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STUDY ON REALTIME DETECTION METHOD OF ANTI ICING ADDITIVE CONCENTRATION IN JET FUEL BASED ON MICRO FLUID CHIP AND ULTRAVIOLET SPECTRUM ANALYSIS

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Abstract–Ethylene glycol methyl fan is the main components of Anti icing additive of jet fuel. the volume percent of Anti icing additive in fuel is 0.1～0.15%. It is a typical detection problem of trace substances in complex organic phase to detecting the content of only 0.1 to 0.15% of the ether substances in jet fuel comprising of by hundreds of kinds of organic matter , so there is no on-line measurement method by now. In this paper , a means is offered that combine micro extraction technology and on-line optical spectroscopy technique . by this way, anti icing additive concentration can be real-time measured and the precision can reach 5%, can meet the need of oil blending control and quality detection.

Keywords:jet fuel, anti icing additive, Online detection, oil quality

1. INTRODUCTION

In order to reduce the freezing possibility of water in jet fuel, A certain amount of anti icing additive is need. The anti icing additive (ethylene glycol methyl fan is its main components) is easily extracted by water, and therefore can not be added in factory like other additives , so it must be added in airport as refueling. In order to realize online control of the anti icing agent adding process and jet fuel quality detection, the online measurement technology of anti icing additive concentration in jet fuel is need. But the jet fuel is a mixture contain of all variety of hydrocarbons and additives, its composition is complex and composition difference of product batches is remarkable, and only 0.1~0.15% the volume percent of Anti icing additive , so the additive concentration measurement is a typical problem of complex organic phase detection of trace substances.

The laboratory method of measuring anti icing additive concentration , such as ASTM D5006 and GB/T1794-1979 (1988), GJB 1008.2-1990, is extracting anti icing additive in jet fuel by pure water, and detecting refractive index of water solution of anti icing additive. The refractive index sensor accuracy can be up to 2 ×10-5, which has been successfully applied in some industrial process online measurement. Anti icing agent in jet fuel although also can change the refractive index of jet fuel, but the changes in the relative value is too small to satisfy the requirement of the measurement precision. For example, for a No.3 jet fuel, 20 degrees Celsius, anti icing agent concentration from 0.05% to 0.15%, the refractive index change is only 7.4 × 10-5.

As the online fiber spectrometer technology matures, the traditional spectrum analysis technology is increasingly being applied to the on-line measurement. In this paper, measurement methods is studied that measure anti icing additive concentration in jet fuel, and the method is a technology that combine a micro fluid chip extraction technology with on-line optical spectroscopy, its precision can reach 5%, can meet the need of oil blending control and quality detection.

2. THE CONSTITUTES OF ONLINE MEASUREMENT SYSTEM OF ANTI ICING ADDITIVE

the constitutes of online measurement system of anti icing additive in Jet fuel is shown in figure 1.

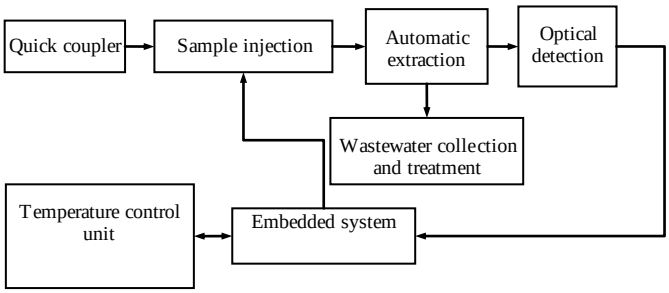

Fig.1 overall structure

This syste mainly includes the Quick coupler, automatic Sample injection, automatic extraction chip, liquid waste collection and processing, optical detection component, embedded computer and temperature control unit.

In order to realize the continuously sampling on the pipeline, a system 20 Size 0 cutting sleeve joint are used in this system. The maximal flows of the Joint is up to 12 l / min, the applicable pressure range of 0.2 ~ 4.2 Mpa.

