Hindawi
Mobile Information Systems
Volume 2022, Article ID 5222074, 6 pages
https://doi.org/10.1155/2022/5222074

Research Article

Application of Ultrahigh Voltage Transformer Oil Purification Software Technology

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Received 6 May 2022; Revised 8 June 2022; Accepted 28 June 2022; Published 20 July 2022

Academic Editor: Muhammad Muzammal

In order to discuss the purification software technology of ultrahigh voltage transformer oil, the index variation trend of antioxidation stability test after each oil adsorption was investigated, and the relationship between the adsorption times and antioxidation stability parameters was obtained. It was proved that the antioxidation stability of the oil was getting better and better with the increase of adsorption times. The composition of hydrocarbon of new oil and recycled oil is analyzed by infrared spectroscopy. The composition of hydrocarbon of new oil and recycled oil is very similar to that of new oil, and their molecular composition structure has not changed much. The experimental results show that: according to dLT929-2005, the absorbance of samples at 1610~720 cm^{-1} was measured, and the values of C_A, C_N and C_P were obtained. A 1 mmNaCl liquid pool is used. Sample ① is the new oil; ② is the last simulated oil regeneration; ③ is the D111 overhaul recycled oil; ④ is again the living oil. It is proved that the composition of the oil is more reasonable and can be reused for adsorption and regeneration. In addition, the aromatic carbon value C_A of oil after adsorption treatment decreases due to natural consumption, and new oil can be added appropriately to increase the carbon value C_A.

1. Introduction

Review of China's development history: since the reform and opening up of China's oil filter industry, especially since the 1990s, the oil filter industry has undergone tremendous changes, and the period from 2000 to 2010 is the golden period of development. Now it can be said that China is the production base of oil filters in the world, including construction, industrial and mining, and cement in general [1]. China's overall level is still low and medium is given priority to, especially because of the country's lack of effective to filter oil machine industry admittance threshold, and the relevant industry regulations, as for the industry technical standard, there is only one JB/T5285-2001 Vacuum Oil Cleaner standard [2]. Looking at the overall level of the society, the production and processing of oil filter involves many industrial manufacturing categories, such as motor, oil pump, vacuum pump, door valve, circuit control, and liquid level control, and even the quality of the most basic steel will determine the service life of the oil filter. Only with progress in all these industrial categories can domestic oil filters make real progress [3].

Now, as good as our mainstream manufacturers, oil filters are basically automatic oil filters programmed by PLC [4], but this has fallen behind foreign countries, and now small factories in other parts of the country are still using the previous manufacturing experience of oil filters. On the one hand, we should not belittle ourselves and see ourselves as worthless [5]. On the other hand, we still need to know clearly that there is still a gap between us and the advanced level in the world [6]. Such a gap is an overall gap. Boer et al. studied and calculated the overall structure and main components of the insulation oil filtration and purification software system. Transformer oil can be treated directly with a mixture of calcium metal and alcohol to remove contamination directly from PCB residues, providing the

possibility of recycling the product. The process includes mixing, stirring, and separation, which is simple and effective [7]. Zhang et al. studied the hydrodechlorination yield of 99.6%, and the remaining CHLORinated biphenyls belong to almost nontoxic o-chlorinated biphenyls and o-dichlorinated biphenyls. A mixture of ethanol and isopropyl alcohol was used to overcome the problem of low compatibility [8]. Izadi et al. studied that proper maintenance is the main condition for the normal operation, good working safety, and long service life of high-energy transformers as part of the electric energy production and distribution system. The modern and widely accepted concept of power transformer maintenance assumes that transformer oil is periodically purified to minimize the concentration of dissolved water and gas, as well as to eliminate the degradation of solid products during oil oxidation as well as paper insulation and transformer internal areas [9].

Based on this, puts forward for uhv transformer oil purification software technology is discussed, and at every time after the oil adsorption index change trend of antioxidant stability test, the number of adsorption and oxidation stability parameters, the relationship between the evaluation of the oil adsorption regeneration frequencies can be proved that with the increasing the number of adsorption, oil oxidation stability and performance is getting better and better.

