

The study of a new rare earth compound vermicular agent for producing the vermicular cast iron

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Abstract. A new vermicular agent is researched by experiments. The new vermicular agent is composed of RE-Mg-ferrosilicon alloy and yttrium-based heavy rare earth. The results of experiments show that when the new agent is used for producing vermicular cast iron, the microstructure of the cast iron is pearlite and ferrite. The graphite morphology gradually transferred from flake to spherical shape with increasing of the amount of vermicular agents, and the hardness increased. In the vermicular agent, the rare earth elements not only can make the graphite morphology transferred to vermicular, but also replace the role of titanium, the role of magnesium is to created self-Stirring condition.

Key words. Vermicular agent, vermicular cast iron, taper constants, yttrium-based heavy rare earth, hardness.

1. Introduction

In 1970s [1], the compacted graphite cast iron began to industrial applications, because the stability of its commercial process, the development of its process is very slow. The influences of vermicular graphite formation are so many, such as the composition and addition amount of compound vermicular agent, vermicularizing treating process, inoculation process, the composition and temperature of molten iron, cooling rate and so on, among these, one key technique in casting production of compacted graphite cast iron is to choose the right vermicular agent.

The vermicular agent is one kind of alterant which is added into molten iron during its solidification, in order to make the graphite forming vermicular shape [2].

Common vermicular agents are mainly divided into two categories: magnesium

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system and rare earth system. Rare earth is ideal metamorphic elements, but also has strong anti-spheroidizing ability. When it is used alone, the rare earth can make the graphite transferred to vermicular shape. But when the rare earth was added into the molten iron, it firstly reacted with some elements, such as sulfur, and then the molten iron was refined. The residual rare earth was acted as the alterant. So the rare earth residue must be within 0.045% ~ 0.075%, the graphite can transferred to vermicular [3]. While the cost of the pure rare earth is so higher, the mixed rare earth metals, rare earth ferrosilicon alloy, rare earth calcium silicon alloy and rare earth magnesium ferrosilicon are often used as the substitute. Considering the economy demands, using the rare earth ferrosilicon alloy as vermicular agent is suitable. But it has advantage only when its addition is less and the amount of sulphur content in molten iron is very low. The a certain amount of calcium is added in the iron, because when only the rare earth ferrosilicon alloy is added, the cast iron has chilling tendency. But on the surface of iron will form a thin film, which based on the interaction between the liquid iron and the rare earth ferrosilicon alloy which was added the calcium. The thin film is composed of oxide and sulfide. The thin film hinders the alloy further reaction with the liquid iron. Furthermore the atomic self-diffusion in liquid iron is weak, as atomic radius of rare earth elements is larger. Magnesium is used to build the self-stirring conditions to make the liquid iron violently boiling, based on its characteristics such as low boiling point, high reaction speed, and high calorific value. So the creep reactions occur spontaneously. At the same time the titanium is added to restrain the strong spheroidizing effect of magnesium [4]. But when using the vermicular agent containing titanium, the processing performance of vermicular cast iron is deteriorated, easy to cause the "titanium pollution" in foundry returns and so on. And when use the rare earth vermicular agent to cast the casting which wall thicknesses have large difference, if the creep rate of thin wall is 50%, the graphite of the thick wall is often flake [5].

This paper developed a new vermicular agent, which is composed of RE-Mg-ferrosilicon alloy and yttrium-based heavy rare earth, based on the sulphur content of placeCitybenxi pig iron is low. The rare earth elements are the main components of the vermicular agent. The magnesium creates mixing conditions. And utilize the ability of rare earth elements which can disturb the graphite spheroidizing process to instead of the role of the titanium, thus eliminate the titanium influence of the vermicular cast iron production. The vermicular cast irons are used as the basis materials to process the bionic vermicular cast iron by bionic laser process.

2. Experimental procedure

2.1. Material

The materials used in this study include pig iron (Z18 pig iron produced in Benxi city), vermicular agent (rare earth magnesium ferrosilicon and heavy rare earth), inoculant, the chemical composition as shown in table 1. Covering agent is 4# Japanese perlite, its chemical composition as shown in table 2.

