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Tandem Electron Beam Welding (Report VII)†

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Abstract

30 kW class Tandem Electron Beam welding apparatus was applied to suppression of welding defects such as A-porosities and R-porosities in deep penetration of mild steel. They were completely suppressed under proper Tandem conditions. Formation and suppression mechanism were also analyzed by transmission X-ray method.

KEY WORDS: (Tandem Electron Beam) (Porosity) (Suppression of Defects) (Transmission X-ray Analysis)

1. Introduction

Electron beam welding has realized a deep penetration welding of thick plates which could not be achieved by traditional heat sources. However, it brought some specific welding defects such as spiking and porosities. The authors have already succeeded to suppress spiking and root porosities in aluminum alloy by Tandem Electron Beam (TEB) welding method[1], however, this result was only for thin aluminum alloy (penetration depth of about 15 mm). In this paper, a new 30 kW TEB welding apparatus[2] was applied to suppress porosities in thick carbon steel (SM-41) (penetration depth of about 80 mm). Sound beads were obtained by advancing angle TEB welding method. Formation and suppression mechanism of porosity were analyzed by transmission X-ray method.

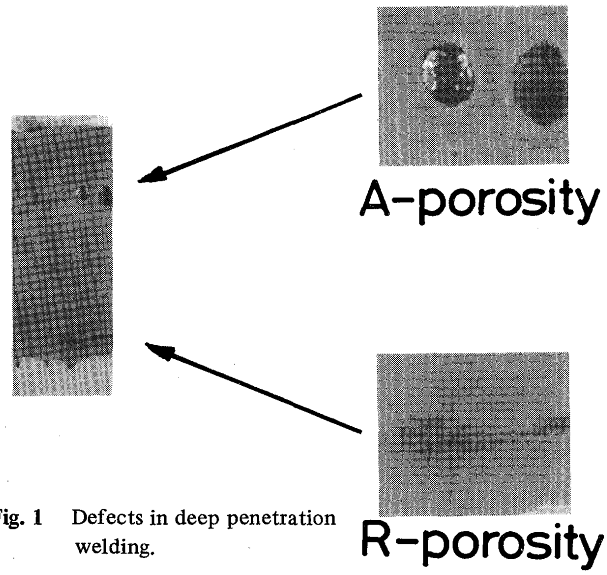

Fig. 1 Defects in deep penetration welding.

2. Welding Defects in Deep Penetration Welding

Figure 1 shows A- and R-porosities observed in electron beam welding of thick carbon steel (SM41). A (Active Zone)- porosity occurs at the middle part of bead. R (Root)-porosity occurs at the root of bead. In this paper, these porosities are evaluated by area ratio between total bead area and porosity area as shown in **Fig. 2**.

Figure 3 shows a_b value dependence on penetration depth and area ratio of porosities formed by 30 kW TEB welding apparatus with single electron beam (SEB) welding mode. A-porosity is most frequently formed on a_b value of about 0.9. Its area ratio is 5%. R-porosity increases with a_b value to 5% at a_b value of 1.1. When a_b value is 0.9 – 1.0, which brings maximum penetration depth, both A- and R-porosities occur. As shown in the longitudinal sections of **Fig. 4**, spiking phenomena occurs below a_b value of 0.9. At a_b value of 1.1, penetration

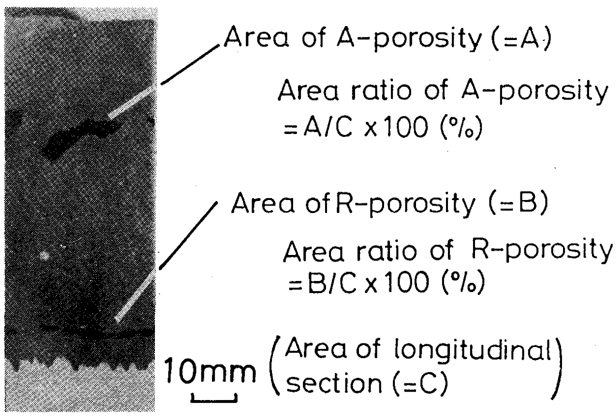

Fig. 2 Area ratio of porosity.