2. Data and Methods

2.1. Research Content

(1) High efficiency compound vacuum oil and gas separation device: developed a highly efficient separation of vacuum container of water in the oil, gas, through the special coalescing filter, will heat the oil in the vacuum chamber indoor, demulsification and oil, water and gas phase separation, and then the oil down to the 3 d flash tower, its special mesh structure, to the oil film repeatedly diluted, making the oil into multi-layer film, increase the contact area of oil film and vacuum environment. In this way, the water and gas in the oil are further taken away quickly by vacuum, and the qualified oil is exported to the fine filtration system [10]. Vacuum processing, secondary set a separation system, effective will vacuum container of oil mist and gas separation, and then the gas is removed by vacuum pump, gathered the oil droplets is returned vacuum vessel, its return oil light components mainly for transformer oil, can guarantee in the process of the oil filter of transformer oil viscosity and density characteristics are not affected, moreover, the oil loss in the oil filtration process is reduced [11].

(2) At present, the world-class high precision filter for incremental multilayer encryption form step by step, mesh from inner to outer tapering, filter wire is coarse fine encryption step by step, the larger particles will be blocked in the outer layer, mechanical impurities in step by step to intercept oil filter of the high filtration efficiency, carrying large amount, increase the service life of filter element [12]. Impurity filtration system: it is necessary to design an efficient filtering system to intercept impurities, which should meet the characteristics of high precision one-time filtration, large flow, and large amount of pollution capacity.

(3) Regeneration system: in view of the waste transformer oil acid value and dielectric loss and other super index projects, through regeneration adsorbent processing, conventional regeneration adsorbent for white soil, diatomite filter element, and activated alumina, but the disadvantages are obvious-low regeneration efficiency, after a long time of transformer oil bubble will dissolve, produce harmful ions. The equipment needs to develop and use polymer adsorption materials and special transformer oil for decolorization and dielectric loss reduction, which can efficiently adsorb transformer oil sol and reduce the dielectric loss of transformer oil to less than 0.02% [13]. Filter elements are installed in the inlet and outlet of the regeneration tank to prevent the outflow of the regeneration adsorbent. Regeneration adsorption tank with bypass valve, if there is no need for decolorization and mediating loss, the switch of regeneration system can be realized by controlling the corresponding valve. It is convenient for fresh oil dehydration and vacuum oil injection of equipment [14].

(4) Low load heating software technology: heater design, need according to the flow speed and initial temperature, the influence of the fixed flow speed, heating tube surface heat load cannot too big, otherwise easy to cause high temperature oil cracking, so need to design the most advanced heating software technology, low load under the heating power of meet the needs of the cold weather, low thermal load, multistage tandem, heating pipelines special design, so that the oil in the heating pipe has a long residence time and ensure that there is no dead point of oil flow so that the oil from the entrance to the exit of uniform temperature rise. Completely solve the problems of local overheating caused by ordinary conduction heating, aging and cracking of oil, and harmful gas generation [15].

(5) Patent blowout preventer software technology: the level control system is designed to adjust the normal level of oil products. The low level and high level are only supplements of the normal level and play an insurance role. Liquid level through the electronic switch detection signal, feedback back to the solenoid valve to control the opening and closing of the pipeline into the vacuum separation chamber, so as to achieve automatic control of liquid level. With the selected foam identification electronic switch, even the oil foam can correctly feedback the liquid level signal, so as to ensure that the oil foam can be accurately controlled, when the foam exceeds a certain

limit, the vacuum system through automatic gas, and adjust the amount of oil, eliminate a lot of foam. More reliable to ensure the stability of the liquid level control system [16].

(6) Pressure protection device: equipped with an overpressure overflow automatic alarm stop protection device, in the case of system or fine filter pressure ≥0.3mpa can automatically stop, so as to effectively protect the whole machine and filter element can realize unguarded [17].

(7) Electric interlock protection: equipment design is lack of phase, fault phase, overload protection and trinity electric control interlock functions, vacuum pump, oil pump, heater interlock together, regardless of the vacuum pump, oil pump, and heater, any part there is a problem, it can realize automatic locking, avoiding the filter oil machine run dry, oil, such as the leakage phenomenon, can prevent equipment damage caused by the wrong operation, ensure that the filter can operate safely under all conditions. At the same time, the designed automatic operation mode can be selected, and its running status can be monitored remotely in real time. And, it can be used for remote fault detection or emergency shutdown functions [10, 18, 19].