Table 1. Chemical composition of materials

Name	Chemical composition (%)								
	Si	P	S	Mn	C	Re	Mg	Ca	Al
pig iron	1.7	0.068	0.03	0.27	4.2	-	-	-	-
rare earth magnesium ferrosilicon	41	-	-	-	-	6	9.8	2.6	-
yttrium base heavy rare earth	42	-	-	-	-	2	7.5	q.s.	<0.8
ferrosilicon grain	≥ 72.3%	≤ 0.036	≤ 0.019	-	≤ 0.15	-	-	-	≤1.47

Table 2. Chemical composition of perlite

Name	Chemical composition (%)						
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O
covering agent	73.4	13.3	1.15	0.78	0.13	2.84	4.47

2.2. Experimental methods

The pig iron is melt in the vacuum induction furnace. The charge dosage of each furnace iron is controlled in 10 kg. The temperature of hot metal is controlled at 1450 °C ~ 1460 °C . The rare earth magnesium ferrosilicon and yttrium base heavy rare earth are mixed in a certain proportion, their particle sizes are 5mm~10mm.

The vermicular treatment and the modification are completed at the same time. The vermicular agent and inoculants were placed in the bottom of the pouring ladle and were tamped. The addition order is yttrium base heavy rare earth, rare earth magnesium ferrosilicon, ferrosilicon particles and perlite. The yttrium base heavy rare earth and the rare earth magnesium ferrosilicon are added in a fixed proportion.

When casting, the liquid iron directly rush into the bottom of the pouring ladle. The pouring ladle used in this study is self-design, unlike the common type. The common ladle is dam type, it is named step type, as shown in figure.1, and the height of the step is about When the vermicular treatment was taken in dam type ladle, the vermicular agents were placed in one side of the dam; the hot metal was poured into the other side. After the hot metal spill over the dam, it began to react with the vermicular agents. By this way, reaction time of various alloy are ensured, and the purpose to increase the absorption rate of vermicular agents and improve vermicular effects are reached. But easy to cause vermicular agents mixed uneven. Used the step type, the vermicular agent and inoculants were placed in ladle bottom, the hot metal was poured on the step, when the hot metal covered the bottom of the ladle, the high temperature of the hot metal caused severe reactions of the magnesium in

the vermicular agent. The stirring effect made the vermicular agent and inoculants even mixed into the hot metal.

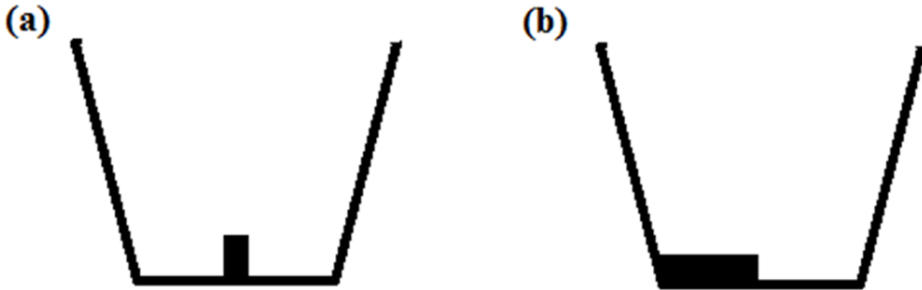


Fig. 1. Pouring ladle used in vermicular treatment (a)dam type (b)step type

After treatment, the liquid iron were poured into coated sand models. Considering the influence of wall thickness on the microstructure and properties of vermicular cast iron, the casting model is designed as a stairway which has the sprue, as shown in figure. 2. the model The model consists of two parts, as shown in figure 3. When pouring, the sand is stacked around the model in order to prevent the liquid iron overflowing the model. The microstructure and hardness of different thickness of casting are discussed.

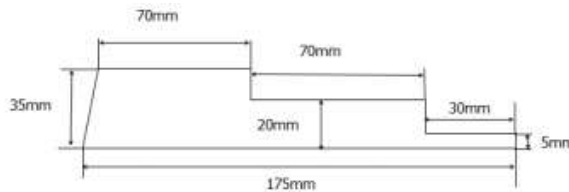


Fig. 2. The casting model used for pouring

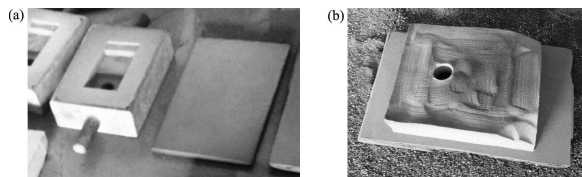


Fig. 3. The coated sand model (a) the parts of model; (b) the whole model

The microstructures of the vermicular cast iron obtained from above experiment are observed by SEM (Zeiss, Evo 18, placecountry-regionGermany). Their harnesses are measured by Brinell tester (Huayin 320HBS-3000, China).

