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Detection and Cause Analysis of Structural Defects in Lead Clamp Weld of Transformer

Zhengli Li[1,2,a] *, Guangxing Liu[1], Mingjian Jian[1, b], Yunguo Feng[1,2],Weitan Cui[2], Tianmeng Fu[2], Ruifeng Zhang[2]

（[1] State Grid Shandong Electric Power Research Institute, Jinan, 250001, PR China;

[2] Shandong Electric Power Industrial Boiler and Pressure Vessel Inspection Center Co., Ltd, Jinan, 250001, PR China;）

[a] 983776583@qq.com, [b] 271299316@qq.com

Abstract: In this paper, the causes analysis of the cracking accident at the lead clamp weld-fusion line of transformer in the extra-high voltage substation was conducted.
On-site non-destructive detection of weld defects was carried out to determine the size and location of the defects. An anatomical analysis of the clamp sample revealed that there was serious incomplete penetration and incomplete fusion in the internal structure of the weld, which seriously affected the structural strength of the weld. The causes of welding defects were further analyzed, and suggestions for improving product quality and strengthening inspection supervision were put forward.

1. Introduction

The first-stage project of a extra-high voltage substation was completed and put into operation in July 20, and the annual inspection was carried out in May 2017. The cracking accident at the lead clamp weld-fusion line on 500kV side of phase A of the #2 main transformer was found during the inspection. After the detection of other types of clamps, such clamp welds were found all defective. The same defects were also discovered when the same type of clamps were detected in other substations in July of the same year. In order to resarch the influence of weld defects on equipment operation, the causes of welding defects were analyzed.

2. On-site inspection

After the cracking of the lead clamp at weld-fusion line on 500kV side of phase A of the #2 main transformer was found, on-site macroscopic inspection for clamps of the same specifications was carried out. It was found that the clamps of phase A of the #1 and #2 main transformers had cracks at the position on the weld. The Figure 1 is the on-site photo. The cracked line clamp aluminum pipe side weld has a full circle of undercut. The cracked clamp weld of the aluminum pipe side had a full circle of undercut, which had a depth of about 2~4mm, as shown in Figure 2 and Figure 3.

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Figure 1 Phase A clamp of the #2 transformer

Figure 2 The clamp weld undercut and crack on phase A of #1 transformer

Figure 3 The clamp weld undercut and crack on phase A of #2 transformer

Penetration testing was performed on all the clamps of #1 and #2 main transformers, a total of 10, and the testing position is shown in Figure 4. There were cracks on the clamp weld-fusion line of the aluminum pipe side and on wiring board side, as shown in Figure 5 and Figure 6.The test results are as follows: the north weld of phase A of #1 main transformer was cracked; There was a crack of 30mm on the west side of the drainage plate in the southern of phase B, no crack in the weld; A crack of 8mm appeared on the west side of the weld in the northern of phase C.A crack of 10mm existed on the west side of the drainage plate in the southern of phase C of the #2 main transformer.

After checking the relevant data, it was found that the material of the clamp was aluminum L3/5083, and the specification of the aluminum pipe was of Φ104×16.

Figure 4 The detection position of the clamp

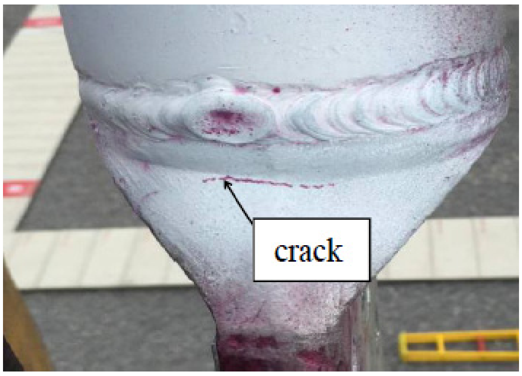

Figure 5 The appearance of the lateral crack of the clamp wiring board

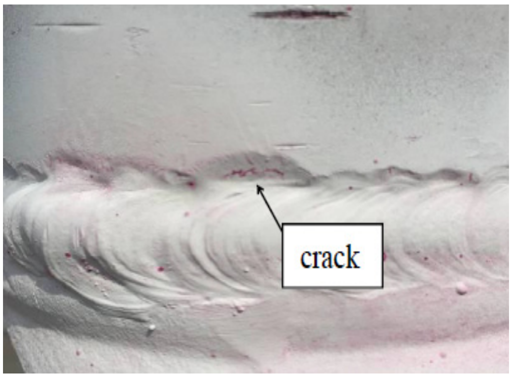

Figure 6 The crack at the fusion line on the aluminum pipe of the weld

3. Sampling test

In order to understand the internal structure of the clamp weld, phase A lead clamp of the #2 transformer was dissected to inspect, and it was found that internal structure of the weld had serious incomplete penetration and incomplete fusion, with the appearance shown in Figure 7 and Figure 8. The measurement showed that the effective thickness of thinnest position of the actual welding was less than 3 mm.

