Study on Microwave Method for Jet Fuel’s Silver Corrosion Test

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Abstract: In this paper, the mechanism of microwave-catalyzed jet fuel’s silver strip corrosion reaction is analyzed from the perspective of microwave chemistry principle, and the influence of microwave conditions on silver strip corrosion reaction is discussed from the aspects of test time, microwave power, load, etc. The optimal reaction conditions for silver strip corrosion are obtained through orthogonal analysis.

1. Analysis of microwave influence on crystalline materials’ surface polarization
The effect of microwave on crystalline materials’ surface properties is mainly the effect on crystalline dielectrics’ surface properties. Dielectric is a substance with high resistivity and poor conductivity. Charged particles carried by dielectric are confined in molecules of dielectric and cannot move macroscopically [1]. Under the action of an external electric field, charged particles in the dielectric will undergo microscopic displacement, causing molecules to polarize. According to the types of microscopic particles participating in polarization, dielectric molecular polarization [2] can be roughly divided into electron displacement polarization, ion displacement polarization, dipole steering polarization (orientation polarization) and interface polarization. The relaxation time of the first two polarizations is between $10^{-15}$-$10^{-16}$ seconds and $10^{-12}$-$10^{-13}$ seconds, while the time of microwave alternating electric field vibration for one week is between $10^{-9}$-$10^{-12}$ seconds. Therefore, microwave will not cause electron polarization and ion polarization, but only dipole steering polarization and interface polarization. Considering that the influence of microwave on the surface properties of crystalline materials is mainly reflected in the polarization of dipoles and interface polarization of crystalline materials, i.e. the polarization of dipoles and interface polarization of dielectrics play a major role in the energy absorption of materials under microwave.

2. Catalytic mechanism of microwave on corrosion reaction of silver sheet
The microwave accelerates the corrosion of jet fuel’s silver flakes mainly from the local accumulation of space charges on the silver flakes surface, resonance absorption of lattice defects on the silver flakes surface and microwave, and reaction diffusion characteristics of covalent bond structure of the corrosion product silver sulfide, etc.

1. The thermal effect of microwave-catalyzed chemical reaction is manifested in that microwave penetrates into the interior of the object at the speed of light and is absorbed by the movement of electrons and ions or the polarization of defect dipoles, which does work on charged particles in the reaction system, causing the temperature of the system to rise, forming an "integral" heating effect.
inside and outside the reaction substance and accelerating the reaction.

2. The thermal effect [3] of microwave-catalyzed chemical reactions is manifested in the electromagnetic field effect and microwave characteristics. It simultaneously affects the overall movement of the colliding “molecular pair” and the movement of the two molecules relative to their common center of mass, causing charged particles such as polar molecules, polar atoms and polar ions in the reaction system to undergo transitions between rotational energy levels, changing their activation states, thus causing the internal energy and potential energy of the initial reaction molecules to be increased and finally accelerating the speed of chemical reactions.

3. The interfacial polarization effect of the metallic silver sheet under the action of microwave will cause the surface free charge to move, causing it to generate macro dipole moment, forming local accumulation of surface space charge, making the metallic silver sheet easier to absorb microwave energy and improving the reactivity of the silver sheet with sulfide.

4. In the microwave field, weak bonds and defective parts on the surface of the silver sheet generate local resonance coupling energy transfer with the microwave, exposing the fresh surface and increasing the reaction interface, resulting in uneven energy on the surface of the silver sheet and forming "microwave hot spots" and corrosion reaction active centers. Sulfide corrosion occurs in these parts. Polar molecules in the system have "mutual friction effect" and "molecular stirring effect". The activity of sulfide ion reaction with the silver sheet is improved by destroying the physical adsorption film on the surface of the silver sheet. 5. Silver sulfide generated by the action of active sulfur in silver flakes and jet fuel has covalent bond components, low electrical conductivity, small dielectric loss factor, shallow depth of action with microwave, difficult occurrence of deep corrosion reaction, and easy occurrence of spread corrosion reaction.

