CASE STUDY OF INLET PIPELINE-DRUM JOINT FAILURE

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The aim of this paper was to determine the influence of welding process in inlet pipeline-drum joint. Failure causes of boiler drum after 60.000 hours were investigated. Drum mantle was fabricated from steel micro alloyed with niobium, but the pipe was of 15Mo3 steel. Several samples from fracture area were taken. Determination of chemical composition, hardness measurement in various zones of welded joint and it's surrounding, optical microscopy, as well as scanning electron microscopy of fracture surface was carried out. On the basis of the obtained results it was possible to define the structural state of welded joint and it characteristics. The structure of needle morphology with high values of hardness is dominant in the heat affected zone that means that the beneficial conditions are induced for origination of cold late cracks.

INTRODUCTION

The higher strength level of steels, that are not assigned for heat treatment and are used for pressure vessel manufacturing, can be obtained by micro alloying with elements as V, Ti, Nb, Zr and B. These steels are well known as microalloyed steels, and the percentage of micro alloying elements in range 1/100 to 1/1000% is showing significant influence on the properties and service behavior of these steels. Pressure vessel made of micro alloyed steels were being tested during the service life, so not only the knowledge of micro alloyed steels but their behaviors during exploitation are significantly expanded. Especially interested investigation area includes dissimilar metal welded joints from which one belongs to micro alloyed category. Aim of this paper was to shed some more light on the knowledge of micro alloyed steel behavior used for pressure vessel. This was done through extensive investigations applied for determination of welded pipeline-drum joint failure cause.

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CASE HISTORY

In welded joint between drum mantle and inlet pipe (6 positions) many through wall cracks appeared after 60,000h in service resulting in steam leakage. Cracks were spreading through the mantle wall, mainly through HAZ of drum material, but somewhere partially through weld i.e. through base drum metal. According to the blueprints, drum mantle was made from microalloyed steel 15NiCuMoNb5 (WB 36), inlet pipe from 15Mo3 steel and as a filler material SH schwarz 3KNi electrode was used. Drum working parameters were 61 bar, 460°C temperature with two phase media, water and steam.

PROCEDURES

After failure, an extensive examination was made on the fracture faces. Several fractographic and metallographic specimens were taken from the fracture faces and were prepared for examination using conventional techniques. Some mechanical properties, as well as chemical analyses were determined, too. Only the results of few examinations will be presented in the paper.

Chemical analysis: Spectroscopic chemical analysis of both base metals (drum and inlet pipe) and a filler material are listed in Table 1.

TABLE 1 - Chemical composition: investigated (1) and standard (2).

Region	ELEMENTS IN % Wt							
	C	Si	Mn	Cr	Mo	Ni	Cu	Nb
Drum (1)	0.20	0.34	0.16	0.31	0.52	1.25	0.70	0.023
Drum (2)	max 0.17	0.25-0.50	0.80-1.20	-	0.25-0.50	1.00-1.30	0.50-0.80	0.02
Pipe (1)	0.13	0.18	0.67	0.09	0.38	0.04	0.05	-
Pipe (2)	0.12-0.22	0.10-0.35	0.40-0.80	-	0.25-0.35	-	-	-
Joint (1)	0.10	0.34	1.20	0.11	0.66	0.30	0.15	-
Joint (2)	0.06	0.31	1.26	-	0.39	1.04	-	-

It is clearly visible that the compatibility between investigated and standard composition for all areas is satisfactory except for carbon content in drum material that is higher then allowed (0,20 instead max 0,17%) and nickel content in filler material that is smaller then standard value. Welding was done in several passes, and all of them (root and all other) were done with the same filler material according to the chemical analysis.

Hardness: Results of hardness measurement in different zones of welded joint with measure positions are given in Table 2. and Figure 1.

TABLE 2 - Results of hardness measurement

Zone										
BM1	pos.	1	2							
	HV	213	287							
HAZ1	pos.	3	4	5	6	7	8	9	10	
	HV	215	219	238	275	317	338	392	332	
FZ1	pos.	11	12	13	14					
	HV	255	288	284	297					
JOINT	pos.	15	16	17						
	HV	229	214	226						
FZ2	pos.	18	19	20						
	HV	179	198	218						
BM2	pos.	21	22							
	HV	132	129							

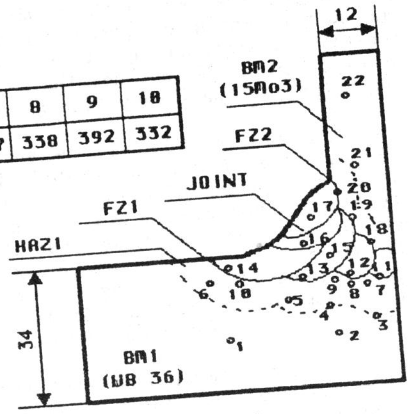

Figure 1 Distribution of measure positions

Comparing with standard data, it is obvious that base material hardness is in range of 182-226.5 HV for WB 36 and 130-160 HV for 15Mo3. However, the HAZ hardness on the boiler side is in very wide region and goes from 215 HV to 392 HV, with conclusion that maximal values of hardness can be find near to the fusion zone FZ1.

Metallography: Three specimens for metallographic analysis were taken from every one of 6 inlet joints. They were prepared by standard techniques and obtained data are presented on Figures 2-10. These photos are showing the structures from different areas of welded joints as well as the base material structures. Structure of the micro alloyed steel is fine grained, as it is expected (No ASTM-10), Figure 1, and it is consisted of the fine grained polygonal ferrite with the secondary phase particles of iron carbides and the fine grain particles of the Nb base. Fine grained normalized structure is included in heat affected zone (HAZ), as well as an overheated area with a mixture of Widmanstatten ferrite, acicular ferrite, martensite, secondary phase particles and segregation on the grain boundaries, Figures 2,3,7,8. Weld structure is mostly consisting of acicular ferrite, Figures 2,3. On various points it is visible that the ferrite is formed on former austenite grain boundaries Figure 9. Structure of the pipe base material is common ferrite-pearlite type, No ASTM-8, Figure 6.

