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Technology and mechanism of a new protein-based core sand for aluminum casting①

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[Abstract] The protein-based binding material is from natural products, which is nontoxic and recyclable. This kind of green binder is earnestly needed by aluminum casting products. The new protein-based core possesses higher strength and easier shakeout. Its tensile strength is close to that of common resin sands. The micro-mechanism of protein binder was investigated by using infrared spectrum, chemical element analysis, SEM and thermal lost-mass analysis.

[Key words] protein; core sand; binder; aluminum casting
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1 INTRODUCTION

The environmental problems are deeply concerned in world wide. The researches of making good use of resource and cleanness process are basic developing trend on nonferrous metals[1]. There are many harmful and toxic elements in commercially used resin binders for aluminum castings. Resin binders and catalyzer which contain poisonous elements make unexpected and incontrolable pollution when they are used[2, 3]. The defective mold and core that can't be recycled in reasonable cost and waste sand that is large amount of solid garbage result in the pollution of the atmosphere, the water and the soil, and reducing the quality of circumstance[4]. In addition, the synthetic resin is expensive as it's from rock oil. Civil and alien foundry experts carrying out the concept of "low pollution and waste, advance property and technology" demand pay good attention to circumstance protection and reasonable resource using when considering efficiency, quality and profit[5].

Foundry binders are required to be low or nonpoisonous, of no horrible smell, not harmful when touched directly by skin, of no poison to the water or environment being leaked out from the waste sand, easy to be decomposed and erased, that is to say, the sand should be easy to recycle. Good core technology properties are suitable to the needs of processes of foundry. Besides higher tensile strength, good flowability of the sand, good surface property, easy shaking out under temperature 650 ℃ for aluminum castings, resistance of moisture absorption and low gas evolution are also required. Easy availability and reasonable cost are important in selecting foundry binder.

Of course, there is not any kind of binder which can meet all the needs. But the protein-based binding material is from farm sideline products, which is cheap, nontoxic and recyclable. The new protein-based foundry binder demonstrated significant advancements in technological and environmental areas.

2 EXPERIMENTAL

The tensile strength and surface hardness of standard "8" sample were the main targets in this paper. The compressive strength and shakeout properties were tested too. The testing method of shakeout property covered: first, making a d 50 mm × 50 mm sample and heating it to a certain temperature for 30 min, then cooling it to the room temperature, last, testing the mass percents of broken cores.

The average testing values of three in five is considered in order to reduce experiment error (get rid of a max and a minimum).

2.1 Materials

Standard sand "NBS50/100(O)" is made in Dalin, China.

The protein binder is a kind of natural amino acid ramification glue. Its molecular formula is $C_{n1}H_{n2}O_{n3}N_{n4}$. Its relative molecular mass is from 20 000 to 250 000. Water is selected to dissolve glue. Its concentration can be adjusted with core strength or temperature etc.

The various binder addition levels and curing pa-

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rameters are as follows. Starch bonding sand: sand 100%, starch 2%, water 5%, curing temperature 180 ℃, curing time 30 min; Oil bonding sand: sand 100%, oil 2.5%, little water and dextrin, curing temperature 210 ℃, curing time 60 min; Fat bonding sand: sand 100%, fat 2.5%, curing temperature 210 ℃, curing time 60 min; Protein bonding sand: sand 100%, protein binder 1.4%, water 7%, curing temperature 180 ℃, curing time 30 min.

2.2 Equipments

"SHN-5" sand muller;

"SWY" tensile strength testing apparatus;

"CORE HARDNESS 647-DETROIT-4" core surface hardness apparatus made in USA;

"Series II-CHN S/O-2400" element analysis apparatus made in Perkin Elmer Company of USA.

3 RESULTS AND DISCUSSION

3.1 Tensile strength and surface hardness

A comparison test between protein sand and various traditional sands is made. The protein sand possesses higher strength (see Table 1). Its tensile strength is close to that of common resin sand. The test also shows that protein samples having 1% binder by mass are as strong or stronger than conventional binder samples. Less content of binder is needed to meet the core demand because of higher specific strength.

Table 1 Performance of sand or core made by various binder

Sand	Compressive strength / 10^{-3} MPa	Tensile strength / MPa	Surface hardness	Special strength / MPa
Protein	6.4	2.47	92.4	1.76
Starch	5.6	0.98	65	0.49
Fat	–	1.9	81.9	0.95
Oil	–	3.4	93	1.36
Cold box*	–	2.25	93	1.12
Hot box*	•	2.5	92.5	1.0
Shell*	–	3.5	94	0.9

* Data from foundry plant of automobile company

The green compressive strength of protein core is higher than that of starch core. And green compressive strength of fat sand or oil sand are very low. Surface hardness expresses the impacting degree of metal liquid against core face. Table 1 shows that the surface hardness of resin sand, oil sand and protein sand is higher than that of fat sand or starch sand.

3.2 Shakeout property

Fig. 1 shows that the shakeout property of starch sand or protein sand is better than that of oil sand. But as we know that oil sand shakes out easily. The TGA curve of protein (Fig. 2) indicates that protein binder has almost decomposed under 600 ℃. So the protein binder cores are very fit for aluminum casting.

