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Analysis of the Fracture Failure of ST90 Coiled Tubing

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ABSTRACT

This article determines the causes of fracture failure of the ST90 coiled tubing through chemical composition analysis, dimensional measurement, metallographic analysis, and hardness testing of the fractured tubing sample. The material test results show that the chemical composition, size, grain size and hardness test results of the fractured coiled tubing meet the standard requirements, and no abnormal results are found. There is mechanical trauma in the fracture and suspected improper operation on both sides of the fracture position, which causes the tube body damage by the stacking of the clamping blocks, that will cause the deformation of the coiled tubing. The thinning of the wall thickness and the increase of hardness will reduce the strength of the tubing, which is the main reason for the fracture of the coiled tubing.

KEYWORDS

Coiled tubing; Hardness test; Metallographic analysis; Fracture

1. INTRODUCTION

Our company (SHINDA (TANGSHAN) CREATIVE OIL & GAS EQUIPMENT CO., LTD) produced a ST90 coiled tubing with φ38.1×3.2, which broke during the customer's use. The total length of the coiled tubing reached 2300 meters, but it unfortunately broke up during the operation, which affected the normal use of the customer. After field investigation and technical analysis, it was determined that the coiled tubing was broken at 1078 meters. This position may be due to the stress concentration point of many factors, which causes the fracture phenomenon. Since the coiled tubing was put into use, it has been operated for 7 times. Each operation may cause different degrees of wear and pressure on the coiled tubing, aggravating the loss speed of the coiled tubing, leading to the occurrence of this fracture event.

2. SAMPLE INFORMATION

SHINDA (TANGSHAN) CREATIVE OIL & GAS EQUIPMENT CO., LTDproduced a disc of φ38.1×3.2 ST90 coiled tubing with a length of 2300 meters, fracture occurs during operation. The fracture position was 1078 meters, and the customer ran the well for a total of 7 times.

The broken tubes with obvious trauma were numbered A1, and the remaining tubes were numbered A2, to analyze the sample.

