

APPLICATION REPORT ON SPECTROMETRIC DETECTION OF GEAR OIL FOR WIND POWER GENERATOR SETS

RDE-20260205-01

FEBRUARY 5, 2026

DITEE OA800H

ASTM D6595，NB/SH/T 0865

KEYWORDS: RDE-OES, OIL ANALYSIS SPECTROMETER, WIND POWER INDUSTRY, DITEE, PREVENTIVE MAINTENANCE

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Industry Background and Necessity of Testing

As the global energy structure transitions towards clean energy, wind power generation, as an important component of renewable energy, continues to expand in its installed capacity and operational scale. Wind power equipment operates in harsh outdoor environments for long periods, enduring complex working conditions such as variable loads, high speeds, and strong vibrations. Among them, the gearbox (including the main gearbox, yaw gearbox, and pitch gearbox) is the core transmission component of wind power equipment, taking on the key function of transmitting the mechanical energy captured by the wind rotor to the generator and achieving speed increase.

Gear oil, acting as the "blood" of the gearbox, not only plays the roles of lubrication, wear reduction, and cooling, but also provides sealing, leakage prevention, rust prevention, and corrosion resistance. Traditional oil testing methods are often time-consuming and labor-intensive, making it difficult to meet the growing testing demands. Changes in the content of metal wear elements (such as Fe, Cu), pollutants (such as Si), and additives (such as P, Zn) in the oil directly reflect the health status of the equipment. Therefore, introducing efficient and accurate Oil Analysis Spectrometer technology is crucial for achieving "condition-based maintenance" and fault early warning for wind power equipment.

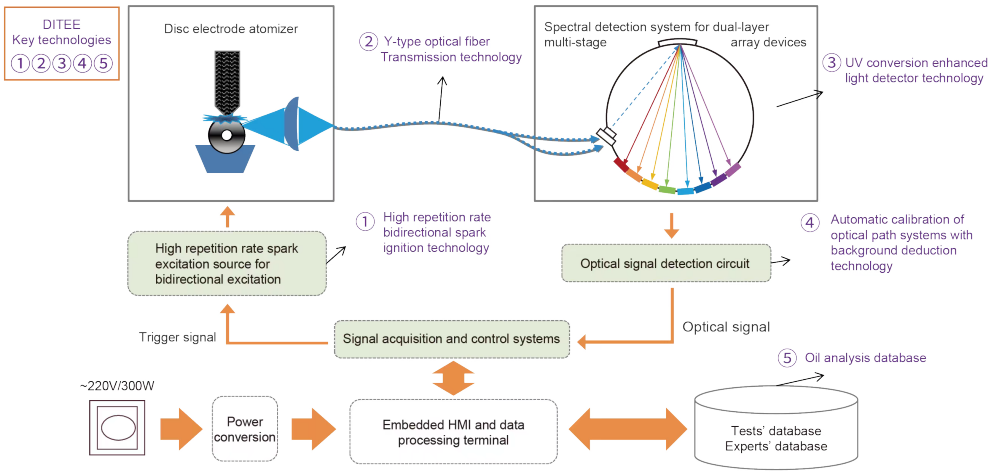


Technical Solution

This report uses the OA800H Oil Analysis Spectrometer from Guangdong DITEE Scientific & Technical Co., Ltd. as the testing tool. Designed specifically for oil analysis, this equipment possesses the following core technical features:

Technical Principles

It adopts a rotating disk electrode atomizer, utilizing a bidirectional excited high-repetition-rate spark/arc as the excitation source, which acts directly on the tested oil sample, vaporizing and ionizing it to produce characteristic emission spectra. The optical signals are transmitted via a Y-shaped optical fiber and analyzed by a dual-layer multi-segment array device spectral detection system composed of full CCD detectors.



High Efficiency and Convenience

No sample pretreatment is required; direct injection is used. A single test takes only 30 seconds, and results are obtained with just one measurement, capable of simultaneously determining 24 elements including Fe, Cu, Cr, Ni, Mn, Si, and P.

Low Maintenance Cost

The equipment operation does not require argon gas or cooling water. The consumables are only standard graphite disk electrodes, rod electrodes, and sample cups, significantly reducing the cost per test.

Environmental Adaptability

It adopts an integrated fully enclosed frame structure design, possessing excellent impact and deformation resistance, making it highly suitable for application scenarios in wind farm sites or mobile testing vehicles.