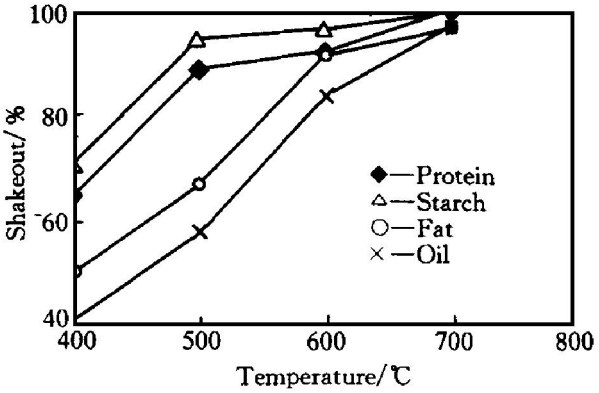

Fig. 1 Shakeout property of various binder cores

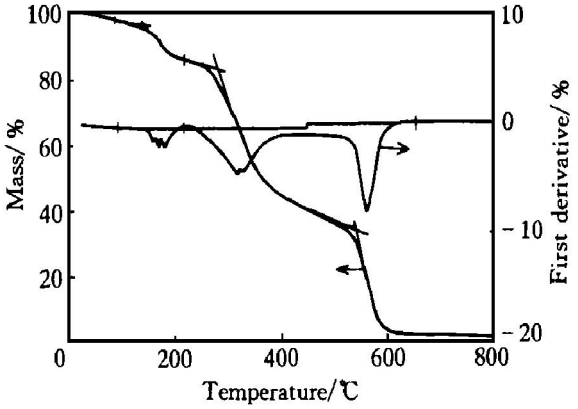

Fig. 2 TGA curve of protein binder

3.3 Recycling property

During production of cores, some defective cores will be made inevitably. With some "spare sand mixture", these defective sand cannot be recycled. The main target of this experiment is to test if they can be reused, that is recycling property of protein-based sand binder, in order to avoid industrial waste.

It is found for the first time that the protein sand is easily recycled. The unused sand mixture or core scraps can be added as new sand. The comparison between new sand and recycled sand shows (Fig. 3) that the recycled sand possesses higher strength because of some binder existing bond active with water. Protein binder takes place a reversible reaction during the curing process so that the sand can be reused. The recyclable property of protein binder is notably superior to resin binders. The lower binder level with the recycled sand is needed to achieve demanded core strength.

During the foundry production process, to avoid scrap core sands entering in mold sand is impossible, which influences the quality of mold sands. Fig. 4 shows that protein core sand almost has no effects on

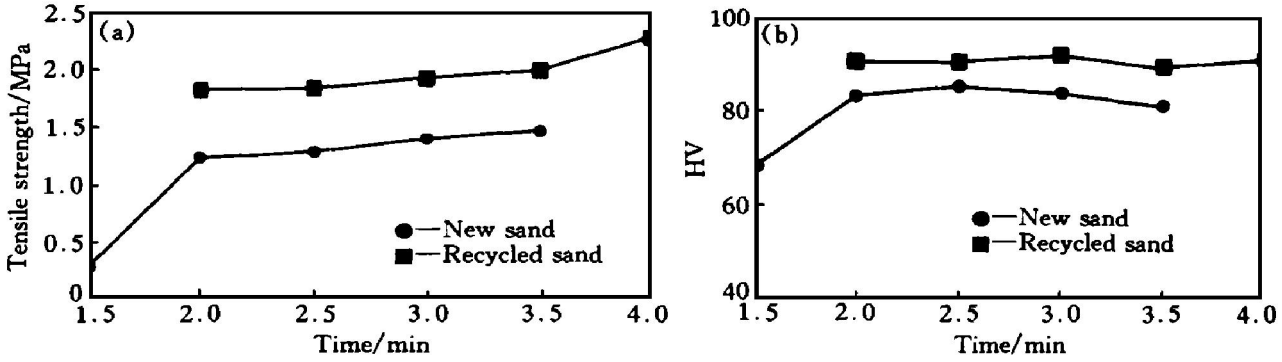

Fig. 3 Performance of cores made by new sand and recycled sand
(The core material levels: sand 100%, binder 1.0%, water 7.0%)
(a) —Tensile strength; (b) —Hardness