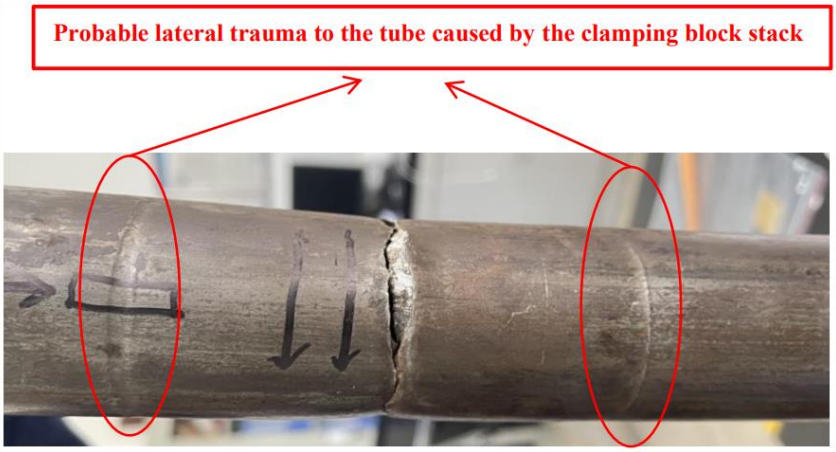


Figure 1. Causing lateral damage exist at both ends of the fractured tubing

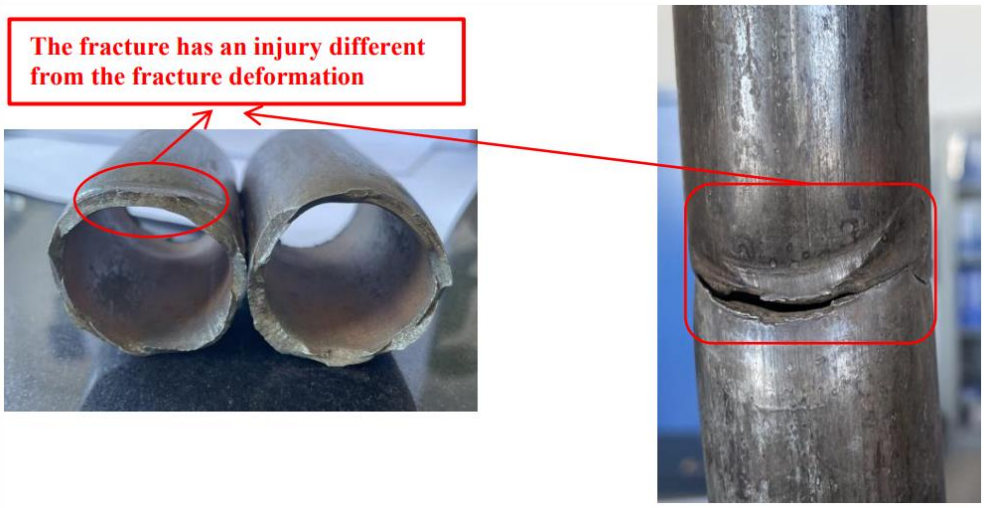


Figure 2. Overall morphology of fracture

3. TEST METHODS AND RESULTS

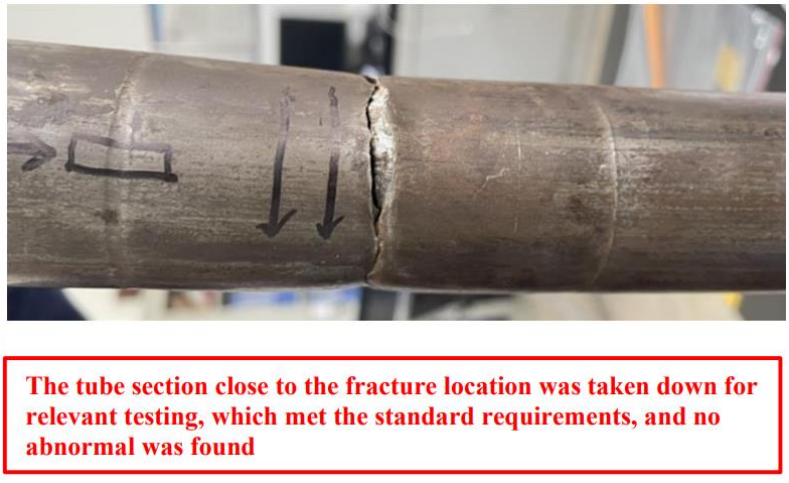


Figure 3. The location near the fracture

3.1. Chemical Composition Analysis

According to ASTM A751-2021, Labspark1000 direct reading spectrometer was used to sample A1 for chemical composition analysis, and the results were shown in Table 1. It can be seen from the analysis results that the chemical composition of the sample meets the technical requirements.

Table 1. Chemical composition test results

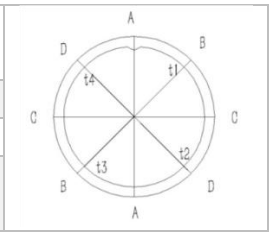
sample number	Element content (wt%)										
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Nb	Ti
A1	0.141	0.137	0.897	0.014	0.001	0.290	0.141	0.593	0.268	0.018	0.016
Technical requirements	≤0.16	≤0.50	≤1.20	≤0.020	≤0.005	/	/	/	/	/	/

3.2. Dimension Measurement

The outer diameter and wall thickness of the unbroken end of A1 and A2 tubes are tested along the axis according to the positions shown in A-A, B-B, C-C and D-D. The results are shown in Table 2 below. The results show that the specifications of tubes meet the standard requirements.

Table 2. Dimensional measurement result

Measuring position	A-A	B-B	C-C	D-D	t1	t2	t3	t4
A1/mm	38.30	38.25	38.28	38.26	3.34	3.31	3.31	3.31
A2/mm	38.31	38.22	38.28	38.17	3.32	3.32	3.31	3.34
Acceptance standard/mm	37.85~38.35				3~3.5			



3.3. Metallographic Analysis of Tube Cross Section Near Fracture Location

Cut off a section of tube ring near the A2 fracture, for A2, YJ-2000 metallographic microscope and image analysis system were used to conduct grain size analysis according to ASTM E112-2013 standard. The results are shown in Table 3. The results show that the grain size of the sample meets the technical requirements, metallographic structure was not abnormal.

