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Application of Diamond-Oil Tester in Refined Oil Pipelines

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Abstract: Diamond-oil tester utilizes information fusion technology to test the oil product interfaces during refined oil batch pipelining based on vibration frequency range of the oil product, electromagnetic absorption and difference and integration of capacitance dielectric constants to conduct overall analysis. By processing signals and combining Kalman filter principle, the tester can realize the interface testing and distinguish for different refined oil products. During the batch pipelining of various refined oil products, by equipping with Diamond-oil testers in the oil product receiving and distributing station, interfaces of different oil products can thus be effectively tested for accurate separation of oil products and ensuring the minimum level of mixed oil. Practices have proved excellent practical results in oil products batch pipelining.

Key words: Diamond-Oil tester; Information fusion technology; Interface of mixed oil

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In refined oil batch pipelining, interface testing for different oils mainly depends on interface testing technologies, and commonly used methods including trace method, density testing method, optical surface testing method, etc. As refined oil categories in batch pipelining grow more complex, one single testing method exposes problems, such as low accuracy, large errors, etc. in daily application. Inaccurate interface testing leads to high mixed oil quantity or even accidents, bringing great loss to the operation unit. Therefore, implementing a multiple-measuring method can provide more reliable results in testing pipeline conveying a number of oil products. Diamond-oil tester adopts information fusion technology to test the interfaces of mixed oil with high resolution, little maintenance effort and greater potential in applications [1].

1. Structure of Diamond-Oil Tester

Diamond-oil tester, adopting the information fusion technology, comprises the temperature sensor, frequency sensor, dielectric constant sensor, conductivity detector, electromagnetic capacity meter, etc. Basic structure is shown in Figure 1. As oil product flows through testing sensors, it will be comprehensively analysed by the instrument empowered by multi-parameter information fusion technology which conducts integral analysis on various characteristics including electromagnetic energy absorption, capacitance dielectric constants, conductivity, vibration frequency, etc. and monitors the interfaces of mixed oil. Furthermore, the tester supports data collecting by means of PLC or DCS to display required information on microcomputers or matching software to display changes of mixed oil during oil product switchover [2-5].

2. Working Principle of Diamond-Oil Tester

Diamond-oil tester mainly utilizes information fusion technology, also known as data fusion or sensor information fusion, to conduct automatic analysis and integral processing based on the observed information collected on a preset time interval by several sensors controlled by computer technology and complete the information processing process necessary for determination and task predication. Based on such definition, multi-sensor system should be the hardware basis for information infusion whose processing target is multi-source information with coordinated optimization and integral processing at its core.

By adopting vibration frequency measuring principle, electromagnetic wave principle, Kalman filter principle, etc., and information fusion technology, the tester obtains multiple groups of data output, hence realizing oil interface testing. The principle lies in that when the oil flows through testing sensors, it will be determined by the instrument empowered by multi-parameter information fusion technology. Based on difference of characteristics of oil products regarding electromagnetic energy absorption, capacitance dielectric constants, conductivity, vibration frequency, etc., the tester analyzes the information in a manner of correlating all measured data and relating them to data model, which is determined by Formula (3) and Formula (4), stored in the system and obtaining the correct results by analyzing the information acquired by all sensors. To monitor the mixed oil interfaces [6-11].