2.2. Test Instrument. 10 L of transformer oil after adsorption treatment was taken from ultrahigh pressure D111(11th overhaul of #1 main transformer). According to the transformer open-mouth cup aging method in operation DL429-91, the container with oil test (containing copper catalyst) was put into the electric blast box with a temperature of 115°C ± 1°C for aging, and 0.5% of old oil (capacity ratio) was added each time for aging. Aging is caused by dielectric loss tan$\delta > 2\%$. Aging boxd 101-2AB electric blast drying box; Syad-b type petroleum product oxidation stability tester; Ai-6000 type oil dielectric loss resistivity measuring instrument; NICOLET FT-IR spectrometer, resolution 4 cm^{-1}.

2.3. Development Plans and Design Schemes for Devices and Equipment. Preliminary solution of integrated equipment: in this design, the regeneration unit, vacuum oil filter unit, and external vacuum pumping unit are integrated, and the switch between the units is controlled by pneumatic valves. Automatic control is realized. In this scheme, the regeneration system is directly installed in the oil filter unit as a bypass system, and the oil flow is reversed through the controllable pneumatic cut-off valve to realize the loading and cutting off of the regeneration unit. At the same time, the regeneration unit system itself can also choose the series and parallel operation mode, series one-time filter oil better, parallel system flow rate is large, processing capacity. Low flow rate, high efficiency or large flow, and multicycle oil filtration.

The multistage parallel vacuuming system can be designed in this function block to filter the vacuum oil and pump the vacuum outside. One side of the oil filter, one side of the transformer vacuum, this design is convenient for a device to complete the operation of transformer vacuum oiling. In the traditional vacuum oil filter, the external vacuuming unit can also be loaded to increase the vacuum degree of the vacuum container and achieve an efficient oil filter. In the external vacuum pumping condition, the superposition of vacuum pumping speed can be realized by switching between two sets of vacuum pump bodies. In addition, the atmospheric starting Roots pump software technology can also ensure that the vacuum required by the vacuuming equipment can be achieved faster. Usually, roots pump pumping speed for vacuum pump 5–10 times. In the crude vacuum pumping stage, the displacement of the roots pump is much larger than the vacuum pump, so the roots pump (usually 4500 Pa) can be started only when the vacuum pump pumps the atmospheric pressure gas (0.1 MPa) to a certain value. After the start of the roots pump, the pumping speed of the system is greatly improved and the ultimate vacuum is soon reached. Vacuum pump pumping to roots pump protection differential pressure time accounts for 80%–90% of the total time. The roots pump can be started at atmospheric pressure by means of roots pump frequency conversion and a special hydraulic coupler. The pumping speed in the rough vacuuming stage is increased by more than 5 times, and the overall vacuuming efficiency will be improved by 50%–70%.

3. Experimental Results and Discussion

The data and relationship between the number of aging adsorption and the tan δ after adsorption, the acid value after oxidation, and the sediment in the oil after oxidation are shown in Table 1 and Figure 1.

As can be seen from Figure 1, the results measured after each oxidation test are within the control range of SH0041-91, namely, the acid value $w(KOH) < 0.4 \times 10^{-3}$ after oxidation. Mass fraction of precipitate in oxidized oil <0.2%, indicating that the oil has good oxidation resistance after repeated regeneration under operating conditions. Moreover, the acid value and the sediment in the oxidized oil showed a decreasing trend with the number of adsorption, indicating that the oil quality improved with the increase of adsorption times, as shown in Figure 2. By comparing the curve in Figure 2, it can be seen that the acid value generated in the oxidation test is positively correlated with the tan δ value of the oil before oxidation or the amount of polar impurities contained in the oil, indicating that the antioxidant stability of the oil has a certain relationship with the tan δ of the oil. The lower the tan δ, the better the antioxidant stability of the oil.

The new oil (sample 1), the new oil (sample 4), and the last simulated adsorption and regeneration oil (sample 2) from Daya Bay under ultra-high pressure were used for ir spectrum analysis, and the obtained spectra were shown in Figure 3. It can be seen from Figure 3 that in the band range of 1600~1700 cm^{-1}, the peaks of the new oil and the recycled oil are smaller than that of the prereclaimed oil; that is, the carbonyl content represented is small, indicating that the

Table 1: Aging adsorption test results.