3. Results and discussion

3.1. Influence of vermicular agent addition amount on microstructure of cast iron

The metallographic specimens are cut from the middle of the intermediate steps of the step castings. The influence of vermicular agent addition amount on microstructures of cast iron is shown in figure.4

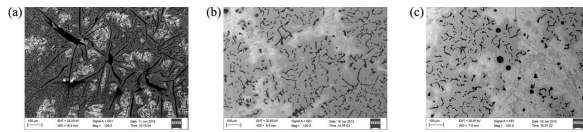


Fig. 4. Microstructures of cast irons with different addition amount of vermicular agent (a) the addition amount of vermicular agent is 0.4%; (b) the addition amount of vermicular agent is 0.6%; (c) the addition amount of vermicular agent is 0.8%

As shown in fig.4 (a), when the addition amount of vermicular agent was 0.4%, the microstructure of cast iron is ferrite and pearlite, and the content of pearlite is obviously less than ferrite. The shape of graphite is thick layer, and they set into the chrysanthemum. Some small worm-like graphite is around of the thick layers.

When the addition amount of vermicular agent was 0.6%, as shown in fig. 4(b), the microstructure of cast iron is still ferrite and pearlite, but the content of pearlite raise. There is not flake graphite. The shape of graphite is worm-like and little amount of spheroidal graphite had produced.

When the addition amount of vermicular agent was 0.8%, as shown in fig. 4(c), the content of pearlite further raise, the vermicular graphite grew up, the number of spheroidal graphite added, and some spheroidal graphite grew large.

From the above, the graphite morphology gradually transferred from flake to spherical shape with increasing of the amount of vermicular agents.

3.2. Influence of wall thickness on the microstructure of vermicular cast iron

The influence of wall thickness on the microstructure of vermicular cast iron is researched, when the addition amount of vermicular agent was 0.6%. The sampling location is the middle of the steps. As shown in figure 5, the microstructure of cast iron is ferrite and pearlite, and the content of pearlite increase with wall thickness decrease. And that the graphite morphology gradually transferred from flake to spherical shape. So the addition of vermicular agent should be increased to obtain vermicular graphite for thick-walled castings.

According to the above experimental results, the vermicular graphite can be obtained by adding proper amount rare earth compound vermicular agent and without adding the titanium element.

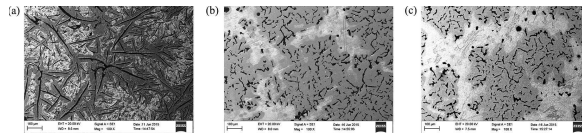


Fig. 5. Microstructures of cast irons with different wall thickness of vermicular agent when the addition amount of vermicular agent is 0.6% (a) the wall thickness is 35mm; (b) the wall thickness is 20mm; (c) the wall thickness is 5mm

3.3. Influence of vermicular agent addition amount on hardness of cast iron

The hardness of specimens which are cut from the middle of the intermediate steps of the step castings are measured. The influence of vermicular agent addition amount on hardness of cast iron is shown in figure.6, the vermicular agent addition amount of No.1 specimen is 0.4%, the vermicular agent addition amount of No.2 specimen is 0.6% and the vermicular agent addition amount of No.3 specimen is 0.8%. It is shown that the hardness of cast iron increase with the amount of vermicular agents.

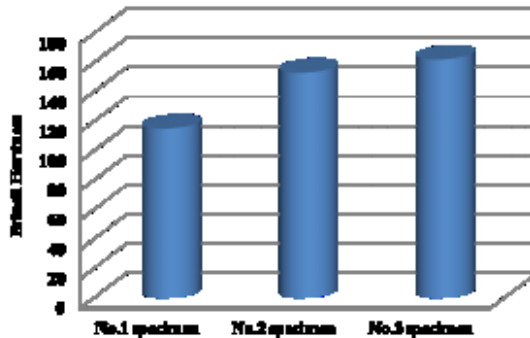


Fig. 6. Hardness of cast iron with different addition amount of vermicular agent

4. Conclusion

When the mixture of RE-Mg-ferrosilicon alloy and yttrium-based heavy rare earth is used as vermicular agent, the vermicular cast iron which microstructure is pearlite and ferrite can be obtained. The graphite morphology gradually transferred from flake to spherical shape with increasing of the amount of vermicular agents, and the hardness increased. In the vermicular agent, the rare earth elements not only can make the graphite morphology transferred to vermicular, but also replace the role of titanium, the role of magnesium is to created self-Stirring condition. The above conclusion is the experimental results in labs; there is a certain distance with the actual production. In the next step, the industrial tests will be carried out to verify the effect of the new vermicular agent; its formula and the process will be

further optimized.

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