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EFFECT OF NORMALIZING TEMPERATURE ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF DUCTILE IRON FOR PIANO IRON PLATE

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Piano iron plate is one of the components that play a decisive role in the quality of piano. In this paper, the effects of normalizing temperature on the microstructure and mechanical properties of nodular cast iron for piano iron plate were studied by normalizing at different temperatures and tempering at the same temperature. The microstructure observation, tensile test and impact test were used to study the effect of normalizing temperature on the microstructure and mechanical properties. The results show that after normalizing at 840 ~ 1 040 °C and tempering at the same temperature, the microstructure of ductile iron is mainly pearlite. In the normalizing temperature range of 840 ~ 1 040 °C, with the increase of normalizing temperature, the impact toughness and elongation of ductile iron increase, while the tensile strength and Brinell hardness show the opposite trend. When the normalizing temperature is 930 °C, the comprehensive mechanical properties of ductile iron are the best. At this time, the tensile strength is 815 MPa, the Brinell hardness is 328 HBW, the elongation is 3,79 %, and the impact toughness is 3,04 J / cm^2.

Keywords: piano iron plate, ductile iron, normalizing temperature, microstructure properties, mechanical properties

INTRODUCTION

The piano iron plate is also called the piano iron bone according to the different names of the piano factories. It refers to the cast iron part that hangs the strings and is one of the piano parts that determine the quality of the piano. Its monomer weight is more than 70 kg, the larger the model, the heavier the weight. An iron plate needs to withstand at least 16 tons of tension from the string.

As a kind of gray cast iron, nodular cast iron has the advantages of high strength, high toughness, high corrosion resistance and low manufacturing cost. It is a relatively successful piano iron plate material. In order to make it withstand the tension of the piano string, how to improve its strength has become an important research issue.

Adding appropriate alloying elements to ductile cast iron can often refine the structure and improve the comprehensive performance. According to the existing research, adding vanadium to ductile iron can improve its performance. The results show that with the increase of vanadium content, the content of carbides in the matrix structure increases, which will obviously refine the bainite structure and ferrite grains, and improve the strength and wear resistance of ductile iron. However, when the vanadium content is 0,4 %, the tensile strength and wear resistance decrease. On the basis of the above research, the spheroidal graphite cast iron with vanadium element was treated at different temperatures, and the microstructure, tensile properties, hardness and impact properties of the alloy under different heat treatment conditions were studied, which provided a reference for the formulation of heat treatment process of spheroidal graphite cast iron with vanadium element in the production of piano iron plate.

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Materials and methods

In this experiment, the medium frequency induction resistance furnace was used to smelt the nodular cast iron with vanadium element. The chemical composition (mass fraction) is: C: 3,7 %, Si: 2,5 %, V: 0,15 %, Mo: 0,5 %, Mn: 0,5 %, Mg: < 0,04, P: < 0,04, S: < 0,04, Fe: Bal. The experimental ductile iron was tempered by box-type resistance furnace. The normalizing holding temperature was 840, 870, 900, 930, 970,1 000 and 1 040 °C, respectively, and the holding time was 2 h. The microstructure of the experimental cast iron was observed on the metallographic microscope, and the corrosive agent was 3 % nitric acid alcohol solution. The mechanical properties of experimental steels in different states were tested on 5105 microcomputer controlled electronic universal testing machine.

Experimental results and discussion

Figure 1 is the graphite appearance of nodular cast iron sample after adding vanadium element. Vanadium

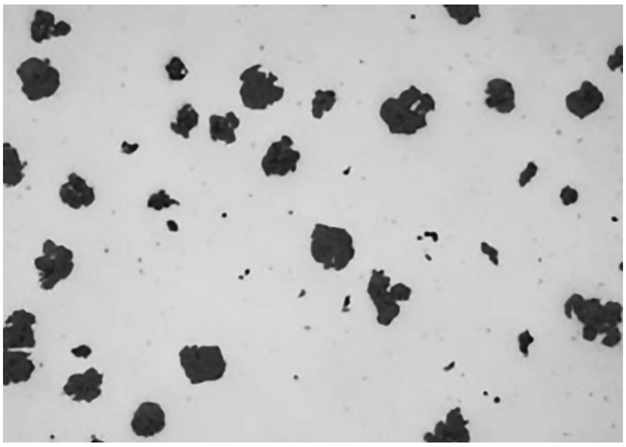

Figure 1 The graphite appearance of nodular cast iron sample after adding vanadium element.

