Microstructure and Fracture Toughness of 18 Ni Maraging Steel Weldments

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1. Material and Experimental Procedure

Weldments of the 18 Ni maraging steel (grade 250) were investigated at room temperature. Welding was done by TIG technique. Maraging steel electrodes HXF 750 were used. Th plates were welded in the annealed condition and then precipitation hardened for 3 hours at 480 °C. Yield strength (0.2 % offset) was measured in the base material, the heat affected zone and weld fusion zone by means of strain gage Extensive metallografic examinations were made of the weld fusion zone and the base metal by means of light and electron microscopy. Electron microprobe analysis was used for establishing the degree of segregation of the alloying elements. Fracture toughness investigations were performed on single edge notched fatigue precracked specimens in three point bending.

2. Results and Discussion

The results of yield strength measurements (0.2 % offset) are presented in fig. 1. It may be seen that the yield strength of the base metal is the highest, the yield strength of the heat affected zone is the lowest with the yield strength of the weld fusion zone falling in the inte mediate position. But since the strain hardening effect wa found to be the highest in the heat affected zone fracture occurs generally in the weld fusion zone. As far as the fracture toughness is concerned the base metal and the heat affected zone show similar values of K_{Ic} (approximately 310 kp/mm$^{3/2}$), while in the weld fusion zone the K_{Ic} was found to be by 40 % lower (Approximately 200 kp/mm$^{3/2}$).

Micrograph of cross section of the TIG weldment (see fig. 2 a) shows the configuration of the welding and the orientation of the dendrites in the "cast" metal as well as in the dark-etching heat affected areas of the weld fusion zone. These areas do not disappear even after the precipitation hardening process. Microscopic examination demonstrated that the dark etching zones within the weldment contain large amount of light etched areas (white constituent), formed during aging at the grain boundaries of dendrites (see fig. 2 b). The microhardness in this areas was only 100 HV, while in the dendritic part of the weldment the microhardness was found to be 530 HV.

Quantitative microprobe analysis demonstrated enrichment of these light etched areas in Ni, Mo and Ti (see fig. 3). This segregation of the above mentioned alloying elements promotes formation of the reverted stabilized austenite during the precipitation hardening process in the weld fusion zone.

Electron microscopic investigations performed on thin foils confirmed the presence of austenite by electron diffraction. The light etched areas have FCC structure. No precipitates formed in the aging process were observed in the white constituent, see fig. 4, while in the base metal and in the dencritic part of the weldments the precipitates were equally distributed.

The presence of austenite causes low rupture resistance. Because of its inferior strength properties the austenite will yield and strain harden before the flow strength of the adjacent martensitic regions is reached.

To avoid the formation of stabilized austenite in order to improve the toughness quality of weldment two heat treatments were introduced:

a) Additional high temperature annealing after welding before precipitation hardening in order to get rid of the segregation of Ni, Mo and Ti.

b) Shorter time of aging at 480 °C.

High temperature annealing after welding (not always applicable to welded structures) leads to lower yield strength of the base metal but improves the yield strength of the weld fusion zone, see fig. 5. However, metallographic examinations did not demonstrate any drastic change in the amount of the stabilized austenite. The increase in yield strength is probably connected with the partial disappearance of dendrites. The fracture toughness of the weldment has not improved essentially, fig. 6.

Short time aging leads to precipitation hardening but only partly prevents formation of the reverted austenite. Although a decrease of the yield strength in the base metal and in the weld fusion zone was observed, the fracture toughness after this treatment was found to be almost the same in the base metal and in the weld fusion zone (K_I approximately 290 kp/mm$^{3/2}$).

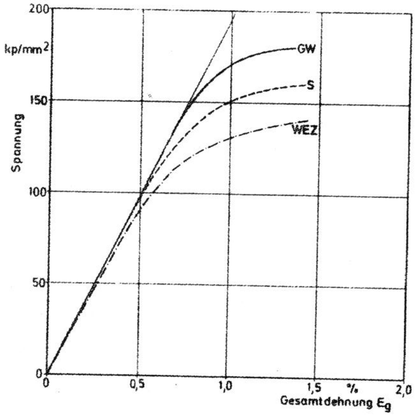


Fig. 1: Stress-strain behaviour of base metal (GW), weld fusion (S) and heat affected zone (WEZ)

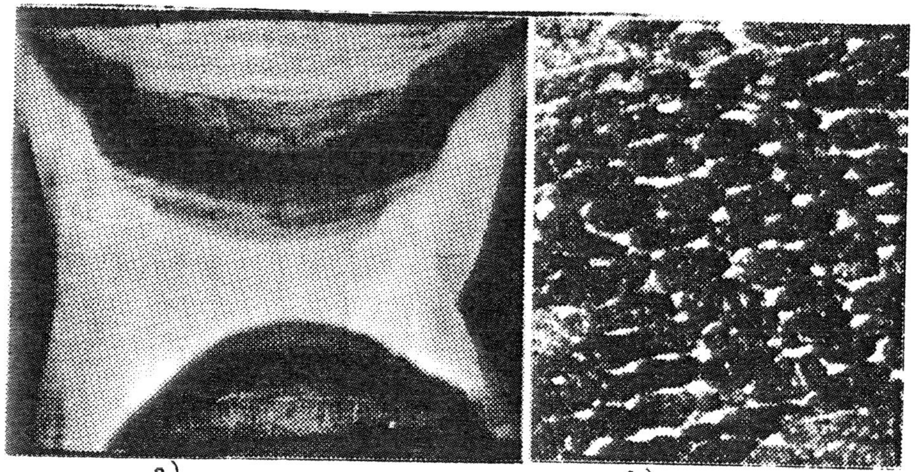

a) b)

