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WELDING FLAWS OF PIPELINE HEAT RESISTANT STEELS

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ABSTRACT
Possible crack-like failures in the vicinity of the welds of fossil fuel power plant components are presented in this paper. Welding defects of differente Cr-Mo-V pipeline heat resistant steels are especially disscussed. These flaws are very unbenefitial because they could provoked crack initiation and their propagation during service.
Keywords: welded joints, defectsCr-Mo-V steels, Pipelines, Thermal Power Plants

1. INTRODUCTION
The chromium, molybdenum and vanadium based heat resistant low alloyed pearlite steels are widely used for the pipelines in the thermal power plants. However, laboratory test results as well as the actual field experience (in vivo testing) have shown that the welded joints of this type of steel have reduced exploitation capabilities as compared with the base material. The main aim of this work is to point out to possible defects occurring in the welded joints with a particular attention to the welding defects in Cr-Mo-V steel that are favorable for the initiation and spreading of cracks.

2. CRACK-TYPE DEFECTS OF WELDED JOINTS.
During design phase, a welded joint has to be considered as a critical construction element. In general, it was observed that during exploitation and thus the exploitation of the pipeline, the crack-type damages occur in the welded zones due to the changes in the material properties and stresses induced.
Difference in microstructure in the heat affected zone (HAZ) and weld is at the same time a clear indication of their different properties and behavior under the influence of mechanical and thermo-mechanical stresses. Therefore, the crack-type fissures can be found in the HAZ as well in the weld itself. The spreading direction of defect can be parallel with the welding direction, perpendicular to the weld or even without any specific orientation Fig.1

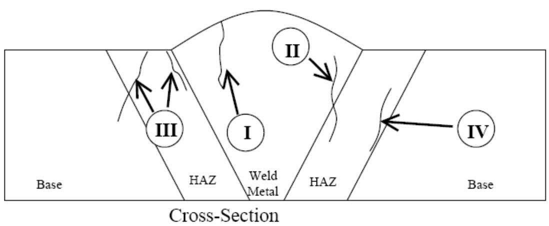


Figure 1. Schematic of the crack location in welded joints.

3. NATURE OF CRACK DEFECTS IN WELDED JOINTS

In respect to the time of formation, different types of cracks occurring in the welded joints can be classified as: the cracks due to fabrication (production) and cracks generated during exploitation. Clearly, a combined action is possible whereby the crack initiation, generally non-detectable using regular testing methods, can occur during the fabrication and that their further development and spreading occurs during exploitation.

Production cracks. Welding cracks generated during different production stages are in the majority of cases detectable during the quality control using non-destructive tasting methods and thus can be removed. However, under certain conditions these cannot be detected when:

- these were initiated and their size was bellow the sensitivity threshold of the control method used.
- geometry of the welded joint makes the control inaccessible.

during quality control its importance are not recognized and adequately evaluated. The production cracks can be hot, cold, lamellar and relaxation types.

Exploitation cracks. Cracks occurring in the welded joints during exploitation are due to:

- overload conditions (exploitation nature only)
- existing errors during fabrication that can grow under operating conditions

This group of cracks comprises: fatigue cracks, stress cracks, overload-induced cracks, stress-corrosion cracks, corrosion fatigue cracks, creep induced cracks.

4. WELDING FLOWS AND REDUCTION OF EXPLOITATION CAPABILITY OF WELDED Cr-Mo-V STEELS

According to the literature data [1,2] there are two main causes responsible for the reduced exploitation capabilities of Cr-Mo-V steel welded joints generally used for steam piping: high sensitivity of vanadium alloyed steels to welding thermal conditions and relaxation and appearance of "soft zones"

It is known [1,2] that small amounts of vanadium added to chromium and molybdenum alloyed heat resistance steels have beneficial effect on their strength and creep resistance (vremenske ?vrsto?e). Under strictly controlled conditions, vanadium precipitates in the metal base in a form of fine homogeneously disperesed carbides resulting in dispersion hardening and thus contribute to the overall strenghtening of material.

On the other hand Cr-Mo-V steels are very sensitive to swelding since the presence of vanadium can intensive the fragility of welded joint in the temperature range 500-700°C [3]. In case when the thermal treatment of welded joints is absent or that prescribed welding conditions were not followed, the increased fragility of favors the appearance of cracks in welded joint and HAZ during exploitation.

