Effect of Catalyst on Quality of 3D Printing Sand Mold/Core

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Abstract: The strength and the dimensional accuracy are two important factors affecting the quality of sand mold/core produced by 3D sand printing (3DSP), which are not only closely related to the reactivity of furan resin and the phase transition of silica sand, but also to the catalyst of furan resin. Taking the furan resin system as an example and using a sand specimen produced by a 3DSP machine, the influence of catalyst on the strength of a 3DSP sand mold/core was studied. Experimental results show that the amount of catalyst of 0.22% to 0.25% by sand weight for the sand mixture is the most suitable for 3D printing core-making. However, it should be noted that the amount of catalyst is less than 0.22%, the tensile strength of a no-bake sand mold/core is higher than that of a 3DP sand mold/core, while the amount of catalyst was more than 0.22%, the result was the opposite.

Keywords: 3D sand printing; catalyst; gel time; sand mold/core.

1 Introduction

3D sand printing is by far one of the most successful technologies applied in foundry[1], which accelerated rapid product development and unit production. 3D sand printing cores differed from traditional sand cores for its lower density, higher porosity and rougher surface quality. During the 3D sand printing process, the substrate will drop 0.2-0.6 mm after recoating sand and jetting binder for one layer. If the curing rate of resin is too low with lower strength, a small amount of relative displacement will occur between the sand layers. Determining the most suitable amount of catalyst of the bonding system for the 3DP process is the goals of this study.

2 Experiment procedures

The sand specimens were prepared with the same silica sand, furan resin binder and sulfonic acids catalyst by no-bake resin sand method and 3DP method, respectively. When preparing no-bake sand samples, 1 kg sand was put into the sand-mixing machine with 0.12%-0.3% catalyst (by sand weight) and mixed for 2 min, then mixed with 1% furan resin for 30 s. After that, the mixed sand was put into the eight-character die to complete the sample preparation within 1 min, and then the tensile strength was measured at 1 h and 24 h.

When preparing the 3DP samples, the 0.12%-0.3% catalyst was mixed with silica sand by the continuous sand mill. 10 kg sand was mixed each time, and then the mixed sand was dried over 12 h in the sack at 25±2 °C, 45±5 RH. Then, the 3DP samples were printed on a Voxeljet VX200 printer using the prepared sand as powders and 1% (by sand weight) furan resin as spray binder. The printed samples were cleaned 2 h after the printing finished, and the tensile strength at 24 h was measured.

3 Results and discussion

A different amount of catalyst was added, and the tensile strength of samples by no-bake sand process and 3DP process were compared. As can be seen from Table 1, as for 24 h strength, it firstly increased with the increasing content of catalyst and went down when the amount of it was more than 0.22%.

Table 1: Effect of catalyst addition amount on strength of no-bake resin sand

Addition amount (%)	Gel time (min)	Stripping time (min)	24h tensile strength (MPa)
0.12	30	100	1.50
0.15	20	55	1.60
0.18	13	51	1.60
0.20	9	36	1.85
0.22	5	28	1.65
0.25	2	18	0.20
0.30	1	12	0.05

Figure 1 compares the tensile strength of 3DP sample and no-bake sand sample as a function of the amount of catalyst. When catalyst was less than 0.22% by sand weight, the tensile strength of no-bake sand was higher than that of 3DP sand, and When catalyst was more than 0.22%, the result was the opposite. The sand core fabricated by 3DP possessed the highest tensile strength when the addition of catalyst was between 0.22% to 0.25% by sand weight. As for the no-bake sand, the tensile strength increased when the addition is less than 0.22%, which decreased significantly when the amount of that was more than 0.25%. As the amount increases 0.22% to 0.3%, the 24h tensile strength decreases from 1.35 to 1.05 MPa, decreased by about 22%. What's more, the best tensile strength of no-bake sand specimen was 37% higher than that of the 3DP specimen.

