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A Case Study on an Investigation of a Defect in a Valve Body for Power Plant

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溶接으로 製造된 火力發電用 밸브 構造物의 缺陷調査

김 송 희*

國 文 要 略

本 硏究는 鑄造 및 溶接을 통하여 製作된 火力發電用 大型밸브에 발생한 缺陷의 原因을 규명하기 위하여 使用된 몇가지 기술에 대하여 언급하였다. 超音波 非破壞檢査로써 內在되어 있는 균열의 位置 및 길이를 豫測하였다. 균열의 根源을 다치지 않게 保存한 채로 試驗片에 對하여 기계적 絕斷을 행하였다. 또한 균열의 原因을 직접 관찰할 수 있도록 액체 질소에서 落錘法을 써서 破斷시켰다. 同時에 균열의 側面樣相과 微細組織과의 관계를 금속현미경 및 전자현미경(SEM)을 통하여서 관찰하였다. 결론적으로 製造時 導入된 缺陷은 용접과정중에 만들어진 것이 아니라 鑄造作業中에 溶融金屬의 共給不足으로 因하여 생긴 氣孔에서 出發하였음을 알 수 있었다.

1. Scope of Investigation

A technical argument between the Steel Company of Australia and John's Welds Pty. was not settle down. The former was a maker of valve seat and valve body by casting while the latter was a welding company asked to weld the two pieces. It was because the two companies did not agree about the reason why the unsound valve product for power plant contains a few small cracks after safe pressure test. So the problem was raised with the author as a technical referee.

This report contains the result of an examination of defects in a cylinder trepanned from a valve body. The objectives of the study were.

(i) to eastablish the weld profile that had been used for welding the valve seat into the valve body ;

(ii) to establish whether the defect occurred in the casting or in the weld or in both ;

(iii) to establish the nature of the defect hidden in a massive bulk metal.

2. External Examination of Cylinder and Valve Seat Weld Profile

The surface of the trepanned cylinder suff-

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ered some demage from the oxygen-cutting which had been necessary for extracting it. Most of this damage was removed by grinding and then by turning it in a lathe. The cylinder was then metallographically polished and etched.

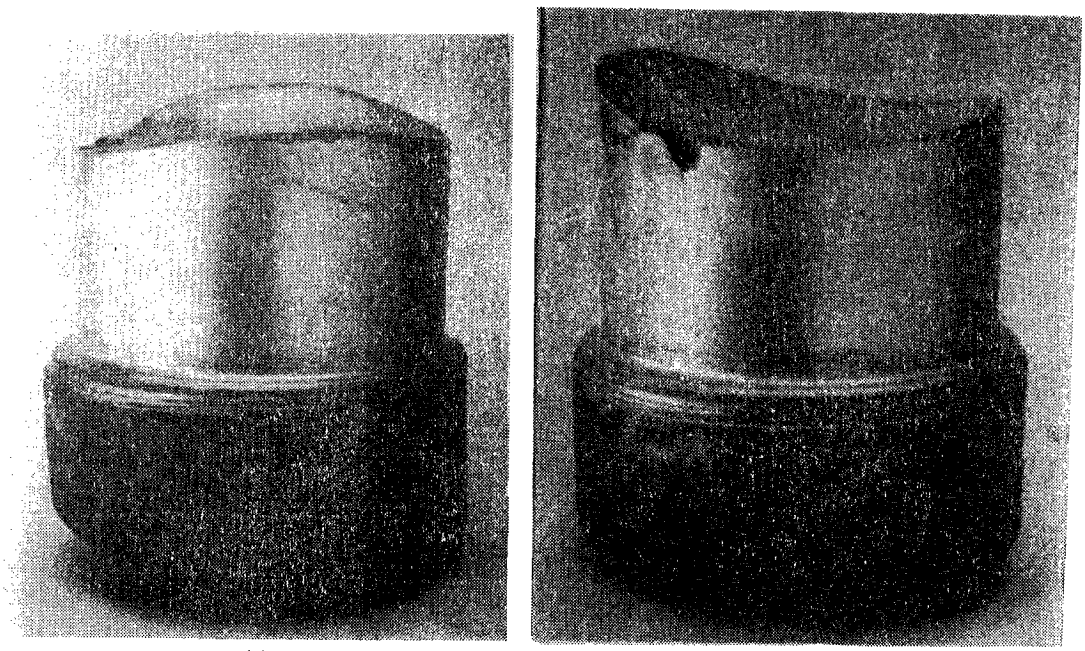
Two photographs of the cylinder and one of the top(which is the inside surface of the body) are shown in Figures la, b and 2a : a sketch of the top of the cylinder is given in 2b.