As an important pillar of the national energy strategy, the installed scale and coverage of wind power generation in China continue to expand. Facing a huge base of equipment operation and maintenance, traditional laboratory oil testing methods, due to their cumbersome processes and long feedback cycles, are no longer able to adapt to the increasingly growing demands for "immediate response" and "refined operation and maintenance". With its high sensitivity in capturing metal wear particles, external pollutants, and lubricating oil additives, as well as its testing characteristics of "rapid screening and precise quantification", Oil Analysis Spectrometer technology has become

the preferred technical means for monitoring the lubrication status of large equipment such as wind turbine gear oil and preventing catastrophic failures.

DITEE OA800H, as a classic benchmark of this series of products, perfectly aligns with this industry demand. In terms of technical implementation, this instrument adopts high-energy arc/spark direct excitation technology, which can instantly vaporize and ionize the tested oil sample without complex pretreatment, thereby producing high-intensity characteristic emission spectra. On the signal acquisition end, the equipment comes standard with CCD (Charge-Coupled Device) detectors across the board. Compared to traditional optoelectronic devices, it greatly ensures the long-term stability and consistency of analytical data under different environments. Relying on mature application experience validated across multiple domestic industries and excellent cost-effectiveness, OA800H can effectively solve the problems of wind power gear oil testing and is an ideal technical choice for elevating the equipment management level of wind farms.

Instrument Performance Verification Experiment

To ensure the authority and reliability of OA800H's data in wind power gear oil testing, rigorous performance verification stages were designed based on industry standards such as NB/SH/T 0865 and ASTM D6595.

Experimental Standards and Sample Settings

The experiment selected internationally recognized CONOSTAN standard samples to establish working curves and verify accuracy. The working curves cover 24 common elements required for wind power gear oil testing, where the concentration range for wear element curves covers 0-1000 ppm, and the concentration range for additive element curves covers 0-6000 ppm, ensuring a wide dynamic range detection capability from trace wear to high-concentration additives.

The specific verification sample used was the CONOSTAN 100ppm 24-element standard sample. This concentration is situated in the critical zone of the common wear warning line for wind power gear oil, which can effectively test the instrument's accuracy at core monitoring points.

1121 CONOSTAN 100ppm 24 Elements Analysis

Element	SD (mg/kg)	Average Concentration	1	2	3	4	5	6
Fe (Iron)	1.76	103.26	104.05	100.81	104.74	101.34	103.65	104.93
Al (Aluminum)	1.05	102.42	103.21	100.76	103.12	101.45	102.73	103.23
Mg (Magnesium)	1.54	104.10	104.89	102.11	105.61	102.67	103.59	105.71
Zn (Zinc)	3.73	102.16	101.28	97.43	103.93	98.52	106.96	104.83
Cu (Copper)	2.51	107.69	109.91	105.75	110.07	104.58	105.99	109.84
Ag (Silver)	0.66	100.46	100.99	100.41	101.05	99.95	99.42	100.90
Ni (Nickel)	1.10	101.72	102.46	100.57	102.84	100.61	101.01	102.83
Cr (Chromium)	0.54	100.80	101.51	99.86	100.94	100.74	100.76	100.97
Si (Silicon)	1.33	101.50	101.94	99.47	102.47	100.19	102.21	102.69
Ti (Titanium)	2.03	100.19	101.64	97.46	101.92	98.06	100.02	102.03
Pb (Lead)	1.21	102.88	103.22	101.23	104.14	102.31	102.10	104.29
Sn (Tin)	0.80	100.31	101.03	99.32	101.02	99.73	99.74	101.02
Mo (Molybdenum)	1.16	99.83	100.85	98.41	100.82	98.59	99.50	100.83
V (Vanadium)	1.74	101.31	102.21	98.72	102.57	99.50	102.09	102.77
Cd (Cadmium)	1.09	100.99	102.41	101.08	100.78	99.29	101.87	100.51
Ca (Calcium)	1.78	102.63	102.66	100.35	104.44	100.89	102.73	104.73
P (Phosphorus)	2.13	100.21	100.23	96.99	101.98	98.41	101.25	102.43
Ba (Barium)	1.53	99.80	101.08	99.31	100.79	96.95	100.08	100.58
B (Boron)	8.75	95.75	84.71	109.28	99.86	92.40	89.40	98.86
Mn (Manganese)	0.68	101.44	102.29	100.45	101.74	100.82	101.59	101.75
Sb (Antimony)	2.05	101.10	101.46	98.63	101.29	99.18	104.38	101.66
Li (Lithium)	1.09	101.75	103.84	101.74	101.75	101.08	100.75	101.37
Na (Sodium)	3.07	100.65	104.62	103.35	98.49	102.02	97.77	97.62
K (Potassium)	4.54	100.91	103.63	105.92	97.11	105.38	97.32	96.10