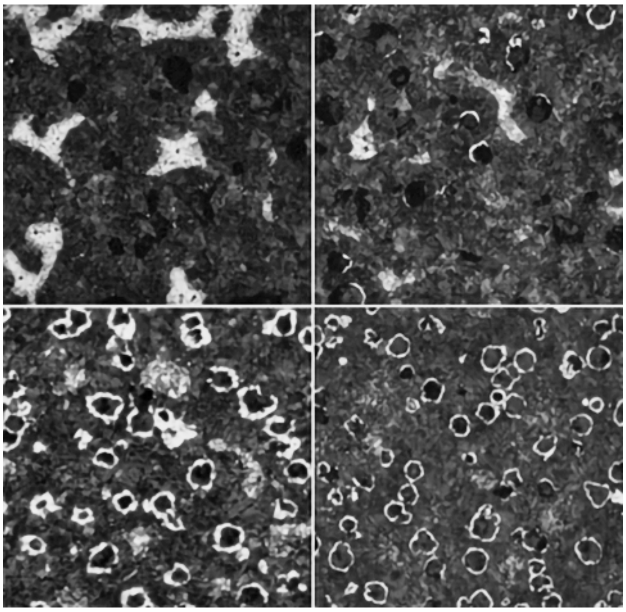

Figure 2 The microstructure of nodular cast iron at different normalizing temperatures.

Table 1 **Mechanical properties of experimental ductile iron at different normalizing temperatures**

Number	Tempering temperature/ °C	Brinell hardness/ HBW	Rm/ MPa	Elongation/%	impact ductility/ J×cm²
1	840	354	842	3,19	2,71
2	870	339	831	3,31	2,89
3	900	335	821	3,59	2,94
4	930	328	815	3,79	3,04
5	970	317	807	3,82	3,06
6	1 000	311	801	3,84	3,08
7	1 040	308	796	3,91	3,11

is an element that strongly promotes the formation of carbides, and the graphite formed in ductile iron has a stronger segregation tendency. This partially precipitated spherical graphite structure not only endows the material with higher strength and hardness, but also enhances the stability of the liquid metal phase in ductile iron, thus providing more solid and reliable physical properties for the product. This improvement effect is achieved by the specific behavior of vanadium in the solidification process of ductile iron. It acts together with other elements on the microstructure of the material and has a positive impact on the overall performance.

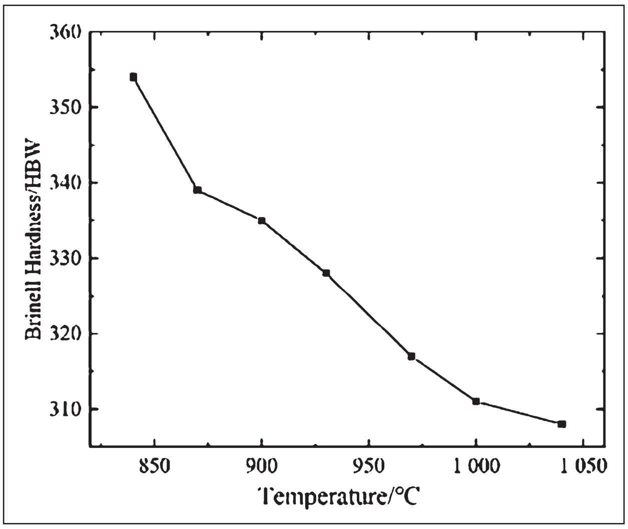

Figure 3 Effect of tempering temperature on hardness of experimental ductile iron

