INVESTIGATION OF MICROSTRUCTURAL AND MECHANICAL PROPERTIES OF SUBMITTED WELDED PARTS – PULLING PIPES

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Abstract

The results of investigations presented in this research work are result of the practical task performed for the welding company. The request for investigation was submitted as result of the existence suspection for using wrong material for production of welded parts. Performed investigation had to confirm or deny this statement. And finally, if wrong filler and base material were used, could these welded parts satisfy in the exploratory conditions.

To answer these questions some basic investigations were performed: determination of chemical composition, tensile testing, hardness measurement and macro and micro metallography. Generally mechanical testing was much higher than required. But it was decided to replace wrong pieces and continue welding as was prescribed by the welding technology.

1 INTRODUCTION

This technical report was prepared on the request of the welding company for the production parts for the railway vehicles. The main reason for the investigation is checking the quality of the welded joint (pulling pipe) because there was suspection of the wrong base material of one welded piece was used (pipe). Welded joint consists of the two parts, pipe and forged part. This welded part is called pulling pipe (Figure 1) after welding the part was subjected to surface treating namely browning. It was detected that the color of the parts after browning is quite different although both part should be made from the same material. Because of that there was a suspection that the material of pipe is not S355 steel, probably some alloyed steel.

Because of that was decided to perform some relevant investigation and to check the material of the suspected part. Checking the quality of the welded joint was very important, because filler material was chosen for the base material S355.

a b

Figure 1. a.) piece of pipe b.) welded pulling pipe

2 PREPARING FOR INVESTIGATION

Considerations of the current situation indicate to decide and to perform the following investigations:

- To perform chemical analysis of the suspect steel pipe,
- To perform mechanical testing of the welded joint tensile testing,
- Hardness testing,
- Macro and micro metallography,
- On the base of chemical analysis to detect type of material (pipe) and to find the standard which define this steels.

3 RESULT OF INVESTIGATIONS

3.1 Determination of chemical composition

The chemical composition of the forged part corresponds to the S355 structural steel. The result of determination chemical composition of the pipe is given in the Table 1. It is so obvious that the pipe is produced from the high alloyed steel. The main alloying elements are chromium (7.99%) and molybdenum (0.43%). It is clear that for production of the pulling pipe is used quite different base material of pipe i.e. S355. Basing of this statement, literature review was made in order to find the designation of the chromium-molybdenum steel used for the pipe production [1-3].

Table 1. Chemical composition of the pipe for production of the welded joint

Designation	C	Si	Mn	Al	P	S	Cr	Mo	V	Ni	Cu
K-329.069	0.185	0.225	0.47	0.01	0.014	0.005	7.99	0.43	0.195	0.11	0.10

According ASTM a 335/a 335M – 03 и EN10216-2 was confirmed that pipe base material is high alloyed ferriting steel - P92 as can be seen from the figure 2 [4]. Pipes from this material are intended for working at high temperatures, until 800 ^{0}C. They have to have resistance to high temperature corrosion and good mechanical properties at high temperatures [5]. It has to point out that there are many variants of this steel [6]. Anyhow, these pipes are not adequate for production of pulling pipe. Generally they are delivered in normalized or quenched and tempered conditions. It is clear that wrong material is delivered and used. These pipes are too much expensive and they are more difficult for welding the pipes are generally heat treated [7].

