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AUTOMOBILE OILS PARAMETERS PREDICTION BY SPECTRAL CHARACTERISTICS[1]

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Abstract: *Determination the parameters of motor oils in the laboratory requires specialized equipment, multiple operations in carrying out the analysis and experience of the technologist who performs it. Modern research in the field of rapid and non-destructive determination of automotive oil indicators is mainly related to the use of spectral characteristics in the near-infrared (NIR) passage using a cuvette. The disadvantage of this method is that it requires preliminary procedures for the preparation of the measurement samples. The use of spectral characteristics in the NIR area requires the use of detectors and light sources that can measure in fewer steps than the more common and accessible devices operating in the visible field of the spectrum. The report examines the possibility of predicting the physico-chemical parameters viscosity and density of automotive oils using their spectral characteristics in the visible area of the spectrum. The results show that the oil density can be predicted with an accuracy of 74% and the viscosity at an accuracy of 85% with low error rates of 2-9% in the range 520-660nm. The results obtained can be used in the design of spectrophotometric sensor devices operating in the visible area of the spectrum for rapid and non-destructive determination of physico-chemical parameters of automotive oils.*

Keywords: *Automotive oils, Spectral characteristics, Partial least squares regression, Physico-chemical indicators.*

INTRODUCTION

In recent years, a number of studies have been made in the development and application of technical tools measuring in a non-contacting way the properties and composition of automotive oils. The operating principles of the devices have being developed are optical, ultrasonic, using gas sensors (Paiva et al., 2015).

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As a preferred method, optical measurement techniques are required. The advantages of these methods: devices that have a simplified construction, facilitated maintenance, low cost of equipment used. A major step in the development of such optical devices is the evaluation of the separation of different automotive oils from one another by various informative features of the spectral characteristics such as wavelengths, coefficients obtained by reducing the volume of data. In addition, the ability to predict different physical and chemical parameters of oils determined in laboratory conditions and requiring specialized equipment, a variety of analytical operations and the experience of the laboratory performing the analysis (Baycheva, 2016). Recent studies in this area are mainly related to the application of spectral characteristics in the near infrared (NIR) area using a cuvette (Nguele et al., 2014; Hirri et al., 2017; Pinheiro et al., 2017). The disadvantage of this method is that it requires preliminary procedures for the preparation of the measurement samples.

The use of spectral characteristics in the NIR area requires the use of detectors and light sources that can measure in fewer steps than the more common and accessible devices operating in the visible (VIS) area of the spectrum.

The purpose of the report is to verify the possibility of predicting physicochemical properties of automobile oils according to their spectral reflectance characteristics in the visible area of the spectrum.

MATERIAL AND METHODS

5 types of automobile oils were used, each of 4 samples – motor, hydraulic, gear oil and rapeseed oil (the rapeseed oil is used as a fuel), purchased commercially. In Figure 1, the automotive oils used, conventionally referred to as oil1, oil2, oil3 oil4 and oil5, presented in general terms.

Rapeseed oil, oil1 | Transmission oil, oil2 | Engine oil, oil3 | Sunflower oil, oil4 | Grape seed oil, oil5

Fig.1. Automobile oils – general view

The obtaining of the spectral reflection characteristics is by a visible spectrophotometer (VIS) presented in (Zlatev, 2016) and mathematical dependencies mentioned in (Glassner, 1989; Smits, 2000). Settings were used: observer 2^o (Stiles and Burch 2^o, RGB (1955)) and D65 (average daylight with UV component (6500K)). From each sample, 20 spectral characteristics were measured.

Measurements were made at room temperature 20-22^{o}C and relative humidity 49-51RH%.

Table 1 shows the mean values of viscosity and density of automobile oils studied under the specified conditions.

Table 1. Automobile oils parameters

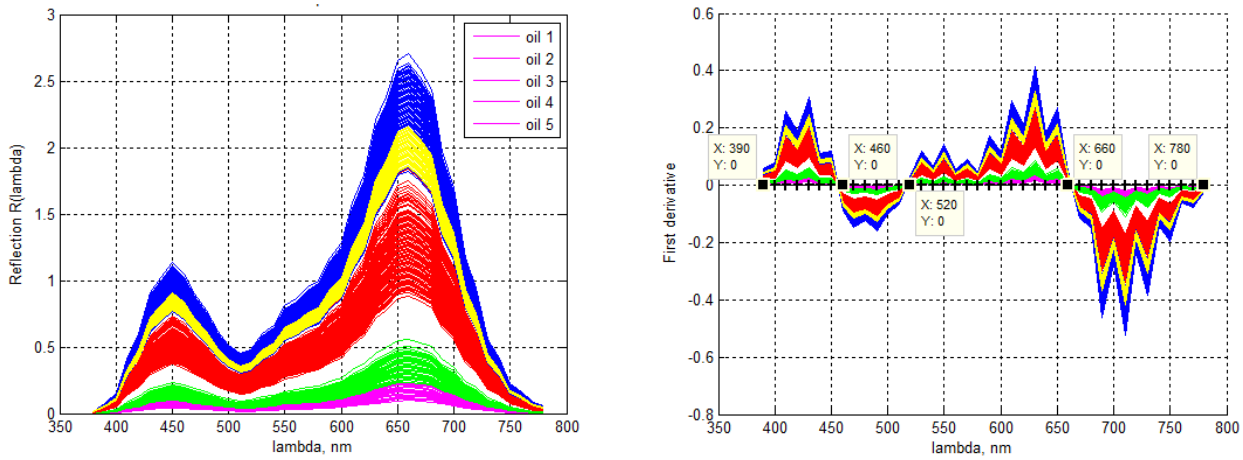
Parameter	oil1	oil2	oil3	oil4	oil5
Viscosity, Pa.s	0,079	0,0704	0,2873	0,0247	0,0466
Density, g/ml	0,9073	0,8292	0,8787	0,9500	0,9210

The selection of information wavelengths of the spectral characteristics is made by their first derivative. This method is described in (Todorova & Atanasova, 2016).