Experimental Data and Precision Analysis

Under standard experimental conditions, continuous repeated tests were performed 6 times on the CONOSTAN 100ppm sample. The experimental data shows that OA800H demonstrated extremely high detection precision. Below is a detailed data analysis targeting key monitoring elements (Iron, Copper, Silicon, Phosphorus) for wind power gearboxes:

- **Iron (Fe):** As the main indicator of gear and bearing wear, the average concentration over 6 measurements is 103.26 mg/kg, with a standard deviation (SD) of only 1.76 mg/kg. Considering the nominal value of 100 ppm, its relative error is extremely small, and the extremely low SD value proves the instrument's exceptionally high stability in capturing wear signals.
- **Copper (Cu):** As the wear indicator for cages or copper alloy components, the measured average value is 107.69 mg/kg, with an SD value of 2.51 mg/kg.
- **Silicon (Si):** As the key indicator for external pollutants (sand and dust), the measured average value is 101.50 mg/kg, with an SD value of only 1.33 mg/kg, showing the instrument's precise recognition capability for pollutants.
- **Phosphorus (P):** As the main component of anti-wear additives, the measured average value is 100.21 mg/kg, with an SD value of 2.13 mg/kg, and the numerical value is almost entirely consistent with the nominal value.

Experimental Conclusion

Through comprehensive testing of 24 elements, the detection results of OA800H are not only of excellent accuracy, but the repeatability data (SD) for all elements remain at an extremely low level. This proves that the instrument fully meets the requirements of ASTM D6595 and NB/SH/T 0865 standards, and possesses the capability to replace large traditional laboratory equipment for high-precision on-site analysis.

On-site Application Case Analysis: Pitch Gearbox Failure Early Warning



When a certain energy company in Shandong was conducting daily operation and maintenance on the wind farms under its jurisdiction, it utilized the DITEE OA800H Oil Analysis Spectrometer to carry out routine spot checks on the Shell 150 gear oil used in the wind power pitch gearboxes. During the testing process, the instrument keenly captured an abnormal signal: the Iron (Fe) element content in the sample soared to 2362 mg/kg. In the wind power industry standards, the limit warning value for iron content in pitch gearbox gear oil is typically 30 ppm (30 mg/kg), and this tested value exceeded the standard by nearly 80 times, categorizing it as an extreme abnormal state. This data broke through the early wear warning scope and pointed directly to severe metal wear failure occurring inside the gearbox. After the testing data was synchronized through the system, the operation and maintenance management department responded rapidly within less than 1 hour, organizing a team to intervene and preventing the fault from escalating further.

The O&M team immediately initiated a standardized emergency response process: "Shutdown & Lockout - Precise Tracing – Disassembly & Inspection – Cleaning & Oil Change - Trial Run & Verification". First, to prevent the equipment from suffering secondary damage, O&M personnel remotely switched the faulty wind turbine into maintenance mode, mechanically locked the pitch angle, and cut off the drive power, eliminating the risk of tooth breakage or bearing shattering that could be caused by continued meshing of worn components right from the source. At the same time, to further lock down the root cause of the fault, technicians used the OA800H to conduct a retest and

multi-element correlation analysis on the oil sample. The retest results confirmed the extreme excess of the iron element once again, while also discovering that the Copper (Cu) element content had risen to 2.4 mg/kg, and the Silicon (Si) element content was 35 mg/kg. Based on this set of "fingerprint data" provided by the spectrometer, the expert team determined the nature of the fault as severe wear of the gear pair, and the abnormal silicon content indicated slight aging of the seals or dust intrusion in the system, which was very likely an auxiliary inducement accelerating the wear.

Based on the precise fault determination, a professional maintenance team rushed to the site with specialized equipment to conduct disassembly and inspection. The scene after disassembly completely corroborated the analytical conclusions of the OA800H: large areas of spalling and local tooth breakage appeared on the tooth surfaces of the planetary gears and sun gear inside the gearbox, the bearing raceways were covered with severe wear marks, and a large amount of metal wear debris had deposited at the bottom of the casing. The maintenance team replaced all failed core components and aged seals according to standards, and used specialized cleaning agents to conduct multiple cycles of flushing on the inner cavity and oil circuits of the gearbox, completely clearing out residual wear debris. Finally, brand new Shell Omala S4 GXV 150 gear oil was filled, restoring the equipment to a standby state.

