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Effect of Vanadium on Austenite Grain Refinement and Martensite Structure

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Abstract. The original austenite and quenched martensite structures of press hot steel with vanadium have been investigated by means of optical microscope and scanning electron microscope. The results show that V exists in the form of dispersed nanoscale VC or (V, Ti) C complex carbide in austenite, which has a significant effect on the refinement of the original austenite grain size. When the heating temperature is higher than 900 °C, the V(C, N) decomposition results in the rapid decrease of austenite grain refinement, however, the austenite grains are still refined due to the drag effect of Ti(C, N) on V(C, N). The combination of vanadium and carbon in austenite can reduce the content of C in quenched martensite, which could promote the formation of strip martensite and avoid the formation of twinned martensite, so as to improve the toughness of materials and improve the problem of hydrogen-induced cracking.

Keywords: Grain size · Vanadium carbonitride · Microstructure

1 Introduction

With the rapid growth of automobile exhaust emissions and the use of passenger cars, collision safety standards are strict year by year, and it is imperative to improve the strength and stiffness of the car body and optimize the structure. In view of this demand, more and more high strength steel and ultra-high strength steel are applied to automobile components [1]. High strength steel has good strength and hardness, but poor plasticity and toughness. In order to improve the overall performance, refining the size of proto-austenite grain is one of the most effective methods [2, 3]. V is one of the rich elements in China. With high solubility in steel, V is one of the most commonly used and effective strengthening elements in micro alloyed steel [4]. Adding a certain amount of V to steel can precipitate carbides of V in austenite, refine the grain size of austenite, and play a great role in improving the strength and toughness of finished products [5]. In this paper, by comparing with V and not add V two kinds of test steel original austenitic organization, and by using electron microscope (TEM), and transmission electricity to its microstructure and precipitation particle morphology observation, the precipitation of VC or (V, Ti) C content to the original austenite grain size refinement effect and its influence to the martensite after quenching organization [6, 7].

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Table 1. The chemical composition of 22MnB5 hot stamping steel.

Sample	C	Si	Mn	V
No. 1	0.25–0.35	0.2–0.4	1.0–1.5	0
No. 2	0.25–0.35	0.2–0.4	1.0–1.5	0.1–0.3

2 Materials and Procedures

Two kinds of high-strength steel plates were designed in the experiment. The specific composition is shown in Table 1.

The samples were heated to 850 °C and 900 °C, respectively, held for 5min, and quenched. Take after quenching specimen made of metallographic specimen after grinding and polishing. The morphology of primitive austenite was observed by optical microscope. Will add V steel specimen using the line cut into 600 μm, punching after sand paper finely ground to 45 μm, electrolytic double injection preparation into TEM specimen, the precipitation phases and martensitic matrix form.

3 Results and Analysis

The optical micrograph of the original austenite morphology of samples No. 1 and No. 2 are shown in Fig. 1 and Fig. 2. The original austenite grain size under different heating temperatures was determined by using the straight-line cut-off method and Image-Pro software. The specific size is shown in Table 2. It can be seen that under different heating temperature, the original austenitic grain size of added V steel is smaller than the one without V.

The precipitation of the v-added steel after hot rolling was analyzed from the microscopic point of view by transmission electron microscopy. The image of transmission electron microscopy is shown in Fig. 3(a). It can be seen that there are nano V and Ti carbides in the steel plate, and the precipitate size is 20–50 nm. The specific morphology was shown in Fig. 3(b). Scattered small nano-scale precipitates can not only refine austenite grain, improve the product strength and toughness, and precipitation of VC or (V, Ti) C consumes carbon in austenite, reduce the carbon content of martensite after quenching, the phase change after plate strip produced by the dislocation martensite formation, avoid twin martensite formation, improve the identity of the hydrogen induced cracking problem, The morphology of martensite after quenching is shown in Fig. 3(c).

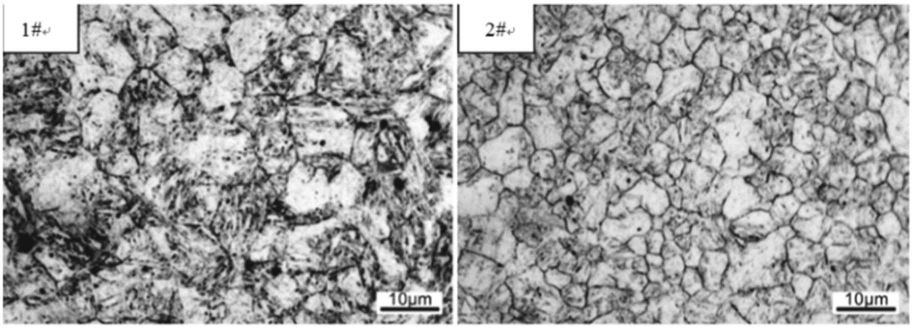

Fig. 1. Morphology of the original austenite at 850 °C.

