

Improved surface of additive manufactured products by coating



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ABSTRACT

The additive manufactured coated sand products had obvious staircases on the surface and lots of small holes inside. The alcohol based refractory coating and the water based refractory coating were applied to improve the surface of the samples. The polygonal samples were used to check the effects of the coatings on reducing the surface roughness. The “8” shape samples were used to compare the effect of dipping time on the moisture content and the tensile strength of samples and the coating thickness. Results showed that the surface of samples could be improved by both alcohol based refractory and water based refractory coating. By the alcohol based refractory coating, the moisture content and the coating thickness increased and the tensile strength decreased with the dipping time obviously. By the water based refractory coating, the moisture content, the tensile strength of samples and the coating thickness kept approximately changeless with the increment of dipping time, which meant it could have enough time to dip to assure the coating's quality on the surface of the samples. In conclusion, it was suitable to apply water based refractory coating and the dipping process to improve the surface of additive manufactured coated sand products.

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1. Introduction

Additive manufacturing is a process of making a three dimensional solid object of virtually any shape from a digital model. It is achieved by using additive process, in which an object is created by laying down successive layers of materials [1–5]. It could manufacture complex parts which are difficult or impossible to fabricate via machining. However, using previous additive manufacturing technology to manufacture complex metallic products is highly time consuming and expensive. A cost and performance balanced approach could be achieved by the combination of additive manufacturing and casting technology [6–10]. Firstly, a complex coated sand mold would be produced by additive manufacturing. Afterwards, the product would be obtained by casting process. However, the layer by layer additive process would restrict the surface finish of the mold [11–14], which would influence the casting's roughness and dimensional precision.

To smooth the surface of additive manufactured coated sand mold, it was suggested to minimize the particle size and the layer thickness [15]. However, it hardly compress the layer thickness too much because of the particle size's restriction and production efficiency's requirement. Another selection was polishing, but that

would damage the part's precision, and some position could be polished. The refractory coating has been widely used in foundry production [16–19]. It is mainly divided into two categories by solvent: alcohol based refractory coating and water based refractory coating. The commonly used coating process includes brush coating process and dip coating process. Brush coating process is convenient to use, but the surface finish critically depends on the operation and usually leaves brush marks. Dip coating process has the best surface finish especially for complex products, which would be suitable to improve the surface of additive manufactured coated sand mold.

Compared to the sample produced by the core box, the sample obtained by the additive manufacturing has lower compactness and rougher surface. The effects of coating on it would be different. The objective of this paper is to optimize the surface of additive manufactured coated sand sample by coating.

2. Materials and methods

In this paper, all the samples were produced by an additive manufacturing machine which adopted profile invalidation method (shown in Fig. 1). To check the coating's improvements on the surface roughness, the polygonal samples with convex surface, concave surface, flat surface and angular surface were manufactured. To investigate the characteristics of the coated sample, such as moisture content, tensile strength, coating thickness, the “8” shape

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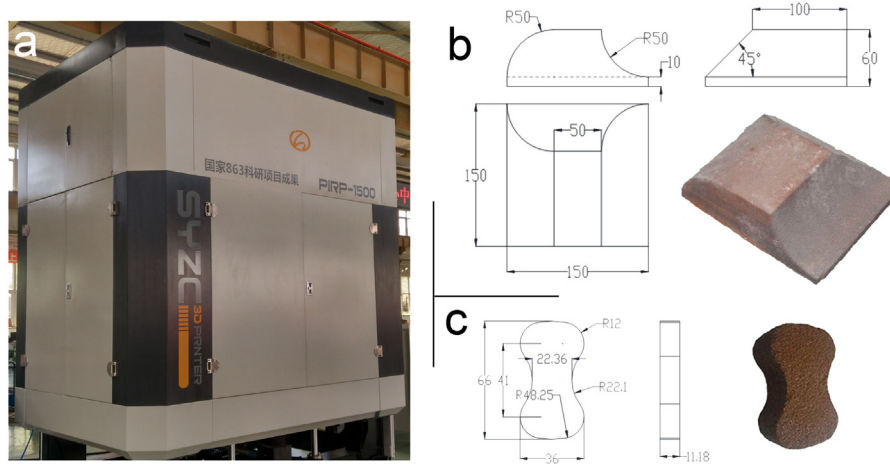


Fig. 1. Samples produced by additive manufacturing: (a) additive manufacturing machine; (b) polyhedral sample; (c) “8” shape standard sample.

