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# Cause analysis of transverse breakage of ultra high-strength steel shell after hydraulic blasting test

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**Abstract**: To ensure product quality, the inspection and analysis were carried out on the ultra high-strength steel welded shell with transverse rupture after qualified hydraulic blasting test. Firstly, we carried out spot investigation of hydraulic blasting test, breakage morphological analysis, investigation on production technology, reexamination of wall-thickness and X-ray film of welding joint; in case of different opinions on fast analysis, then, we carried out contrast detection and analysis on stripe of fracture, metallographic analysis on cross section of welding joint, TEM detection and analysis on fracture, and inspection and analysis on welding size and offset. The analysis results showed that, the transverse rupture of test sample after hydraulic blasting test was caused by the failure of part incomplete joint penetration on welding joint, which was due to welding arc deviation. Therefore, with the improvements of welding equipments, tooling and operation methods to prevent radial and weld offset, the welding quality was assured and improved. .

**Keywords: Ultra high-strength steel; welded shell; hydraulic blasting test; transverse breakage; failure analysis**

## 1 Introduction

There is a kind of shell that is machined by assembly welded ultra high-strength steel. One shell was random collected from a lot after 100% qualified hydraulic test for hydraulic blasting test with a qualified test result accorded with the acceptance. But it's found that the rupture shape was different from usual. In the past, there was a vertical rupture in the middle of the shell or a short transverse breakage at the end of vertical rupture. But there was a transverse rupture instead of vertical rupture, which separates the head cover and cylinder. Investigation and inspection have been carried out considering the quality of product, although the acceptance specification has not requirement for the breakage form..

## 2 Test site investigation and inspection analysis

Figure 1 shows the fracture is located at the welding part between head cover and cylinder, including welding joint and HAZ as well as base metal.

Figure 1. Transverse breakage shell

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According to the investigation, the test equipment was in good condition, and the pressure gauge within the validity period was checked before using. The test was carried out by professionals without change.

The raw material of all components and parts of shell was inspected and accepted by acceptance specification and complied with the requirements of GJB 5063-2001[1]. The machining and heat treatment quality was also qualified.

Recheck the wall thickness of cylinder and welding part with special detector. The result was qualified.

Recheck the X-ray film of welding joint after welding, quenching and tempering. Intricate edge of welded seam after welding on the film had been almost eliminated with no crack and blowhole after polishing and burnishing. There was still no crack and blowhole on the X-ray film after quenching and tempering.

Please see figure 2 for macroscopic appearance of fracture.

On the top of circle in figure 2, there were 3 connected terraces (see figure 3). Other part of fracture was the normal ductile fracture.

Figure 2. Macroscopic appearance of fracture

Figure 3. Terrace of the fracture on the head cover

Inspect the fracture via high magnifier, and there were paralleled curve which like the processing mark just fit the head and end. And there were no radiation and headstand Y crack caused by breakage of material.

Through the analysis of fracture, the terrace is the processing end surface of head and the joint between cylinder parts, which was not fused completely. In other words, the reason of transverse breakage was caused by the defect of part incomplete welding between head and cylinder.

## 3 Further inspection analyses.

### *3.1 Metallographic examination and analysis*

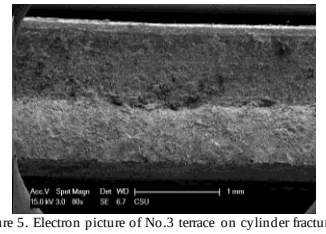
Sample two pieces of intersecting surface from No.3 terrace and its axisymmetric part for metallographic examination. It was showed from figure 4 of the welding quality problem instead of abnormal organization and raw material defect.

Figure 4. Intersecting surface organization of terrace（40×）

After times of annealing, quenching and tempering, the tissue morphology of welding seam and HAZ of cylinder shell shows no big difference. But it showed from figure 4 of strip feature on the terrace and right part organization, other than on the 45 °part and left upper corner. Thus it can be seen, the 45 °part and left upper corner was the welding seam, and the terrace and right part was the HAZ and base metal. This also showed that, the terrace of fracture was the weldment end face without melting in advance, causing the incomplete welding.

### *3.2 Detection and analysis of electron microscopy*

Sample 4 pieces of specimen from fracture of cylinder for electron microscopic analysis in CSU. No. 1, 2 and 3 were from the terrace, and No. 4 was from their axisymmetric part. Please see figure 5 for electron picture of No.3 terrace.