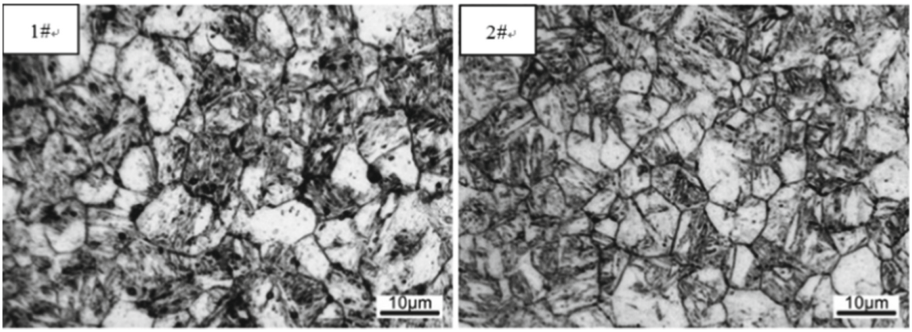

Fig. 2. Morphology of the original austenite at 900 °C.

Table 2. The original austenite grain size at different heating temperatures.

Sample	850 °C	900 °C
No. 1	5.9	7.5
No. 2	3.4	5.9
The percent of grain refinement	42	21

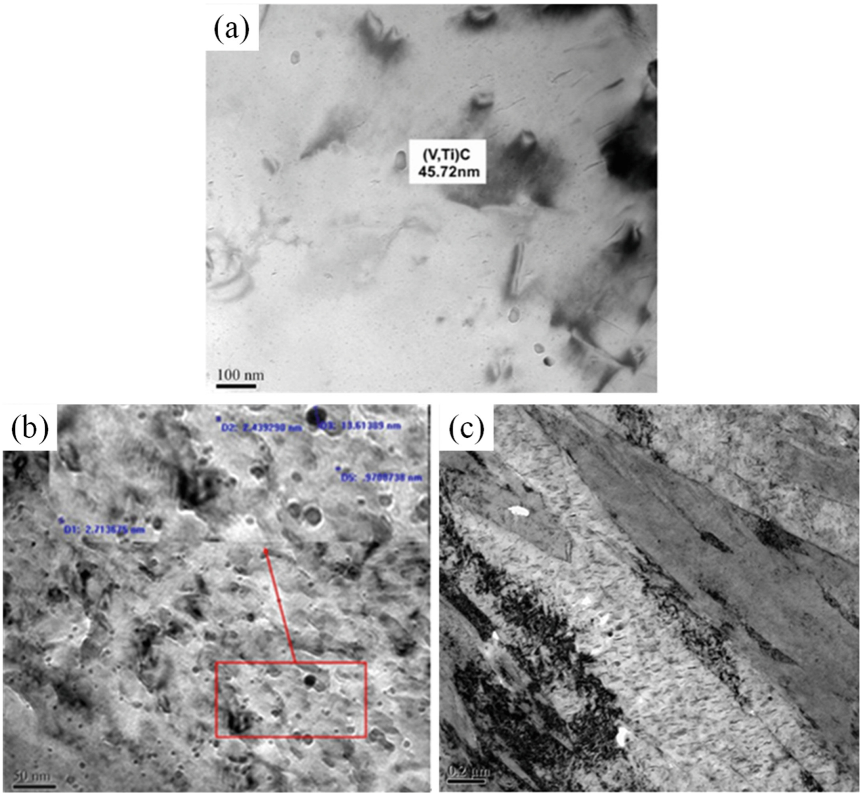

Fig. 3. TEM images of sample.

4 Discussion

Theoretically, the strength of quenched martensite increases with the increase of carbon content, but the increase of carbon content will lead to the formation of twin martensite, reducing the toughness of the material. Meanwhile, twin martensite has a ridge, which is easy to enrich hydrogen on this ridge, causing hydrogen cracking of the material. Thermo-calc software was used to calculate the amount of VC precipitation in the test steel with V changing with temperature. According to theoretical analysis, almost all the martensite after quenching is martensite, and the proportion of twin martensite is very small. In order to prove this conclusion, transmission electron microscopy was used to observe the microstructure of martensite obtained by quenching V test steel, and the results are consistent with theoretical calculation.

5 Conclusion

(1) V exists in the form of VC or (V, Ti) C complex carbides in austenite. The size of V is small and nanoscale, and the distribution of V is dispersed, which has an obvious effect on the refinement of the original austenite grain size.

(2) When the heating temperature is higher than 900 °C, the effect of V(C, N) on the refinement of austenite grain decreases rapidly due to the increasing amount of V(C, N) resolution, and the effect of Ti on the refinement of austenite grain is still certain due to the drag effect of V resolution.
(3) V can consume C in austenite, reduce the content of C in quenched martensite, promote the formation of strip martensite, avoid the formation of twin martensite, improve the toughness of materials, improve the problem of hydrogen-induced cracking.

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