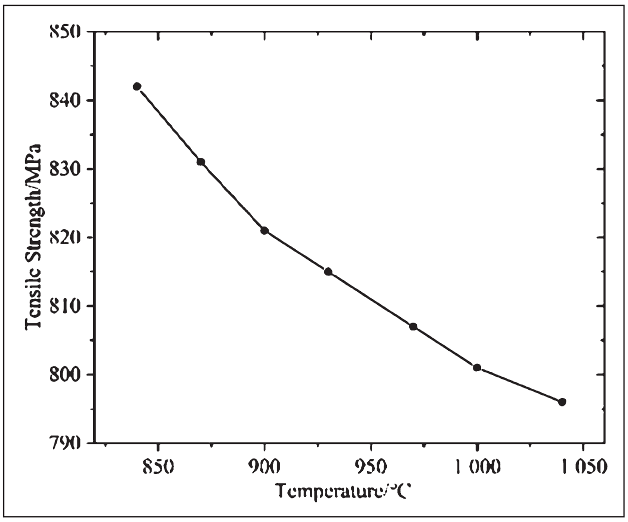

Figure 4 Effect of tempering temperature on tensile strength of experimental ductile iron

Figure 2 is the microstructure of nodular cast iron at different normalizing temperatures. Compared with the as-cast nodular cast iron, the morphology and distribution of graphite balls in the normalized nodular cast iron structure have not changed basically, but the matrix structure has changed significantly. The matrix of the normalized nodular cast iron is mainly black pearlite, and there is a small amount of ferrite and a dark white structure distributed in the island between the graphite balls. The Scanning Electron Microscope (SEM) analysis of the dark white structure shows that the internal structure is needle-like distribution, which is similar to the parallel arrangement of sub-slices, showing obvious lower bainite characteristics. Based on this, we believe

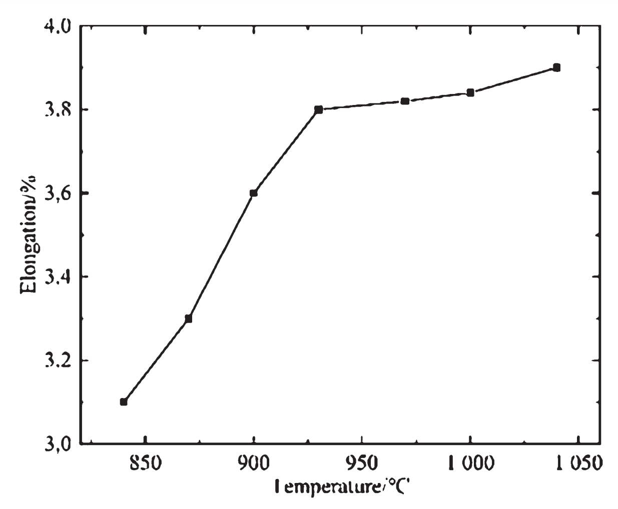

Figure 5 Effect of tempering temperature on elongation of experimental ductile iron

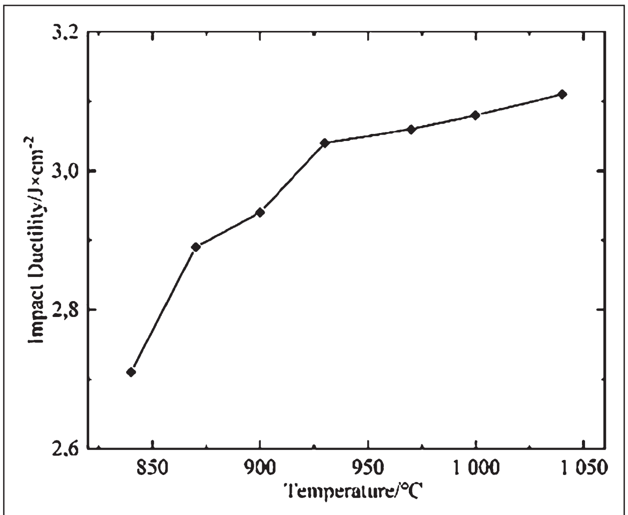

Figure 6 Effect of tempering temperature on impact toughness of experimental ductile iron

that the dark white structure in the normalized nodular cast iron is the lower bainite structure. It can be seen from the above analysis that the normalizing temperature mainly affects the relative content of bainite and pearlite in the matrix structure.

