Research on Water-Based Quick-drying Coatings for Foundry and the Film-Forming Mechanism

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Abstract: In this paper, the influence of refractory aggregates, binders, and other components on the performance of the coating was studied through single-factor tests using water as the carrier liquid. The optimal ratio of the coating was determined using the orthogonal test method: 75% of refractory aggregate (white corundum powder: bauxite powder = 6:4), 4.5% of acrylic emulsion, 3% of sodium bentonite, and the remaining balance was water and additives. Under the conditions of a temperature of 25 ± 5 ℃ and relative humidity of ≤ 50% RH, the drying time was ≤ 50 minutes, gas evolution was 9.3 mL/g, wear loss was 0.0217 g, suspension property was 99%, and high-temperature crack resistance was grade I. The film-forming mechanism of water-based coatings was studied using scanning electron microscopy and Fourier transform infrared spectroscopy. The results indicated that the water-based quick-drying coating prepared in this study has the advantages of a compact and smooth film, fast drying speed, high film strength, and low gas evolution, which can meet the requirements of casting production.

Keywords: water-based quick-drying coating, drying time, acrylic emulsion, orthogonal experiment

1 Introduction

During the casting process, a layer of coating is applied to the surface of the mold (core) to enhance its surface quality and effectively prevents or minimizes casting defects[1]. Water-based coatings have excellent suspension, thixotropy and leveling properties. It is non-toxic and odorless which can meet the criteria for energy conservation, emission reduction, and environmental protection. This coating offers a promising market prospect in the future. Many domestic and international research institutions and foundries had conducted studies on the water-based coatings [2-6].

At present, the primary obstacle which hinders the widespread use of water-based casting coatings is the long drying time, and drying needs specialized drying equipment. This not only increases production costs but also prolongs the production cycle. This study investigates the influence of refractory aggregate, acrylic emulsion, and sodium bentonite on the drying time of water-based coatings through experiments. The coating components and their optimal ratios were determined through orthogonal testing. The film-forming mechanism of water-based coatings was examined using SEM and FTIR spectroscopy.

2 Experimental procedure

The main raw materials used in the test are white corundum powder (100-200 mesh), high alumina powder (200-300 mesh), acrylic emulsion (commercially available), sodium bentonite (commercially available), and water. The coating was prepared using a combination of gentle stirring and high-speed stirring. Initially, the additives and water were added to the mixing tank for gentle dispersion (5-10 minutes), followed by the refractory aggregate for high-speed dispersion (20-40 minutes). Subsequently, the binder suspending agent was added and mixed at low speed (5-10 minutes) before being packed for use.

The evaluation of coating performance primarily depends on drying time, wear loss, and gas evolution. The drying time of the coating was measured using the QGZ-24 automatic coating drying time tester. Gas evolution was analyzed using the SFL type gas evolution tester, and coating wear loss was assessed with the SUM type coating wear resistance tester, following the guidelines of JB/T 9226-2008.

3 Result and discussion

The influence of refractory aggregates on the effectiveness of coatings.

White corundum was mixed with bauxite in a 6:4 ratio, using varying proportions of 60%, 70%, 80%, and 90%. The study aimed to achieve consistent viscosity by adjusting the amount of carrier liquid. The technical specifications can be found in the accompanying figure 1. Analysis of the figure indicates that the most desirable overall properties, including drying time, are achieved when the refractory aggregate content was at 80%.

The influence of acrylic emulsion on the effectiveness of coatings:

The acrylic emulsion comprises 2-6%, and the technical specifications of the coating were delineated in the figure 2. Examination of the graph indicates that the drying time and overall properties demonstrated optimal performance at an acrylic emulsion content of 5%.

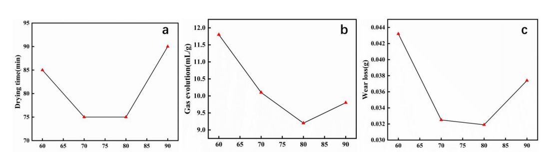

Figure 1 Relationship between refractory aggregates and coating performance

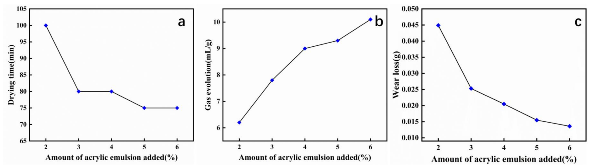

Figure 2 Relationship between acrylic emulsion and coating performance

The influence of sodium bentonite on the effectiveness of coatings:

The sodium bentonite comprises 2-6%, and the technical specifications of the coating were delineated in the figure 3. Examination of the graph indicates that the drying time and overall properties demonstrated optimal performance at an sodium bentonite content of 3%.

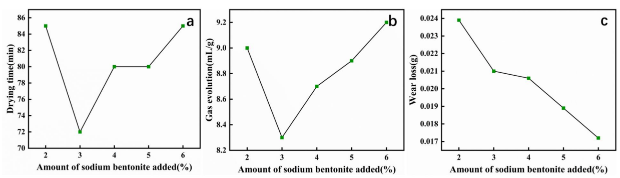

Figure 3 Relationship between sodium bentonite and coating performance

The influence of other components on the drying time of coatings:

The study investigated the impact of quick-drying additives, water-reducing agents, and ethanol on the drying kinetics of coatings. Findings indicated that the combined application of 0.25% quick-drying agent, 0.5% water-reducing agent, and 3% ethanol resulted in a coating drying time of 50 minutes.

Orthogonal experiment to determine the optimal ratio:

A three-factor, three-level orthogonal experiment was conducted to ascertain the optimal composition of the coating. The range analysis revealed that the most efficient blend consisted of 75% refractory aggregate (white fused alumina powder: bauxite powder = 6:4), 4.5% acrylic emulsion, and 3% sodium bentonite. The technical properties of the coating at this optimal proportion were outlined in Table 1.

Table 1. Optimizing the blending ratio of technical indicators

Suspension 48h	Gas evolution ml/g	Wear loss g	Drying time min
99	9.3	0.0217	50

Study on the Film-Forming Mechanism of Coatings:

See Figure 4 for the microscopic morphology, infrared spectrum, and film-forming mechanism of the coating.

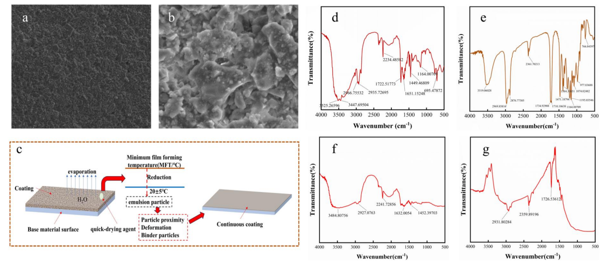

Figure 4 The microscopic morphology, infrared spectrum, and film-forming mechanism of the coating

4 Conclusion

The high glass transition temperature and high minimum film-forming temperature of acrylic emulsion coating bonding system can significantly improve the drying time of water-based coatings. The content of refractory aggregate and sodium bentonite can affect the amount of coating carrier liquid. Through the analysis of coating micro-morphology, infrared spectrum and film-forming mechanism, it was found that the curing speed of the binder, the content of carrier liquid, and volatilization speed were the key factors affecting the drying time of water-based coatings. In this experiment, the room temperature drying time of the water-based quick-drying coating is ≤ 50 minutes, which can meet the casting requirements.

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