	T/P9	T/P91 X10CrMoVNb9-1	E911 X11CrMoWVNb9-1-1	T/P92 X10CrWMoVNb9-2	X20CrMoV11-1
C	max. 0.15	0.08 - 0.12	0.09 - 0.13	0.07 - 0.13	0.17 - 0.23
Si	0.25 - 1.00	0.20 - 0.50	0.10 - 0.50	max. 0.50	0.15 - 0.50
Mn	0.30 - 0.60	0.30 - 0.60	0.30 - 0.60	0.30 - 0.60	max. 1.00
P	max. 0.025	max. 0.020	max. 0.020	max. 0.020	max. 0.025
S	max. 0.020	max. 0.010	max. 0.010	max. 0.010	max. 0.020
Al	max. 0.040	max. 0.040	max. 0.040	max. 0.040	max. 0.040
Cr	8.00 - 10.00	8.00 - 9.50	8.50 - 9.50	8.50 - 9.50	10.0 - 12.50
Ni	-	max. 0.040	0.10 - 0.40	max. 0.040	0.30 - 0.80
Mo	0.9 - 1.10	0.85 - 1.05	0.90 - 1.10	0.30 - 0.60	0.80 - 1.20
W	-	-	0.90 - 1.10	1.50 - 2.00	-
V	-	0.18 - 0.25	0.18 - 0.25	0.15 - 0.25	0.25 - 0.35
Nb	-	0.06 - 0.10	0.06 - 0.10	0.04 - 0.09	-
B	-	-	0.0005 - 0.0050	0.0010 - 0.0060	-
N	-	0.030 - 0.070	0.050 - 0.090	0.030 - 0.070	-
Cu	max. 0.30	max. 0.30	-	-	max. 0.30

› Table 1 - Comparison of the chemical compositions of steels T/P9, T/P91, E911, T/P92 and X20CrMoV11-1 according to EN10216-2

Figure 2. Chromium-molybdenum steels according SA-355M (P9, P91 u P92)

3.2 Tensile testing

This type of investigations should discover which is maximal tensile force which could be standing out by pulling pipe. For such investigation was predicted doing of the round tensile probe. But during machining the probe welding defects were detected, figure 3. Because of that was decided to make tensile test of the complete pulling pipe (technological probe). Two probes were exterminated and results of investigations are given in the table 2. According information's from the designing department, tensile force should be 3 tons. It can be concluded that this condition is fulfilled, because obtained values for the tehsile probes were more than nine tones.

Figure 4 shows broken surface of the pulling pipe. It is visible that fracture appears through welded joints which consist of two welds. Deformation of the broken surface is not uniform around the volume.

Table 2. Results of investigations of technological probe pulling pipe (влечна цевка)

Probe number	Force, t
1	9.5
2	9.6

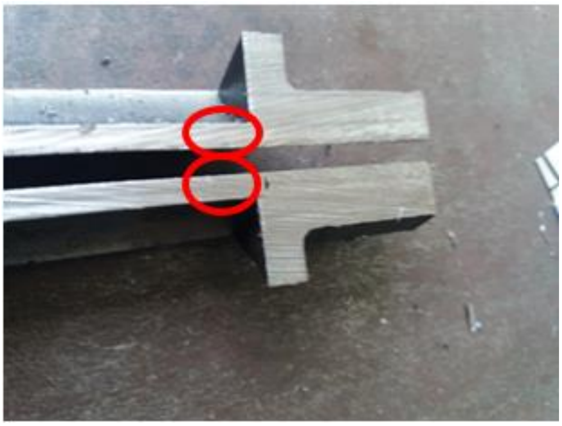

Figure 3. Lack of penetration

Figure 4. Fracture of the pulling pipe as result of the tensile testing

3.3 Metallographic investigations

Prepared macro-metallographic specimen is shown at the figure 5 It is clearly seen from the macro specimen that Nital etches only forged part made of S355 steel, but pipe made of ferritic steel P92 is not etched. It can be seen from the figure 5 that welding was performed with two passes. Micro-metallographic investigations didn't d discover some welding defects.