In this paper, the realization method of micro fluid extraction and the measurement theory of anti icing addictive concentration in jet fuel by ultraviolet visible absorption Spectral analysis.

3. ON-LINE EXTRACTION METHOD OF ANTI ICING ADDICTIVE IN JET FUEL

Ethylene glycol mono-methyl ether is the main component of anti icing additive, its constitutional formula is HOCH2CH2OCH3 and is well soluble in water, so you can use micro fluidic chip technology to reverse extraction the anti icing agent in jet fuel, and get ethylene glycol mono methyl ether water solution.

Micro fluid chip is a kind of technology of fluid manipulation in the micron scale space developed on the basis of capillary electrophoresis technique. The concept of micro fluid chip were first proposed by Swiss researchers Manz and Widmer in1990. A capillary electrophoresis microchip analysis device were developed In 1992, the device realizes the real application of micro fluid chip technology. Micro fluid chip technology has an ability to Integrate the basic functions of chemical and biological laboratory to a few square centimeters chip, has a broad prospect in application. Micro fluid chip technology as continuous sampling and separating in micro scale can realize the automatic extraction, this means it is now possible for online continuous concentration measurement of anti icing addictive in jet fuel .

3.1 liquid-liquid extraction micro fluid chip

Micro fluid chip consist of professional experimental function area and micro channel, micro channel is tens to hundreds of microns in diameter. controlling the fluid pressure and flow rate, the chip designed reasonably can ensure that the Reynolds number is less than 2000, the fluid is always showed typical laminar flow in micro channel. Flowing in the same direction in the channel format multiphase laminar flow phenomenon. This phenomenon is called the channel laminar flow effect. By the laminar flow effect, no film mass-transfer, Chemical reaction detection and separation enrichment can be realized that is impossible in macro system.

Micro fluid chip show better extraction behaviors and more obvious scale effect than micro channel due to relatively small volume, less diffusion length and the larger the liquid-liquid interfacial characteristics. The interfacial area of molecular diffusion is inversely proportional to the diffusion scale, 100 μm micro liquid phase extraction can achieve the effect of violent shaking of separating funnel. When scale is less than 250 μm, the scale advantage will be very obvious[1].

In micro fluid chip liquid-liquid extraction system, the main factors affecting the extraction efficiency were organic and aqueous phase velocity, extraction channel surface Ratio, the diffusion length, reaction rate. With the traditional extraction method (including solvent micro extraction), micro fluid chip extraction separation has unique advantages, they are as follows[1,2].

(1) in the micro channel two immiscible liquid flow can realize steady laminar flow state, maintain continuous contact in phase interface, while the two solvents miscible can also form the phase interface in the channel, which are difficult to implement by the conventional analysis methods.

(2) short diffusion length shortens the extraction equilibrium time. Conventional analysis method needs tens of minutes to complete the extraction operation, in the micro channel only tens of seconds, or even shorter.

(3) With larger specific surface area. With larger specific surface area，micro extraction system increase the specific surface area, reduce the diffusion length, shorten the time needed for substance diffusion.

(4) at the same time liquid-liquid extraction separation the concentration can be detected directly.

(5) hybrid, extraction, separation and other chemical operations unit can be integrated on the same chip.

Therefore, the microfluid chip technology can realize the efficient extraction of anti icing additive.

3.2 design of liquid-liquid extraction microfluid chip for anti icing addictive in jet fuel

Micro fluid control liquid-liquid extraction is one of the latest development separation technology in Analytical chemistry. Although after a long time of development, but in recent years, the flow of micro fluid extraction is still about a few ml each minute. A increase of liquid -liquid extraction flow is important to the realization of automatic and high efficient modern analysis. In this paper, turbulent liquid-liquid extraction was used to improve the system flow and reaction rate. By this way, the velocity and flow can be increased to a certain extent than laminar ones, multiphase liquid-liquid contact area and specific surface can be enlarged, and the limitation of traditional micro fluid control system is overcome to certain partly.