The prediction of physico-chemical parameters by spectral characteristics is realized by the method Partial least squires regression (Mladenov et al., 2015). The evaluation criteria used are Coefficient of determination (R^2), Sum of Squired Errors (SSE) and the Root Mean squired errors (RMSE).

RESULTS AND DISCUSSION

The selection of information wavelengths is made by a first derivative of the spectral characteristics. Figure 2 shows the spectral characteristics of all used automotive oils and their first derivatives. When using the first derivative, it is clear that ranges of spectral characteristics change. They are defined by the crossing of the null axis of the first derivative.



a) spectral characteristics b) first derivative with defined ranges

Fig.2. Spectral characteristics and first derivative of automobile oils

Table 2 presents the four ranges (d1-d4) defined by the first derivative of the spectral characteristics. In addition, the full spectrum (d5) from 380nm to 780nm was used in the work.

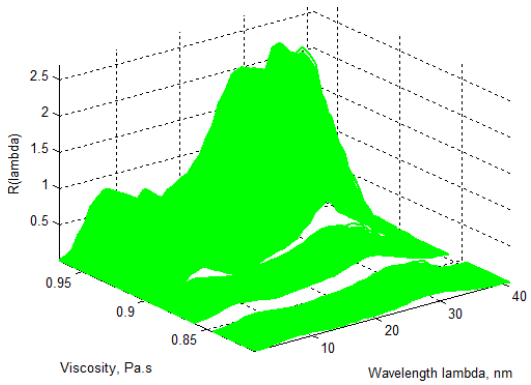
Table 2. Spectral characteristics ranges

Name	d1	d2	d3	d4	d5
Range, nm	380-460	460-520	520-660	660-780	380-780

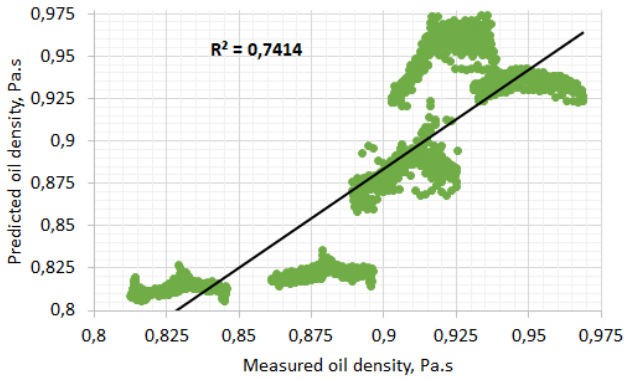
The possibility of predicting the physico-chemical parameters of automotive oils according to their spectral characteristics has been checked. The Partial least squires regression is used.

Two latent variables are needed to describe the spectral characteristics. The higher the number of these variables does not increase the prediction accuracy and increases the processing time of the experimental data.

Figure 3 presents an example of predicting the density of automotive oils by spectral characteristics. The full spectrum 380-780nm is used. The prediction accuracy is 74% with SSE=0,17 and RMSE=0,03.



a) spectral characteristics and viscosity



b) Prediction accuracy for density

Fig.3. Prediction of viscosity and density of automobile oils by spectral characteristics in range d5

Table 3 presents the results of an examination of the possibility of predicting the density and viscosity of automotive oils.

Density prediction is possible with an accuracy of 74% using the full range of the spectral characteristics. As informative stands range d3 (520-660nm), where errors have the smallest values (2-9%) in comparison with the other ranges.

The prediction of viscosity by spectral characteristics is possible with greater accuracy 85%. Again in the range d3, predictive errors are low (6-7%).

Table 3. Prediction accuracy of automobile oils parameters by spectral characteristics

Parameter	Density			Viscosity		
Range	**R^2**	**SSE**	**RMSE**	**R^2**	**SSE**	**RMSE**
d1	0,74	0,31	0,04	0,85	0,19	0,96
d2	0,74	0,32	0,04	0,85	0,12	0,79
d3	0,74	0,09	0,02	0,85	0,07	0,06
d4	0,74	0,14	0,03	0,85	0,16	0,90
d5	0,74	0,17	0,03	0,85	0,13	0,80

CONCLUSION

The report examines the possibility of predicting the physicochemical parameters viscosity and density of automotive oils using their spectral characteristics in the visible area of the spectrum.

The results show that the oil density can be predicted with an accuracy of 74% and the viscosity at an accuracy of 85% with low error rates of 2-9% in the range 520-660nm.

The results show the potential for using spectral reflectance characteristics in the visible area for rapid and non-destructive determination of physicochemical parameters of automotive oils. This provides a solution to the major problem in the cuvette methods used and the continuous preparation of the samples for analysis.

The data obtained can be used as a guideline for the design of optically active devices for express and non-destructive determination of the physico-chemical parameters of automotive oils.

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