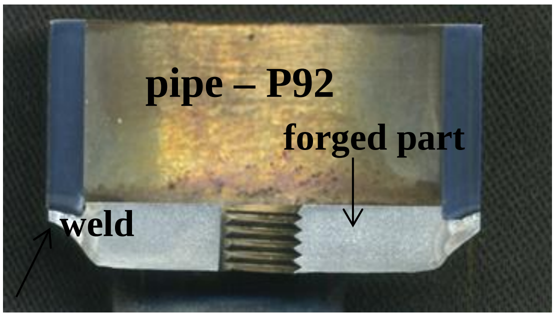

Figure 5. Macro specimen of the welded joint

3.4 Hardness measurement

Hardness measurement was performed on the metallographic specimens (figure 6). Vickers method was implemented in this investigation. The lowest hardness values has pipe produced from S355 structural steel i.e. 165HV (base material). The hardness of HAZ is much higher and has value of 197 HV. The hardness of the ferric steel is 230 HV which is the highest measured value. It’s in accordance with our assumption because this steel (pipe) contains chromium and molybdenum. Hardness in HAZ is even higher and has value of 243. Probably the pipe was normalized before use. Dendritic microstructure of the weldmet has the highest hardness of 260 HV. Both welded parts have the highest microstructure in the HAZ.

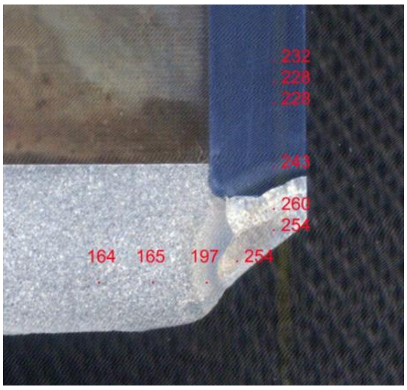

Figure 6. Hardness measurements in the welded joint

3.5 Micro-metallography

From the micro-metallographic picture, figure 7 could be concluded that there is distinct segregation in the weld metal as result of big difference in the chemical composition between high alloyed base metal (ferritin steel with Cr and Mo) and no alloyed filler material. .

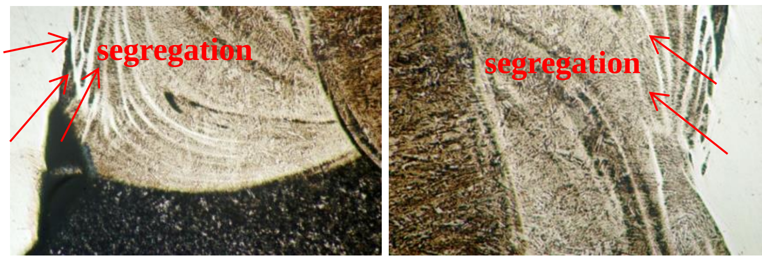

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Figure 7. Segregation in the weld metal

Figure 8 show segregation between the pipe P92 and unalloyed weld metal G3Si1. Figure 9 presents transition region between forged part and weld metal. There is no segregation in this case.

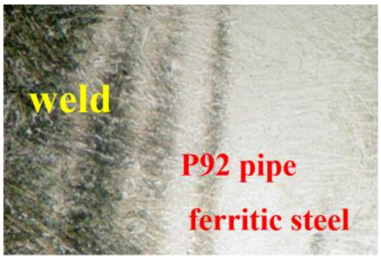


Figure 8. Transition region between weld metal (G3Si1) and P92 pipe

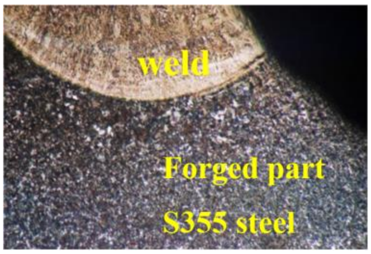


Figure 9. Welded joint between forging part S355 and G3Si1 filler metal

From the figure 10 can be see microstructure of the two passes. It is beinitic martensitic microstructure which has high hardness value.