The designed micro fluid chip adopt “Y” feed channel, consist of three layers that is made of quartz substrate. In the middle of the quartz glass sheet (500 μm in thickness), 0.2 mm diameter channel are cut by laser processing, four 1 mm diameter little holes are bored at the end of the channel. The glass flake with channel is sandwiched between two layer glass flake, on corresponding positions of up flake two entrance and two exits hole are processed. The contact surface of Each glass flakes are finished and bonded at 1150 ℃ high temperature or directly fixed with screws.

Micro fluid chip is composed of three regional, they are oil-water mixing zone, oil-water extraction and separation zone, as shown in figure 2. A overall micro fluidic chip have fixture, sealing system and support platform in the structure.

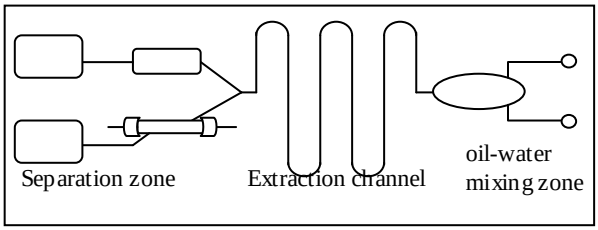

Fig.2 Micro fluid chip structure diagram

Oil and water two phase fluid flow into different channels of the micro fluidic chip, velocity and pressure are adjusted by a peristaltic pump, two phase is fully mixed to form a “water in oil” (W/O)emulsion droplet in oil-water mixture zone, and flow into the mixing / extraction channel in the turbulent state. because of the hydrophilicity of anti icing additive and molecular diffusion, the anti icing additives get

into the aqueous phase in these two regions, the extraction function is realized.

Water droplets extracted are absorbed into the collection channel after they flow through oil-water separation zone comprised of super hydrophilic porous material, Finally gather into the micro flow cell integrated on the chip.

4. MEASUREMENT PRINCIPLE OF ANTI ICING ADDITIVE CONCENTRATION

4.1 UV spectrum measurement method of anti icing additive aqueous solution

According to the literature, the maximum absorption rate of ethylene glycol monomethyl ether water solution appears in the 200nm to 210nm[3]. For a quantitative study, ultraviolet visible absorption spectrum of 5%, 10%, 13%, 15%, 17%, 20% anti icing additive water solution (volume percent) are gotten at room temperature, as shown in fig.3. We can see from the experimental results, the peak appears at 205nm, consistent with literature results.

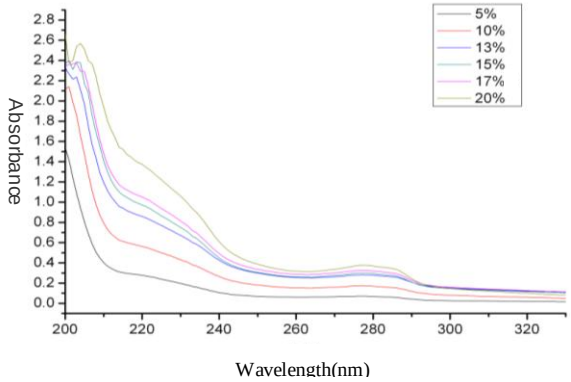

Fig.3 Uv absorption spectrum of anti icing additive water solution

It is evident from figure 3 that along with the increasing of anti ice additive concentration in aqueous solution, absorbance of UV spectra increase gradually, showing a good correlation. Choice 220nm to 280nm wavelength band, we use the "line of best fit" between concentration (y) and absorbance (x) to estimate their correlation, as shown in formula (1), the a, b are coefficient.

$$y=ax+b \qquad (1)$$

For band selected, the fitting results are as shown in table 1.