depth is 15mm shallower than maximum value, and the bead width around surface is widen, which is not a well-shape bead. As clearly seen in cross sections, at a_b value of around 0.98 bead width is wide at the depth where A-

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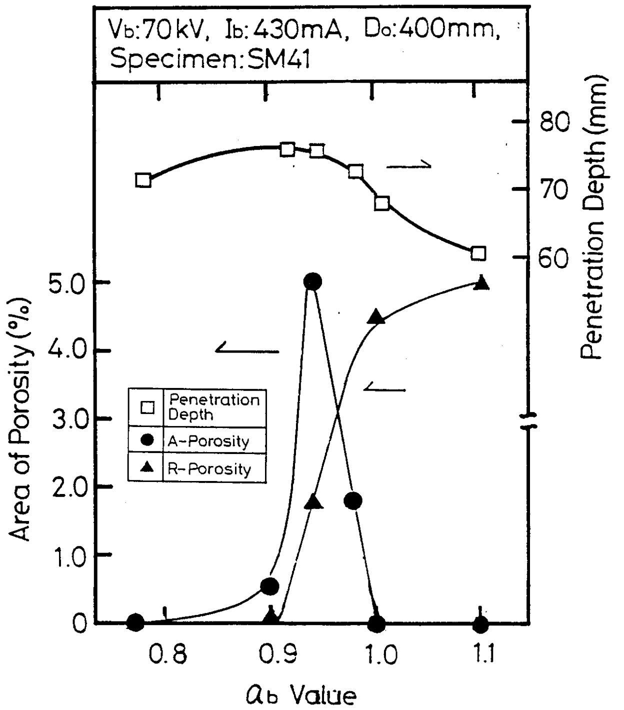

Fig. 3 Dependence of porosities on a_b value.

porosity occurs, and a neck is seen on the part of just above this depth.

3. Formation Mechanism of Porosity

In order to clarify the formation mechanism of porosity, beam hole behavior during welding was observed dynamically by the transmission X-ray method[3], as shown in **Fig. 5**. **Figure 6** shows typical shapes of the beam holes and corresponding bead sections. It is clear that beam hole is enlarged at the depth of R-porosity and A-porosity. Film analysis shows that the beam hole perturbes just on this widen parts. Behavior of other parts are comparatively steady.

The formation mechanism of porosities is thought as follows. The stagnation of molten metal at the depth around the focal point interrupts the discharge of gas or metal vapor outside the beam hole. This causes the expansion of the beam hole. Furthermore, this stagnation of molten metal delays the solidification of this part. This leads the formation of porosity and the segregation of impurities.

4. Suppression of Porosity by TEB Welding Method

Because the formation of porosity is concerned with the non-smooth flow of molten metal and the stagnation of molten metal, TEB welding method which can control the flow of molten metal to be uniform and steady was applied in order to suppress the porosities. Beam configuration of TEB weldig method are shown in **Fig. 7**. The first beam is impinged perpendicularly against the specimen with the same conditions of single electron beam welding in **Fig. 3**. At the same time, the second beam impinges to the beam hole or molten pool of the first beam to suppress the stagnation of the molten metal.