The renains of the oxygen-cutting scouring can be seen in the photographs. Regarring the top view(Figure 2), the three sets of chisel marks were made at S. C. O. A. to show where sub-surface defects were predicted on the basis of their ultrasonic N. D. I. The N. C. I. operator suggested that the defects under the two longer marks could possibly be linked so that it was in fact one defect and, further, that the defect under the shorter mark was not expected to be large : as will be seen one major defect was indeed found as was the smaller defect (Figure 4).

Two conclusions can be made from these Figures :

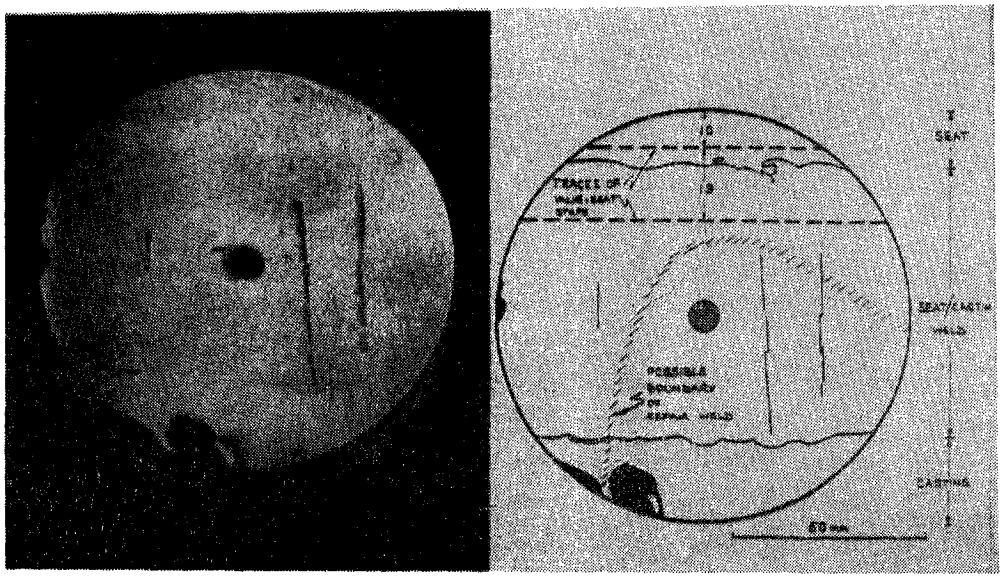
(i) The weld profile is such that the width of the band of weld metal at the pipe surface is between 65 and 70mm. Further, it may be deduced that the two weld boundaries are, respectivcly, about 80mm and 145mm from the inside face of the pipe : this deduction is made on the basis that the location and dimensions of the valve seat are as given in the design drawing provided by S. C. O. A. -i. e. the vertical step of the valve seat visible in Figure la is 73mm from the inside fce of the pipe. (A sketch of the profile is given in Figure 6).

(ii) A weld repair had been made to the casting before the valve seat had been welded in place. This repair is visible in Figure la and lb. An estimate of its extent is sketched in Figure 2b and in Figure 6.



(a) (b)

Figure 1. Two views of the sides of the trepanned cylinder.



(a) (b)

Figure 2. The top of the cylinder : i.e. inside face of body.

3. Examination of Sections Cut Through Cylinder

3. 1 Section made approximately parallel to pipe axis

A cut was made as shown in Figure 3. A photograph of the section face nearer the inside pipe face is shown in Figure 4. The major defect in the casting can be seen as can the weld repair and some smaller defects. Also shown in Figure 4 are the locations of the section cuts described in § 3. 2.

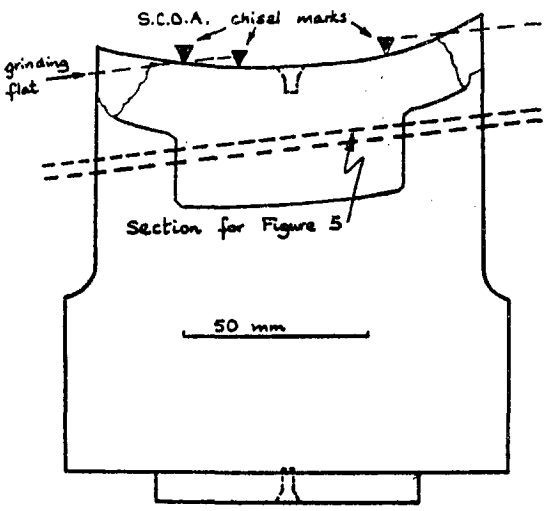


Figure 3. Location of section for Figure 4.

