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CRITERIA OF REPAIRING TUBE SURFACE DAMAGES BY OVERLAY WELDING

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The present article discusses the removal of tube surface mechanical damages and gives some guidelines for repairing the damages without replacing the tube. The mechanical damages introduced by pneumatic hammer lance into heat surfaces at removing of refractory concrete or refractory off tubes in every boiler burning solid fuel are to be repaired. This kind of external damages on the tube might be a reason for bursting of tubes in the operation. The article presents some criteria and practical results about the repairs of these mechanical damages.

Introduction

Within a shutdown the heat surfaces are mechanically cleaned from deposits tightly sticking to the tubes usually by compressed air-hammers. At removing of deposits by pneumatic hammer lance, mechanical damages are produced on outer surface of tubes, which might be a reason for bursting of tubes in the operation. Similar surface damages might also be induced at removing of refractory concrete or refractory off tubes in every boiler burning solid fuel.

The above-mentioned damages extend from the tube surface into the tube wall but they do not penetrate the wall.

The present article discusses the removal of such tube surface damages without replacing the tube.

Description of Damages

At removing the heat-resistant concrete from bottom tubes (Ø 63.5 × × 3.35 mm, average wall thickness 4.18 mm) of the recovery boiler, mechanical damages were produced on the outer surface of these tubes. The damages caused by pneumatic hammer lance might be classified according to their shape as point and pit damages (Fig. 1). Point damages are those of conical or pyramidal form punched into the outer surface of the tubes. Pit

Fig. 1. Mechanical damages on the tubes

damages are transversal or longitudinal ditches made by pneumatic hammer lance into the outer surface. Longer pits were 25–45 mm long. The shape of the damage was, to some extent, dependent on the form of lance.

The damages caused by lance with pointed end had distinct boundaries with sharp edges overlapped on the outer surface of tubes. A lance with blunted end bruised the tube wall forming a bulge inwards the tube wall, but did not extend through it. The maximum depth was 3–5 mm from the edges of the damages; the minimum depth could be only the trace.

The damages were located on the tubes chaotically, on some tubes there were none, on the other ones there were many, whereby the minimum distance between two damages in that case was about 8–10 mm.

Methods of Repairing the Damages

For repair of the damages, first it would be necessary to establish the depth of the damage, in order to decide if the damaged tube has to be replaced or be repaired by overlay welding. As mentioned before the depth of the damage serves as a criterion for it.

According to Andritz-Ahlstrom the overlay welding can be done if tube wall thickness is more than 2.9 mm, and the thickness of the base metal unaffected by weld pool shall be $s < 2$ mm [1]. In conformity with instructions of AS *Eesti Energoremont*, the maximum depth of a damage repaired by overlay welding is $s < 3$ mm, but not more than 1/2 of the tube wall thickness [2].

After detection of damages, the repairing was carried out in two stages. Within the first one, test tubes were prepared on which damages produced by a core and similar to actual ones were provided and thereafter repaired by overlay welding. Within the second stage, the real damages were repaired in the same way.

Preparation of Test Tubes

Test pieces were prepared of a not-operating tube and a tube that had operated in the recovery boiler furnace and which had been cut out of the furnace bottom tubes. On the surface of both tubes, damages were generated by strokes on the core.

Specification of Test Tubes and Produced Damages:

	Steel St 45.8	Steel St 35.8
Measures	63.0 × 6.3 mm	63.5 × 4.5 mm
Operating hours	0 h	115,000 h
Sign	N	O
Depth of damages	2 and 3 mm	2 and 3 mm

Tubes with Actual Damages

The material of the tubes with actual damages was St 35.8. Before the formation of damages the tubes had operated in the boiler furnace for 139,000 h; after repairing the damages by overlay welding, the exploitation of the tubes continued for 8000 h.

Specification of Furnace Bottom Tubes and Damages:

	Steel St 35.8
Measures	63.0 × 4.5 mm
Operating hours	147,000 h
Number of damages	85
Depth of damages from the edges	0–5 mm

Technology of Welding

The damages were repaired under recommendations [2] worked out by AS *Eesti Energoremont.*

Before the welding the damaged place and its surrounding zone within 20 mm were mechanically cleaned, and a smooth passage from the edges of the damage to the tube surface was prepared by grinding.

