ANALYSIS OF FAILURE IN BOILER DOWN-PIPES

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The results of damage examination of boiler down-pipe are presented. The investigation program included: static tension test at room temperature, impact bend test, hardness measurement and metallographic examination. The obtained results lead to the conclusion that damage parameter based on specific work determined during static tension test can be used as a material damage measure. Coincidence between fracture type and material damage has been found.

The results of damage examination of boiler down-pipes made of ferritic-perlitic steel are presented. These down-pipes were cut out of a failed boiler in one of Polish power plants. The failure took place in one down-pipe at the convex portion of the pipe bend (knee). The investigation program included: static tension test at room temperature, impact bend test, hardness measurement and metallographic examination. Yield point (σ_{YS}), ultimate tensile strength (σ_{TS}), rupture elongation (A_5) and specific strain work (W_s) were determined during static tension test. Impact resistance (KU) and hardness (HV) were also measured. Two down-pipes that had worked 56749 hrs (designated 1 and 5) a virgin one (designated A) as well as specimens made of the failed down-pipe (designated F) were used in the examination.
The mean values of the obtained results are listed in Table 1. The specimens that were cut out in the vicinity of the pipe bend (knee) were designated K while those cut out of the down-pipe portion located further from the knee were designated P. The relative value of the

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difference of specific strain work has been assumed by Żuchowski (1) to be the damage parameter:

$$D_W = \frac{W_{os} - W_s}{W_{os}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where: W_{os} - specific strain work required for breaking a specimen made of undamaged material, W_s - specific strain work required for breaking a damaged specimen. For undamaged material $D_W = 0$ while for failed one $D_W = 1$.

The damage parameter D_W was used for damage evaluation of the analysed down-pipes. It was assumed that material of specimen made of virgin down-pipe taken from the portion located far from the pipe knee was undamaged. Thus for these specimens (designated AP) damage parameter was equal to zero ($D_W = 0$). The values of damage parameter D_W have been calculated (using eq.1) for all examined specimens. The mean values of damage parameter are also listed in Table 1. Analysis of the values of mechanical properties listed in Table 1 showed that majority of them are in good agreement with the corresponding Polish Standard demands for unfailed down-pipe. Only the values of rupture elongation (A_5) for the specimens designated 1K and 5K were slightly lower than those required by Polish Standard. No information on maximum hardness of examined down-pipe material can be found in Polish Standards, so, mechanical properties cannot be used for damage assessment in unfailed down-pipe with sufficient reliability. Analysis of damage parameter values obtained for virgin and unfailed down-pipes showed that the lower the distance from pipe knee, the higher the damage parameter value. The damage parameter values obtained for specimen designated 1K and 5K are close to that obtained for specimens made of failed down-pipe, so, material of exploited down-pipe is damaged to a high extent. It means that exploited down-pipe must be withdrawn from service. The conclusion was confirmed by the results of hardness measurement of specimens made of pipe bends. The hardness obtained for specimens made of down-pipe knees was close to that obtained for failed down-pipe.

Fractography was carried out on the fracture surface of specimens which were broken during tension tests. An essential difference between the results obtained for specimens made of virgin and exploited down-pipe has been observed. Ductile transcrystalline fracture has been observed for ruptured specimens made of virgin down-pipes (fig.1) and for exploited with low material damage (fig.2). For specimens made of exploited down--pipes with high material damage a mixed fracture (ductile transcrystalline and cleavage intercrystalline) has been found. It was found that intercrystalline fracture appeared in these specimens whose hardness was higher than 170HV, rupture elongation was lower than 22% and damage parameter $D_w > 0.35$. The share of intercrystalline fracture in specimens made of exploited down-pipe changed from 0.5 - 5% as a function of material damage (fig.3). Higher share of intercrystalline fracture (up to 10%) has been found for specimens made of failed down-pipe (fig.4). Coincidence between fracture type and material damage has been found. The greater the value of damage parameter D_w, the greater the share of intercrystalline fracture.

