Use of Vanadium in Long Steel Products

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Vanadium has been widely used in long steel products such as forging grades, reinforcing bars, sections, tubes, rails, springs and wire rods. Vanadium is the preferred addition in long steel products because of the much higher solubility of its carbonitrides in austenite and **lower** sensitiv**ity** to carbon level compared to niobium and titanium. Vanadium provides precipitation strengthening and grain refinement, resulting in good combination**s** of strength and toughness. The precipitation strengthening can be maximized by management of nitrogen level and the preferential precipitation of vanadium with nitrogen also minimizes the risk of nitrogen strain aging. In addition, vanadium enables desired strength levels **to be attained** at lower carbon content, which is beneficial **for** ductility and weldability. Furthermore, vanadium contributes to temper resistance and provides secondary hardening for quenched and tempered steels. Fine vanadium carbides also act as strong trap sites for diffusible hydrogen, leading to good delayed fracture resistance.

The relatively low solution temperature of vanadium carbonitirdes permits the use of energy efficient, low reheating temperatures. Conventional hot rolling or forging with high finish working temperatures, which are inevitable for production of long steel products, can be used for vanadium microalloyed steels to achieve **the** required mechanical properties and service performance. In addition, the properties of vanadium microalloyed steels are relatively insensitive to changes in processing conditions.

Keywords: Vanadium microalloyed steel, precipitation strengthening, grain refinement, hydrogen trapping, long steel product

1. Microalloying Choice for Long Products

Microalloying has been increasingly used in long steel products to increase strength and eliminate expensive heat treatment steps while maintaining adequate performance. Microaddition of vanadium is predominant in long steel products because of the significantly greater solubility of V(C,N) in austenite compared to niobium and titanium. The high solubility of V(C,N) in austenite minimises the risk of cracking during continuous casting and permits the use of conventional hot rolling or forging practices, which take place in the recrystallized austenitic phase, followed by air cooling, to produce the desired microstructure and properties. Vanadium is fully dissolved in the austenite during normal reheating temperatures (1150°C-1250°C), either for rolling or forging over the entire spectrum of carbon concentrations relevant to long products as shown in figure 1. Vanadium exhibits relatively lower solute drag coefficient in austenite compared to other micoralloys, therefore vanadium microalloyed steels recrystalize during hot rolling or forging and austenite grains are refined by repeated recrystallization. The majority of vanadium added to steels remains in solution in austenite up to the start of transformation from austenite to ferrite and precipitates in ferrite as fine V(C,N) particles during/after the austenite to ferrite transformation, providing substantial and predictable precipitation strengthening regardless of carbon content.

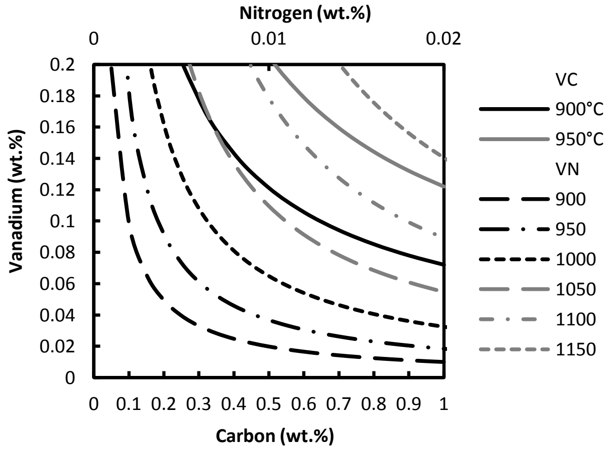

Fig. 1 Solubility isotherms of VN and VC in austenite and the solubility products used to calculated the isotherms are according to Tukdogan [1]

Niobium carbonitride has lower solubility in austenite than vanadium, therefore niobium is normally used in steel to produce fine grained microstructures by precipitating in austenite to prevent recrystallization during