REHEAT CRACKING STUDIES BY SCANNING AUGER AND ELECTRON MICROSCOPY INVESTIGATIONS

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REHEAT CRACKING STUDIES BY SCANNING AUGER AND ELECTRON MICROSCOPY INVESTIGATIONS

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Résumé - Dans cette contribution les effets de ségrégation intergranulaire et la fragilité de deux aciers soudables ont été étudiés. On a fait des essais de fluage suivis d'analyse des surfaces de rupture par spectrométrie d'électrons Auger et on a examiné, par microscopie électronique en transmission la forme et la précipitation des carbures.

Abstract - In this paper the effects of grain boundary segragations and the brittleness of two weldable steels were studied with creep tests followed by Auger analysis of fracture surfaces and electron microscopy of carbide morphology and precipitation.

Reheat cracking of fine-grain steels has received considerable research attentions in recent years [1-5]. It occurs if the postweld martensite or bainite is tempered in the vincinity of 600 °C for few hours. In addition to the loss in thoughness which is a result of tempering in this range, the fracture mode often changes from transgranular cleavage to brittle intergranular separation along the prior austenite grain boundaries. In this paper we report a study about the effects of phosphorous, sulphur and nitrogen in reheat-cracking.

Experimental studies
The chemical compositions of the steels used for this study are shown in fig. 1. The samples are weld simulated in air at 1300 °C for 5 sec

	Element, wt %										
	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	As
Steel A	0,19	0,24	0,98	0,012	0,009	0,52	0,23	0,06	0,06	0,05	0,002
Steel B	0,17	0,28	1,18	0,005	0,006	0,06	0,52	0,68	0,01	0,06	0,006

Fig. 1: Chemical Compositions

followed by an air cooling. Then they are isothermally tempered at 600 °C under load. After a short duration of creep test the fractures of both steels are fully intergranular. The fracture surface contains many brittle and ductile intergranular facets. The change from brittle to ductile intergranular fracture mode is not abrupt. In the same samples grain boundaries fractured in a brittle mode and grain boundaries which fractured in a ductile mode are to be found. The fractographic study leads to an intergranular weakening in these steels. Auger electron spectroscopy was used to determine the cause of this weakening. Notched Auger samples were machined from broken creep specimens and fractured in the Auger spectrometer at a pressure of $5\cdot10^{-10}$ Torr. Transmission electron microscopy was used to examine the precipitation of carbides along the grain boundaries as well as within the grain.

Results

Steel A: Phosphorous and nitrogen are detected in each one of the investigated intergranular regions but not in the cleavage fracture. [fig. 2]. An Auger map of phosphorous from a predominately intergranular region is shown in fig. 3. On the grain boundaries there is a high level of phosphorous segregation, on the cleavage area between them no P is found. A line scan from the intergranular to the transgranular region shows a strict association of P and N with the grain boundaries. [fig. 4]. The sputtering profile demonstrate that the P-signal decreases to less than 10 pct of the starting point after a sputtering depth of 0,8 nm.