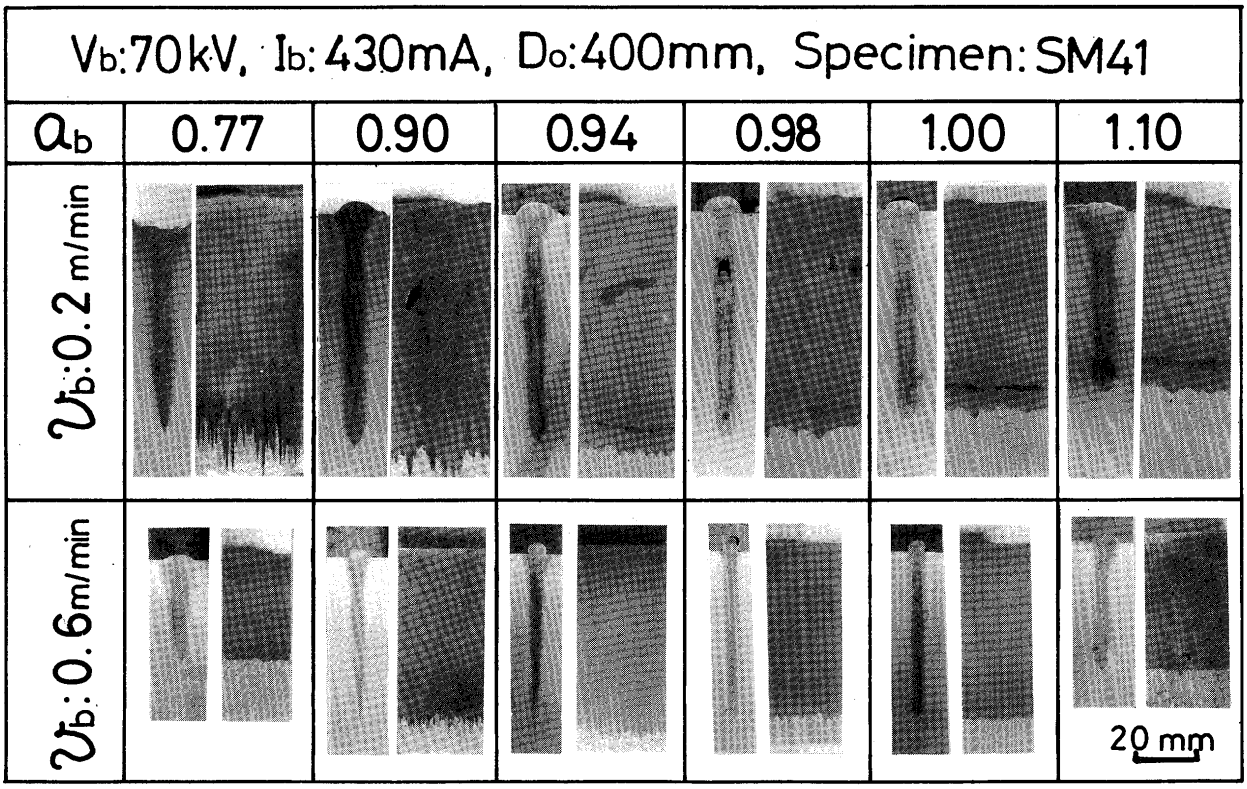

Fig. 4 Examples of transverse and cross sections of beads welded by single electron beam welding.

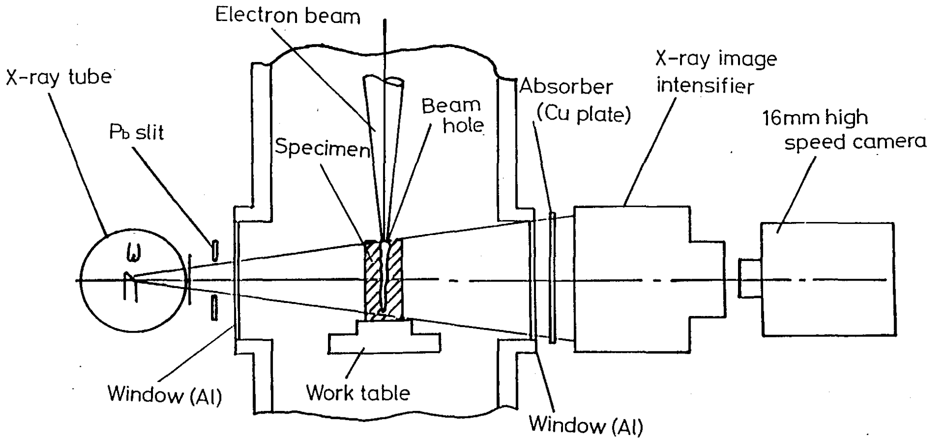

Fig. 5 Transmission X-ray method.

