Application of alcohol based spraying coating on green sand mould for steel casting

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Abstract. A kind of coating suitable for green sand steel casting was developed. The practical application showed that the strength of the coating was high enough with no crack and no peeling under room temperature after drying the spraying coating, the performance of the coating for anti-cracking was good under high temperature, and the gas evolution of the coating was low. Using the coating, the casting surfaces finish appeared very good.

1. Introduction
Sodium silicate or resin sand molding is most used for steel casting production. Due to high cost of sodium silicate sand and resin sand molding, also difficulty for shakeout, deoxidization and recycling, many foundries began to use green sand molding instead them. Green sand molding which is low cost, high efficiency, occupies an important position in the casting production [1-3]. However, directly using green sand mould to cast steels is liable to bringing about burnt-on sand, sand inclusion, sand holes or/and other casting defects, therefore, the appropriate coating matching is necessary, and the development of fireproof coating for steel casting by green sand molding is of great significance.

2. The characteristics of green sand casting steel coating
Pouring temperature in steel casting is high, up to 1550~1600 °C, it requires coating being with resistance to high temperature and burnt-on sand for steel casting mould. The strength of green sand is poor, brushing coating on the surface of green sand mould will be easy to bring up the sand, so it is not suitable for brushing, and spraying is preferred. Water-based paint will further increase the sand surface moisture, causing sand strength lower, at the same time increase the gas evolution, and drying process influence the production efficiency, so alcohol based spraying coating is more appropriate.

Since the permeability of green sand mould is low, and gas evolution tendency of it is larger, the gas evolution of alcohol-based coating should be as small as possible. Spraying process requires that the refractory particle should be fine, requires that the coating should be in good adhesion strength on mould sand, be good permeability, and be more resistant to cracking and peeling.

In general, after spraying, the coating could dried by ignition, also can be natural dried. But light dry may be easy to cause coating peeling and cracking, because the volatile solvent burn fast, the coating dry too quickly, shrink sharply, and the strength of sand mould surface is basically low and get to be lower due to the solvent infiltration. Therefore, air drying after spraying coating would be preferred.

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advisable.

3. The component of spraying coating for green sand steel casting

3.1. Refractory aggregate
It is generally believed that zircon powder is the most suitable refractory aggregate for cast steel coatings [4]. However, the production practice shows that the single zircon powder coating may not completely resist burnt-on sand, and zircon powder coating is expensive [5]. Besides zircon powder, other high fire resistance of the aggregate such as white corundum, brown corundum, bauxite, is relatively economy, with which the burnt-on sand resistance would be better than that of the single zircon powder coatings as long as the ingredient is appropriate[6, 7].

For a long time, the ingredient of coatings only focus on composition of additives such as binder, suspending agent and accessory ingredient, ignore the collocation of refractory aggregate. Really for one kind of good quality coating, the kinds of refractory aggregate, in which the collocation about particle size are also important to be considered, in addition to the appropriate additives proportion. If the aggregate particles are too coarse, the spraying nozzle would be blocked, too fine, the coating will be not conducive to reducing crack tendency [4]. Taken together, a certain proportion of white corundum and brown corundum blended in with zircon powder as refractory aggregate was adopted in our scheme. Aggregate particles mesh distribution was between 220 ~ 325 mesh.

3.2. Agglomerant
Coating must have sufficient strength both at room temperature and at high temperature. Agglomerant of alcohol-based coating for room temperature involve resin, rosin, polyvinyl butyral (PVB), and for high temperature involve bentonite clay, refractory clay, phosphate, ethyl silicate and so on. Considering coating strength, crack resistance and fast drying characteristics, an appropriate constituent of organic and inorganic agglomerant blended as a multiple adhesion agent was proposed to satisfy the necessary strength for both room temperature and high temperature [8].

