ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING

Vol. VIII 2008 No. 4

Structure and hardness changes in welded joints of Hardox steels

S. FRYDMAN, Ł. KONAT, G. PĘKALSKI
Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław

In the article, the structure and change in hardness of the welded Hardox 400 and Hardox 500 steels have been presented. It has been shown that structures of lower wear resistance are being created as a result of welding those materials in the "as delivered" state (i.e. with the tempered martensite structure) within the heat-affected zones. They are as much as up to 90 mm wide, and that causes their non-uniform and fast wear in the anticipated applications. Based on microscopic tests and hardness measurements a method of thermal joints treatment has been proposed, consisting in their hardening and low-temperature tempering (self-tempering) at the heat-affected zones. It leads to reproduction of that area structure, similar to the native material structure. In the laboratory conditions, a heat treatment differing from the usual practice (stress-relief annealing or normalizing) has not led to welding incompatibilities (cracks).

Keywords: *wear-resistant alloys, martensitic steels, welded joints, hardness changes, structures*

1. Introduction

Based at test results concerning Hardox 400 and Hardox 500 steels collected among others in [1], a proposal has been formulated of using those materials in the surface mining machinery construction. The own test results [2–4] confirm good weldability of the materials and very high strength properties of the joints obtained. As a result of heat processes during welding, damage is being introduced into the as delivered structures in the heat-affected zones (tempered martensite). It introduces significant change in such area hardness, as well as local drop in wear resistance. Similar phenomena are being observed in structural components cut out of metal sheets using welding methods.

Significance of such phenomena is high when intending to use Hardox steel plates for brown coal excavator parts, which are exposed to wear in the dynamic load conditions (chutes, hoppers, dumpers and scoop structure elements). The significance is even higher, because they are usually being fixed to the main structure by welding. Unfavourable structure and joint hardness appearing in low-carbon and low-alloyed steels may be reversed by heat treatment of such joints (Figure 1). In case of toughened steel, martensitic steel, as well as hyperquenched and aged aluminum alloys, the issues look different from the usual practice.

In the works [7, 8] they have been presented in relation to toughened steels in the following statements:

- in the heat-affected zone a problem of soft layer appears, which determines the strength of the whole structure,
- in the heat-affected zone of steel joints, hardened and tempered before welding, changes appear which lead to creation of tempering zones of lowered hardness and tensile strength.

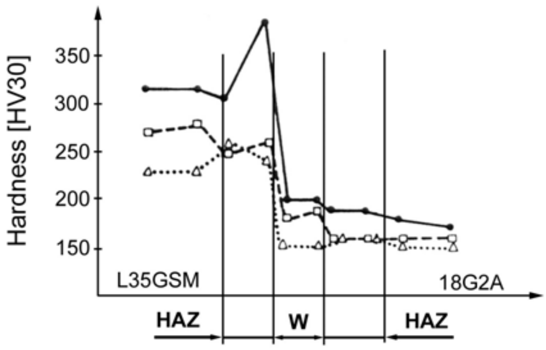

Fig. 1. Hardness distribution in welded joints of the L35GSM cast steel with 18G2A steel:
● – as delivered, □ – after stress relief annealing, Δ – after normalizing, W – joint area,
HAZ – heat-affected zone [5, 6]

Authors of the works [7, 8] and [9–11] state, however, that due to the proper chemical composition of materials and proper selection of welding conditions and parameters, it is possible to obtain structures of similar material properties to the base one in the heat-affected zone, without additional efforts. In case of welding with limited line energy the "soft layer" is very narrow and the joint exhibits no clear reduction of mechanical properties. This is interpreted as "reinforcing" activity of neighbour structural areas, as a result of three-axial stress creation in that zone.

Table 1. Chemical composition of Hardox 400, Hardox 500, HTK 700H and HTK 900H steels

Material	C	Si	Mn	P	S	Cr	Ni	Mo	B
	Maximum values [%]								
Hardox 400	0.320	0.700	1.600	0.025	0.010	0.300	0.250	0.250	0.004
Hardox 500	0.300	0.700	1.600	0.025	0.010	1.000	0.250	0.250	0.004
HTK 700H	0.180	0.450	1.400	0.025	0.010	0.500	0.300	0.030	0.002
HTK 900H	0.180	0.450	1.500	0.025	0.010	1.000	0.300	0.040	0.003
AR 400	0.240	0.700	1.700	0.025	0.010	1.000	0.700	0.500	0.004

Table 2. Structural properties of investigated steels

Material	Structure
Hardox 400	martensitic
Hardox 500	martensitic
HTK 700H	martensitic – bainitic
HTK 900H	martensitic
AR 400	martensitic