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A Study on Heat Resistance of High Temperature Resistant Coating

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A high temperature resistant coating has been developed, which is mainly for heavy oil production pipes deserved the serious corrosion. The coating has excellent physical and mechanical performance and corrosion resistance at room and high temperature. In order to simulate the underground working condition of heavy oil pipes, the heat resistance of the high temperature resistant coating has been studied. The development and a study on the heat resistance of the DHT high temperature resistance coating have been introduced in this paper.

Keywords *: high temperature, coating, heat resistance, corrosion protection, heavy oil*

1. Introduction

During the development of the heavy oil, there are a lot of pipelines, including thermal lines, injection-production line and gathering lines. Because of the co-action of high temperature and corrosion media, the corrosion rate of the pipelines and relevant equipment is accelerated. The heat resistance coating applied on pipelines gathering heavy oil extraction is required not only to prevent the steel pipeline from corrosion of underground environment but also to resist heat or wet-heat up to 250℃.[1] The high temperature resistant coating for heavy oil production pipes should be developed and applied.

2. The development of coating

After investigating and analyzing many kinds of heat resistant resin, we chose four kinds of resin to test, including epoxy organic silicon resin, urushiol titanium, urushiol silicon and modified heat resistant silicon resin. The varnish film was prepared with above four kinds of resin. In order to test the heat resistance of the varnish, the mechanical properties including adhesion, flexibility and impact resistance of the varnish were tested before and after heated. The test results show that the mechanical properties of the all four varnish films of A, B, C, D are very good before heating test. However, the mechanical properties of the varnish film B, C, D decrease sharply after heating test, but the adhesion, the flexibility and the impact resistance of the varnish film of A resin can keep good properties. Therefore, we determined the epoxy organic silicon resin as binder of high temperature resistant coating.

The coatings are prepared by using epoxy organic silicon resin as binder and using different systems of pigment and filler, such as glass flakes, mica powder and others. Then by testing their heat resistance at 350℃, water resistance (boiling, 1000 hours), cold-heat cycle, dry-wet cycle and so on, the pigment and filler system with good comprehensive performance had been determined at last.

3. The physical and chemical properties of the dht coating

After the binder, pigment, filler, auxiliary and other components have been chosen, a lot of coating formula tests have been made and their properties were tested, the DHT high temperature resistant anti-corrosion coating had been developed. It has shown that the coating has excellent physical and mechanical performance and corrosion resistance at room temperature shown in Table 1.

4. A study on heat resistance of the coating

4.1 The determination of heat decomposition temperature of the DHT coating

Thermal Analysis System of Type PE-7 was used to analyze the heat losing weight of high temperature

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Table 1. The properties of DHT high temperature resistant coating

Test item	Technical specification	Test standard
Coating color	Iron red	GB 1729
Viscosity (4-cup), s	>30	GB/T1723-1993
Surface dry (25℃), min	30	GB/T1728-1979
Though dry (25℃), h	1	GB/T1728-1979
Adhesion, grade	1~2	GB/T1720-1993
Flexibility, mm	1~2	GB/T1731-1993
Impact resistance, cm	50	GB/T1732-1979
Water resistance (100℃, 1000h)	Intact	GB/T1733-1993
Heat resistance (300℃, 200h)	No blister, no cracking	GB1735-1979
10%NaOH, 3 months immersion	No objection	GB1763-1979
10%HCl, 3 months immersion	No objection	GB1763-1979
3%NaCl, 3 months immersion	No objection	GB1763-1979
Cold-heat cycle (10 cycles)	No blister, no cracking	-20℃, 3h / 300℃, 3h
Dry-wet cycle (10 cycles)	No blister, no cracking	250℃, 3h / 3%NaCl, 3h