The effect of thermal cycle of the welding process was minimized by selection of requisite current and electrodes of minimum diameter. On the horizontal tube the overlay welding was performed by one or two passes, damages up to 2 mm were filled by one pass, the deeper ones by two passes. For decreasing the influence of residual stress and thermal cycle, the second pass was made after cleaning of the first pass from molten metal and cooling below 100 °C. After overlay welding the fixed place was cleaned up to the level of tube surface.

Results of the Research

The changes in the properties of test tubes and furnace bottom tubes after overlay welding were determined by changes in mechanical properties and microstructure. Microhardness of the base metal was determined in the middle of tube wall cross-section before and after the repair, in addition to that microhardness in the pass and in the heat-affected zone was determined after welding.

At determination of microhardness, no relationship between the microhardness and depth (2 or 3 mm) of the repaired damage was observed (the Table).

Microhardness of the Test Tubes by HV 10

Material	Base metal before overlay welding	Base metal after overlay welding	Heat-affected zone	Pass weld
St 45.8 (new tube)	128–136 132*	136–157 146*	151–170 158*	216–235 227*
St 35.8 (old tube)	136–145 140*	136–157 156*	146–197 159*	217–233 225*

* Average.

As seen in the Table, the microhardness of the base metal increased after overlay welding on both the old and new test tubes, from 140 to 156 HV, and from 132 to 146 HV, respectively. In the heat-affected zone the microhardness of both tubes was almost the same, 158 and 159 HV, the values exceeding the microhardness of the base metal, but not indicating the hardening microstructure.

Microhardness of the pass weld 227 and 225 HV conforms to the carbon steel weld microhardness.

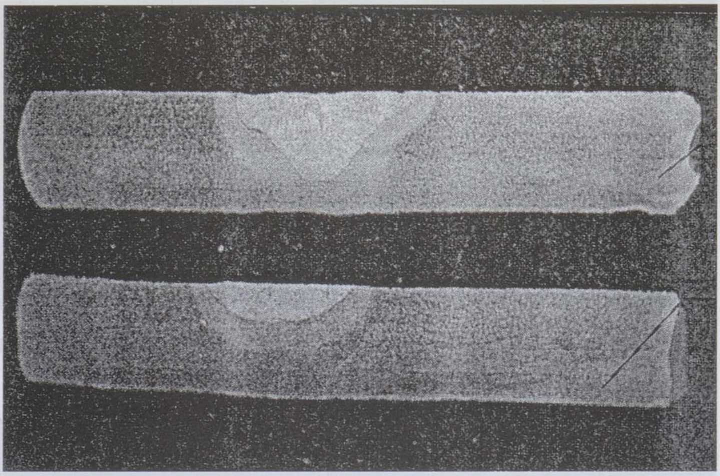
The changes in mechanical property R_m (tensile strength) of the old as well as of the new test tube after overlay welding were minimum, from 403 to 400 N/mm^2 on the old test tube, from 445 to 432 N/mm^2 on the new tube, respectively.

Macrostructure

Macrostructure study of the test tubes (Fig. 2*a*,*b*) and of the furnace bottom tube (Fig. 3*a*) after overlay welding revealed that the passes were free from defects. On the furnace bottom tube, only a slightly extending bulge with the diameter of 10–12 mm was noticeable on the inner wall opposite the passes. The passes consist of three passes in succession. The maximum depth of the damage was 2.3 mm, and the thickness of the tube wall was between 4.3 and 4.5 mm. The length of the damage extended up to 19 mm.