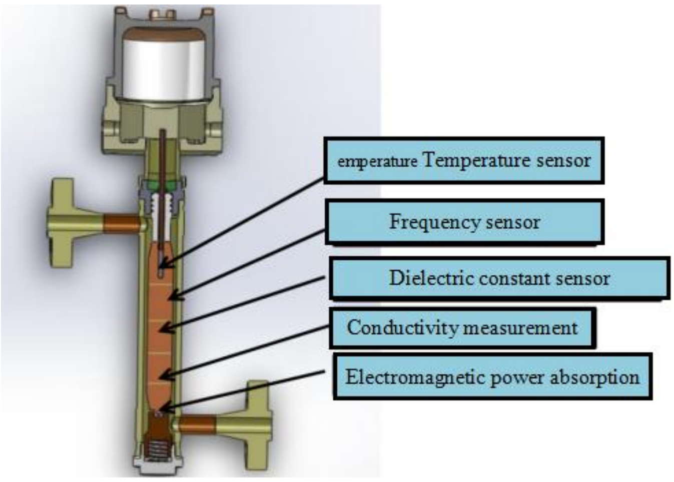

Figure 1. Structure Diagram of Diamond-oil Tester

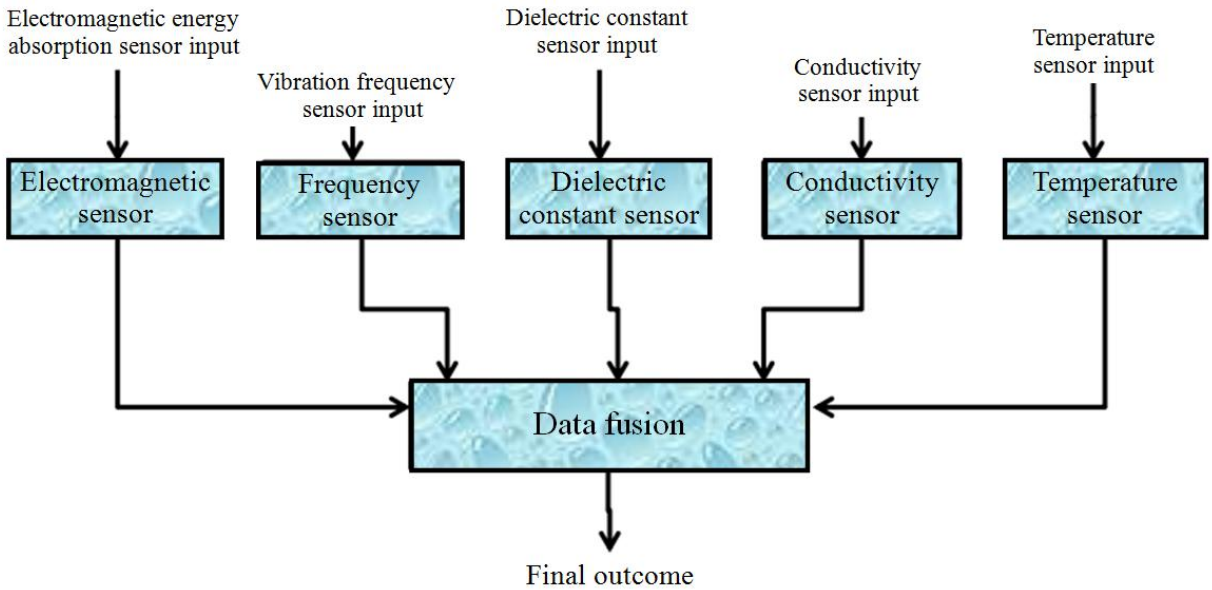

Figure 2. Diagram for Diamond-oil Tester Information Fusion

2.1 Principle of Measuring Vibration Frequency

Tuning fork vibration is a mature technique in measuring vibration frequency. The sensing element is a kind of elastomer which maintains itself in a syntonic status by feedback electronic system. Whenever measured oil product flows through it, the sensing element will change its resonance frequency in a certain pattern. The frequency change complies with the rules that when the density of measured oil products rises, total weight will increase, causing vibration frequency to decrease, vice versa. By a certain amount of calibration, vibration frequency and density shares a definite relation. Therefore, by testing the resonance frequency of the sensing element, the density of oil product can be measured. Its relation can be expressed in the following Formula (1):

$$\rho = K_0+K_1T+K_2T_2 \qquad (1)$$

In the formula, ρ means liquid density, T means the vibration cycle of the sensor output while K_0, K_1, K_2 mean sensor constants which are calibrated when leaving factory. Therefore, oil density can be expressed via vibration frequency and thus the determination of interfaces among different oil products.

2.2 Principle of Electromagnetic Wave

The amount of energy absorbed by oil varies when a fixed-frequency electromagnetic wave passes through different oil products or electromagnetic waves in different frequencies pass through the same oil product is different, the absorbed energy complies with Lambert-Beer's law:

$$R = R_0e^{-\mu cl} \qquad (2)$$

In the formula, R means penetrating energy, R_0 means incident energy, μ means absorptivity, c means medium concentration, l means medium thickness.