Table 3. Results of grain size rating

A2	grain size
Weld	10.5
HAZ	10.5
Base material	11.5
standard request	≥8

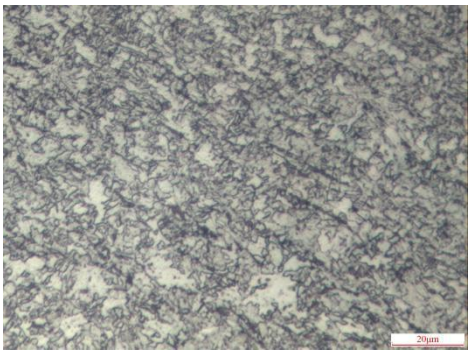


Figure 4. Base material

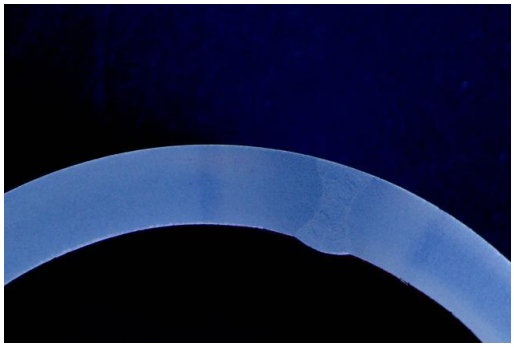


Figure 5. Macroscopic surface of metallographic

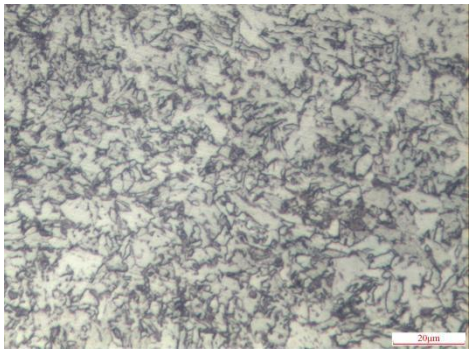


Figure 6. Weld 500X

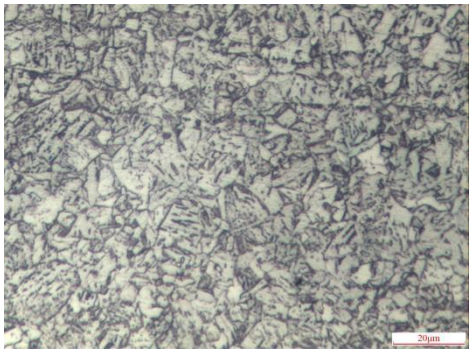


Figure 7. HAZ 500X

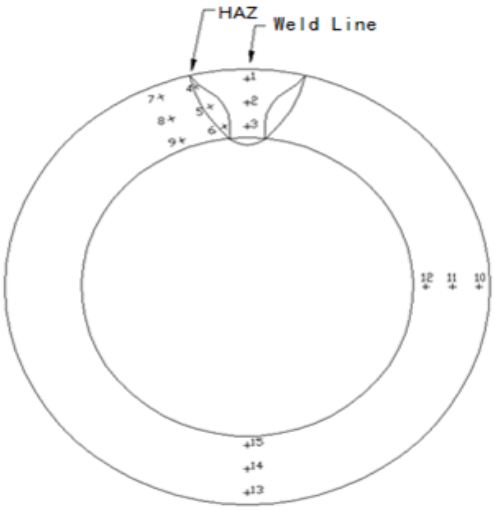


Figure 8. Through-wall Hardness Test Impression

3.4. Hardness Testing of Tube Cross Section Near Fracture Location

Cut off a section of tube ring near the A2 fracture, for A2, 200HVS-5 digital display small-load Vickers hardness tester was used to perform the hardness test according to ASTM E384-22 standards, and the hardness conversion was performed according to ASTM E140-2012b (2019) e1. The hardness test position of the original tube is shown in Figure 7, and the data are shown in Table 4. The results show that, the hardness data meet the technical requirements and the hardness is uniform.

Table 4. Hardness test result

A2	Weld line			HAZ			Base material			90°zone			180°zone		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Measured value	98.5	98.5	98.5	97.0	97.0	97.0	97.0	96.5	97.0	96.0	97.0	96.5	98.5	98.5	98.0
Average	98.5HRB			97.0HRB			97.0HRB			96.5HRB			98.5HRB		
Test Requirement	≤22HRC (248HV)														
	Below 20 HRC, HRB is used														

3.5. Metallographic Analysis of Fracture

Sample the area of the A1 tube containing the injury, YJ-2000 metallographic microscope and image analysis system were used to conduct grain size analysis according to ASTM E112-2013 standard. [1] The results are shown in Table 5. The results show that the grain size of the sample meets the technical requirements, However, the wall thickness at the damaged site became thinner and deformed.