The sample	A_{1604}	A_{720}	C_A (%)	C_N (%)	C_P (%)
①	0.162	0.074	16.95	49.56	33.49
②	0.085	0.123	9.002	54.10	36.89
③	0.107	0.138	11.27	50.83	37.90
④	0.083	0.158	8.80	52	39.20

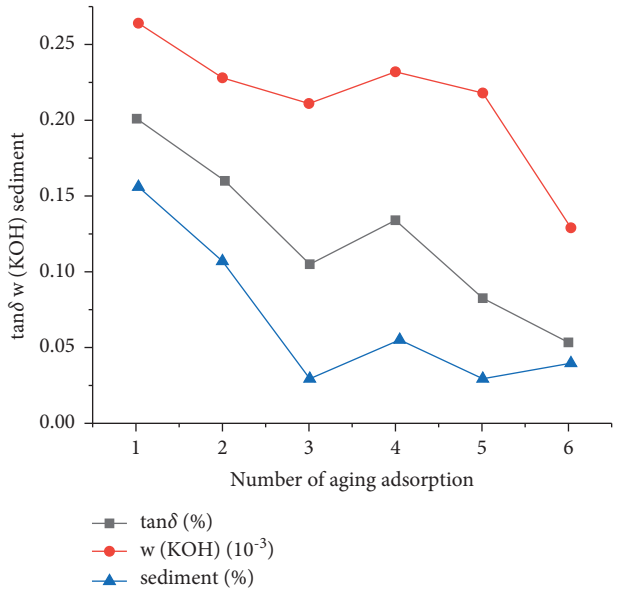

Figure 1: tan δ the relationship between acid value and precipitation and adsorption times.

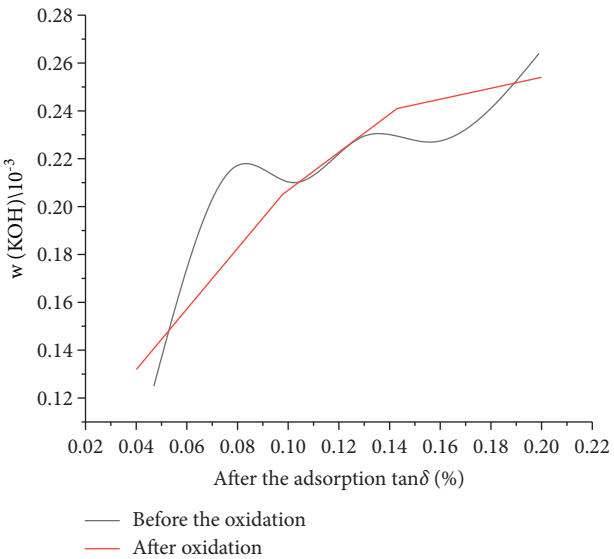

Figure 2: The relationship between acid value after oxidation test and tan δ before oxidation test.

carbonyl and other active substances in the reclaimed oil are reduced, the active free radicals in the oil are reduced, and the oil is refined. The peak of anoxic oil is strong in wave 1118 cm^{-1}, which represents the contraction vibration peaks

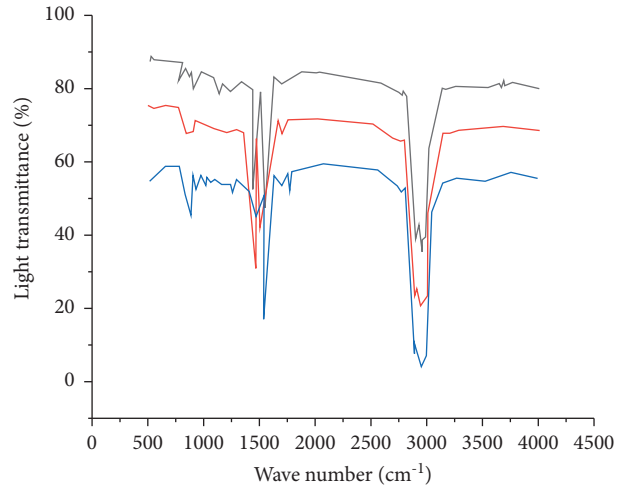

Figure 3: Comparison of ir spectra of three oil samples.