3.3. Suspending agent
Coating must be of good suspension stability, so as to facilitate transportation, storage and stirring to be uniform seriflux before spraying. Due to the compatibility problems to be blended into alcohol solvent, the suspending agent for alcohol-based coating is not a lot, and the suspensibility of alcohol-based coating is always less than that of water-based coating. The suspending agent for alcohol-based coating involves PVB, sodium-based bentonite, lithium-based bentonite, organic bentonite, and some commercial suspending agent such as SN suspending agent, etc. PVB and resin would form a dense protective film which does not facilitate the resin combustion gas to go out of coating and prone to blistering while burning coating, should not be added much. Sodium-based or lithium-based bentonite need water to be swelled, water will be increased in coating, which reduce the strength of sand mould surface, and is not conducive to quick drying, meanwhile, water precipitation would decrease coating stability. It is clear that neither sodium-based bentonite nor lithium-based bentonite is suitable for spraying coating. No matter what kind of coating, bentonite can't be added much, otherwise cracking will be likely to occur on coating.[4, 8, 9] As comprehensive consideration, the organic bentonite, a small amount of PVB, were added as the suspending agent.

3.4. Solvent
The solvent of coating was a kind of mixture based on anhydrous ethanol with other alcohol solvent, in which compatibility of mixture within coating would be improved, leading to quick drying.

3.5. Additives
Adding additives can improve wettability, dispersion, permeability, adhesion strength of coating, reduce or eliminate the tendency of cracking and peeling. Additives commonly used that could
enhance permeability and dispersion are JFC and OP-10[3, 4, 9].
In order to improve the agglomeration of the coating, and to reduce the tendency to burnt-on sand, an oxide sintering agent was appended.

4. Testing of coating performance

4.1. Viscosity, Baume degree and suspension property
Test of viscosity was by flow cup with a tapping hole of diameter Φ6 mm on the bottom, Baume degree test was by Baume scale, and the test of suspension property was by quiet placing in graduated flask.[4]

4.2. Coating strength at room temperature
Sand particles falling down from a viscosity cup to hit a coated glass surface until the coating was chafed, weighing the weight of the sand dropped out once the coating was abraded, the total weight of the sand was as the evaluation index of surface coating strength, seeing the reference for specific operation. [4]

4.3. Crack resistance at high temperature
A Φ60mm × 60mm cylinder specimen was made from green sand with washing silica sand 50/100 mesh (old and new sand ratio of 1:9), which contain 3.0% bentonite and 3.5% water. The sample was sprayed coating with thickness of 0.5-0.8 mm, air dried, then was put inside a furnace within which high temperature atmosphere was to 1200℃, staying 2 minutes, the coating crack could be observed if it was likely to crack. [4, 5]

4.4. Gas evolution
Scraping coating powder and crushing down, weighing accurately for 1.0 g, the gas evolution of coating at 850℃ could be measured by SFL type recording gas evolution test apparatus. [4, 5]

4.5. Cracking and peeling resistance at room temperature
Evaluation of cracking situation of coating while drying after spraying on green sand moulds at room temperature was by actual observation.

4.6. Sintering and stripping property
Casting steels actually, sintering and stripping performance of the coating was evaluated by actual observation.

5. Ingredient of coating and the main performance
Referring to the domestic and foreign literature [1-11], by some tests in laboratory and production trial in workshop, an appropriate ingredient of coating was determined, which is shown in table 1. Coating performance is shown in table 2.

| Table 1. Ingredient of coating for spraying alcohol-based green sand mould (%) |
| Zircon powder + corundum | Organic bentonite | Organic binder | Inorganic binder | PVB | Additives | Mixture solvent | remainder |
|---------------|-----------------|--------------|---------------|-----|----------|----------------|--------|
| 66            | 2.0-3.0         | 1.0-2.0      | 1.5-2.5       | 0.2-0.5 | 2.0-5.0  | solvent       | remainder |

| Table 2. Performance of coating for spraying alcohol-based green sand mould. |
| Viscosity (Φ 6 flow cups)/s | Baume degree/Be | Suspension property (24 h)/% | Density/ g·cm³ | Coating strength at R.T./g | Resistance to cracking at H.T. (1200℃,120s) | Gas evolution /ml·g⁻¹ | |
|--------------------------|------------------|-------------------------------|----------------|--------------------------|-----------------------------------------------|-------------------|
6. Application of the coating

6.1. Production trial and effect show
Alcohol-based spraying coating for green sand was used in steel foundry, in Tongling Branch, CSR Yangtze Co., Ltd.. Surfaces of the green sand moulds for casting bolsters and frames were sprayed with coating. After drying in the air, no crack or peeling was observed on the coating film, and the casting surfaces finish were good, as shown in figures 1 and 2.