TABLE 1 - The mean values of Obtained results

Specimen designation	σ_{YS}	σ_{TS}	A_5	KU	HV	D_w
	MPa	MPa	%	J/cm^2		
AP	354	503	29	144	162	0.00
AK	347	496	27	140	164	0.06
1P	330	469	20	131	182	0.16
1K	345	474	20	127	188	0.37
5P	335	460	24	134	180	0.30
5K	366	472	19	133	177	0.40
F	-	597	9	-	239	0.56

REFERENCES

(1) Żuchowski, R. Specific Strain Work as a Measure of Material Damage, Trans. 7th Inter. Conf. on Structural Mechanics in Reactor Technology, Chicago 1983, North-Holland 1983, vol,L pp.39-46.

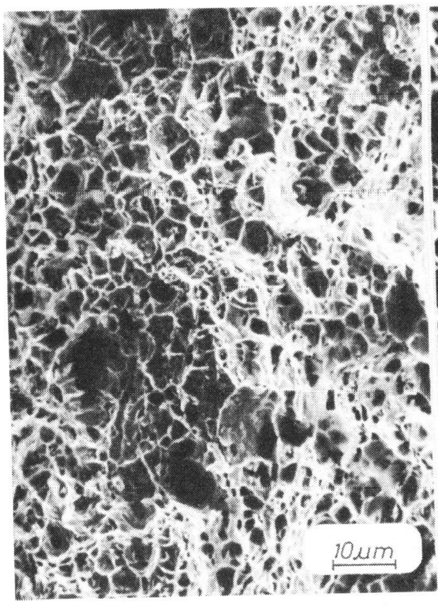

Figure 1 Virgin material
$D_W = 0$

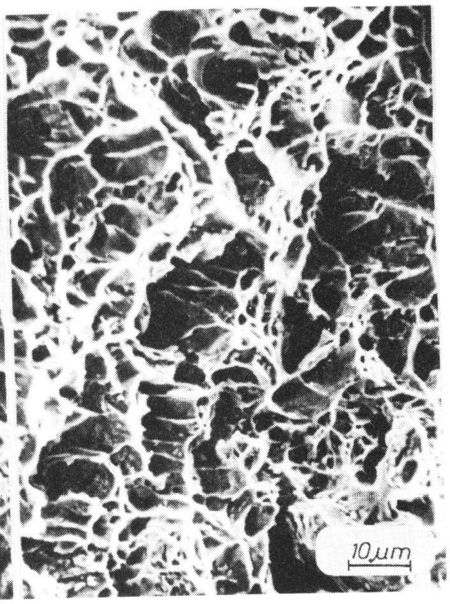

Figure 2 Exploited material
$D_W = 0.26$

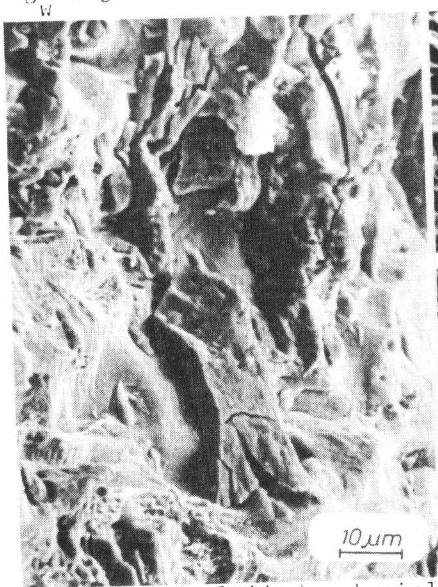

Figure 3 Exploited material
$D_W = 0.51$

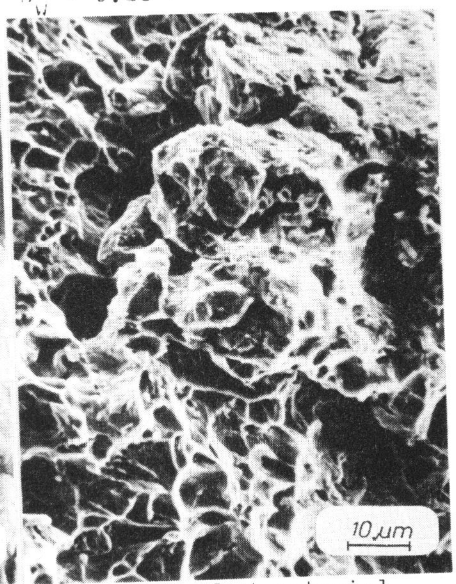

Figure 4 Failed material
$D_W = 0.56$