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Study on Multi–Microalloying with Boron, Titanium and Rare–Earth Elements in Structural Medium Carbon Cast Steel

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In order to raise the quality of metallic material, the multi– microalloying are widely used and it plays an important role in metallic material field. Microalloying elements (MAE) eliminate the non–metal impurities or change its behavior, so that it could restrain its harmful effects and does alloying action. In consequence, it totally makes better quality of cast steel.

In this paper, the effects of multi–microalloying with B, Ti and RE on micro–structure and mechanical properties of structural medium carbon cast steel are discussed. The result shows Boron and Titanium raise the strength of medium–carbon cast steel and Rare–earth elements not only make the grains fine but also make better inclusion's shape and form effectively, so that it enormously improves its toughness.

In recent years research results that enhanced the properties of steel by joining boron and titanium together in the production of structural steel and also combined superior effect of Rare–earth elements had been published.

But no one has ever published the result that the structure and properties of medium–carbon cast steel multi–microalloyed with B, Ti and RE elements had been raised equal to one alloyed simultaneously with more than two alloying elements including Cr, Mn, Ni, Mo etc. This paper shows the result that multi–microalloying with B, Ti and RE elements gave a great influence on the microstructure and properties of medium–carbon cast steel compared to the alloyed cast steel with Cr, Mn, Ni, Mo etc.

Boron micro–alloyed in steel can raise its hardenability and toughness. In order to raise the effect of Boron in molten steel, it is essential to decrease the content of oxygen or to fix the nitrogen, to make better distribution of brittle boron phase and add the alloying elements can raise the temperature of austenite grain growth; that kind of elements could be titanium and Rare–earth elements.

To calculate the effective content of Boron, we have suggested the following empirical formula.

$$B_{effective} = B_{all} - \left[(N - 0.001\,3) - \frac{Ti}{5} \right] \tag{1}$$

If we could fix all of the rest nitrogen by adding enough of titanium, $B_{effective}=B_{all}$, therefore, Eq. (2) could be rewritten as the following.

$$Ti=5(N-0.001\,3) \tag{2}$$

The effects of microalloying elements such as B, Ti, RE, etc could substitute the effect of traditional alloying elements including Cr, Mn, Ni, Mo, etc and also enhance the mechanical properties of medium carbon cast steel totally.

Boron improves the hardenability and hardness penetration of medium carbon cast steel and can make its structure fine and also Titanium can prevent the oxidation of B and makes the Austenite grain fine owing to forming of Ti–carbonitride. RE elements can improve the effect of Boron and plasticity and ductility of medium carbon cast steel remarkably by affinage and grain refining. So the mechanical properties of medium carbon cast steel multi–microalloyed with B, Ti, RE elements are equal to Cr–Ni–Mo medium carbon cast steel or 1.2 times higher and 1.5 times higher than Cr–Mn–Si medium carbon cast steel.