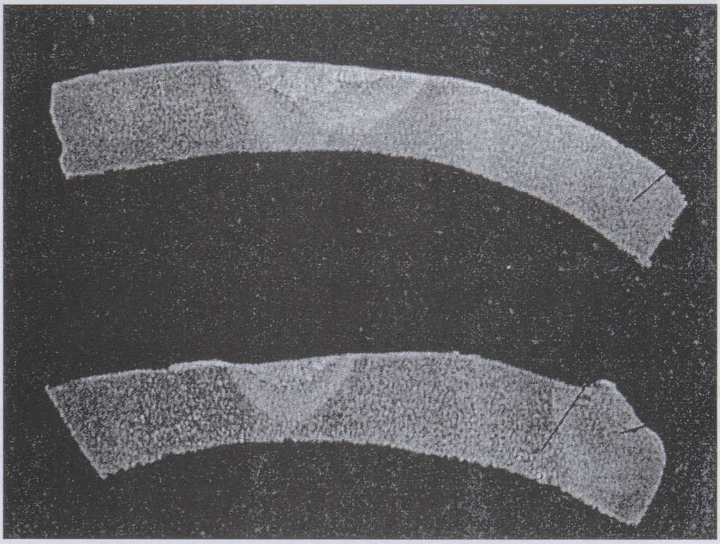
The situation on the place of the bottom tube, where the thickness of the wall was 4 mm and the depth of the damage 3.0 mm (Fig. 3*b*), was different. One can see a bulge with the height of 1 mm, deeply protruding from the tube inner wall. The heat-affected zone is easily observable.

a



× 2.5

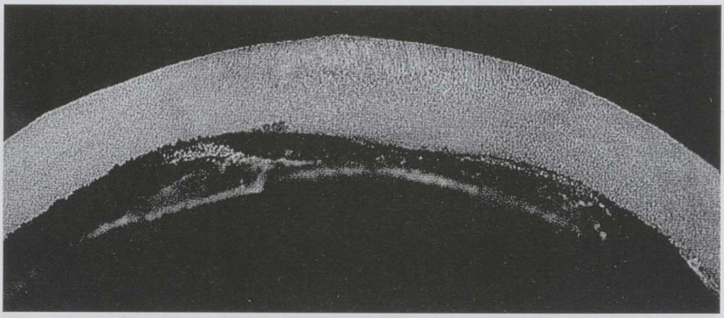
b



× 2.5

Fig. 2. Macrosection of test tubes after overlay welding:
a – test tubes N3 (wall thickness in the place of welding 6.4 mm; pass depth 4.8 mm) and N2 (6.2 and 2.2 mm, respectively);
b – test tubes O3 (wall thickness in the place of welding 4.0 mm; pass depth 1.6 mm) and O2 (3.5 and 1.1 mm, respectively)

a



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b

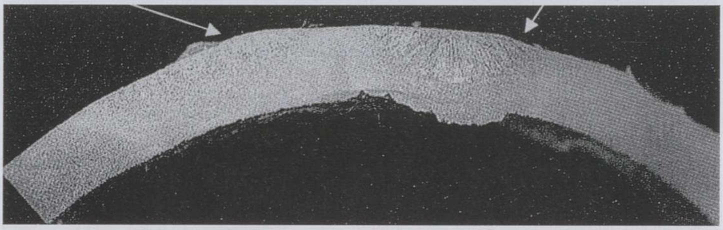

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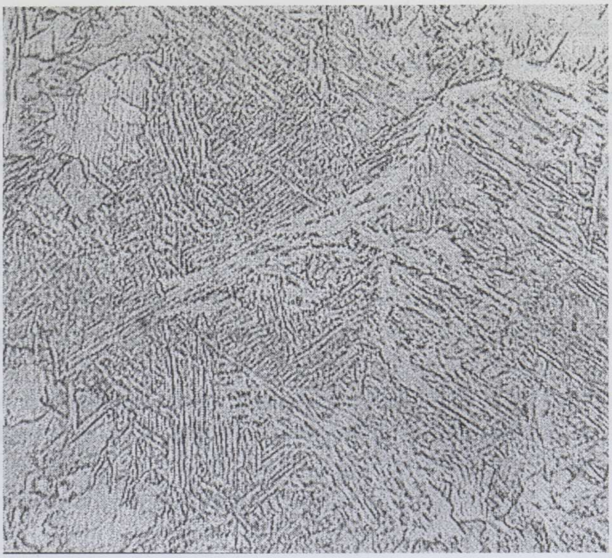
Fig. 3. Macrosection of furnace bottom tubes after overlay welding:
a – tube wall thickness in the place of welding 4.3–4.5 mm; pass depth 2.3 mm, length 19 mm);
b – tube wall thickness in the place of welding 4.0 mm; bulge thickness 1 mm; pass depth 3 mm

