthenes, olefins or aromatics compounds [1]. However, the exact composition of gasoline depends on the characteristics of the raw material, on their production process, on its use as a final product and on the specifications imposed by regulatory agencies [1]. In Brazil, the gasoline produced at refineries can not be directly commercialized at gas stations. Brazilian law states an addition of anhydrous ethanol, with a volume percentage between 20 % and 25 %, to the gasoline distributed and commercialized [1,2]. Therefore, ethanol must be mixed with pure gasoline blend (gasoline A), in a controlled process, before the gasoline distribution by the refineries. This procedure is carried out at refineries, with the aid of large tanks.

Ethanol-gasoline blend (gasoline C) has some advantages over the pure gasoline blend. The inclusion of ethanol increases the fuel octane number, improves the thermodynamic performance of the product and provides better performance for combustion engines [3,4]. Furthermore, the combustion of ethanol-gasoline blend provides significant reduction in the emission of air pollutants, such as carbon monoxide, carbon dioxide and hydrocarbons [3,4]. Therefore, its use is indicated to reduce the greenhouse effect and to mitigate global warming. Another interesting aspect is that the ethanol comes from the fermentation of biomass (sugar cane in Brazil), a renewable natural resource [5]. The production of this biofuel is being promoted worldwide, mainly to compensate an energy demand created by the likely shortage of oil in the near future [5].

It is true that such benefits are conditioned to the production and use of a fuel with high quality that fulfills the specifications imposed by the legislation. However, the fuel may be illegally modified (adulterated) in order to maximize the profit derived from its sale [1,2,6]. This malpractice causes losses to the consumer, to the state and to the environment. In Brazil, one of the main forms of gasoline adulteration is the illegal addition of ethanol, in proportions higher than those stated by the legislation [1,2].

Aqueous extraction method is the standard test employed to determine the content of ethanol in the ethanol-gasoline blend [7]. Although widespread, this technique presents high response time (approximately 15 minutes) and low resolution. Besides, aqueous extraction method is subject to errors of parallax and also dependent on a skilled operator to its correct implementation. Therefore, the development of alternative tools able to perform the ethanol-gasoline blend analysis is of great interest.

Optical fiber sensors, such as the long period gratings (LPG), when applied as refractive index transducers, show unique properties that allows its use for such purposes [8,9]. Among its features are the electromagnetic immunity, the electrical passivity, non-chemical reactivity, the small physical size, low response time, as well as the possibility of wavelength encoding. Furthermore, these devices can present superior sensitivity, dynamical range and resolution characteristics when compared to conventional transducers and/or methods.

Some studies about the application of optical fiber sensors to determine the ethanol concentration in gasoline have been reported in the literature [8,10,11]. However, a comparison between the metrological characteristics of optical fiber sensors and traditional measurement systems is still incipient.

In this context, the aim of this work is the characterization of a LPG sensor as a tool to determine the content of ethanol in

This work is supported by CAPES, CNPq, FINEP, Fundação Araucária and ANP (PRH10-UTFPR).