3. Analysis of influencing factors on corrosion reaction of silver sheet catalyzed by microwave

3.1. Analysis of influence of microwave test time on corrosion reaction results

Oil samples with corrosion grade 2 are selected for corrosion test by microwave rapid determination method, and the results of different test times are observed, as shown in Table 1.

| Time  | Corrosion level | Phenomenon                                           |
|-------|----------------|-----------------------------------------------------|
| 1 min | level 1        | light brown                                         |
| 2 min | level 1        | light brown                                         |
| 3 min | level 2        | The light brown color increases and the corrosion area expands. |
| 4 min | level 2        | Brown becomes heavier and corrosion area expands.    |
| 5 min | level 2        | Light brown contact lines and boundary lines begin to appear |
| 6 min | level 2        | The pale brown color of the boundary line has increased. |
| 8 min | level 2        | The markings on the border turned pale purple.       |
| 10 min| level 2        | Purple is getting heavier and spreading to one side. |
| 12 min| level 2        | Purple becomes heavier and its area expands.         |
| 15 min| level 2        | The boundary line turns blue, the purple area on one side |
| 17 min| level 2        | The boundary line turns blue, the purple area on one side expands, and the grade 2 corrosion feature is obvious. |
| 20 min| level 2        | Area of the blue boundary line is enlarged, and purple area is enlarged to the edge of silver sheet, causing serious corrosion. |

Judging from the above test results, the sample had little effect on the silver sheet 2 minutes before the test, and began to have effect on the silver sheet about 3 minutes before the test, and the corrosion to the silver sheet gradually increased with the time. The test results of 10 ~ 15 minutes are comparable with those of SH/T0023-1990(2006) standard method.
3.2. Analysis of influence of microwave power on corrosion reaction results

For oil samples with corrosion grade 2, the corrosion test shall be conducted by microwave rapid determination method. The microwave power shall be adjusted to 50mA, 100mA, 150mA and 200mA respectively. The test results are shown in Table 2.

| Power   | time  | phenomenon                          |
|---------|-------|-------------------------------------|
| 50mA    | 15min | corrosion is relatively light, and the corrosion phenomenon can be grade 1. |
| 100mA   | 15min | The corrosion is aggravated, and the corrosion level 2 phenomenon is relatively weak. |
| 150mA   | 15min | The corrosion is serious, and the corrosion level 2 phenomenon is obvious. |
| 200mA   | 15min | Increased corrosion                  |

It can be seen that when the microwave power is 50mA, the corrosion phenomenon is relatively light and can be classified as grade 1 corrosion. With the increase of microwave power, the corrosion phenomenon also increases. When the microwave power is 150mA, the grade 2 corrosion phenomenon is more obvious. It can be seen that when the microwave power is close to 150mA, the results of the silver strip corrosion microwave rapid test method are better comparable with the test results of SH/T0023-1990(2006) standard method.

3.3. Analysis of Influence of Microwave Loading on Corrosion Reaction Results

Take 8 groups of oil samples, including 6 Class 2 oil samples, 1 Class 3 oil sample and 1 Class 4 oil sample. The determination results are shown in Table 3.

| Oil sample | Phenomenon                | Corrosion level |
|------------|---------------------------|-----------------|
| Level 2    | Blue, Purple, Black Plaque| Level 2         |
| Level 3    | Uniform Black Film        | Level 3         |
| Level 4    | Uniform depth blackening  | Level 4         |

The results show that it is basically consistent with 2 ~ 3 loads, slightly relieved but not obvious, and can still be classified as grade 2 corrosion. It shows that increasing microwave load has no obvious effect on corrosion results.

3.4. study on the addition of microwave absorbent for jet fuel silver plate corrosion

The following experiments were conducted to determine the amount of microwave absorbent.

Microwave absorbent with mass percentages of 8%, 10%, 12%, 14%, 20% and 30% (corresponding volumes of 4 mL, 5 mL, 6mL, 7 mL, 10ml, 15ml) were taken, respectively, and poured into jet fuel (46 mL, 45 mL, 44 mL, 43 mL, 40ml, 35ml), which were corroded by silver plates to form 50mL mixed solution. After treating the silver in accordance with SH/T0023-1990(2000) standard method, it is suspended in the oil sample of the corrosion detection bottle. Put the corrosion test bottle containing the oil sample into a special microwave container and place it in the center of the microwave rapid tester (in order to minimize the error, the special microwave container for each test is placed in the same position), and adjust the microwave power of 150 mA. The reaction time was 10min. After the reaction, the surface corrosion of the silver sheet was observed. The experimental
results were shown in table 4.