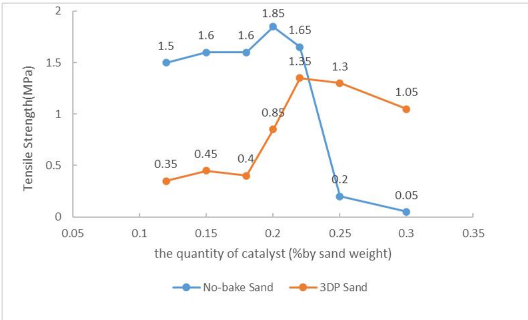

Figure.1: the tensile strength of specimen by no-bake sand and 3D sand printing with different amount of catalyst

Sand compaction

The density of 3DP specimen (1.35-1.45 g/cm^3) is less than that of no-bake sand (1.45-1.55g/cm^3) for the sand spreading pressure in 3DP process is less than that of no-bake sand. The sand compaction was a main technical specification for sand casting and became more and more important in the 3DP process. The porosity of the 3DP specimen reached up to 40% because the raw sand concentration was up to 95% by the two-sieve screening method or the three-sieve screening method [8]. The sand was covered with binder by capillary action without fully stirring as in the no-bake sand[2]. As illustrated in Fig. 2, the 3DP specimen showed fewer and smaller adhesion bridges compared with the no-bake sand specimen, which is the reason why the 3DP specimen had lower strength than no-bake sand under the same amount of binder and catalyst. The liquid binder flowed slightly by gravity and surface tension in large space because of lower compaction, resulting in a longer gel time, which would deteriorate the strength of the specimen.

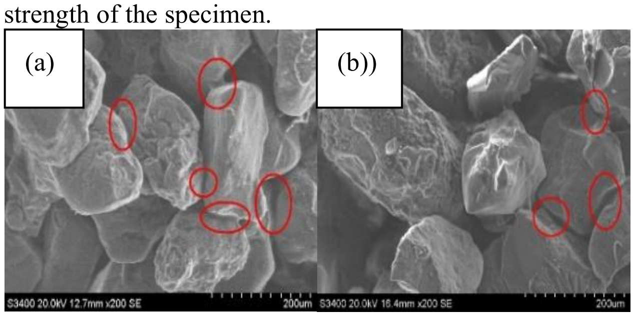

Fig. 2: SEM image of no-baked sand (a) and 3DP sand (b)

Catalyst crystallization

As shown in Fig. 3, the sulfonic acids could crystallize on the sand surface after solvent evaporated in the process of drying mixed sand. For better recoating sand, the sand mixed catalyst was dried for more than 12h, and most of the solvent was lost during drying.

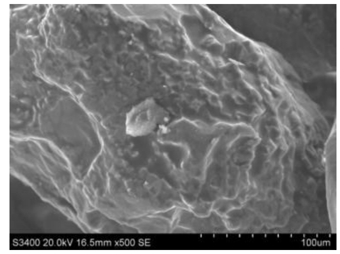

Fig. 3: SEM image of acid crystallization on sand

In the 3DP process, the binder printed on the sand, the sulfonic acid of catalyst needs to be dissolved in the binder, which provides the H^+ required for the curing of the resin. During the process of forming the network from the resin to the body structure, a considerable amount of acid has not been dissolved, which cannot move to the adhesion bridge in the form of ions from liquid, resulting in an insufficient acid amount. Therefore, the catalyst in the 3DP did not fully function and strength was lower compared to the self-hardening mold/core. In this case, when the amount of catalyst was less, the acid of the catalyst reacting with binder was dissolved while the binder was being cured, so that the strength was lower; this is an unavoidable problem during the use of the sulfonic acid-based catalyst in the 3DP process. To reduce the gel time, excessive catalyst was added to increase the sulphur amount which would be corrosive to the recoater. To sum up, the key point to solve this problem was to promote activity of a catalyst which could gel in a short time with less amount, or to develop a new catalyst without crystallization or corrosion. Besides this, wet-recoating is another effective way to solve the above problems.

4 Conclusions

The amount of catalyst had significant impact on sand strength. The most suitable amount of the catalyst in 3D sand printing was 0.22% to 0.25% by sand weight. The compaction rate of the sand mold/core was low, resulting in bond bridges with low number and small area, which caused the strength of the 3DP sample to be lower than that of no-bake sand. Sulfonic acids catalyst would crystallize and redissolve during 3DP process, which required sufficient amount of acid to improve the tensile strength.

Reference

[1] Hartmann C, Silberhorn J, Erhard P, et al. On the mechanism of binder migration in furan binder jetting of sand molds and cores[J]. Additive Manufacturing, 2024, 83: 104073.

[2] Yang W D, Jia P F, Ma Y Y, et al. Modeling and simulation of binder droplet infiltration in 3D printing technology. Nanotechnology and Precision Engineering, 2017, 15(4): 246-253.