Figure 1. Spraying coating on (a) half mould of a side frame (b) an end of mould of side frame (c) upper mould of a swing bolster and (d) lower mould of a swing bolster in production.
6.2. Discussion

6.2.1. Influence of bentonite and agglomerant on coating. Appropriate amount of bentonite and agglomerant, is the guarantee for good suspending and rheological properties of the coating, also the guarantee for wet strength after spraying, for dry strength at room temperature after drying, for high temperature strength while casting, of the coating. If bentonite in coating were not enough, or too much, cracking or peeling is likely to occur on the coating after spraying. This is because insufficient bentonite could lead to low wet strength, and too much of bentonite could lead to big shrinkage and cracking. If agglomerant were not enough, dry and wet strength of the coating would be low, that is liable to cause crack. Once crack occur at wet coating in the process of drying, the crack will be easy to extend, become a long crack and cause peeling on the coating after drying, as a result, the coating would have to be out of effect. Too much of organic agglomerant, maybe beneficial to the improvement of the wet and dry strength, but would cause a large gas evolution, thus pinholes might appear on casting surfaces.

6.2.2. Influence of additives on coating. Two additives are worth noting. First, wetting agent, which promote wetting between coating and mould, should be in moderation, too much would lead to poor film-forming, even to local crack, and too little, would lead to poor permeability and poor adhesion on mould surface in some local surfaces, as a result, it would be difficulty for coating to "take root", bring about uneven shrinkage strain on the coating in the process of drying, thus would lead to peeling and cracking. Sometimes, even though no cracking and peeling at coating, the whole coating is going to fall off due to inadhesion to moulds, which immediately lose shielding effect because of cracking or being washed away at high temperature while casting pouring. The second, flake sintering additives, involve several oxides added, are to counter the oxide consumption in reaction with such as SiO₂ and Al₂O₃ existing in sand mould surfaces. Redundant oxide would accumulate on the metal surface, form a kind of molten sintering layer that would be easy to peel off from casting due to the difference of contraction coefficient, avoiding burnt-on sand on casting, and casting surfaces would be clean. Too little oxide added would lead to poor/no resistance to burnt-on sand, and too much, would lead to deterioration of the coating strength.

6.2.3. Influence of the solvent. A kind of mixture solvent based on anhydrous ethanol added other alcohol solvent such as isopropyl alcohol, methanol and n-butyl alcohol under the appropriate proportion, was used, which would be the guarantee of wet strength of coating. Single use of ethanol or industrial alcohol, coating is prone to crack. This may be the consequence that the single anhydrous ethanol solvent would evaporate too fast, causing the coating drying fast before it penetrate into sand mould.

6.2.4. Influence of coating spraying process. Spraying process is important besides the quality of coating must be qualified, and the adjustment of process would be necessary to adapt depending on the change of seasons. In 20-25℃ environment, the baume degree suggestion of coating 58-63 would be more appropriate. In hot summer above 30℃, the baume degree suggestion 56-60, and in cold winter below 10℃, the baume degree could be adjusted to 60-63, but not more than 65. If baume degree were too high, it is difficult for the coating to penetrate into the sand mould before air dried, and if baume degree were too low, solvent permeability is too much to deteriorate sand strength, that would be easy to cause the coating crack and peeling. Spraying pressure suggestion is 0.2-0.35 Mpa. If the pressure were too high, coating grain will rebound, make against form coating. The spraying nozzle height to the mould surfaces should be appropriate with 500-700 mm, too low for the height is similar to the
consequences of too high for the pressure. Conversely, too high for the height is similar to the consequences of too high baume degree because the solvent would be lost fast in the air.

7. Summery

7.1. The developed coating is good and feasible
The spraying coating developed for green sand casting steel, is of high wet strength, of good cracking resistance at room temperature and high temperature. No burnt-sand occurrence on steel castings and the surface finish of castings were good, after spraying on green sand moulds before casting.

7.2. Matters needing attention about preparing coating
To prepare coating for green sand casting steel as spraying coating, attention should be paid to the amount of bentonite, appropriate addition of additives and the use of mixed alcohol solvent, so as to avoid crack and peeling, to ensure the coating sintering layer formed under high temperature reaction, then the surface of casting to be easily peeled off and to avoid burnt-sand.

7.3. The correct spraying process is necessary
The correct spraying process could ensure to achieve the best effect of the coating.

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