| The amount of microwave absorbent added | Heating time | Power  | Phenomenon                                      |
|----------------------------------------|--------------|--------|------------------------------------------------|
| 8%                                     | 10min        | 150mA  | pale yellow                                    |
| 10%                                    | 10min        | 150mA  | mauve                                          |
| 12%                                    | 10min        | 150mA  | purple and wheat yellow                        |
| 14%                                    | 10min        | 150mA  | corner is blue                                 |
| 20%                                    | 10min        | 150mA  | one side Angle is blue, the corrosion is serious |
| 30%                                    | 10min        | 150mA  | without obvious markings, the whole silver piece is wheat yellow |

After the reaction, special microwave container with a large number of solution, the corrosion detection of the volume of a solution with the increase of the amount of microwave absorber is reduced, that with the addition of more weibo absorber, reaction system explosive boiling phenomenon is serious, the evaporation of mixture in the glass container wall rapid condensation, flow to the bottom of the container. It can be seen from the experimental phenomenon that the addition amount of microwave absorbent is not the more the better, but has an optimal value. According to the reaction results, when the addition amount of microwave absorbent was 10%, 12% and 14% respectively, the reaction effect of silver sheet was better. When the addition amount of microwave absorbent was 12%, the corrosion phenomenon of silver sheet was blue, purple and wheat yellow, and the reaction effect was the best.

Then microwave absorbents with mass percentages of 10%, 12% and 14% (corresponding volumes of 5 mL, 6mL and 7 mL) were taken and poured into jet fuel (45 mL, 44 mL and 43 mL) with silver plate corrosion level 2 to form 50mL mixed solution. The silver plate was treated as SH/ t0023-1990 (2000) standard and suspended in the oil sample of the corrosion detection bottle. Put the corrosion test bottle containing the oil sample into a special microwave container and place it in the center of the microwave rapid tester. Adjust the microwave power of 150 mA. Take out the flask and measure the temperature at 4, 6, 7, 8, 10, 12, 14, 16, 18 and 20 min after heating.

Analysis of experimental results: when the addition of microwave absorbent was 10%, 12% and 14%, the temperature rise rate of the reaction system increased with the increase of the addition of microwave absorbent. However, when the addition of microwave absorbent was 12% and 14%, the difference of temperature rise rate was relatively small, and from the reaction of silver plate, when the addition of microwave absorbent was 12%, the corrosion reaction effect of silver plate was better, which was consistent with the color of SH/ t0023-1990 (2000) stipulated silver plate corrosion test method for jet fuel. Therefore, the best value of microwave absorbent is 12%. It was found that the reaction rate of active sulfur in silver plate and jet fuel could be effectively improved by adding microwave absorbent, but the more the amount of microwave absorbent, the better. With the increase of the addition amount of sensitizer, the active sulfur was also diluted, thus reducing the effective collision probability between the active sulfur and the silver sheet, and the corrosion rate of the silver sheet showed a downward trend. Therefore, the addition amount of sensitizer had an optimal value.

4. Study on optimum experimental conditions for silver strip corrosion

Through the research results of influencing factors of microwave-catalyzed silver flake corrosion reaction of jet fuel, it is shown that microwave power, test time and dosage of sensitizer have great influence on the corrosion degree of silver flake.

The experimental results show that the test results of microwave-catalyzed silver strip corrosion at the time of 10 ~ 15 minutes and the microwave power of 150mA are quite comparable with the test results of SH/T0023-1990(2006) standard method, and the increase of microwave load has little effect
on the corrosion results.

The effects of microwave power, test time, dosage of sensitizer and volume of reaction system on the corrosion rate of silver flakes are investigated by orthogonal test method. According to each factor, three levels are selected to form a four-factor three-level orthogonal table, and the optimal combination of four factors is obtained, namely, the optimal experimental conditions: the dosage of sensitizer is 5ml, the reaction time is 15min, the microwave power is 150mA, and the volume of the reaction system is 50ml.

5. Conclusion
In this paper, the mechanism of microwave catalytic accelerated silver strip corrosion was analyzed. By investigating the influence factors of microwave test time, microwave power and microwave load, it is concluded that the best test conditions of microwave catalytic silver strip corrosion reaction were 5ml of sensitizer, 15min of reaction time, 150mA of microwave power and 50ml of reaction system volume.

References
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