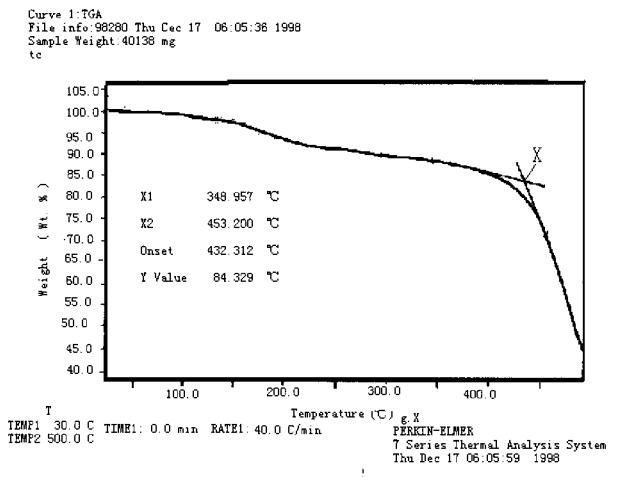

Fig. 1. The thermal analysis curve of DHT coating

resistant anti-corrosion coating; the conclusion curve was shown in Fig. 1.

It can be seen from the Fig. 1 that with the increase of the temperature there is a slow decrease of weight of the coating, below 250℃. As residual solvent had not been volatilized before test, there is a slow drop of the coating weight; When temperature increase over 345℃, the coating decomposed sharply. In conclusion, we may say that the heat decomposition temperature of the high temperature resistant anti-corrosion coating was 430℃ shown at point X in Fig. 1 at 40℃/min of rising rate of temperature.

4.2 The effect of temperature on physical and mechanical property of the coating

After the coating was heated at the different temperature lower than 430℃ of the heat decomposition temperature for 3 hours, the test result of the mechanical properties of the coating was shown in Table 2.

Table 2. Test result of coating properties after heating at different temperature

Temperature(℃)	200	250	300	350	400	430
Impact resistance, cm	50	50	50	50	50	35
Adhesion, grade	1	1	1	1	1	1
Flexibility, mm	1	1	1	1	1	1

As shown in Table 2, after the coating was heated at the different temperature lower than 430℃ of the heat decomposition temperature for 3 hours, the mechanical properties of the coating such as the adhesion, flexibility and impact resistance, can keep good state, but when the coating was heated at 430℃ of the heat decomposition temperature for 3 hours, the impact resistance of the coating decreases obviously. It has been shown that the coating has been deteriorated obviously.

4.3 The losing weight of coating film at different temperature

The samples were made with tinplates coated DHT coating. The thickness of the coating is about 25μm. The weight of the coating is the weight of the tinplate coated DHT deducting the weight of the tinplate. The tinplate coated DHT and the tinplate were placed in stove with certain temperature for 3 hours. The percentage of losing weight of coating film at different temperature is obtained by quantifying both the tinplates and comparing blank

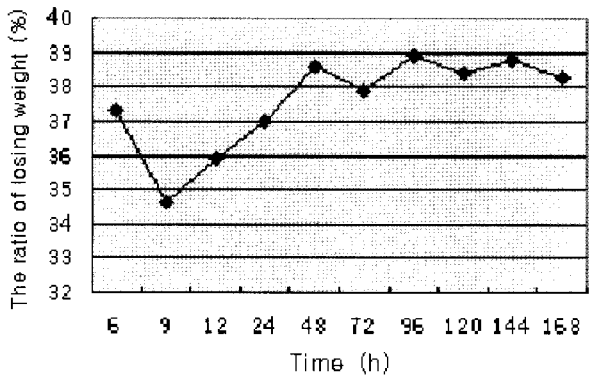

Fig. 2. The relationship between losing weight of DHT coating ratio and heating time at 350℃

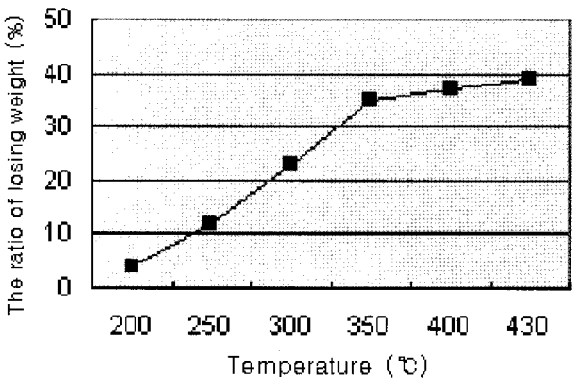

Fig. 3. The relationship between losing weight of DHT coating ratio and heating

samples.

