Infrared Spectroscopy Application in Determining T501 Antioxidant Content in Transformer Oil and Turbine Oil

Abstract:

The antioxidant T501 plays a crucial role in prolonging the operational lifespan of transformers and turbines. Therefore, its determination is essential for the safe operation and maintenance of oil-filled high-voltage electrical equipment. Currently, methods for detecting T501 antioxidant content in transformer oil and turbine oil include spectrophotometry, liquid chromatography, and infrared spectroscopy. When comparing the instruments and reagents used, spectrophotometry and liquid chromatography require significantly more equipment and materials than infrared spectroscopy. Additionally, the use of methanol as a solvent in these methods poses a severe toxicity risk, which is not conducive to the personal safety of laboratory personnel. Regarding sample pretreatment, spectrophotometry and liquid chromatography involve complex procedures for treating test oil samples and standard oil samples. Moreover, the experimental steps are numerous, and the use of glass instruments is extensive, making it challenging to achieve success in a single attempt.

The Lambda FTIR-7600 Fourier Transform Infrared Spectrometer is used to determine the T501 antioxidant content in transformer oil and turbine oil. The method is characterized by its simplicity, high precision, short analysis and detection time, low reagent consumption, significantly improving work efficiency, and enhancing economic benefits.

Keywords:

Infrared Spectroscopy, Transformer Oil, Turbine Oil, Antioxidant, Quantitative Analysis

1. Principle

In transformer oil and turbine oil, the addition of antioxidant T501 results in the appearance of a phenolic hydroxyl stretching vibration absorption peak at the wavenumber of 3650 cm -1 (2.74 μm) in the infrared spectrum. The absorbance of this peak is directly proportional to the concentration of the antioxidant T501. By plotting a standard curve, the mass percentage content of T501 antioxidant in the oil sample can be determined.

2. Experimental Conditions:

Instruments and Accessories:

FTIR Fourier Transform Infrared Spectrometer 7600
Fixed liquid cell

Analysis Conditions:
Resolution: 4 cm^{-1}
Number of scans: 64
Scanning range: 4000～400 cm^{-1}

Reagents:
All reagents are of analytical grade unless otherwise specified.
Carbon tetrachloride, base transformer oil (provided by the customer, can be prepared independently), T501 antioxidant.

Other:
Analytical balance (accuracy 0.0001g)
Earpiece ball
Micropipette (20-200μL)

3. Preparation and Testing of Standard Samples and Samples

1) Preparation of Standard Oil

Weigh 0.5g of T501 antioxidant (weighed accurately to 0.0001g), heat it to no higher than 70℃, and dissolve it in 99.5g of base oil to make standard oil containing 0.50% T501. This oil should be stored in a dark bottle and can be used for three months. Then, weigh 2.0g, 4.0g, 8.0g, 12.0g, and 16.0g of this oil, dissolve them in 16.0g, 12.0g, 8.0g, 4.0g, and 2.0g of base oil, respectively, to obtain standard oils with T501 contents of 0.05%, 0.10%, 0.20%, 0.30%, and 0.40%.

2) Drawing of the Standard Curve

(1) Use a micropipette (20-200μL) to extract 0.50% T501 standard oil and slowly fill the liquid absorption cell.
(2) Place the liquid absorption cell filled with standard oil on the absorption cell rack of the Fourier Transform Infrared Spectrometer and record the infrared spectrum in the range of 3800 cm^{-1} to 3500 cm^{-1}. Repeat the scan three times. If the difference between the maximum and minimum absorbance values A calculated from the three scans is greater than 0.010, the measurement needs to be repeated; otherwise, take the arithmetic average of the three measurement results as the final result.
(3) Follow the above method to measure the infrared spectrum of standard oils with T501 contents of 0.05%, 0.10%, 0.20%, 0.30%, and 0.40%.
(4) Read the maximum absorbance value A (accurate to 0.001) at 3650 cm^{-1}.

3) Testing of Oil Samples

(1) Use a micropipette (20-200μL) to extract standard oil samples and slowly inject them into the same liquid absorption cell used to draw the standard curve.

(2) Under the exact same instrument conditions as used for the standard curve, measure the absorbance of the oil sample following the above method and calculate the absorbance value.

(3) Use the obtained A value to find the weight percentage content of T501 on the standard curve.

4. Testing Result

1) Drawing of the Standard Curve

Referring to the related standard for the determination of T501 antioxidant content in transformer oil and turbine oil, establish the standard curve for the antioxidant. Obtain the infrared spectra for base oil with T501 antioxidant contents of 0%, 0.05%, 0.10%, 0.20%, 0.30%, 0.40%, and 0.50%, respectively. Record the infrared spectra in the range of 3800 cm^{-1} to 3500 cm^{-1}, as shown in the figure below. Repeat the scan three times, and take the arithmetic average of the three measurements as the final result.

