ANALYSIS OF UNDERCLAD CRACKING ON EXPERIMENTAL RING OF REACTOR PRESSURE VESSEL

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Identification of real underclad cracks on a ring of a reactor pressure vessel made of 15Ch2MFA steel. Metallographical and fractographical examination of cracks. After cutting of the ring the experimental surfaced layers in the selected regions of the ring were studied. The 15Ch2MFA steel strips were surfaced in the test jig with forced rigidity. The results obtained from the real crack are compared to those from laboratory tests.

INTRODUCTION

In CSFR the underclad cracks were for the first time identified on a ring of low-alloy 15Ch2MFA steel with experimental two-layer austenitic clad (1). The experimental N2d ring made of 15Ch2MFA (3Cr07Mo03V) steel was in its size comparable with the components of VVER 440 reactor pressure vessel. The underclad cracks occurred on this ring in critical zones close below the clad, where precipitation hardening of coarse-grain structure takes place (2). VÚZ Bratislava also participated in the evaluation of the character of defects and reasons of their formation (3). This work is aimed to find morphological characteristics of cracks and analysis of the zone of segregates, on which a corrosion-resistant deposit was surfaced.

EXPERIMENTAL DATA

The ring of the pressure vessel (Ø 3.8m x 1.2m; h = 140 mm) was made of 15Ch2MFA steel containing:

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0.14% C, 0.4% Mn, 0.24% Si, 0.013% P, 0.017% S, 2.93% Cr, 0.14% Ni, 0.72% Mo, 0.31% V. The ring was surfaced with Sv07Ch25N13 and Sv08Ch19N10G2B strips and subsequently heat treated at 665 ± 15 °C /25 h. Two specimens (A and B) were used for analysis. The specimen A had underclad cracks formed in surfacing of corrosion-resistant deposit on the ring and in subsequent heat treatment (Fig. 1). The specimen B - a segregate was identified after cutting up the ring, on which clads were applied to simulate critical conditions, necessary for the formation of underclad cracks.

Analysis of the specimen A. After clad removal such cracks were identified (Fig. 2), which corresponded to the scheme in Fig. 1 by their geometrical configuration. In the zone of cracks an increased concentration of inclusions occurred. Intercrystalline character of cracks is evident.

The chosen crack was opened and analysed fractographically. Overall character of the crack is demonstrated in Fig. 3. Grains coarser at the surface, gradually become smaller, in the lower part there are already intercrystalline facets of dimple morphology and finally the crack passes to transcrystalline one with dimple morphology. Fine particles, containing Mn, Fe, S and Si were identified on the facet surface.

From the crack a carbon replica was extracted. Its intercrystalline character was demonstrated again and fine structure of the facet surface was analysed. Probably slip traces on grain boundaries were identified (Fig. 4). On other places the slip band marks were identified (Fig. 5), which reflect plastic strain of a material (4). It is presumed, that besides plastic strain of individual grains they can cause grain boundary failure (5). Carbidic phase was also extracted on the replica (Figs. 4,5). Prevailingly M_7C_3 carbide is concerned, M_3C carbide occurred in the minority.

Conclusions from results of the A specimen analysis:

a/ a set of intercrystalline cracks in the critical zone because of the occurrence of underclad cracks was found out

b/ in the zone of cracks there is increased occurrence of oxysulphides. Fine oxysulphides were identified on intercrystalline facets

c/ in the study of fine morphology of the intercrystalline facets the slip traces on grain boundaries and slip band marks were probably identified

d/ M_7C_3 carbide was expressively prevailing in the phases segregated on grain boundaries

Analysis of the specimen B. The specimen B differs from the specimen A especially in the fact, that after cutting up the experimental ring the segregates were identified and to these places real surfacing with a strip was applied with the aim to form degraded state of coarse-grain zone, in which underclad cracks will be formed at heat treatment. In the analysis the surfaced layer was successively ground off to the interface with the base metal. Results from the analysis can be concluded into the following items:

a/ in the zone of segregates, where great amount of inclusions and eutectic phases was identified, the zone with intercrystalline facets was localized (Fig. 6)

b/ after opening these cracks it could be stated, that the crack has intercrystalline character, but with expressive dimple morphology. The surface of these facets was covered with great amount of oxysulphides (Fig. 7)

c/ cracks on the specimen B were caused by surfacing of a corrosion-resistant strip, but decohesion was caused first by abnormally high contamination of grain boundaries with oxysulphides and/or eutectic.

CONCLUSIONS

In comparison of the above-mentioned specimens the difference in their rigidity during surfacing is evident. The specimen A was a part of the rigid ring and the specimen B was surfaced as a free segment. It was shown, that in such different conditions, in spite of high contamination of the specimen B, the underclad cracks were not formed. However, if the ring material was surfaced in the jig with forced rigidity (6), intercrystalline failure in the critical zone was evoked (Fig. 8). Morphological features, which can be designated as slip traces on grain boundaries, were probably analysed on the surface of intercrystalline facets of the specimen A. Simultaneously slip bands (Fig. 5) were identified, which prove the range of plastic strain in the critical zone during surfacing of the ring inner surface.

