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Measuring the refractive index of crude oil using a capillary tube interferometer

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Abstract

A method for measuring the refractive index of low-transparent crude oils using a capillary tube interferometer is described. The method is based on analyzing the resulting transverse interference fringe patterns in terms of their positions with respect to the lens/capillary tube interferometer. The refractive indices of seven blended crude oils of low transparency were measured with accuracy of up to six decimal digits and were related to the API gravity of the oils. The ray tracing inside the capillary tube is explained and the transverse bell-shaped interference fringes are interpreted.

Keywords: Interferometry; Refractive index; Non-fractionated crude oil

1. Introduction

The refractive index is an important optical parameter for crude oils that is used in various calculations related to their specific compositions [1], in measuring oil slick thickness [2], and in a number of industrial applications such as predicting the onset of asphaltene precipitation [3] and measuring the solubility parameter [4]. However, there has been no formal endorsement for the refractive index to be used as a true identification parameter for non-distilled (non-fractionated) crude oil. The reason behind this has to do with the low transparency and the high volatility characteristics of crude oils in addition to the lack of a simple measuring method that can report their refractive indices with adequate accuracy. Refractometric methods, for example, can attain accuracy in the vicinity of 10^{-4} only, and they are suitable only for the transparent fractions of crude oils (light fractions). They cannot be used, however, to measure the refractive indices of the non-fractionated crude oils directly because of the low-transparent nature of these oils. In such cases only estimates of these refractive indices can be given by extrapolating data from several oil/hydrocarbon mixtures of these crude oils [4].

To measure the refractive index of liquids with accuracy better than 10^{-4}, on the other hand, interferometric techniques must be used instead. The literature is rich of different interference-based methods for measuring the refractive index of liquids [5–15]. However, the majority of these methods require a reference sample, and they are either not suitable for low transparent samples or they employ complicated setups that require a number of optical components and delicate alignments.

In the present work we describe a simple interferometric method for measuring the refractive index of low-transparent non-fractionated crude oils, which require neither a reference sample nor an elaborate setup. The method was recently developed to examine optical fibers [16,17], and has been modified in this work to include capillary tubes filled with crude oil samples in place of the optical fibers. It differs from the other capillary-tube methods in that the laser beam impinges on the capillary tubes in a form of a sheet that covers the whole width of the capillary tubes as opposed to a single narrow beam hitting particular areas. Consequently, the transverse interference fringes will be formed in a vertical arrangement with locations directly

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