Table 1

Parameters of samples made by additive manufacturing.

Parameter	Condition
Layer thickness	0.30 mm
Room temperature	25 °C
Modeling material	Coated sand
Laser power	90 W
Scanning speed	230 mm/s

Table 2

Parameters of alcohol based refractory coating (ABRC) and water based refractory coating (WBRC).

Parameter	Condition
Baume degree of ABRC	70
Baume degree of WBRC	70
Solvent of ABRC	Ethyl alcohol
Solvent of WBRC	Water
Aggregate of ABRC	Zircon
Aggregate of WBRC	Zircon
Viscosity of ABRC (30 r/min)	500 mPa s
Viscosity of WBRC (30 r/min)	1200 mPa s
Yield stress of ABRC	3.70 Pa
Yield stress of WBRC	3.90 Pa

samples were made according to the Chinese National Standard GB2684–81. The parameters of the samples made by additive manufacturing are shown in the Table 1.

The alcohol based refractory coating and the water based refractory coating with zircon aggregate were used, and the baume degree of coating was set to 70 for both alcohol based refractory coating and water based refractory coating. The parameters of the two coatings are shown in Table 2. The polygonal samples were dipped into the alcohol based refractory coating and water based refractory coating for 5 s respectively. Then the samples with alcohol based refractory coating were ignited and the samples with water based refractory coating were heated at $180 \pm 10^\circ\text{C}$ for 3 h. Afterwards, the surface roughness of coated samples was examined by visual observation and portable roughness instrument TR200. The “8” shape standard samples were divided into two groups. The dipping time was set to 1 s, 3 s, 5 s, 10 s, 30 s. Each sample was dipped into the coating with one dipping time. It should measure the weight of each coated sample immediately when it was taken out of the coating. Then each sample was heated at $180 \pm 10^\circ\text{C}$ for 1 h and weighed with the dry coating. The weight difference was considered as the moisture content. Afterwards, the tensile strength was measured by a SWY Hydraulic universal strength testing machine. The coating thickness at cross section was measured

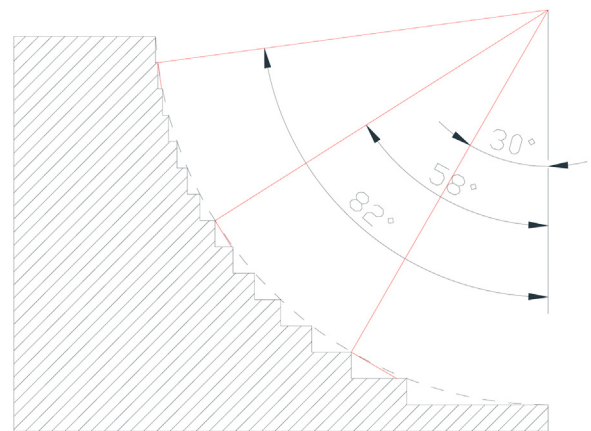


Fig. 2. Surface staircases changed with the surface normal of additive manufactured sample.

by a microscope. Each set of experiments repeated three times and the mean value as a result of the experiment.

3. Experimental results

3.1. Characteristics of additive manufactured sample

Due to the layer by layer additive process, the polyhedral sample would have obvious staircases. If they were not treated, the rough surface on the mold would be transferred to the final casting. As shown in Fig. 2, the staircases were affected by the layer thickness and the angle of surface normal. As shown in Fig. 3, the coated sand was composed of high grade silica sand, catalyst and phenol-formaldehyde resin. When heated at curing temperature, it would have high tensile strength due to the bonds between particles. However, there were large number of micro-scale holes in the additive manufactured coated sand sample.

3.2. Comparison of coated samples

3.2.1. Surface roughness

Through dip coating process, the surface of polyhedral samples were improved to a large extent by both alcohol based refractory coating and water based refractory coating. As shown in Fig. 4 and Table 3, it had 0.30 mm height staircase before treatment. After dip coating process, the staircases were eliminated by coating and the surface became much smooth. The surface roughness decreased to

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