Analysis of Characteristics and Research on Processing Method of the High Viscosity DW-1 Colloid

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Abstract. All the variation of the viscosity characteristics of the high-viscosity DW-1 colloid at different temperatures are mainly analysed in the paper. Based on the experimental data, it concludes that the heat treatment method at 45-65°C can keep the colloid with good fluidity within 15 minutes. The inhibitory effect of organic solvents on solid particles in colloids is also studied. By adding an appropriate proportion of Butanone to the DW-1 colloid, a better colloidal particle treatment effect is obtained and the colloid curing speed is increased by about 2 times within 24 hours. Finally, the treatment methods and effects of colloids before spraying are summarized.

1. Introduction

High-viscosity DW-1 colloid is often used for spraying the thermal insulation layer of rocket tanks[1]. In order to make the spraying work stable and efficient, and to prevent clogging when spraying DW-1 colloids containing solid particles, appropriate treatment is required. The method can make the colloid maintain good fluidity and inhibit the solid particles in the colloid system. By analysing the viscosity change characteristics of colloids at different temperatures, the heat treatment method to maintain good fluidity was researched. To analyse the influence of organic solvents on the solidification characteristics of colloids, the dissolving and inhibiting effects of organic solvents on the solid particles in the system were studied too. At last, it obtained a suitable and effective treatment method for DW-1 colloid comprehensively.

2. Colloidal Material Composition and Viscosity Analysis

2.1. Composition and properties of colloidal materials

High viscosity DW-1 type colloid is a two-component adhesive. The component A is an isocyanate-terminated polyurethane prepolymer. The component B is a kind of amino benzyl methane. The colloid is made up of two components according to a 5:1 mass ratio. The main physical parameters at normal temperature are shown in Table 1. The surface tension coefficient of colloids can be calculated by simulation models like continuous surface force [2] and computer-aided experiments[3].
### Table 1. Standard value of physical parameters of DW-1 colloid (25°C).

| Parameter                  | Value |
|----------------------------|-------|
| Viscosity /mPa·s           | 4500  |
| Density/kg·m⁻³             | 1050  |
| Surface Tension /N·m⁻¹     | 0.015 |

#### 2.2. Analysis of Influencing Factors of the Viscosity of the Colloid

The viscosity of DW-1 colloid is affected by many factors. On the one hand, according to the theory of fluid dynamics, Newtonian hydrodynamic viscosity can be expressed by Newton's formula \([1/1/1]\). The higher the temperature is, the smaller the internal friction resistance is and the lower the fluid viscosity is. For non-Newtonian fluids \([5]\), the higher the temperature, the lower the temperature, the lower the fluid viscosity too.

\[
\mu = \frac{\tau}{du/\,dy}
\]  

Where, ——Internal frictional resistance per unit area of fluid, ——Velocity gradient.

On the other hand, the viscosity of DW-1 rubber will increase with the curing reaction. The higher the temperature is, the faster the curing reaction speed is, the faster the viscosity growth speed is too. Thus, it shows the rapid decrease of fluidity.

The viscosity change of the thermal insulation layer DW-1 adhesive is related to temperature and time at the same time, which is the result of the comprehensive influence of the friction and the progress of the curing reaction in the system.

### 3. Research on Viscosity Characteristics and Heating Method the Colloid

#### 3.1. Analysis of the Viscosity Characteristic at Room Temperature

The characteristics of the viscosity of DW-1 colloid at room temperature over time were studied. 25g of component A and 5 of component B were used to prepare 30g of DW-1 colloid. The prepared DW-1 colloid viscosity was measured at 25°C, and the measurement time interval was 1 minute. Take three readings for each measurement and calculate the average value. The changes in colloidal viscosity within 20 minutes are shown in Table 2.

### Table 2. Measured value of colloidal viscosity within 20min at room temperature (25°C).

| Time/min | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Viscosity/mPa·s | 4380 | 4461 | 4602 | 4770 | 4932 | 5124 | 5340 | 5553 | 5784 | 6012 |

| Time/min | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Viscosity/mPa·s | 6309 | 6609 | 6975 | 7242 | 7587 | 8007 | 8334 | 8754 | 9195 | 9651 |

According to the experimental data, the curve of the DW-1 type colloid viscosity with time at room temperature is plotted, as shown in figure 1.
It can be seen from the graph that with the progress of the curing reaction, the viscosity of the DW-1 type colloid gradually increased and exceeded 9600 mPa s in 20 minutes, and the viscosity increased by about 120% with a larger increase. In addition, the viscosity increased by about 37% in the first 10 minutes, and increased by about 53% in the last 10 minutes. It can be seen that the rate of increase is gradually accelerating. At normal temperature, the viscosity of DW-1 colloid increases rapidly, and its fluidity becomes worse in a short time, which will affect the normal operation of the colloid spraying system. It is necessary to study the proper temperature range of colloid heat treatment.