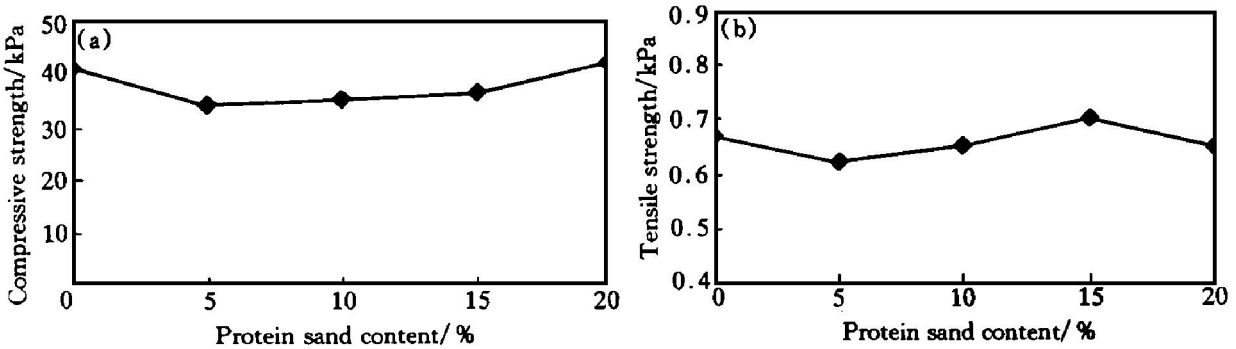

Fig. 4 Influence of protein sand on strength of green sand
(a) —Green compressive strength; (b) —Hot-green tensile strength

green sand properties.

3.4 Microstructure and curing mechanism

Protein is composed of about 20 kinds of α-amino acid[6,7]. The influence of protein binder on the environment was investigated by using infrared spectrum, chemical element analysis and theoretical analysis. The results (Fig. 5) show that the main chemical elements in protein are C, H, N and O. There are no noxious or harmful elements at normal temperature, such as S and P, and no possibility producing NO_x in foundry process because of N reducing

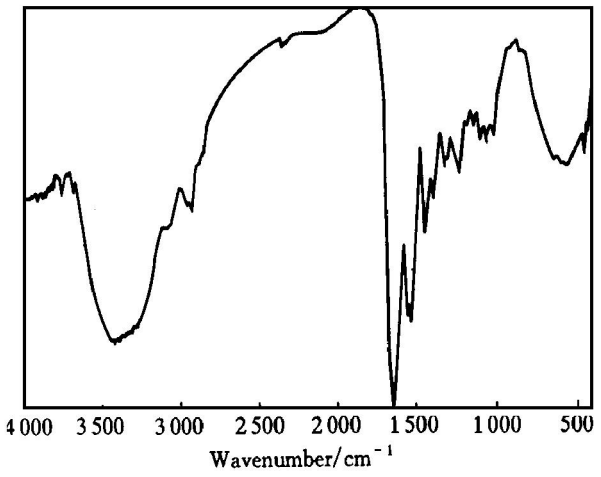

Fig. 5 IR spectrum of protein glue

only 1.56%. It is proven that the protein binder is an environmental and benign material. As a flocculation agent, protein glue is used to purify drinkable water[8].

Being a kind of natural polymer, protein has very complex structure. The curing process is to turn one passel complex materials to another same complex materials[9]. The dehydration occurs between amido and hydroxy when heating amino acid. Its reaction formula is as follows:

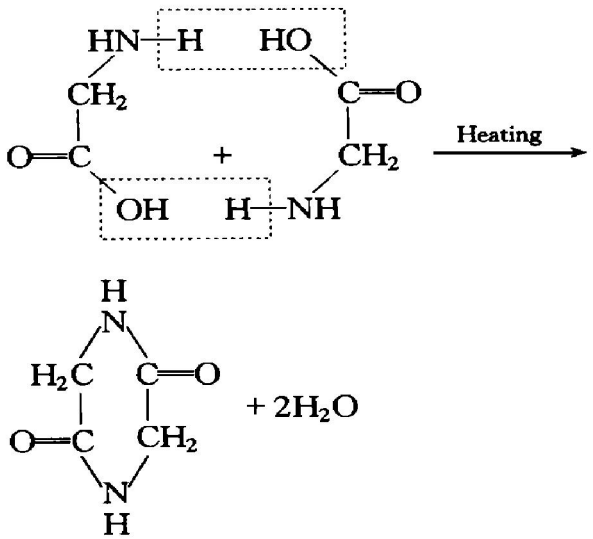

Fig. 6 is SEM photo of protein binder surface. It presents continuous web strtachments between the sand grains appear very similar to those of other

binders[10, 11] (see Fig. 7).

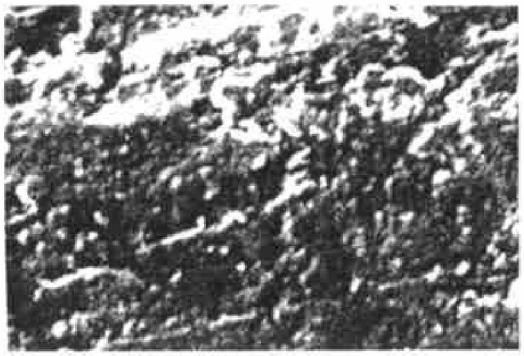

Fig. 6 SEM photo of protein binder

Fig. 7 SEM photo of protein sand core

4 CONCLUSIONS

1) The sand core made by protein-based binder possesses higher tensile strength and excellent shake-out property under 650 ℃, is very fit for aluminum casting.

2) The protein sand is easy to recycle. The unused sand mixture or core scraps can be used as new sand. This is notably superior to resin binders.

3) There are no noxious or harmful elements and no possibility producing poisonous materials in foundry process. It is proven that the protein glue is an environmental and benign sand binder.

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