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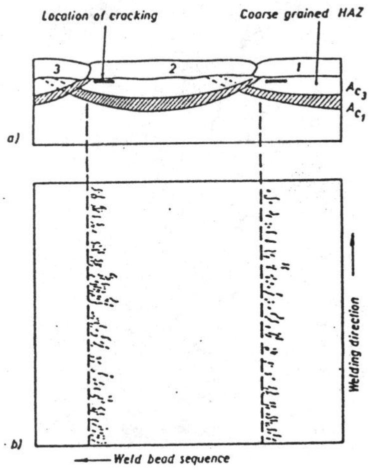

Fig.1 Location and orientation of underclad cracks

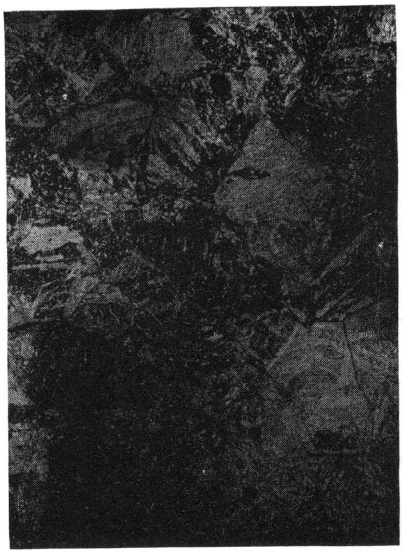

Fig.2 Characteristic intercrystalline cracks

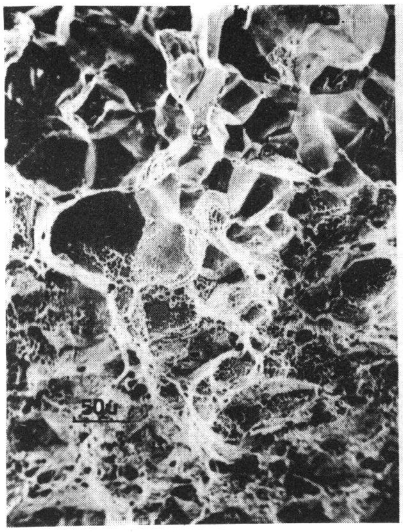

Fig.3 Intercrystalline underclad crack

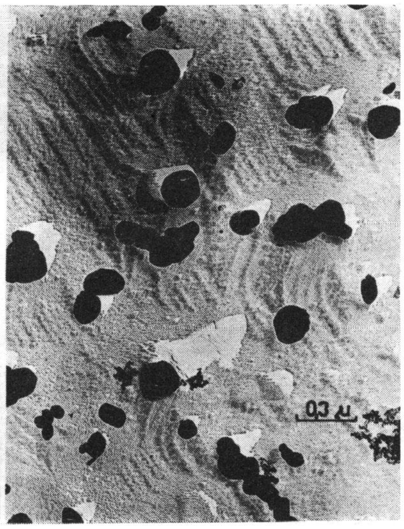

Fig.4 Slips on grain boundaries

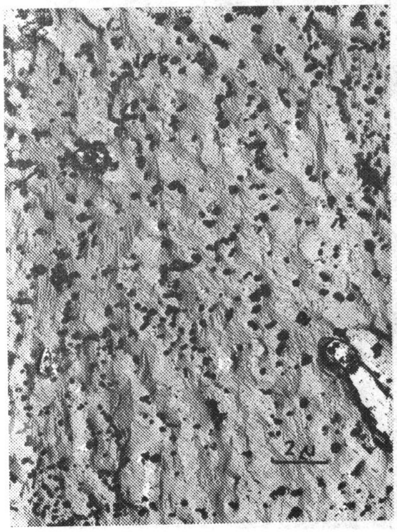

Fig.5 Slip band marks

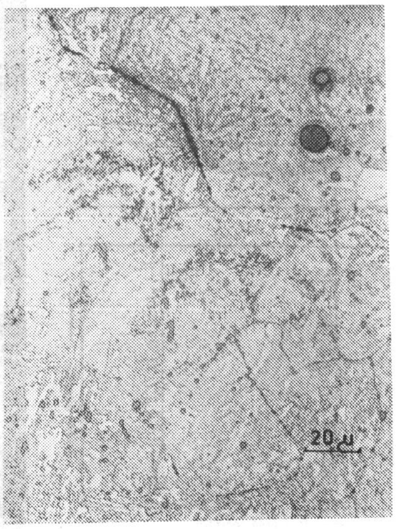

Fig.6 Intercrystalline cracks in a segregate

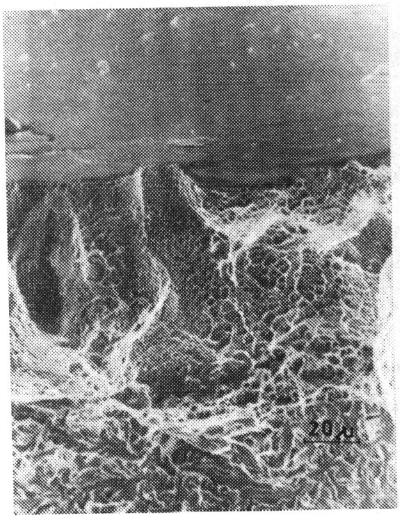

Fig.7 Intercrystalline crack after opening

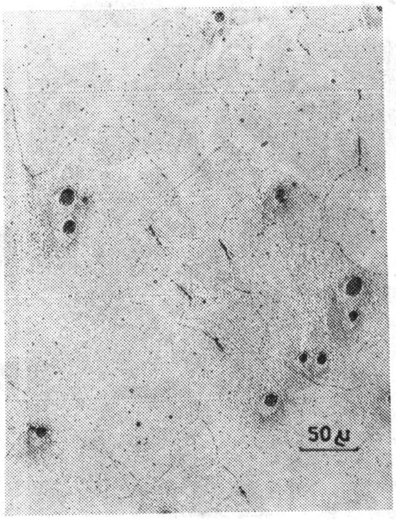

Fig.8 Intercrystalline cracks induced in the jig with forced rigidity