3.2 Research on Influences of Temperature on Viscosity Characteristics

Low temperature can reduce the solidification reaction speed of the colloid and delay the viscosity growth rate; while high temperature can reduce the internal friction of the colloid system, thereby improving the fluidity of the fluid, and it can also reduce the viscosity to a certain extent. Therefore, it is necessary to obtain the colloid through research Suitable temperature range for good fluidity. The low temperature 5°C, high 95°C and different heating temperatures were selected to study the viscosity change characteristics of DW-1 type colloid.

(1) Viscosity characteristics of DW-1 rubber at low and high temperatures.

The DW-1 colloid prepared by the same method is used to measure and record the change data of viscosity with time while keeping the temperature at 5°C. The measurement interval is 1 min. The measurement results are shown in Table 3. According to the measurement results, draw the curve of the colloidal viscosity change with time at the low temperature of 5°C, as shown in figure 2.

| Time /min | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
|-----------|------|------|------|------|------|------|------|------|
| Viscosity/mPa·s | 12152 | 12571 | 12850 | 13094 | 13378 | 13588 | 13815 | 14081 |

| Time /min | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   |
|-----------|------|------|------|------|------|------|------|------|
| Viscosity/mPa·s | 14271 | 14404 | 14580 | 14768 | 14974 | 15198 | 15443 | 15661 |

At low temperature of 5°C, the viscosity of DW-1 colloid basically increased linearly with time. The viscosity value increased by 18.5% within 10 minutes, and the growth rate was significantly slower than that at normal temperature, but the initial value of the colloid at 1 minute The viscosity reached 12152 mPa s. The viscosity characteristics of the DW-1 colloid under the heating condition of 95°C water bath were also studied. The viscosity measurement value of the colloid at 95°C for about 5 minutes exceeded the range. It can be seen that the excessively high temperature greatly improved the gel curing speed. The speed of viscosity increase is also significantly accelerated.
It concludes that when the temperature is too low, the curing speed of DW-1 type colloid is slowed down, but the friction in the colloid is large, resulting in poor fluidity; when the temperature is too high, the internal friction is reduced, it improves the fluidity to a certain extent, but the acceleration of curing speed leads to the excessive increase of viscosity. Therefore, simple low-temperature or high-temperature processing cannot make the DW-1 colloid meet the normal working requirements.

(2) Variation of initial viscosity of DW-1 rubber at different temperatures.

Based on the above analysis and research, the change characteristics of the initial viscosity of DW-1 colloid at different temperatures were studied. Prepare another 7 groups of DW-1 colloids according to the same ratio, and measure the initial viscosity value at 7 different temperatures for 1 minute. All the measurement results are shown in Table 4.

Table 4. Initial colloid viscosity measurements at different heating temperatures (1 minute).

| Temperature/℃ | 5    | 15   | 25   | 35   | 45   | 55   | 65   | 75   | 85   | 95   |
|---------------|------|------|------|------|------|------|------|------|------|------|
| Viscosity/mPa·s | 12152 | 7975 | 4380 | 2670 | 925  | 231  | 1127 | 3481 | 4347 | 4930 |

According to the measurement results, the curve of the initial viscosity of DW-1 colloid at different temperatures is plotted, as shown in figure 3. The analysis found that the initial viscosity of the DW-1 type rubber was higher when the temperature was lower than normal temperature, which was because the internal friction was large and the fluidity was deteriorated. As the temperature increased, the initial viscosity was obviously obviously within a certain range decrease, then show a slight upward trend.

Figure 3. Initial colloid viscosity at different heating temperatures.

Figure 4. Colloid viscosity change at 55 ℃ heating temperature.

The reason for the analysis of this change rule is that in the proper heating temperature range, the friction in the colloid is reduced and the fluidity is enhanced. At this time, the acceleration of the curing speed has less effect on the system, and the Colloid shows lower viscosity than normal temperature; When the temperature exceeds this range, the curing reaction speed increases sharply and becomes the dominant factor of the system viscosity, reaching a higher viscosity value in 1 minute. The suitable heating temperature range obtained from the study is about 45-65℃. A heating temperature of 55℃ was selected to further determine the change in colloid viscosity with time. The viscosity is continuously measured and recorded. The measurement interval is still 1 minute. The measurement results are shown in table 5. According to the measurement results, the characteristic curve of the viscosity of DW-1 adhesive at 55℃ heating time is plotted, as shown in figure 4.
Table 5. Colloid viscosity measurement value at 55°C heating temperature.