DISCUSSION AND CONCLUSIONS

According to the literature (1-3), as a consequence of precipitation of small carbide and carbonitride particles on the Nb or/and V basis, which are coherent with ferrite matrix, dispersion strengthening of micro alloyed Mn steels is occurring. Maximal strengthening is obtained up to the 0.03% Nb or 0.015% Nb and 0.015% V if the both elements are presented. However, fine dispersed particles inhibit the austenite grain growth, what is the case with manganese steels during the overheating, so the final micro alloyed steel structure is always very fine grained.

Also, literature data (1) is showing that the carbon equivalent (CE) as index of welding capabilities for micro alloyed steels should be considered with criticism which means that it can be slightly bigger then common limits. Therefore it is recommended if the carbon equivalent is bigger then it is allowed, maximal hardness in the HAZ must be limited up to 300-320 HV, which can be done with special precautions during welding. Regarding affinity of micro-alloyed manganese Nb/V steels to quench structures, if neither of these rules are respected, cold cracks are appearing in the HAZ.

Obtained data clearly indicates that in investigated case neither of this crucial conditions weren't satisfied. At first, calculated CE for investigated compositions, according to the MIZ relation, is 0.67-0.68 what is significantly more then allowed. This data is simultaneously showing possibility of welding difficulties, respectively to the great heat amount. Extremely high hardness values in overheated area of HAZ are indicating that neither the second limiting factor, hardness, is not fulfilled because the all obtained values are higher then 320 HV. Great hardness values, as well as a great residual stresses in HAZ are a consequence of quenching structures, which are shown on a metallographic photos. As a consequence of presented structural characteristics great number of late cracks has occurred in investigated drum.

On the basis of the obtained results it can be concluded that:

-value of CE has a great importance on micro alloyed steel weldability;
-micro alloyed Mn steels with Nb have affinity for appearance of quenching structures in HAZ, if the great heat amount is applied as in investigated case;
-unfavorable HAZ structures and residual stresses caused during exploitation origination of cold late cracks which lead to the failure of investigated drum.

REFERENCES

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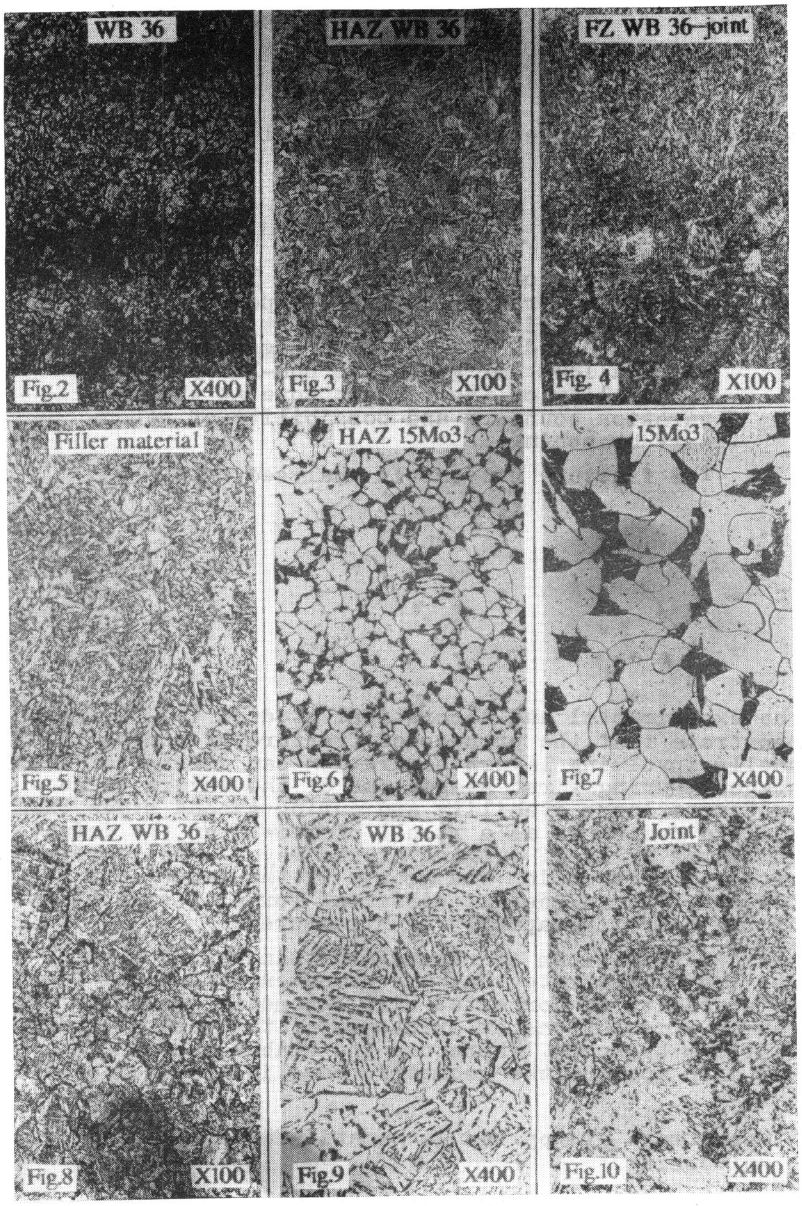

Figures 2-10 The Appearance of structure surface