of the C-O bond and C-O-C bond, indicating that there are more oxygen-containing polar bonds before anoxic oil, but not after anoxic oil and new oil. In addition, the spectra of the regenerated oil and the new oil are very similar on the whole, especially in the 2952~2855 cm^{-1} C-H stretching vibration peak, 1456~1376 cm^{-1} C-H deformation vibration peak, 1606 cm^{-1} benzene ring C = C vibration peak are completely the same, indicating that the oil regeneration does not change the composition of the oil and can be relieved to adsorb and filter the oil for many times. At 725 cm^{-1}, the peak of regenerated oil and new oil is strong, which means the number of chain hydrocarbon $CH_2 < 4$, the frequency is stable at 720 (long chain hydrocarbons), indicating that the new oil and the recycled oil have more cycloalkanes or longer molecular chains, and no small molecule degradation products. It is proved that the composition structure of transformer oil is more reasonable without the increase of small molecular components. As can be seen from the above study, the beneficial composition of oil has not changed significantly or become better. The most commonly used characteristic index of hydrocarbon structure family composition is in the standard C_A, C_N, and C_P which reflect the structural characteristics of pure hydrocarbon molecules and the average molecular structural characteristics of hydrocarbon mixtures. According to DLT929-2005 cm^{-1}, the absorbance of the sample at 1610~720 cm^{-1} was measured, and the value C_A, C_N, C_P obtained. Use a 1mmNaCl liquid pool. Infrared spectra of samples ①~④ were performed, respectively. The absorbance values at 1,604 and 720 were shown in Figure 4. Sample ① is the new oil; (2) is the last simulated oil regeneration; (3) is the D111 overhaul recycled oil; (4) is again the living oil.

As can be seen from Figure 4, the C_A of new oil ① is larger, and the C_A of on-site regeneration ③ is also larger due to the addition of new oil, which is larger than the C_A of simulated regeneration ② and before regeneration ④. This is the main difference between the composition of new oil, recycled oil, and waste oil. When C_A is small, the gas extraction performance and antioxidant performance of the oil

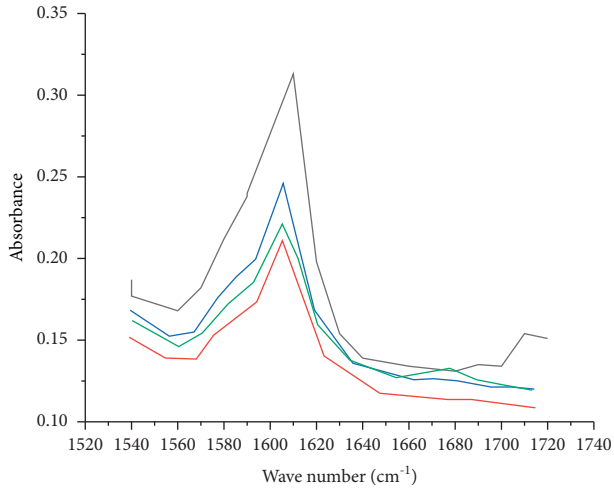

Figure 4: Infrared absorption intensity test of oil samples ①~④.

will be slightly worse, so C_A certain amount of new oil should be added, that is, C_A should be added. In addition, after regeneration, C_N increases due to the transformation of C_A, which makes the composition of oil naphthalized. This transformation is caused by natural oxidation of C_A, not by adsorption, because C_A in oil sample ④ is almost the same as that in oil sample ②.

4. Conclusions

For without inhibitors in the operation of the uhv transformer oil oxidation stability after many adsorption treatment no loss and has a tendency to increase, the antioxidant capacity of the product was not destroyed, not adding an inhibitor of uhv transformer oil adsorption process for many times, can be and keep its good chemical and electrical properties. Infrared spectrum analysis also showed that the regeneration of transformer oil refining oil, the composition did not change, small molecular components did not increase, and the composition of oil more reasonable structure. The lower the absorption of transoil to tan δ, the better the antioxidant stability of the oil. However, the correlation between oil tan δ and antioxidant stability needs further tests to be accurately determined. The ultrahigh voltage transformer oil is adsorbed and added with a small amount of new oil; that is, the oil treatment method of adding aromatic hydrocarbon is proper and effective. The adsorption treatment did not reduce the C_A value, which was caused by the natural consumption of thermal oxidation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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