Identification of real underclad cracks on
a ring of a reactor pressure vessel made of
15Ch2MFA steel. Metallographical and fracto-
graphical examination of cracks. After cut-
ting 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 rigidi-
ty. 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 experi-
mental 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). VZU Bratislava also participated in the
evaluation of the character of defects and reasons of
their formation (3). This work is aimed to find morpho-
logical characteristics of cracks and analysis of the
zone of segregates, on which a corrosion-resistant de-
posit 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 S507Ch25Ni3 and S508Ch19Ni10Cr2B 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). Carbide phase was also extracted on the replica (Figs. 4,5). Predominantly M₇C₃ carbide is concerned, M₃C 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 cut-
tting up the experimental ring the segregates were identi-
fied 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 in-
cclusions and eutectic phases was identified, the zone
with intercristalline facets was localized (Fig. 6)
b/ after opening these cracks it could be stated, that
the crack has intercristalline 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 dif-
ference in their rigidity during surfacing is evident.
The specimen A was a part of the rigid ring and the speci-
cimen B was surfaced as a free segment. It was shown,
that in such different conditions, in spite of high con-
tamination of the specimen B, the underclad cracks were
not formed. However, if the ring material was surfaced
in the jig with forced rigidity (6), intercristalline
failure in the critical zone was evoked (Fig. 8). Mor-
phological features, which can be designated as slip
traces on grain boundaries, were probably analysed on
the surface of intercristalline 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.

REFERENCES

(1) Holý, M. et al., Zváranie, Vol.38., 1989, No.1,
pp. 1-6.
(2) Smáha, J. et al., Tlz 8581, Čv. SKODA Plzeň,


(4) Bošanský, J., Kovové materiály 6, XII, 1975, pp. 694-704.


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