

Vanadium Titanium Structural Steels

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Titanium is a useful micro alloy, in that it forms a nitride at a high temperature, which enables it to be used for controlling the austenite grain size of steels, and it also forms a carbide at a lower temperature, which can be used for precipitation strengthening of ferrite. Although it was for a while used in the U.S.A. for the production of high strength strip steels, it was replaced by vanadium nitrogen steel. This was due to the difficulty in controlling the composition of the highly reactive alloy. With modern steel making developments, in particular the adoption of vacuum treatment, it is now possible to control the titanium additions more accurately, and titanium is finding an increasing use in high strength steels. Even so, care has to be used in the processing of the steel to avoid a.) coarse precipitates of titanium nitride forming in austenite which have no value in the steel and b.) grain boundary precipitates of titanium carbide which can cause embrittlement.

The combination of vanadium and titanium additions to microalloy steels creates a very attractive potential, as the titanium offers the opportunity to produce a fine grain austenite during rolling and also a fine grain size in the fusion line region of the HAZ, thus increasing the toughness of welds, while the vanadium produces increased strength as a result of precipitation in the ferrite, and also contributes to the toughness of welds through the promotion of intragranular ferrite in the fusion line region of the HAZ.

These steels can be used in the as rolled or the normalised conditions.

These steels were first proposed some years ago as a result of studies in Japan, but attempts to produce them commercially especially in Europe were not successful, because the properties could not be produced consistently from cast to cast. Recently however, Vanitec, in collaboration with British Steel laboratories in Rotherham, have made a study of these steels and have identified the parameters which have to be controlled to ensure reproducibility of properties.

In order for the titanium nitride to be effective in controlling the grain size of austenite, (i.e. preventing grain growth of recrystallised austenite), the titanium nitride particles must be in a size range of 5 nm and 40 nm. Their size is primarily controlled by the speed with which the steel cools immediately after solidification, as the titanium nitride particles form in the at temperatures just below the solids of the steels.

The particle size can however be increased by precipitation of other microalloy precipitates which form around the titanium nitride articles immediately after they precipitate. If niobium is present in the steel, niobium nitride will form around the titanium nitride particle, and make them too large to be effective in controlling grain growth. Vanadium nitride can also form around the titanium nitride particles, but unlike the niobium nitride, the vanadium nitride goes back into solution fairly easily and quickly during reheating for rolling, providing a sufficiently high reheating temperature is employed. (1200–1250 °) .

In order to achieve the maximum refinement of grain size, some control rolling can be applied to the steels at the end of the rolling schedule. This ensures maximum toughness and also contributes to the yield strength. In the case of steels which are used in the normalised condition, an appropriate normalising temperature must be used to obtain the steels with the optimum grain size and precipitation. It has, however, been found that there is a strong relationship between the grain size of the as rolled plate and that of the normalised plate. This is il-

lustrated in Fig 1.

It is essential to control the composition of the steel carefully, particularly the nitrogen content, to ensure that steel has the correct grain size. It is essential that the steel has a sufficiently high nitrogen content to ensure that:

- a. There is sufficient titanium nitride to control the grain growth of austenite during rolling.
- b. There is sufficient nitrogen to give the maximum precipitation of vanadium carbonitride in the ferrite.
- c. (In the case of normalised steels) there is sufficient nitrogen to produce adequate aluminium nitride to control grain growth during normalising.

On the other hand, if the nitrogen content is too high, it can encourage the growth of the titanium nitride particles rather than the formation of additional particles, with the result that the grain refinement during rolling is impaired.

It has been found that there is a tendency for vanadium nitride to form with the titanium nitride, and to make the particles too large to control grain growth during rolling, but if a high reheating temperature is used, the vanadium nitride goes into solution.

In the as rolled condition, the grain size of the ferrite is not quite as fine as that found in some control rolled niobium steels, but sufficiently fine to enable the requirements of specifications to be met, and such steels have been used for bridge construction in low temperature environments.

The steels can also be used in the normalised condition, and such steels are proposed for off shore structures. A typical steel composition and properties are given in table I. Good toughness is also obtained in the HAZ in both the as welded and post weld heat treated conditions as can be seen from table II.

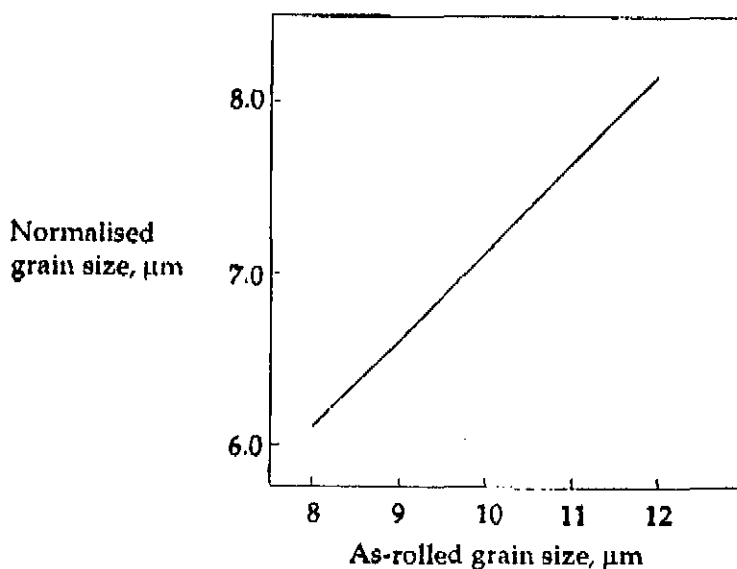


Fig.1 Relationship between as-rolled and normalised ferrite grain size for 20mm plates of V-Ti steel

Table I Composition and mechanical properties of production cast of vanadium-titanium steel

Composition, (wt %)												
C	Mn	Si	S	P	Ni	Cr	V	Cu	Ti	Al	N	CE _{11W}
0.11	1.60	0.35	0.004	0.013	0.06	0.02	0.07	0.05	0.016	0.020	70 ppm	0.40
Mechanical Properties												
Yield Strength			Tensile Strength			Elongation			Reduction of Area			
N/mm ²			N/mm ²			%			%			
340			510			29			74			

Table II Charpy and CTOD properties of 50mm plate from a production cast of vanadium-titanium steel

	35J Transition temperature		CTOD min crack length at -10°C	
	As-welded °C	PWHT °C	As-welded mm	PWHT mm
Parent plate	-90	-60		
Fusion Boundary	-80	-60		
Intercritical / Subcritical HAZ	-80	-85		
Subcritical HAZ			1.03	1.02
Intercritical HAZ			0.22	0.56