Microstructure

In the microstructure of the test tubes no changes were observed after overlay welding, both the old and the new test tubes retain their normal carbon steel ferrite perlite microstructure, whereby the part of perlite is less in the structure of the old test tube. Irrespective of whether the depth of the repaired damage was 2 or 3 mm, the microstructure of both the test tubes in heat-affected zone was similar. No hardening structures were found anywhere.

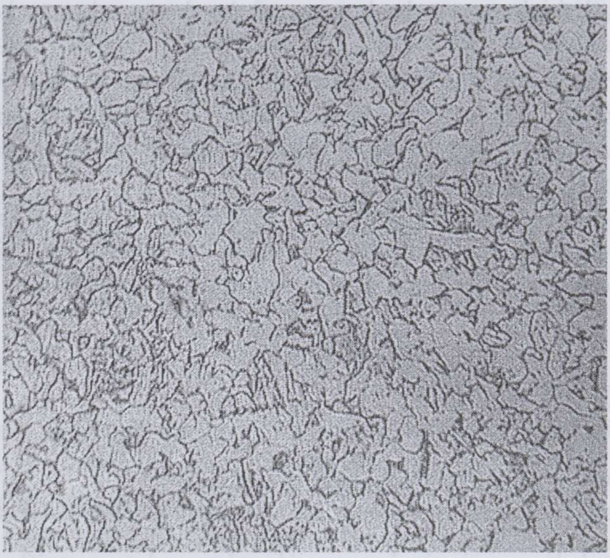
Directly in the fusion zone between metal and heat-affected zone with the width of 0.1–0.3 mm the recrystallization in the structure had taken place – weakly expressed large-grain Widmannstatten structure was observed. Such a structure characterizes the overheating of carbon steel.

Overlay metal had the dendritic structure, which is characteristic to casting metal.



× 500

Fig. 4. Macrosection of metal on the bulge. Microstructure – large-grain martensite



× 500

Fig. 5. Macrosection of heat-affected zone. Microstructure – partial recrystallization to the large-grain Widmannstannen structure

The microstructure of the base metal of the furnace tube did not differ from the microstructure of the test tubes. The differences in the microstructure of steel appeared in the form of extended bulges. Complete recrystallization of the structure had taken place in the extended bulge (Fig. 4) as a result of overheating – its microstructure was large-grain martensite. Overheating during the welding process and the following quick cooling caused large changes in the structure of the furnace tubes.

Figure 5 shows that partial recrystallization had occurred in the small bulge, structure of the steel was similar to the structure in the fusion line of the overfusion metal and base metal demonstrating the large-grain Widmannstatten structure.

Changes in the microstructure of repaired bottom tubes are dependent on the depth of damages. The repairing of a deeper damage resulted in more changes in the metal microstructure.

Conclusions

1. Mechanically caused damages on the tube surface are repairable by welding if the following requirements are taken in account:
   - the wall thickness around the damage has to be more than 3 mm
   - the wall thickness at the bottom of the damage has to be more than 2 mm
   - the diameter of the welding electrode has to be not more than 2-2.5 mm and welding must be done using weak welding current
   - after welding, every welding pass has to be cooled slowly to avoid hardening of the structure
2. Repairing the mechanically caused surface damages by overlay welding in accordance with the above-mentioned requirements, will leave the mechanical properties and microstructure of steel unaltered.

REFERENCES

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2. Технологические рекомендации по устранению механических повреждений посредством сварки на поверхности экранных труб содорегенерационного агрегата (Technological recommendations for reparation of mechanical damages by welding on the outer surface of tubes of a soda recovery unit) [in Russian] : AS *Eesti Energoremont*.

Presented by A. Ots
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