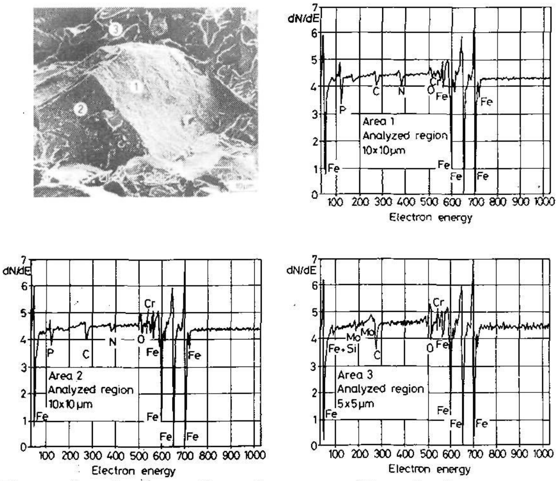


Fig. 2: Auger-Spectrum Steel A

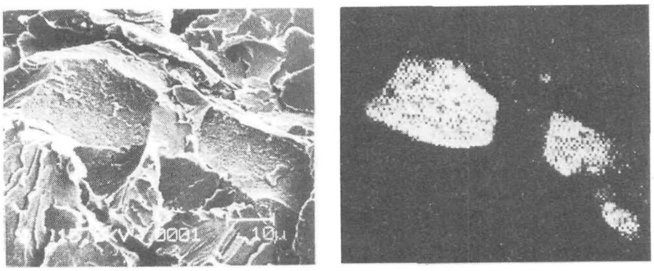


Fig. 3: P-Map from the fracture surface

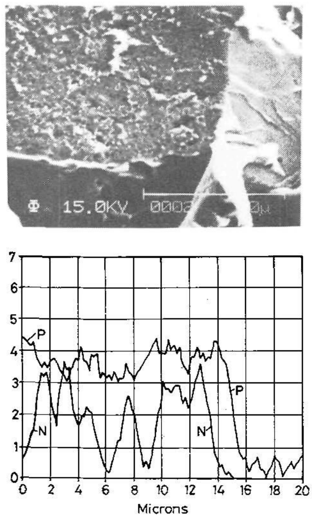


Fig. 4: P and N Line Scan Steel A

The fracture morphology is characterized by smooth grain boundaries and intergranular facets with a dimple nature. [fig. 5]

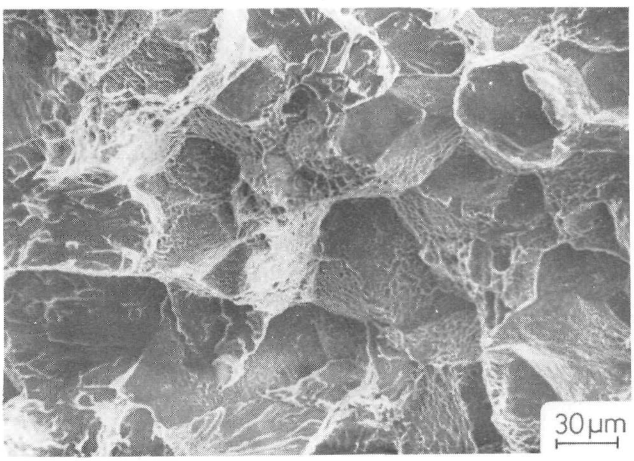
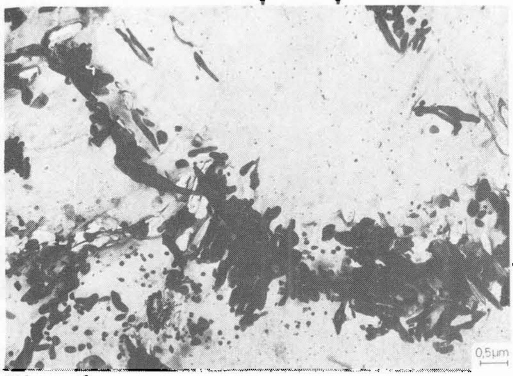


Fig. 5: Scanning electron micrograph of the intergranular fracture

VN precipitations



g.b. carbides

Fig. 6

The transmission electron micrograph shows the precipitation of $M_{23}C_6$ boundary carbides and the fine VN precipitations in the grains [fig. 6].

Steel B: In this steel sulphur, phosphorous, nitrogen and manganese are detected along the grain boundaries at a fairly high level [fig.7]. If we convert the peak to height ratio to at.pct. values, in these samples, we find a sulphur to manganese ratio of 2:1. This is greater than the 1:1 ratio in MnS. In steels manganese is very difficult to detect because its Auger peaks overlap those of Fe. In this case we cannot decide whether sulphur segregates without manganese. The Auger map of P and S shows that both impurity elements are enriched on the prior austenite grain boundaries [fig. 8]. It is probable that the grain boundaries contain Sulphur in precipitated (MnS) as well as in an unprecipitated form.