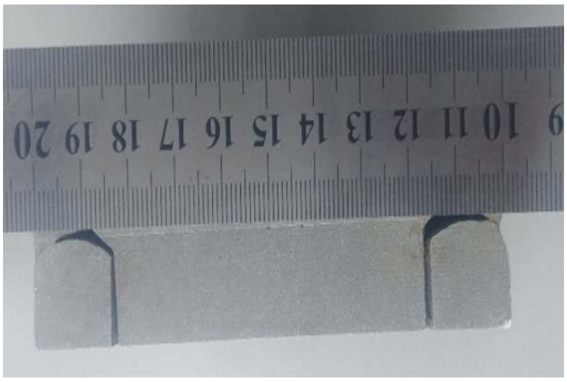

Figure7 The longitudinal section morphology of the weld

Figure8 The appearance of welding joint at weld fracture

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4. Cause analysis

(1) The cause of welding technology

Welding seam adopts no grooving process, pipe side welding surface adopts circular design with wall thickness as radius, and rod side welding surface adopts 45degree inclined plane. When butting, the butt type was formed as shown in Figure 9.The natural voids in the lower half of the fittings could not be welded.

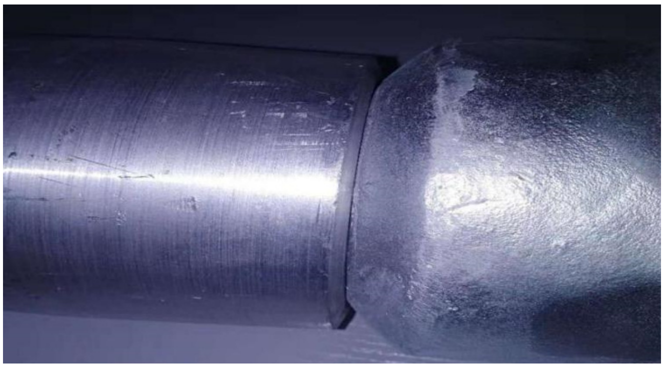

Figure9 Welding butt type

(2) Improper welding process

It can be seen from the cross-sectional view of the weld shown in Figure 10 that there was a serious arc bias phenomenon during the welding process. The groove of the rod side was well welded, and a large part of the groove at the side of the pipe fitting was not completely melted.

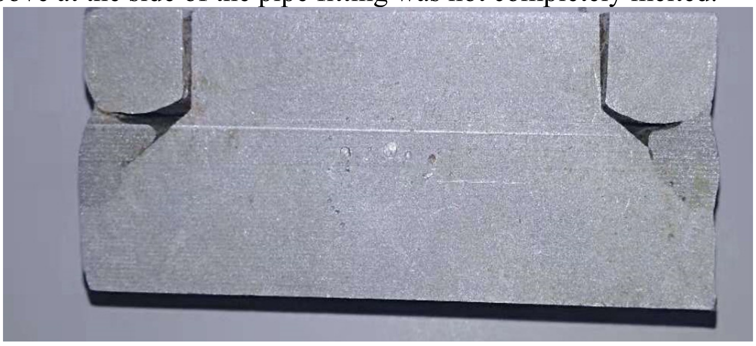

Figure10 Welding arc deflection

(3) Ineffective supervision

The quality supervision on the clamp is mainly based on the national standard GB/T 2314-2008 "General technical specification of electric power fittings" and the electric power standard DL/T 768.6-2002 "Manufacturing quality of electric power fittings: weld assemblies".

Among them, the requirements of the clause 3.7.5 in GB/T 2314-2008 " General technical specification of electric power fittings" for the appearance quality of welded assembly are: 1) The weld should be of fine and flat squamous shape, and should be sealed, with the depth of undercut no more than 1mm; 2) The weld should be free from defects such as cracks, pores and slag inclusions.

The requirements of the clause 7 in DL/T 768.6-2002 " Manufacturing quality of electric power fittings: weld assembly " for the appearance of welded assemblies are that: all welds should be visually inspected first, and the unqualified welds found in the visual inspection are not allowed to be undergone other inspection items. The weld shall have a uniform squamous and corrugated surface and keep consistent in length. The size of the weld should meet the design requirements, and the edge of the weld should be smoothly transitioned to the base metal. No coating or slag is allowed on the surface of the weld. The spatters on the weldment must be cleaned. All welds of galvanized weldments shall be sealed. Visual inspection should be carried out on eyes or with a 5-fold magnifying glass, and it might as well by magnetic powder or penetration testing method. The weld should not have apparent defects beyond the allowable value.

The above two standards only stipulate the appearance inspection on the weldment, and do not require the internal defect detection.

5. Conclusions

(1) All the clamps of the main transformer were discovered cracked on the clamp weld-fusion line of the aluminum pipe side and on wiring board side after on-site penetration inspection, mainly weld cracking, and the length of the cracks was different, which seriously affected safety of the equipment.

(2) Sampling tests found that the internal structure of the weld had serious incomplete penetration and incomplete fusion. The effective thickness of thinnest position of the actual welding was less than 3mm, which seriously affected the structural strength of the weld, then caused the weld cracking after the equipment had been installed and operated for a period of time.

(3) The main reason of the defect formation was the problems of the welding process formulation and implementation . The non-grooving and welding arc bias directly led to weld quality defects. The standards applicable to the supervision and testing do not require the internal quality of the welded assemblies, which causes vacancies in the product acceptance. It is recommended to improve the content of relevant technical standards and increase the relevant regulations on the detection on internal defects in welds.

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