Variation $R_0 = R^{e\mu cl}$ can be deducted via the above formula while $R_0 = Re^{(\mu 1c1l1 + \mu 2c2l2 +...)}$ can be used for mixtures, among which μ_1, c_1, l_1 and μ_2, c_2, l_2 represent the sensor fixed dimension in absorptivity, medium concentration and medium thickness of two different oil products respectively. Although the absorptivity for two oil products is different, the values of absorptivity of different oils are constant and the transmission energy of electromagnetic wave I is absorbed by the receiver at a constant value. As determined by $R_0 = Re^{\mu cl}$, incident energy R_0 can only change according to the density of oil products, leading to changes of electric current R in the transmitter. The change in current is fed to the controller, and after magnification, it will be used as the standard signal. By integrated calculation with the frequency signal, an integral RH value will be generated for the monitored oil. This RH value is then monitored for changes in order to monitor the interfaces of mixed oil [12-16].

2.3. Signal Process and Fusion Kalman Filter Principle

This system includes frequency sensing element, electromagnetic sensing element, dielectric constant sensing element, conductivity sensing element and temperature sensing element. All gathered data will be processed according to Kalman filter principle which can be described by a linear stochastic differential equation:

$$W(k) = A\,W(k-1) + B\,U(k) + T(k) \qquad (3)$$

$$Y(k) = SW(k) + V(k) \qquad (4)$$

In above-mentioned two formulas, $W(k)$ means the system status at k moment, $U(k)$ means the control amount over the system at k moment. A and B are system parameters, in this system, they are matrixes. $Y(k)$ means the measured value at k moment, S means the parameter in measuring system, for this measuring system, S means matrix. $W(k)$ and $V(k)$ presents noises in process and measured noises (i.e. measuring error). Kalman filter is the best information processor for satisfying aforesaid conditions. By previous algorisms, the best result, that is, the output integral RH value, can be obtained [17-20].

3. Application of Diamond-Oil Tester in Batch Pipelining of Oil Products

One refined oil pipeline of CNPC mainly transports 0# diesel, 93# gasoline and 97# gasoline. A Diamond-oil tester is deployed in Pengzhou Station on the pipeline, installation diagram is shown in Figure 3. In 2011, the integrated tests were conducted on the interface between 0# diesel and 93# gasoline and the interface between 93# and 97# gasoline.

Figure 3. Diagram for Diamond-Oil Tester in Pengzhou Station Site

It is the tendency chart of the tester between 8:00 and 9:30 on Nov. 27, and the oil front arrived in at 8:20 on Nov. 27. When the 93# gasoline was replaced by diesel, the change was obvious, and the interface display is shown in Figure 4.

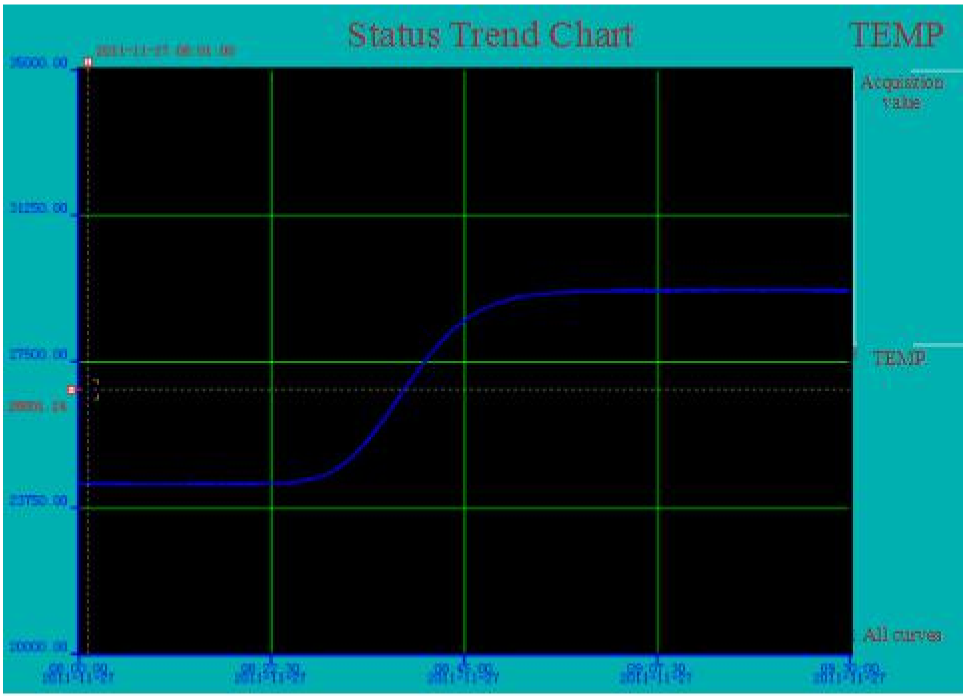

Figure 4. Interface Detection Drawing between 93# Gasoline and 0# Diesel

The tester distinguished the interface between the 93# gasoline and 97# gasoline between 12:12 and 13:42 on Dec. 6. The interface display is shown in Figure 5.