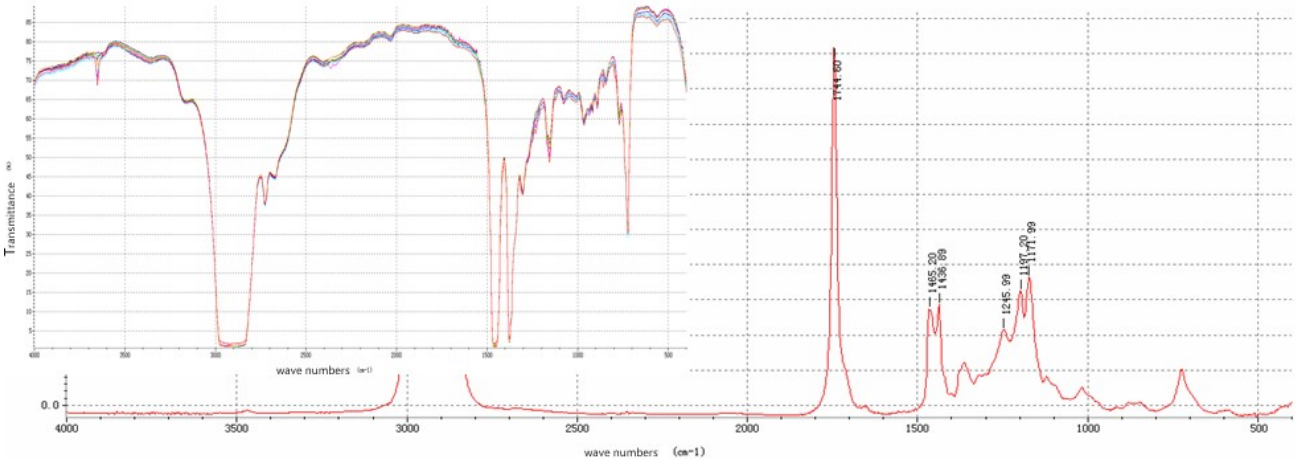

Chart1: The purple spectrum line, green spectrum line, deep blue spectrum line, yellow spectrum line, bright blue spectrum line, mauve spectrum line, and red spectrum line in Figure 1 correspond to base oils with T501 antioxidant contents of 0%, 0.05%, 0.10%, 0.20%, 0.30%, 0.40%, and 0.50%, respectively.

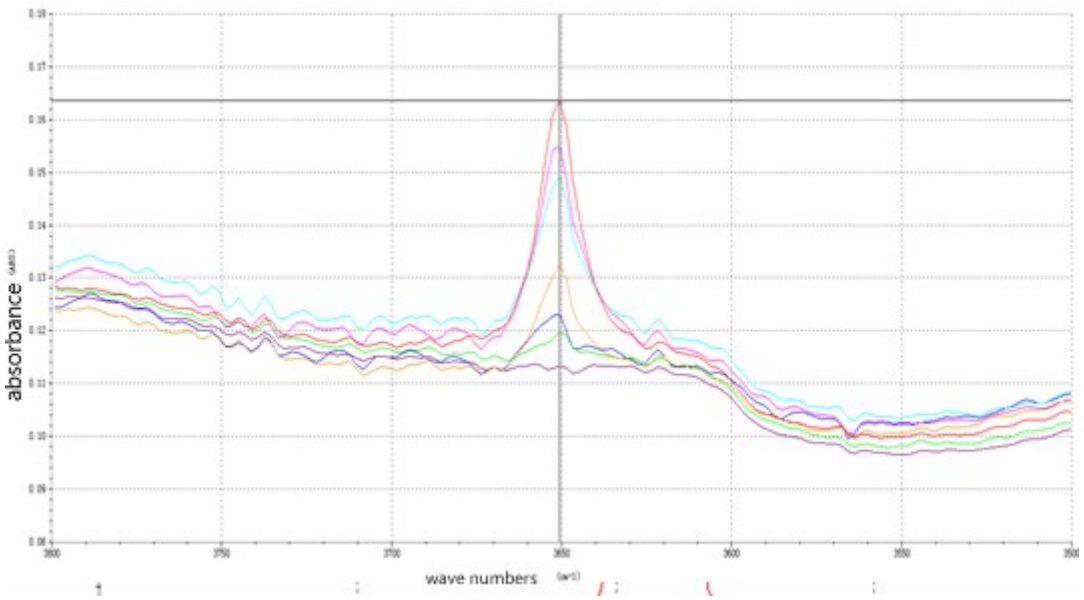

Chart 2: zooms in on a portion of Figure 1, capturing the infrared spectra in the range of 3800-3500 cm^{-1}

2) Test Results

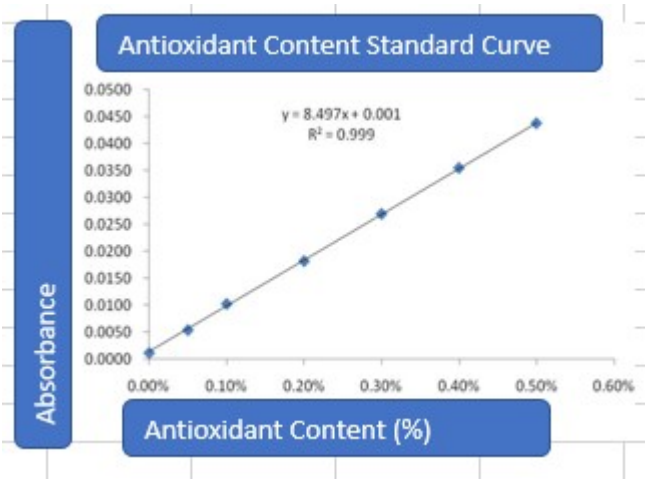

Chart 3 Standard Curve of T501 Antioxidant Content

3) Calculation of Content

The standard curve for antioxidant content in transformer oil is y=8.497x+0.001, so the antioxidant content in the oil sample is approximately 0.0883%.

5. Experimental Conclusion

The use of infrared spectroscopy to determine the content of T501 antioxidant in transformer oil is accurate and fast, with a working curve close to R^2=1, fully meeting the requirements of quantitative testing.