Table 5. Results of grain size rating

A1	grain size
Base material	11.0
standard request	≥8

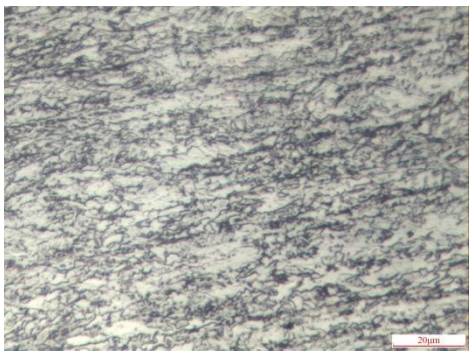


Figure 9. Base material

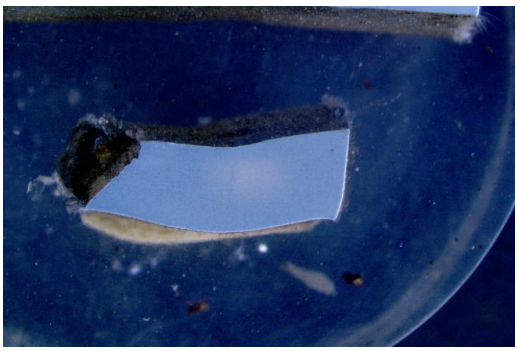


Figure 10. Macroscopic surface 6.8X

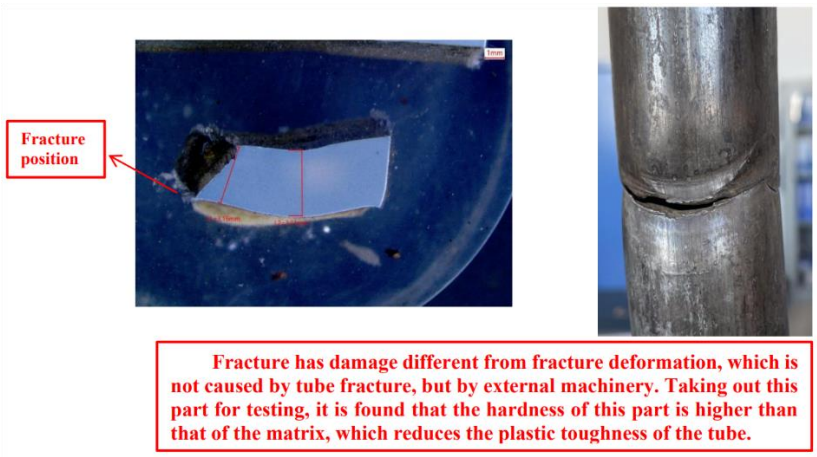


Figure 11. The macroscopic picture shows obvious deformation and the wall thickness at the breaking point is reduced 6.8X

Sample A2 was sampled at the location of the tube side damage that may have been caused by the clamping block, [2] YJ-2000 metallographic microscope and image analysis system were used to conduct grain size analysis according to ASTM E112-2013 standard. The results are shown in Table 6. The results show that the grain size of the sample meets the technical requirements, However, the wall thickness at the damaged site became deformed.

Table 6. Results of grain size rating

A2	grain size
Base material	11.0
standard request	≥8

3.6. Hardness Testing of Fracture

For A1 and A2 damage sites, hardness tests were performed using a 200HVS-5 digital display small load Vickers hardness tester according to ASTM E384-22, hardness conversion according to ASTM E140-2012b (2019) e1. The data are shown in Table 7. The results show that the hardness of the damaged site is higher than that of the tube and is not uniform.

Table 7. Hardness test result

A1	Damage location			Base material-1			Base material-2		
	1	2	3	4	5	6	7	8	9
Measured value	100.0	99.0	97.0	99.5	98.0	98.0	99.0	97.5	98.0
A2	Damage location			Base material-1			Base material-2		
	1	2	3	4	5	6	7	8	9
Measured value	99.0	98.0	96.0	98.0	97.0	96.0	98.5	98.0	96.5
Test Requirement	≤22HRC (248HV)								
	Below 20 HRC, HRB is used								

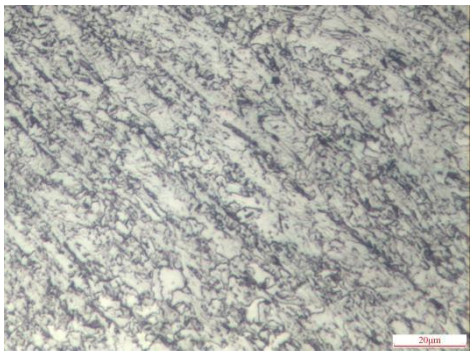


Figure 12. Base material 500X

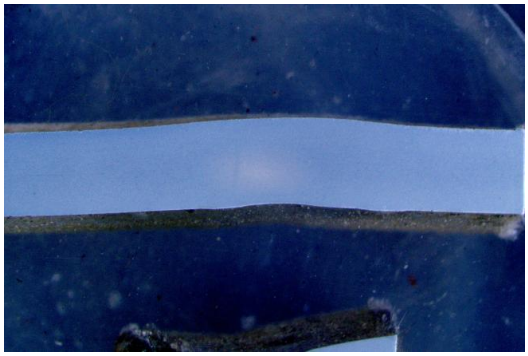


Figure 13. Macroscopic surface 6.8X

Figure 14. The macroscopic picture shows the wallthickness at the damaged site became deformed 6.8X

4. SUMMARY

The material testing outcomes indicate that the chemical composition, dimensions, grain size, and hardness of the fractured coiled tubing are in compliance with standard specifications. No anomalies have been detected in the test results.

We suspected improper operation on both sides of the fracture position, which causes the tube body damage by the stacking of the clamping blocks, that will cause the deformation of the coiled tubing. The thinning of the wall thickness and the increase of hardness will reduce the strength of the tubing [3], which is the main reason for the fracture of the coiled tubing.

ACKNOWLEDGEMENTS

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