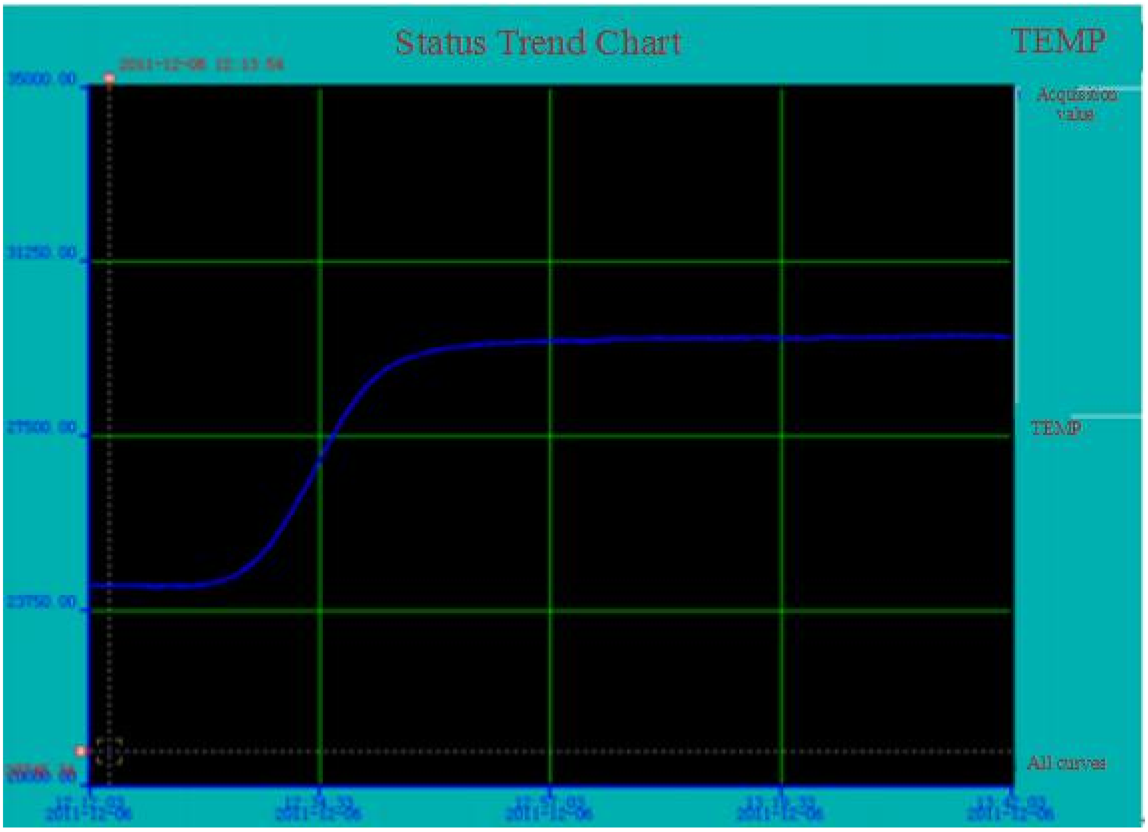

Figure 5. Interface Detection Drawing between 93# Gasoline and 97# Gasoline

As indicated in practical application, Diamond-oil tester demonstrates good sensitivity, reliability and practicability with good testing results during multi-oil product batch pipelining.

4. Conclusion

To sum up, Diamond-oil tester utilizes information fusion technology to test the oil product interfaces during refined oil batch pipelining based on vibration frequency range of the oil product, electromagnetic absorption and difference and integration of capacitance dielectric constants to conduct overall analysis. By processing signals and combining Kalman filter principle, the tester can realize the interface testing and distinguishing for different refined oil products. After analyzing the application in refined oil pipelines, the tester is proved to be accurate in determining interfaces among different oil products and therefore worth wide implementation and application in refined oil batch pipelining.

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