INFLUENCE OF THE ADDITION OF ALLOYING ELEMENTS BORON AND CHROME ON PROPERTIES OF STRUCTURAL STEEL

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General

Alloying elements such as boron and chrome are usually added intentionally to alloy steel to influence the properties in particular the hardenability. For example, boron is intentionally added to high strength fine grain steel and wear resistant steel to influence the properties in a positive way.
Starting from certain contents of alloying elements the steel grade is designated as alloy steel and not anymore as non-alloy steel. Actually, steel products are frequently sold in the European market as non-alloy steel although the content of boron or chrome is higher than the limit for a non-alloy steel grade. Possible effects of those alloying contents are not clear for the end user. This customer information shall highlight the normative background for non-alloy steel grades and shall give some hints regarding the effects of boron or chrome addition on processing.

Limit of boron and chrome for a non-alloy structural steel

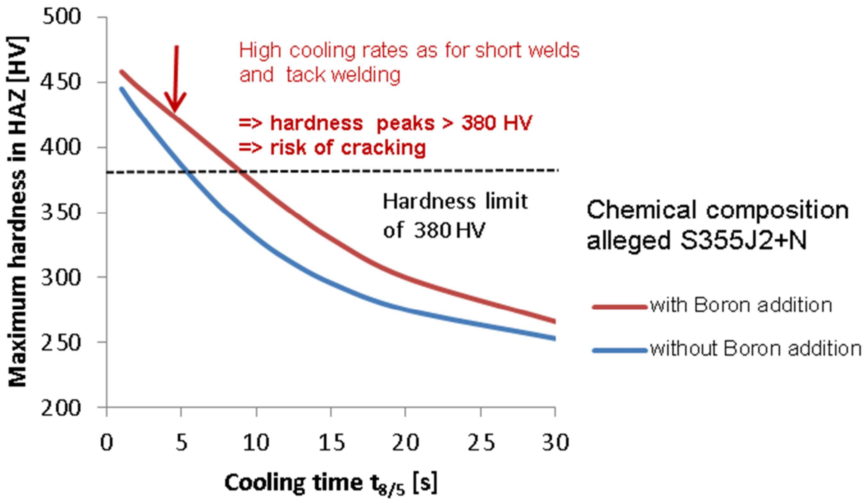
EN 10025 standardizes hot rolled products of structural steel. Part 2 of EN 10025 covers very common steel grades such as S235JR+N or S355J2+N. The title “Technical delivery conditions for non-alloy structural steels” clarifies that only non-alloy steel grades are covered. EN 10025 concretely refers to EN 10020 “Definition and classification of grades of steel” which clearly specifies limits of alloying contents for non-alloy steel grades:
Boron content shall be lower than 0.0008 % and the chrome content lower than 0.30 %.
CE marking according to EN 10025 of boron-alloyed steel beyond these limits is therefore dubious albeit daily praxis. Following EN 10025-2, intentionally added boron shall be given in the inspection document. Anyhow, steel products are in the market where boron is not given on the certificate although added beyond the limits of EN 10020. This may be due to the fact, that boron is even not one o the 14 elements for which a certification of the content can optionally be agreed.

Influence of alloying elements boron and chrome on the properties of structural steel

If cooling at relatively high rates, cold cracking can happen in the heat affected zone HAZ of a weld. High cooling rates are common for manual tack welding and welding of temporary assembling aids.
The maximum hardness in the HAZ essentially influences the risk of cold cracking: The higher the hardness, the lower the ductility, the higher the risk of cracking. As a consequence of this fact, all guidelines to avoid cold cracking take into account the content of alloying elements which influence the hardenability.
EN 1011 part 2, for example, considers hardening elements in a formula for a so called carbon equivalent CE(V).

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

The influence of a chrome content of 0.30 % on the maximum hardness and the risk of cracks is rated as high as the influence of the addition of 0.06 % carbon.
The investigation being basis for EN 1011-2 did not explicitly consider the effect of boron. Thus, the formulae for the carbon equivalents in EN 1011-2 do not take into account the boron content.
In addition to this, Yurioka's formula[1)] rates the hardening effect of free boron by approximation as a function of the contents of boron and the boron binding nitrogen. With this formula the hardness of an alleged S355J2+N was calculated with the actual boron content. To show the effect, the hardness was also calculated in the same way but without the boron content. The following diagram plots the maximum hardness in the HAZ against the cooling time $t_{8/5}$.



1) Yurioka, N., et al. Study on carbon equivalents to assess cold cracking tendency and hardness in steel welding, Proc. AWRA symp. Pipeline welding in the 80's, Melbourne, Australia.

Adding boron, may significantly increase the hardness compared to a non-alloy steel. For common cooling rates $t_{8/5}$ up to approximately 10 s, the maximum hardness can be significantly higher than 380 HV and the toughness of the micro structure can be lowered. Guidelines for welding procedure qualifications such as EN ISO 15614 deem hardness higher than 380 HV to be a crack risk for non-alloy steel.
Furthermore, the addition of boron may affect

- the properties of the heat affected zone HAZ close to oxy-cuts.
- the grain size of a normalising micro structure depending on the contents of Ti and Al.

Thus, the addition of boron may always affect the properties of parts made of non-alloy heavy plates if processing steps as welding, oxy-cutting or heating to temperatures > 800°C as for normalising are performed.

To avoid problems due to boron, EN 10225 limits the boron content for steel grades for offshore applications more stringent than EN 10025 / EN 10020 to a maximum value of 0.0005 %.

Contact

Your contact for Dillinger Hütte heavy plates are the local sales agencies. Please find your contact at http://www.dillinger.de/dh/kontakt/weltweit/index.shtml.en.

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