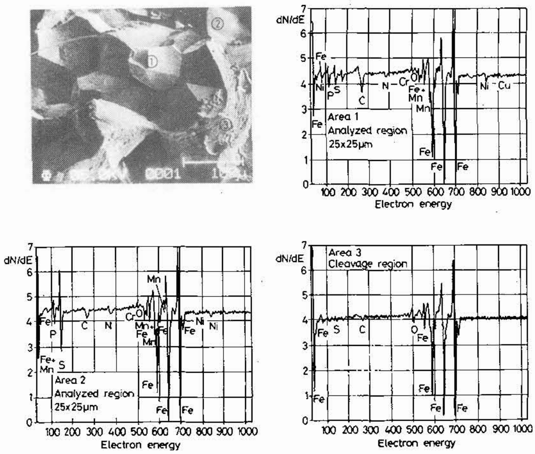


Fig. 7: Auger-Spectrum Steel B

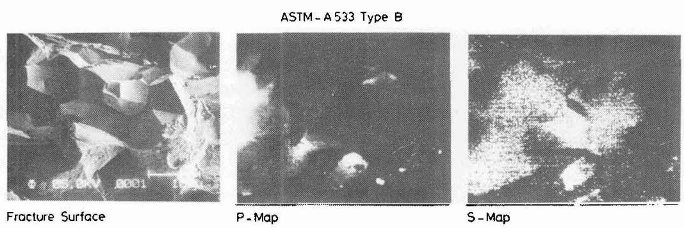


Fig. 8: P and S-Map from the fracture surface

The fracture morphology shows that the samples were predominately fractured along the prior austenite boundaries. We find fracture surfaces with smooth grain boundaries and g.b. with voids associated with MnS precipitations [fig. 9 a, b].

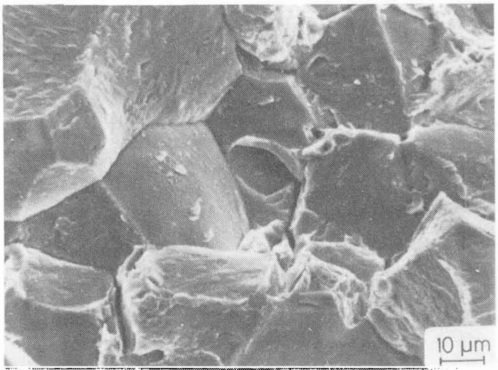


Fig. 9a: Smooth g.b.'s Steel B

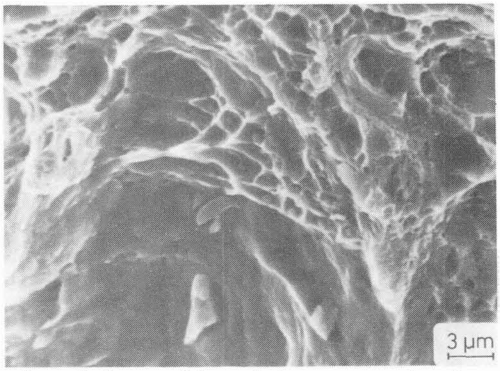


Fig. 9 b: Voids with MnS Steel B

Fig. 10: TEM of the carbide precipitations Steel B

By means of transmission electron microscopy we identified M_3C, M_7C and Mo_2C precipitations mostly in the grains. Often the boundaries are free of precipitation [fig. 10].

Discussion:
One of the reasons of weld reheat cracking is a combination of impurity segregation and carbide precipitation during tempering [6]. The carbide phases solidly dissolved during the heating phase of the welding process. During tempering treatments in the range of 550 to 630 °C the precipitation processes take place. Concerning the steel A precipitation of carbides and nitrides with high dispersion degree caused precipitation hardening in the grain. The residual stress relief during annealing must be realized by creep on the grain boundaries. During austenitisation or tempering treatment impurity elements, primalary P, S and N segregate to the grain boundaries.
The steel A forms $M_{23}C_6$ precipitations along the prior austenite grain boundaries while the steel B does not incline to the precipitation of carbides along the grain boundaries. In this steel MnS particles can be observe along the grain boundaries by means of scanning electron microscopy. The segregation of impurity elements and the precipitation of carbides and sulfides lead to weakening of the g.b. We are not yet able to decide whether the precipitation or the impurity segregation alone causes the reheat cracking or both weakening mechanisms must be present.

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