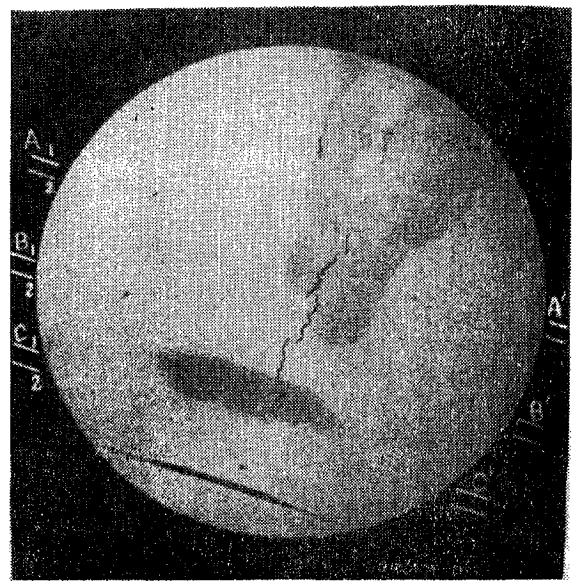
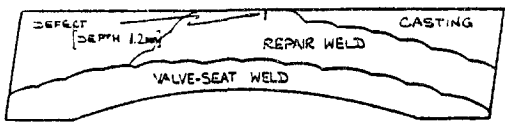


Figure 4. Cross—section of cylinder. Sections AA′, BB′, CC′ are described in 3. 2

3. 2 Sections made approximately perpendicular to pipe axis

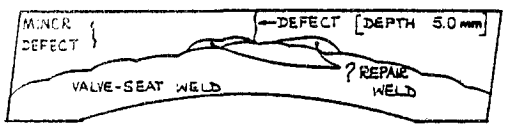
To ascertain further the extent of the defect visible in Figure and to ascertain its relationship to the valve seat weld three sections were made as shown in Figure 4 (viz. AA′, BB′ and CC′). These three sections exposed 6 faces (A_1, A_2, B_1, B_2. C_1, C_2) also labelled in Figure 4. No defect was visible on faces C_1 or C_2 which, essentially, means that the defect was not found in the value seat. Sketches of the other four faces are shown in Figure 5 together with photographs of three of them.



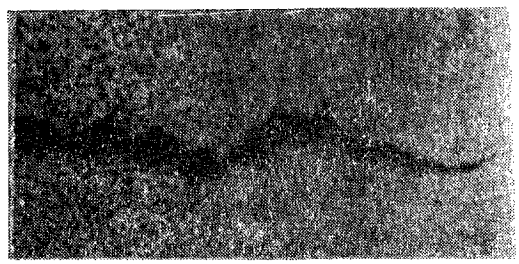
Face A1

Face A2

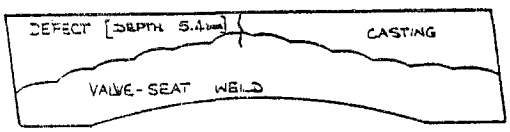
X0.8



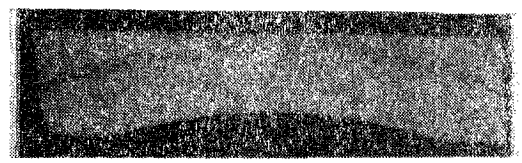
Face B1



X30



Face B2



X0.8

Figure 5. Appearance of four faces revealed by sections AA′ BB′ as defined from Figure 4.

The evidence of Figure 5 shows that the defect lies almost entirely in the casting. It terminates either near the repair weld boundary, see Faces A_1, A_2, B_1, or near the valve seat weld boundary, see Face B_2 : the tip of the defect may lie a small distance inside the weld but the profile suggests that the defect did not start in the weld(or the weld boundary) and then run into the casting-see, especially, Face B_1.

An estimate can be made of the extent of the defect from the evidence of Figures 4 and 5. This profile is shown in Figur 6 together with the profile of the valve seat weld(very

approximately) of the repair weld. It should be noted that the defect comes very close to or even intersects the surface machined in the casting to take the valve seat. It must be appreciated that Figure 6 has been sketched without breaking open the entire defect so that the boundaries shown are not at all exact. It is also obvious that any portions of the defect which lay in the weld repair region have been destroyed by that repair.