The percentage of losing weight of coating film at different temperature is shown in Fig. 2. It can be seen from the Fig. 2 that the percent of losing weight of coating film increases with the increase of temperature. The lower the temperature, the slower the decomposition rate of the organic component in the coating, the lower the rate of losing weight. And the higher the temperature, the faster the decomposition rate of the organic component in the coating, the higher the percent of losing weight. When the temperature is up to 350℃ ,the increasing of losing weight is very slowly, because the parts of lost-able in the coating have lost basically at 350℃.

4.4 The effect of heating time on physical and mechanical property

After the coating was heated at 350℃ for different time, the test result of the mechanical properties of the coating was shown in Table 3.

Table 3. Test result of coating properties after heated for different time

Time, h	6	9	12	24	48	72	96	120	144	168
Impact resistance, cm	50	50	50	50	50	50	50	25	25	25
Adhesion, grade	1	1	1	1	1	1	1	1	1	1
Flexibility, mm	1	1	1	1	1	1	1	1	1	1

When the test temperature was up to 350℃, during 96 hours, the coating performance kept in good. But with time prolonging the impact resistance decreased obviously. This shows that the coating can't be used for a long time at 350℃.

4.5 The losing weight of coating film in different heating time

After the coating was heated at 350℃ for different time, the percentage of losing weight of the coating was tested and the result is shown in Fig. 3. It can be seen from the Fig. 3 that the percentage of losing weight of the coating doesn't change basically with heating time prolonging at 350℃. This shows that the dependence of losing weight of the coating on heating time is inferior at the certain temperature.

4.6 The cold-heat cycle resistance of the coating

In order to test the temperature change resistance of the coating, the samples of high temperature resistant anti-corrosion coating were placed in the stove at 350℃ for 3 hours, then take them out and placed them in refrigerator at -20℃ for 3 hours, after 10 cycles test, the coating appearance has no changed.

4.7 The Corrosion resistance of the heated coating

In order to simulate the underground working condition of heave oil pipeline, the samples of high temperature resistant anti-corrosion coating were placed in the stove at certain temperature for 3 hours, then taken them out and immerse them in 3% NaCl solution or 10% HCl solution for 3 hours, after a number of cycle test, the coating appearance was inspected. The results are shown in Table 4.

As shown in Table 4, heat resistant coating was damaged quickly during a few cycle of heating at 350℃ and immersion; According to the cycle test of heating at 300℃ and immersion, salt resistance of coating is good, but acid resistance is poor. After 10 cycles of heating at 250℃ and immersion test, the coating still keep excellent salt resistance and acid resistance. It shows that DHT coating has good performance in condition of 250℃.

Table 4. Test result of corrosion resistance of coating after heating

Test condition	Cycles	results
250℃, 3h / 3% NaCl, 3h	10	no objection
250℃, 3h / 10% HCl, 3h	10	no objection
300℃, 3h / 3% NaCl, 3h	10	no objection
300℃, 3h / 10% HCl, 3h	8	Corrosion pin-holes
350℃, 3h / 3% NaCl, 3h	4	Corrosion pin-holes
350℃, 3h / 10% HCl, 3h	2	perishing

5. Conclusion

The heat decomposition temperature of the DHT high temperature resistant anti-corrosion coating is 430℃. At the heat decomposition temperature, the properties of the coating drops remarkable. At the temperature less than 430℃, with the increase of the temperature the deterioration of the coating is accelerated.

The DHT high temperature resistant anti-corrosion coating has good performance in condition of corrosive environment at 250℃.

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