During the normalizing process, both the normalizing time and temperature affect the properties of the material. In general, the best ratio can be obtained by controlling the parameters. The mechanical properties of the experimental ductile iron at different normalizing temperatures are shown in Table 1.

The hardness of the alloy was evaluated by the Brinell hardness method. The Brinell hardness curve of the experimental titanium alloy at different normalizing temperatures is shown in the diagram. In order to avoid experimental errors, hardness measurements were carried out at different quadrants of the plane of the sample block. It can be seen from Figure 3 that with the increase of normalizing temperature, the hardness of ductile iron decreases gradually. When the normalizing temperature is 840 °C, the highest hardness is 354 HBW, and when the normalizing temperature is 1 040 °C, the lowest hardness is 308 HBW.

Figure 4 shows the relationship between the normalizing temperature and the tensile strength of the experimental ductile iron. It can be seen from Figure 4 that with the increase of normalizing temperature, the tensile strength of ductile iron increases gradually. When the normalizing temperature is 840 °C, the maximum tensile strength is 842 MPa, and when the normalizing temperature is 1 040 °C, the minimum tensile strength is 796 MPa.

Figure 5 is the effect of tempering temperature on the elongation of experimental ductile iron. It can be seen from Figure 5 that when the normalizing temperature is 840 °C, the elongation of ductile iron is 3,19 %. With the increase of normalizing temperature, the elongation increases significantly. When the normalizing temperature is 930 °C, the elongation increases to 3,79 %. With the further increase of normalizing temperature, the elongation does not change significantly. When the normalizing temperature increases to 1 040 °C, the elongation increases slightly to 3,91 %.

The impact toughness reflects the ability of the material to resist deformation and failure under impact load, and its size reflects the impact toughness of the material. Figure 6 shows the effect of normalizing temperature on the impact toughness of experimental ductile iron. It can be seen from Figure 6 that as the normalizing temperature increases, the impact absorption energy of ductile iron increases significantly first and then tends to remain unchanged. When the normalizing temperature is 840 °C, the minimum impact absorption energy is 2,71 J / cm^2. After the normalizing temperature increases to 930 °C, the impact absorption energy increases significantly to 3,04 J / cm^2.When the normalizing temperature is further increased to 1 040 °C, the impact absorption energy increases slightly to 3,11 J / cm^2.

CONCLUSION

It can be seen from the test results that the Brinell hardness, tensile strength, impact toughness and elongation of the experimental ductile iron after normalizing do not increase or decrease monotonously with the increase of annealing temperature. The change rate is that with the increase of normalizing temperature, the strength and hardness of ductile iron decrease gradually, and the plasticity and toughness increase gradually. When normalizing at 930 °C, ductile iron has good comprehensive mechanical properties.

CONCLUSION

In this paper, the nodular cast iron with vanadium element is taken as the research object. After normalizing treatment, the morphology and distribution of graphite balls in the structure of graphite cast iron basically did not change, but the matrix structure changed significantly. The matrix of normalized ductile cast iron was mainly black pearlite, and there was a small amount of ferrite and a dark white structure with island distribution between graphite balls.

After normalizing treatment of nodular cast iron, the matrix structure is a large amount of pearlite, a small amount of bainite and a small amount of ferrite. When the normalizing temperature is 930 °C, the comprehensive mechanical properties of the sample are the best. The tensile strength is 815 MPa, the elongation is 3,79 %, the impact toughness is 3,04 J / cm^2, and the Brinell hardness is 328 HBW. This study has a certain guiding role in the development of piano iron plate material.

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Note: The responsible translator for English language is J. J. Wang – Heilongjiang Taiqi Tertiary Education Training Institute Co. Ltd, China.