The second cause for reduced exploitation capability of welded Cr-Mo-V steels for steam pipeline is closely related to the welding conditions and often cannot be avoided even when the prescribed parameters of welding technology and tempering are respected. In other words, during welding of these steels, formation of soft (zones of lower strength) occurs in the heat affected zones specifically in the zones where the heating of is in the vicinity of Ac1 temperature.

In these regions of welded joints and specifically in those highly strengthened, as is the case of Y and T splits and but welded joints of heat piping where the pipe dimensions change, the formation of cracks can occur in a very short operating time.

The crack appears on the side of metal with a lower strength and is of intercrystalline nature. Rack initiation occurs generally outside of the fusion zone, whereas the crack spreads through the HAZ. Under certain conditions the crack can be initiated in HAZ. Crack direction coincides with the direction of the bending occurring during linear expansion of steam piping under heating conditions.

In the steam piping it was found that an abrupt dimensional changes occurs due to the design of the welded shapes, rapid increase in stress concentration due to bending whereby the stress concentration coefficient can reach the value of 10 [4]. Also, during long term exploitation, the strength of welded joints with soft zones can significantly be reduced [5].

One of the means to reduce the crack formation susceptibility of these welded joints and thus stress concentration coefficient is machining and polishing of the welded joint face or making adequate transitions using suitable inserts.

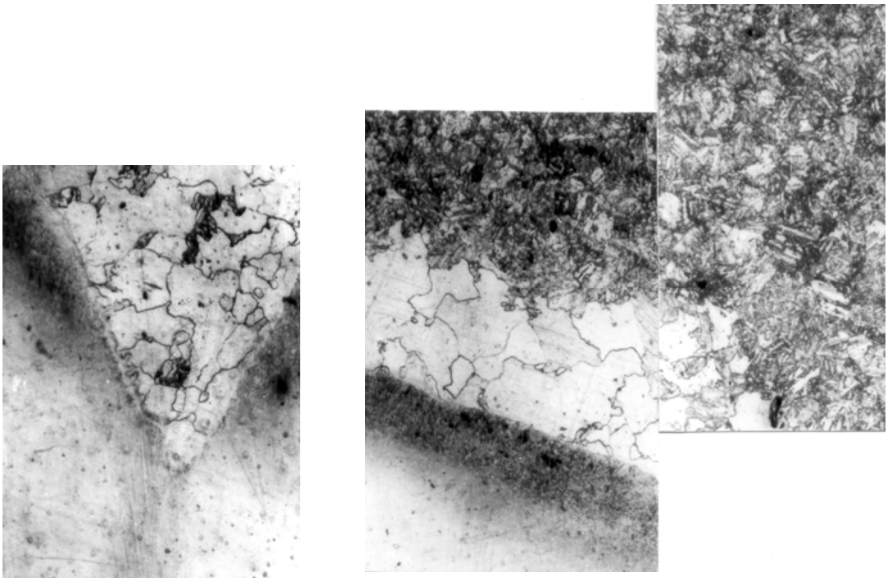


Figure 3. Decarbonized zone in welded zone of CrMo steel steam piping

Another form of welding defects occurring in Cr-Mo and Cr-Mo-V steels for steam piping is the formation of "decarburized zone" - the region of practically pure ferrite. Fig. 3, with reduced mechanical strength and the width determined by the welding conditions.

5. WELDING PROBLEMS OF HEAT-RESISTANT STAINLESS STEELS.

In the case of stainless steels prolonged operation in the temperature range 550-850^oC initiates reaction between carbon and chromium resulting in the formation of $Cr_{23}C_6$. carbide. The carbide particles are nucleated at the austenite grain boundaries and due to their growth and coarsening the content of dissolved chromium in the base metal is reduced. The reaction that occurs is typical case of diffusion transformation whereby the time of carbide precipitation is temperature dependent. When depletion the chromium content in the base reaches certain critical vales, the steel become "sensitive" and corrosion occurs along the grain boundaries.

This property of stainless steel is of particular importance during welding with the same (austenite) or different classes of steels (ferritic, martensitic) since the base material in the HAZ under the influence of thermal cycling can reach the temperature range where the carbide reaction takes place.

The common method of preventing the sensitization of stainless steels is stabilization by alloying with 0.5-1% Ti or Nb. These elements are more susceptible to chromium carbide formation and thus bind carbon before it can react with chromium. Also, reduction of carbon content to level of 0,03 - 0,06 % is the method presently commonly used and with beneficial effects.