Table 1 results of the regression analysis

Wave length(nm)	coefficient		Correlation coefficient
	a	b	
220	-0.10985	0.07194	0.99321
220	-0.10508	0.06452	0.99369
230	-0.10061	0.05661	0.99361
235	-0.08656	0.04655	0.99292
240	-0.06208	0.0333	0.99893
245	-0.04255	0.0254	0.99867
250	-0.03259	0.02157	0.99699
255	-0.02628	0.01911	0.99481
260	-0.02296	0.01786	0.99293
280	-0.03092	0.02058	0.99609

From the results of the analysis it can be seen that correlation coefficients of regression equation can reach above 0.99 in all the selected band, showing a good correlation between absorbance and concentration.

4.2 on-line spectrum measuring device

The structure of the measurement system is shown in Figure 4, its main part is a micro fiber spectrometer. the spectrometer use the CCD charge coupled device to achieve photoelectric detection, so this measurement system is characterized by small size, low energy consumption and suitable for on-line measurement [3,4]. Due to greater light absorptivity of quartz fiber to the light less than 200nm in wave length, liquid core optical fibers are used in this measurement system, so the cutoff frequency is 175nm.

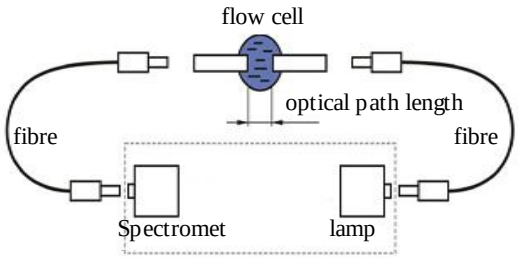

Fig.4 the structure of the measurement system

By using the measurement system, absorption spectra of the 2% and 0.2% anti icing agent water solution are measured as shown in Figure 5. the concentration ratio of extraction was 4, corresponding anti icing addictive concentration in jet fuel is 0.5% to 0.05%. By contrasting to Figure 5, It can be seen that detected spectral shape is alike at about 200 nm.

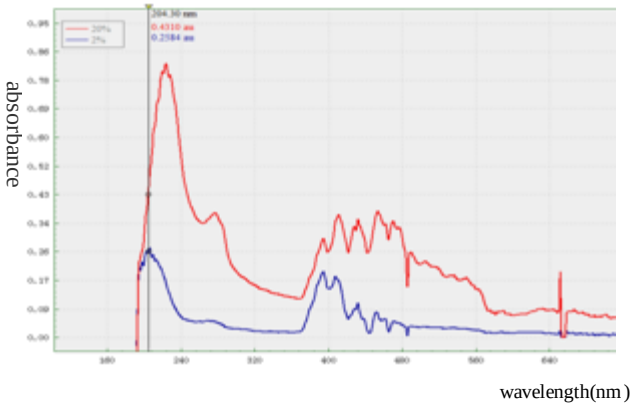

Fig.5 measurement result of designed spectrometer

In order to realize the concentration measurement, the integral for absorbance is calculated in 190nm to 240nm band, is as follows.

$$S_{Au} = \int_{190}^{240} A_u d\lambda \qquad (2)$$

In the formula, S_{Au} is absorbance and λ is wavelength. According to the formula (2), the corresponding between the concentration and SAu can be established. We got the corresponding table from 0.5% to 0.05 % and 0% concentration(pure water), so anti icing additive concentration in jet fuel can be calculated.

5. CONCLUSION

With CCD solid state integrated device, Fiber optic spectrometer can meet the need for online measurement by its fast response. Because the flow cell can be integrated into the micro fluidic chip, an integration of the micro fluidic extraction and spectral analysis is realized, the equipment volume is further reduced, the structure is simplified, the performance of on-line measurement is improved. This paper uses the 0.2mm diameter, 20mm length flow pool, detection delay is not more than 10 seconds, anti icing agent concentration measurement error is less than 5%.

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