Extended Use of Vanadium in A New Generation of Flat Rolled Steels

Stanislaw Zajac

KIMAB (previously Swedish Institute for Metals Research)
SE-11428, Stockholm, Sweden
Stanislaw.Zajac@simr.se

Abstract - Vanadium is best known as an eminent element for strong and easy controllable precipitation strengthening. The principal reason for this is the larger solubility product of its carbo-nitrides resulting in a lower solution temperature and a larger capacity to dissolve them at elevated temperatures. Precipitation strengthening of polygonal ferrite has been studied intensively in recent years and the use of vanadium for precipitation strengthening is a well established technology in HSLA steels with ferrite-pearlite microstructures. The benefits of precipitation strengthening are now being extended on bainitic steels with high and ultra-high strengths. The precipitation reactions in bainitic ferrite are, however, less well exploited for the obvious reasons. On the one hand, bainite is the most complicated microstructure of steel and there are still controversies regarding the formation of bainite. On the other hand the fine scale of precipitation within bainitic ferrite was very difficult to investigate using conventional experimental techniques. New developments in thermodynamic and kinetics of phase transformation as well as in advanced metallography are shown to offer new possibilities for solving these problems.

Recent experimental data strongly suggest that vanadium can also by effectively use for ferrite grain refinement. It is shown in this paper that vanadium contributes to the formation of two types of intragranulary nucleated ferrite; polygonal ferrite and acicular ferrite. Intragranular polygonal ferrite nucleates on VN particles which grow in austenite during isothermal holding or slow cooling. There are two ways in which VN particles can be induced in austenite of V-microalloyed steels. The first alternative is to modify the steel composition to obtain a high density of MnS inclusions or other particles which may act as nucleation sites for VN, without substantially changing the processing conditions. The second alternative involves a strain-induced precipitation of VN in austenite during hot rolling in the temperature range of VN precipitation. The intragranular polygonal ferrite forms in the narrow temperature range, between 650-600°C for the investigated compositions. Slower continuous cooling promotes also profound nucleation of ferrite on the prior austenite grain boundaries.

Acicular ferrite microstructure forms in V-microalloyed steels during isothermal transformation at lower temperatures and during continuous cooling at the optimum cooling rate. The acicular ferrite microstructure was obtained in V-microalloyed steels containing either high or very low nitrogen levels. This suggests that vanadium on its own can promote the formation of the acicular ferrite microstructure.

The goal of this paper is to present an expanded view on the role of vanadium in ferrite grain refinement and precipitation strengthening.