| Time /min | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Viscosity/mPa·s | 231 | 252 | 294 | 309 | 354 | 390 | 426 | 456 | 501 | 549 |
| Time /min | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  |
| Viscosity/mPa·s | 612 | 717 | 903 | 1380| 2013| 2742| 3579| 4545| 5409| 6201|

According to the analysis chart, it can be found that the initial viscosity of the DW-1 colloid is only 231 mPa·s at 55°C, and the fluidity is greatly improved compared with that at normal temperature. The heat treatment method at this temperature makes the colloid substantially maintain a lower viscosity of less than 2000 mPa·s within 15 minutes, which is significantly lower than that at normal temperature. In general, the colloid obtained by the heat treatment method at 45-65°C has good fluidity, which is more suitable for the stable and efficient colloid spraying of the DW-1 colloid.

4. Research on Processing Method of Colloid Powders by Organic Solvent

4.1. Research on the Effect of Organic Solvent on Colloid Powders

The component B in powder form in DW-1 type colloid determines that it is a solid-containing fluid, and an appropriate treatment method is required to suppress solid particles in the system. Butanone solvent is selected as the research object in this paper. It has strong solubility and good volatility[6]. DW-1 colloid sample A was prepared according to standard methods at room temperature. Sample B was used as a control group, and the mass ratio of component A and component B was still 5:1. During preparation, the component B of DW-1 colloid was prepared into a saturated Butanone solution, and then mixed with component A. The mass ratio of the B component to the Butanone used was 1:2.2. The standard colloidal sample A was opaque milky white, and the sample B containing butanone solvent was transparent light green. Observe the microscopic state of the two colloids through a microscope, as shown in figure 5. Sample A has a lot of opaque particles and bubbles. Because sample B dissolves the solid particles in the system using butanone, the interior of the colloidal system is basically transparent except for a few small bubbles. It can be seen that the treatment method using organic solvents has a better dissolution and inhibition effect on the solid particles in the DW-1 colloid.

![Figure 5. Microscopic states of two types of DW-1 colloids.](image1)

4.2. Research on the Influence of Organic Solvent on the Curing Characteristic of the Colloid

The addition of organic solvents changed the shape of the B component in the colloidal system. In order to study its effect on the solidification characteristics of the colloid, the hardness of the two colloids were measured and analysed at room temperature. Take the average of the three measurement
points for each measurement. Continuous measurement of the curing hardness of DW-1 colloid sample A and sample B (containing solvents) was performed at 12 h intervals. The change of curing hardness of colloidal sample A and sample B with curing time is shown in table 6.

| Curing time /h | Sample A hardness /HA | Sample B hardness /HA |
|----------------|------------------------|------------------------|
| 24             | 19.2                   | 57.2                   |
| 36             | 56.8                   | 76.2                   |
| 48             | 67.2                   | 78.2                   |
| 60             | 76                     | 81                     |

According to the measurement results, draw the solidification hardness curve of colloidal sample A and sample B, as shown in figure 6.

It can be found from the analysis chart that the hardness of the colloidal sample A after curing for 24h is only 19.2HA, and the hardness of sample B has reached 57.2 HA. The curing speed within 24h is about 2 times higher than that of sample A; Curing after 48 hours, the hardness growth rates of A and B both slowed down significantly, and the hardness gradually became consistent. After the two colloidal samples were cured for 60 hours, the surface of the cured layer of Sample B was relatively flat and the overall texture was relatively compact, and there were uneven grain protrusions in the cured layer of Sample A. The two kinds of solidified colloids were sliced and observed, and the obtained microscopic state is shown in figure 7. According to the figure, it can be seen that the size of the solid particles in the system of Sample A is smaller than that at the beginning, but the amount of particulate matter is still large; except for the occurrence of some pores in sample B, the composition in the system is relatively uniform, and it basically contains no particulate matter.
Based on the above analysis, the organic solvent has a better inhibitory effect on the colloidal particles, and at the same time accelerates the solidification speed of the colloid, which can shorten the production cycle of the thermal insulation layer to a certain extent. It is conducive to improving production efficiency too.

5. Conclusions
(1) The viscosity of DW-1 colloid is related to temperature and time at the same time, and its fluidity is the result of the combined influence of internal friction and curing reaction.
(2) Based on the experimental data, the viscosity change characteristics of DW-1 colloid at normal temperature and different heating temperature of 5-95 °C were analysed. The heat treatment method of 45-65 °C can keep the colloid to maintain good fluidity in 15 minutes.
(3) The inhibitory effect of organic solvents on colloidal solid particles was studied with butanone. When the mass ratio of colloid component A: component B: butanone was 5: 1: 2.2, a better colloid particle treatment effect was obtained and the curing speed of the colloid was increased about 2 times within 24 hours.

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