. Figure 5. Electron picture of No.3 terrace on cylinder fracture

The time of electron microscopy after breakage was a little long with rust on the fracture. But it still showed the cutting process mark instead of breakage mark on the electron picture. The edge part of shell of No.4 specimen and No.1~No.3 specimen showed the ductile fracture appearance of more dimple.

### *3.3 Detection and analysis of welding seam size*

The detection and analyzes of welding seam size of transverse fractured shell had been carried out to find out the reason of uncompleted welding. Table 1 is the calculation result of welding seam size of head, cylinder terrace.

**Table 1** calculation table of welding eccentricity detection in shell with incomplete penetration

| Position | Weld Width L | Weld Width of cylinder L1 | Weld Width of head L2 | Total weld width of head L3 | Axial width of shear zone of head L4 | Axial width of shear zone of cylinder L5 | Deviation value L6 |
|---|---|---|---|---|---|---|---|
| Middle of Terrace No.1 | 6.3 | 1.7 | 4.6 | 5.0 | 0.4 | 0.4 | 1.9 |
| Middle of Terrace No.2 | 6.1 | 1.8 | 4.3 | 4.9 | 0.6 | 0.6 | 1.9 |
| Front of Terrace No.3 | 6.0 | 2.4 | 3.6 | 4.8 | 1.2 | 1.2 | 1.8 |
| Middle of Terrace No.3 | 6.0 | 2.1 | 3.9 | 4.7 | 0.8 | 0.8 | 1.7 |
| Rear of Terrace No.3 | 6.0 | 2.3 | 3.7 | 4.7 | 1.0 | 1.0 | 1.7 |

*Note: formula of welding deviation calculation: L6=0.5L-L1+L5*

From Table 1, it's showed that the reason of uncompleted welding is the center of pool was deviated from the welding joint. Some deviation reaches about 1.9mm in maximum.

## 4 FMEA conclusion and improvement suggestion

### *4.1 FMEA conclusion*

The result of hydraulic blasting test site investigation, production process investigation, measurement and fracture detection and analyzes, metallographic examination, electron microscopy and welding seam location and measurement showed the reason of transverse fracture of shell under hydraulic blasting test was part uncompleted welding between head and cylinder part. And the reason of part uncompleted welding was the central of weld pool deviated from the welding joint

### *4.2 Improvement suggestion*

Overhaul of welding fixture and welding machine to eliminate the deviation of weld pool from welding joint caused by misfit and unstable of welding machine, fixture and operation. The welder should let the cylinder shell racing for a distance before welding, and then begin weld after confirming the welding center fit the weldment. At the same time, confirm the center of weld pool fit the welding joint or the deviation value in the allowable limit, and the weldment was welded completely.

Increase the sensitivity of NDT to solve the problem of uncompleted welding when misfitting. Ensure the accurate and precise of NDT.

Review the welding quality of all the batch to ensure the quality and reliability.

### *4.3 Effectiveness*

This batch of shell has been handled carefully after review of welding quality.

After the application of above measures on follow-up product, the operation of welding have been improved and the problems of misfitting and deviation have been strictly controlled with good result, therefore the transverse fracture has not happened afterwards.

## 5 Discussion

### *5.1 Migration of weld pool is the cause of transverse fracture of shell sample*

The influence factors of part uncompleted welding of welding joint are insufficient energy of welding line, deviation of welding center and misfitting of welding, etc. When checking the welding seam location and measurement, it was found that the width of welding seam has little change but the location of center of welding seam and welding joint deviate a lot. In this case, therefore, the uncompleted welding fault was caused by the severely deviation of center of weld pool from welding joint.

### *5.2 Transverse breakage is not allowed happen for this kind of shell*

When this kind of cylinder shell was pressured by the liquid or gas inside, the stress in axial direction was the half of the vertical.[2] So the fracture form should be vertical breakage or the small transverse crack at the end of main vertical fracture. The result of transverse breakage indicates the problem of wall thickness or material. For welding part, it could be the welding seam problem. Therefore, this kind of the shell after hydraulic blasting test should be deemed as unqualified product to analyze the reason, even though there was no stipulation for fracture form in the acceptance.

## 6 Conclusions

(1) The reason of transverse breakage of this ultra high-strength steel was the part uncompleted welding failure between head and cylindrical part. And the reason for the uncompleted welding was the misfitting of weld pool to welding joint

(2) The welding quality of this kind of shell has been assured and improved, after the measures of prevent misfitting and welding seam deviation taken on welding equipments, tools and operations.

(3) This kind of the shell after qualified hydraulic blasting test with transverse fracture should still be deemed as unqualified product, even though there was no stipulation for fracture form in the acceptance.

References

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