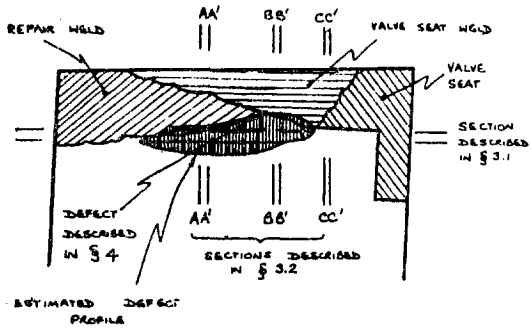
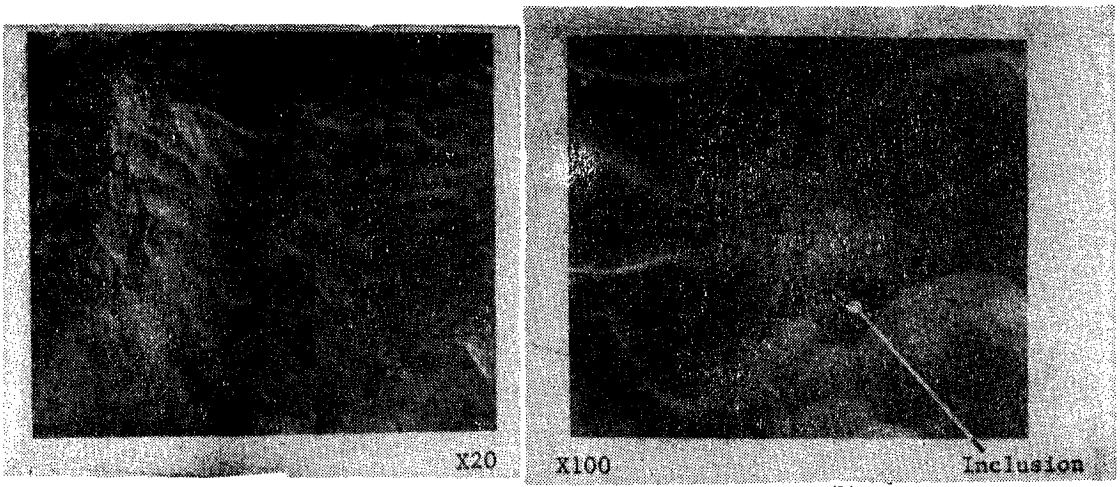


Figure 6. **Estimated extent of the defect, of the repair weld and of the valve-seat weld.**

4. Examination of Defect Surface

The nature of the defect visible in the cross-sections described in § 3 is not perfectly clear although the presumption is made that if is a casting defect. This is on the basis both of the profile of the defect and its location. It was decided to break open the slice of steel lying between the sections AA′ and BB′. The surface so revealed was heavily oxidized but its nature was now clearly that of a casting defect. Figures 7 a, b are scanning electron micrographs of this surface and the outlines of dendrites are clearly visible.

Three types of surface are evident in Figure 7, labelled 'p', 'q' and 'r'. Area p consists simply of exposed dendrites and is characteristic of a loss of feeding liquid metal. Area q may be the same as p, but it is more likely a crack which has propagated between dendr-



(a) (b)

Figure 7. **Surface of defect.**

ites whilst a film of liquid was there(or, perhaps, solid just below the solidus temperature) : what is sure is that the scale of the structure in area q is the same as that of area p so that the separation process was governed by the dendrite shape. The third area, 'r', has not been interpreted : it is possibly a transgranular crack formed at some lower temperature-

but, nevertheless hot enough to be heavily oxidized. It should be noted that the heavy oxidation implies that the defect was connected to the atmosphere when it formed. The surface contained various inclusions one of which is seen in Figure 7. No detailed survey was made of these but one contained predominantly calcium and sulphur and another contained predominatly iron, calcium and silicon.

5. Conclusions

The following conolusions can be made from this study : —

5. 1 The valve seat weld profile has been established. It is desribed in § 2 and is sketched in Figure 6.

5. 2 Aweld repair was detected in the casting.

5. 3 The defect deduced from the S. C. O. A. ultrasonic inspection was observed. It was identified as a casting defect lying beneath the repair weld and beneath the valve seat weld.

5. 4 There is some evidence that the casting defect was very colse to, or even intersected, the surface machined in the casting to receive the valve seat and to make the weld preparation. To verify this the rest of the defect will need to be broken open in the way described in § 4.