Fig. 2: TIG weldment of 18 Ni maraging steel;
a) cross section macroscopic 6,5 : 1
b) weld fusion zone 1200 : 1
NiCoMo-etchant

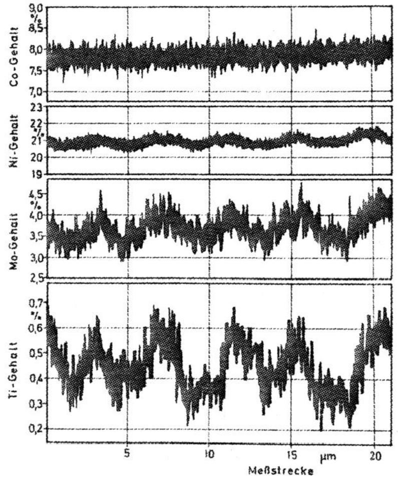
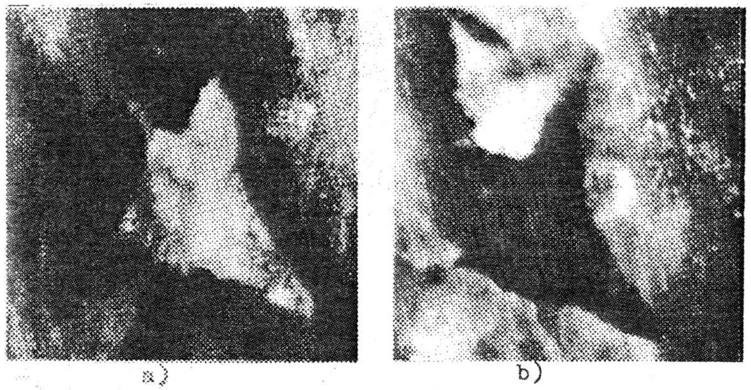


Fig. 3: Distribution of alloying elements in the weld fusion zone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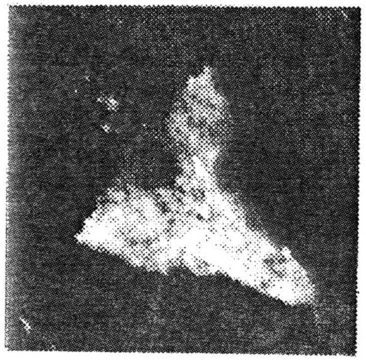
c)

Fig. 4: Transmission electron micrographs of thin foils of the weld fusion zone; 24 000 : 1
a) light field
b) dark field, using reflex of precipitate
c) dark field, using reflex of FCC-structure

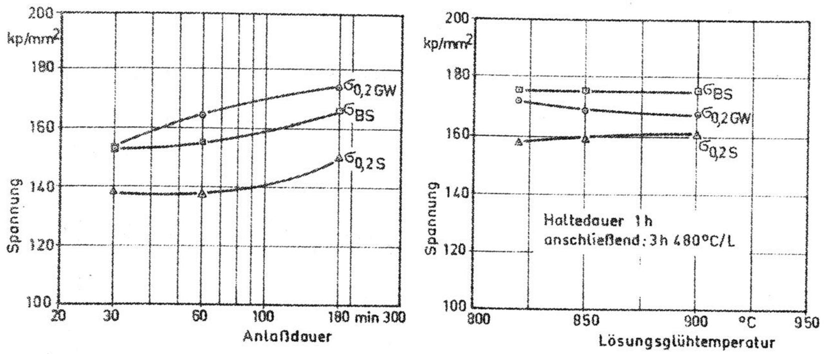

Fig. 5: Strength properties of base metal and weld fusion zone after applying different heat treatments

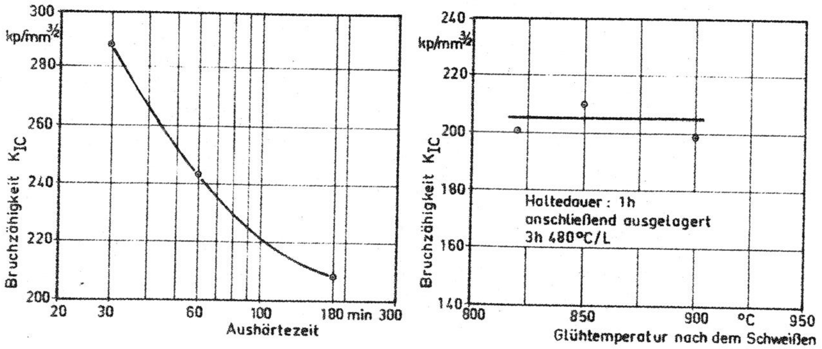

Fig. 6: Fracture toughness of the weld fusion zone after applying different heat treatments