During the verification stage after the repair was completed, the OA800H played a key role once again. The O&M team conducted a no-load jog and a loaded trial run on the pitch gearbox. After 60 minutes of no-load operation, an oil sample was drawn on-site again for spectrometric detection. The results showed that the iron content had dropped significantly to 3 mg/kg, and elements such as copper and aluminum had also fallen back to normal ranges. In the subsequent 72 hours of continuous monitoring, O&M personnel conducted oil analysis every 4 hours; the iron content consistently stabilized within 5 ppm, and the equipment operated without abnormal noise or oil leakage, with all parameters meeting standards. At this point, the major hidden danger of this wind turbine was successfully eliminated, and it resumed normal grid-connected power generation.

Optimization of O&M Strategy and Value Summary

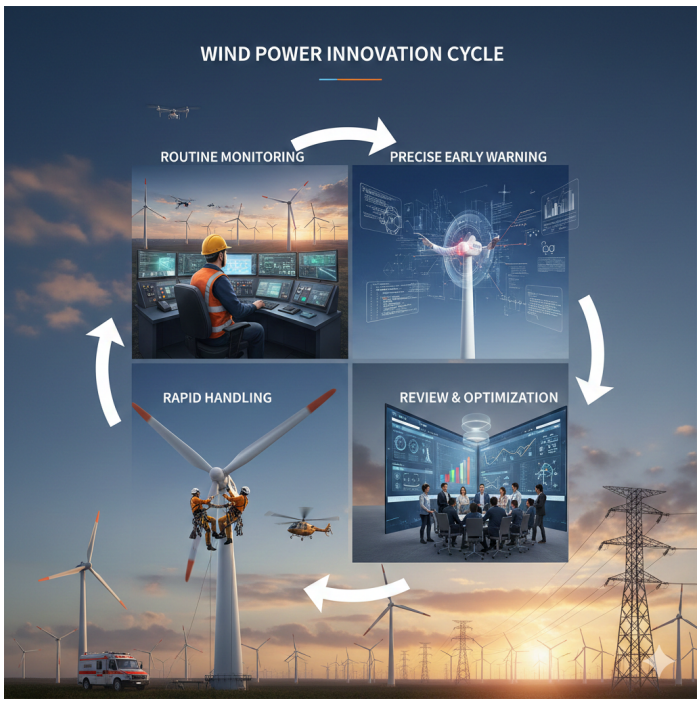
Economic and Safety Value

In this case, from the discovery of data anomalies to response and handling, the entire process took less than 1 hour. OA800H helped the enterprise visualize the originally "hidden" internal wear problems, avoiding equipment scrapping and unplanned prolonged downtime caused by delayed fault discovery, significantly reducing power generation losses and maintenance costs.

Establishing a Closed-loop Management System

Based on this successful experience, the energy company optimized its wind power O&M management system:

- **Increased testing frequency:** Oil testing for onshore wind turbines was upgraded from "once every 3 months" to "once a month," with key turbines achieving "routine weekly monitoring."
- **Closed-loop management:** Formed a scientific equipment management closed loop of "Routine Monitoring – Precise Early Warning – Rapid Handling – Review & Optimization."



Conclusion

Through detailed instrument performance verification and real on-site fault cases, this report comprehensively evaluated the application value of the DITEE OA800H Oil Analysis Spectrometer in wind power gear oil testing, and reached the following conclusions:

Outstanding Performance, Compliant with Standards

In the testing against CONOSTAN 100ppm standard samples, OA800H demonstrated extremely high accuracy and repeatability, fully complying with industry standards such as NB/SH/T 0865 and ASTM D6595, and is capable of precisely monitoring core elements of concern in wind power such as Fe, Cu, Si, and P.

Strong Practical Applicability, Precise Early Warning

In the actual case of an energy company in Shandong, OA800H successfully captured an extreme anomaly of iron content at 2362 mg/kg, and assisted in locking down the root cause of the fault through multi-element analysis. Its rapid (30 seconds/sample) and on-site testing capability helped the enterprise visualize originally hidden internal wear, drastically shortening the fault response time.

Significant Economic Benefits

The instrument's characteristics of requiring no argon gas and no complex pretreatment greatly reduce the cost per test. Through the closed-loop management of "Routine Monitoring - Precise Early Warning - Rapid Handling", it effectively evades unplanned prolonged downtime and major component damage of wind power equipment, providing strong technical support for wind power enterprises to optimize O&M management and reduce full life-cycle costs.

In summary, relying on the advantages of high efficiency, precision, convenience, and low cost, the DITEE OA800H Oil Analysis Spectrometer is fully feasible for promotional application in the gear oil testing of wind power generator sets. It can be widely applied to routine monitoring and fault early warning of gear oil in onshore and offshore wind farms, helping wind power enterprises optimize O&M management processes, elevate the refinement level of equipment O&M, reduce unplanned downtime losses, ensure the safe and stable operation of wind power equipment, and provide technical support for the high-quality development of the wind power generation industry.