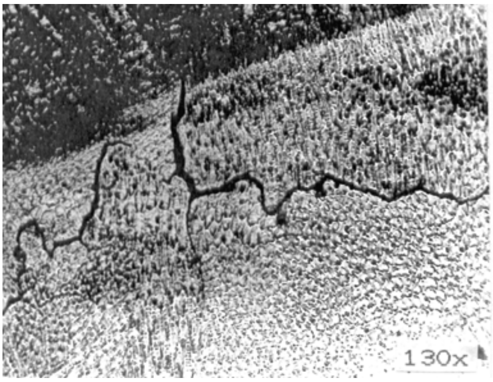
However, the problem sensitization of steel is still critical because there are welded joints of thermal power generating components that were in use for a long period of time.

Based on examination of welded joint that was

- made by welding low alloyed Cr-Mo-V steel (heat pipes base material) with additions of high alloyed austenite
- was exploited for a long period of time at temperature 350^oC,
- was underwent fracture

and analysis of the results enabled to conclude that in the weld seam sensitization occurred Fig. 3 causing stress cracking.

Although it was pointed out that this process requires temeperature in the range of 550-850^oC, its initiation in terms of more perceptible diffusion activity of atoms of alloying elements is perceptible at all temperatures exceeding 450^oC [7,8], whereby the initiation and ending of the process is temeprature dependent and is determined from the C curve. However, based on the results of extensive testing it was concluded that sensitization is not only temperature but also time determined process [9].



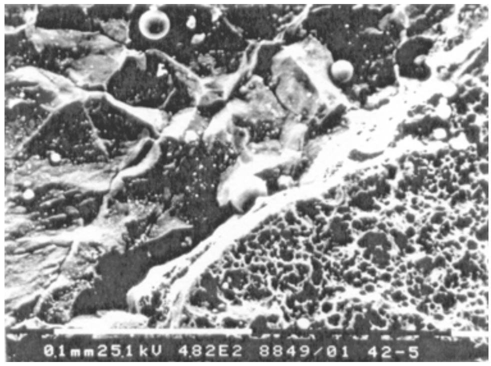


Figure 3. Austenitic structure of weld - boundary between transition and different direction of dendrite propagation. Fracture due to stress corrosion. Figure 5. SEM image of fracture between transitions made with two different electrodes: ferritic and austenitic

6. COMMENT

The welding defects and welded joins are numerous and are undesirable both from the point of view of exploitation and operating capabilities of thermal power systems. Numerous laboratory tests as well as on-site inspection indicate that chromium-, molybdenum- and vanadium-based steels used for steam piping showed that under certain welding conditions defects can be formed that can not only affect the lifetime of steam pipe material but also increase susceptibility to cracking and fracture. Respecting the prescribed welding requirements as whole under the condition that the welding technology is adequately applied and applied and that all detrimental effects are considered can prevent the occurrence of these defects.

7. REFERENCES

[1] Experience with the use of steel 14MoV63, VGB, 1984, internal publication

[2] E.I.Krutasova, Nade`nost metalla energeti?eskogo oborudovanija, Moskva, Energoizdat, 1981.

[3] K.Laha, K.Rao, S.Mannan, Effects of Post-Weld Heat-Treatment on Creep Behavior of 2,25Cr-1Mo Ferritic Steel Base, Weld Metal and Weldments, Proc. of 5th Int. Conf. on Creep of Materials, Lake Buena Vista, Florida, USA, 1992., pp. 399-422

[4] V.A.Vinokurov, V.D.Prohorenko, Svaro?noe proizvodstvo, No5 (1974) 23-25

[5] V.N.Zemzin, @aropro?nost svarnih soedinenii, Moskva, Ma{inostroenie, 1972.

[6] D.Jones, Engineering materials, Pergamon Press, Oxford, 1993.

[7] C.Bagnall, I.Le May, Some Metallurgical Aspects of Joining 300 Series Stainless Steel, Unusual techniques and new application of metallography, Vol. 1, Ed: Gray and Cornwellm ASM, 1985, pp. 47-59

[8] J.B.Lee, W.Eberle, J.A.Somsak, A New Test for Determining Intergranular Corrosion Properties of Stainless Steel, Unusual techniques and new application of metallography, Vol. 1, Ed: Gray and Cornwellm ASM, 1985, pp.19-27

[9] V.Sijacki, A.Milosavljevic, A.Markovic, Z.Stamenic, A.Bratic, D.Milanovic, Microstructural characteristics of joints after repair welding with austenitic electrode after prolonged service, Proc. of Intern. Symp. on Materials ageing and component life extension, Milan, Italy, 1995., Vol.2, pp. 723-733