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Research Article

Partial Least Squares (PLS) Integrated Fourier Transform Infrared (FTIR) Approach for Prediction of Moisture in Transformer Oil and Lubricating Oil

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Fourier transform infrared (FTIR) spectroscopy has been advocating a promising alternative for Karl Fischer titration method for quantification of moisture in oil. This study aims to integrate partial least squares regression (PLSR) approach on FTIR spectra for prediction of moisture in locally accessible transformer oil and lubricating oil. The oil samples spiked with known moisture concentrations were extracted with acetonitrile and subjected to analysis with an FTIR spectrophotometer. The PLSR model was built based on 100 training/test splits, and the prediction performance was measured with the percentage root mean squares error (% RMSE). The range of concentration studied was between 0 and 5000 ppm. The marker region of moisture was found at 3750–3400 and 1700–1600 cm^{-1} with the latter demonstrating a better predictive ability in both lubricating oil and transformer oil. The prediction of moisture in lubricating oil was characterized with lower % RMSE. At concentration less than 700 ppm, the prediction accuracy deteriorates suggesting poor sensitivity. The PLSR was implemented on IR spectra of a set of blind samples, verified with Karl Fischer (for transformer oil) method and Kittiwake (for lubricating oil) method. The prediction was encouraging at concentrations above 1000 ppm; at lower concentrations, the prediction was characterized with high percent error. The algorithm, validated with 100 training/test splits, was converted into an executable program for prediction of moisture based on FTIR spectra. This program can be used for prediction of other substances given that the marker region is identified. FTIR can be used for prediction of moisture in oil nevertheless the sensitivity and precision is low for samples with low moisture concentration.

1. Introduction

Moisture analysis is a routine monitoring activity for utility companies. The presence of moisture in transformer oil and lubricating oil will lead to break down of transformer and machinery. In transformer oil, moisture reduces its dielectric strength whilst in lubricating oil, it affects the oil viscosity causing corrosion to the machinery. Conventionally, the moisture in oil is determined using the Karl Fischer titration method. The method demonstrates sensitivity as low as 10 ppm; however, it is expensive involving various solvents and is time consuming [1, 2].

Fourier transform infrared (FTIR) spectroscopy has been advocating a promising alternative for quantification of moisture in oil, integrating partial least squares regression (PLSR). This technique has been employed for lubricating oil [3–7], transformer oil [8, 9], fuel oil [10], turbine oil [11], and biodiesel [12] with promising sensitivity as low as 50 ppm [6]. The advantage of FTIR is that it allows rapid analysis with minimal sample preparation and is inexpensive. It also permits on-site monitoring for application of utility oil nevertheless the quantification is oil-specific, requiring individualised calibration.

In this study, we employ the PLSR approach on FTIR spectra for prediction of moisture in locally accessible transformer oil and lubricating oil. The model was validated based on exhaustive training/test splits and was applied on a set of blind samples, verified with Karl Fischer and Kittiwake