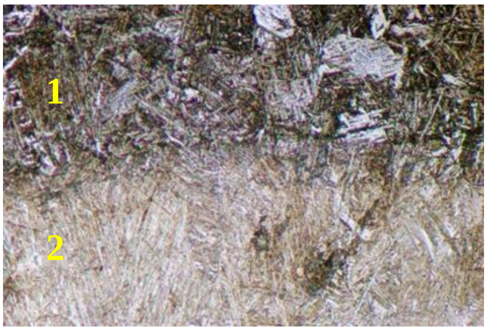
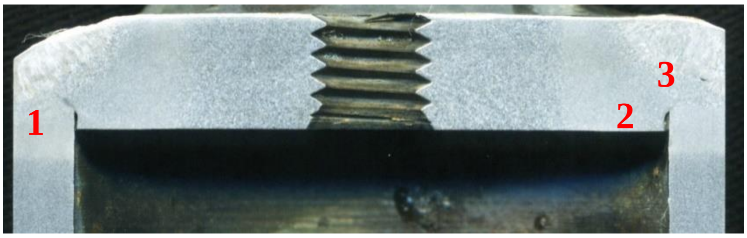


Figure 10. Microstructure of the weld passes

Figure 11 show microstructure of the complete welded joint starting from the weld metal towards the coarse engrained HAZ, fine grained HAZ and base metal feritic P92 steel. Etching was done with oxalic acid.

Figure 11. Microstructure of the welded joint

Figure 12a presents macrostructure of the welded joint formed between forged part and pipe, both of them from S355 steel. In this case proper base material was used. But in this case another problem appears. The two cracks and incomplete fusion between welding passes appeared in the welded joint. Defects are denoted with red numbers in the figure 12. It is obvious that cracks appeared as results of big distance between forging part and pipe. Besides, as result of type of joint pipe edges are not beveled. Figure 13 presents macro photo after beveling of pipe. It can be seen that situation is much better, and defects in the welded joint didn’t appeared.



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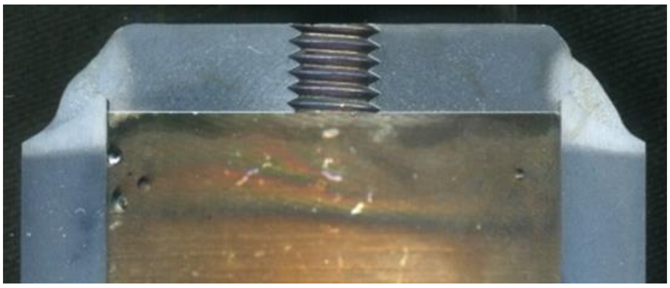

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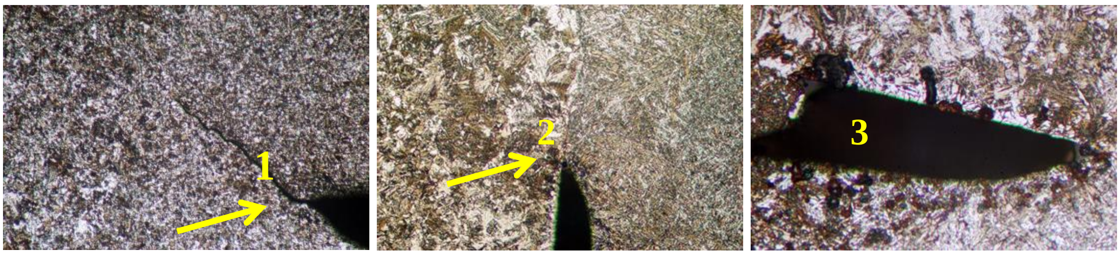
Figure 12. Micro photo of the welded joint a. without beveling b. after beveling.

The figure 13.1 show the microstructure immediately to the cracks number 1. It can be clearly seen the point where the crack starts Microstructure in the vicinity of the crack number 2 is shown in the next figure 13.2. And lack of fusion is between two passes is shown in the figure 13.3



1 2 3

Figure 13. Crack 1 Defects in the welded joint

4 CONCLUSIONS

Determination of the chemical composition confirmed that for welding was used pipe P92 instead pipe from of S355 steel.

Micro-metallographic analysis showed segregation in the welded joint’

Tensile testing of the technological probe showed that maximal tensile force ids more than nine tons which is three times higher than us necessary

Beveling of the pipe edges supsupress welding defects like lack of penetration

5 LITERATURE

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