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Spheroidizing kinetics of eutectic carbide in the twin roll-casting of M2 high-speed steel

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Abstract

High-speed steel M2 strip has been experimentally produced by using a twin roll strip castor. The microstructure of the strip and the eutectic carbide in the cast-rolled strip were examined in detail. The spheroidizing procedure of the eutectic carbide in the twin roll cast M2 high-speed steel strip was investigated with the method of annealing, quenching and tempering. The results show that the eutectic carbide was gradually spheroidized with the increase of heating temperature and holding time through coarsening and accumulation of eutectic carbide, dissolving and breaking up of net work eutectic carbide, and precipitating and coarsening of secondary carbide. The kinetics analysis of coarsening and accumulating of eutectic carbide, and coarsening of secondary carbide in the high-speed steel strip were made based on the experimental results, and the growing transient velocity equations of carbide were deduced. The mechanism of cast-rolling enhancing the spheroidizing of eutectic carbide in M2 steel was discussed.

Keywords: Twin roll strip casting; High-speed steel; Eutectic carbide; Spheroidizng; Kinetics

1. Introduction

The eutectic carbide in high-speed steel is in a network state. Therefore, it has a serious effect on the ratio of the end product in the subsequent process and the mechanical properties of the products. In order to improve the microstructure of high-speed steel in the as-cast state, the conventional method being used is heavy forging. However, the eutectic carbide changes into a banding structure, but the carbide segregation still exists. When the forging ratio is small, the eutectic carbide in the centre part of the ingot is still in the network state. Therefore, so many technological methods were tested, such as modification, alloying, heat treatment and combined modification heat treatment, and so on. The research workers want to modify the pattern and the distribution of the eutectic carbide in the cast high-speed steel by using these ways. But these methods either change the composition of the steel or make the processing complex. These problems can be resolved by using the twin roll strip casting process. It can produce high-speed steel strip with homogeneous distribution of alloying elements and is free from carbide in network state.

In this paper the production process of high-speed steel strip using the near net twin roll strip casting technology was described and the features of the microstructure of the as-cast state strip were analyzed. The research on the spheroidizing process of eutectic carbide in the strip being cast was carried out using the isothermal annealing method, the effect of kinetics factors on the spheroidizing of eutectic carbide and the mechanism of rapid cooling of twin roll strip casting process promote the spheroidizing of eutectic carbide during the subsequent heat treatment process were analyzed.

2. The strip casting process of M2 high-speed steel and the as-cast state microstructure

2.1. The processing features of twin roll strip casting and the casting process of high-speed steel strip

The near net twin roll strip casting is a new technical process which uses the two counter rotating rolls as the mould,

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Table 1
The composition of the steel used in experiments (wt.%)

	C	W	Mo	Cr	V	Si	Mn	S	P
Standard	0.82–0.88	5.5–6.75	4.5–5.5	3.8–4.4	1.75–2.20	0.40	0.40	0.03	0.03
Experimental	0.85–0.88	6.13–6.29	4.85–5.0	3.90–4.09	1.78–1.83	0.40	0.40	0.03	0.03

and produces thin strip directly form molten metal. Its feature is that the solidification of the molten metal and plastic deformation takes place simultaneously. Therefore, it has many advantages over the conventional process. It can enormously shorten the process, reduce the energy consumption and initial cost of products, improve the microstructure of the product, and can produce products which are difficult to form. The average cooling rate of the process is approximately 10^2 to 10^3 °C/s, this process solidifies the cast steel approximately 1000 times faster than normal and can produce the strip with thickness of 2–4 mm. Because of this rapid cooling, twin roll strip casting is expected to offer a potential for producing products with new characteristics [1,2].

The main purposes of the experimental study on M2 steel by twin roll strip casting are as follows:

(1) High-speed steel M2 is of type precious alloy steel. As compared with conventional processes, the twin roll strip casting process can significantly reduce energy consumption and the prime cost of products.
(2) Rapid solidification would be favorable to improving mechanical properties of M2 tools.
(3) High-speed steel has a rather low melting point which if favorable to twin roll strip casting.

The experiment is carried out on the twin roll strip casting mill at state key laboratory of rolling and automation, Northeastern University. The rolls are made from steel with internal water cooling. The diameter of the rolls is 600 mm, the width of the rolls is 300 mm, the maximum casting speed is 60 m/min. An induction furnace used to melt the steel in experiments is of medium frequency with power 150 kW and its capacity is about 250 kg of steel. The melting point of high-speed steel M2 is about 1423 °C and the chemical compositions of the steel M2 used in experiments are shown in Table 1.

The thickness of the strip being cast is 1.0–2.5 mm which depends on the rolling pressure, pouring temperature and casting speed. The surface quality of M2 twin roll cast strip product is much better than that of carbon steel strip being cast and is good enough to meet the demand for milling cutter manufacturing.

During cast-rolling the molten high-speed steel is poured into the roll gap through a nozzle, where it is soon solidified and rolled into thin strip. The temperature of the cast-rolled high-speed steel strip delivered from the roll gap is about 1300 °C. After cast-rolling the thin strip is cooled in air rapidly and is sheared into pieces about 500 mm length. Then the sheared pieces are immediately rolled at about 1000 °C with various reductions on a conventional Ø300 mm four-high mill. After rolling, these strips are piled up and annealed. After annealing the high-speed steel strip becomes soft and the hardness value becomes less than 260 HB, which is enough to meet the demand for further working.

2.2. Microstructure of high-speed steel strip in cast state

X-ray diffraction analysis of high-speed steel strip in as-cast-rolling state shows that its microstructure is mainly composed of martensite, residual austenite and alloy-carbonate. The strip at room temperature after cast-rolling is very brittle and shows brittle fracture. In as-cast-rolling state it has very great hardness HRC = 65–70. The crystal grain is very fine and the average diameter of grain is even less than 3–5 μm, resulting from rapid solidification during the cast-rolling process. The microstructure of as-cast-rolled high-speed steel is shown in Fig. 1.

The results of X-ray diffraction and TEM analysis shows that there are three kinds of carbide in the as-cast state strip, they are M_6C, M_2C and MC. The size of the primary carbide in the as-cast-rolled M2 steel strip is generally about 0.2–3 mm, the average size is 1.5–2 mm. Compared to the normal steelmaking process and powder metallurgy process, the carbide particles in the as-cast state products were not only small, but also uniformly distributed. X-ray diffraction result shows that the residual austenite content in the as-cast state strip is about 7%, this is much smaller than that of 22–28%

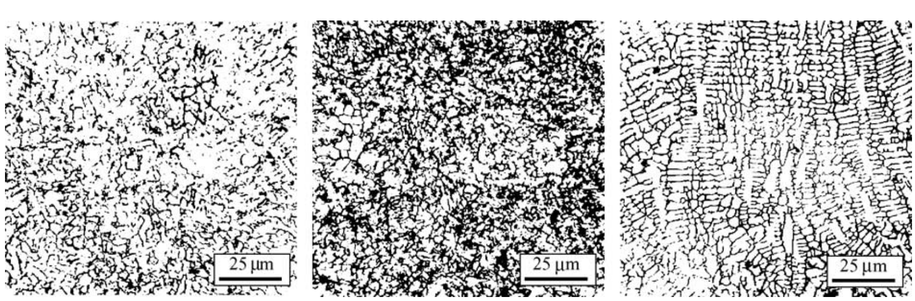

Fig. 1. The microstructure of as-cast-rolled high-speed steel.