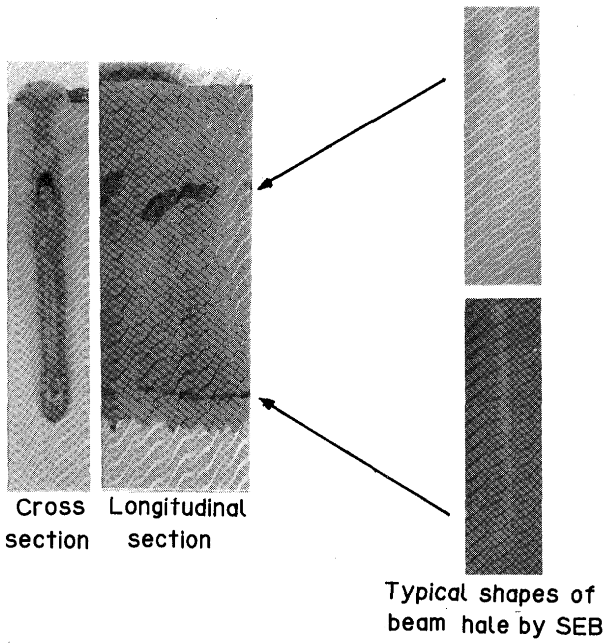

Fig. 6 Typical shapes of beam hole by single electron beam welding.

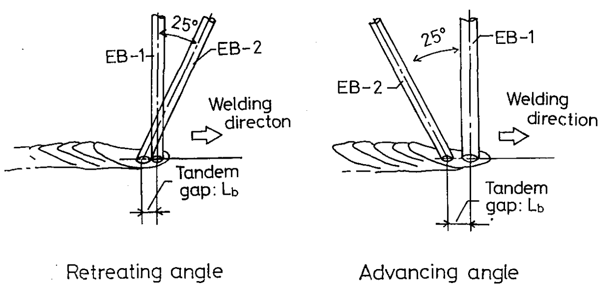

Fig. 7 Beam configuration of TEB welding method.

There are two modes of incident direction. One is the retreating angle of 25° and another is the advancing angle of 25°.

Figure 8 shows area ratio of R-porosity observed in retreating angle TEB welding with several Tandem Gap and second beam power. Welding condition of the first beam is W_b = 30 kW, a_b = 0.9, v_b = 0.2 m/min. These

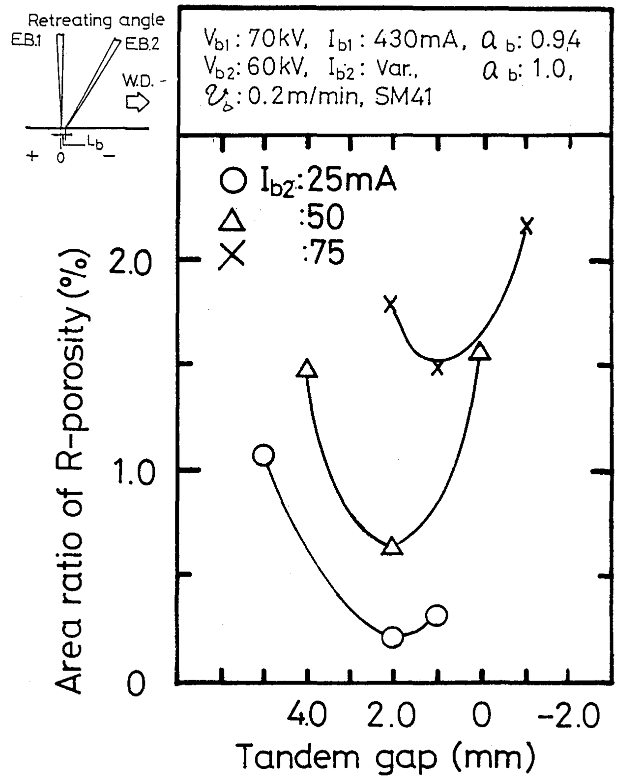

Fig. 8 R-porosity in retreating angle TEB welding.

are the parameters which brought maximum penetration depth in **Fig. 3**. The power of the second beam is 1.5, 3.0 and 4.5 kW, which correspond to the power ratio of 5.0, 10.0 and 15.0%, respectively, because the power ratio of 10% was the optimum in previous report[4)] of shallow (about 15mm) penetration bead. While A-porosity is suppressed completely, R-porosity does not suppressed and increases with the power of the second beam. Typical examples of bead on each power ratio are shown in **Fig. 9**. As clearly shown, the neck below the surface which results A-porosity is suppressed.

Figure 10 shows the results in advancing angle TEB welding. The second beam power of 10% of the first beam with 8 mm Tandem Gap can suppress both porosities

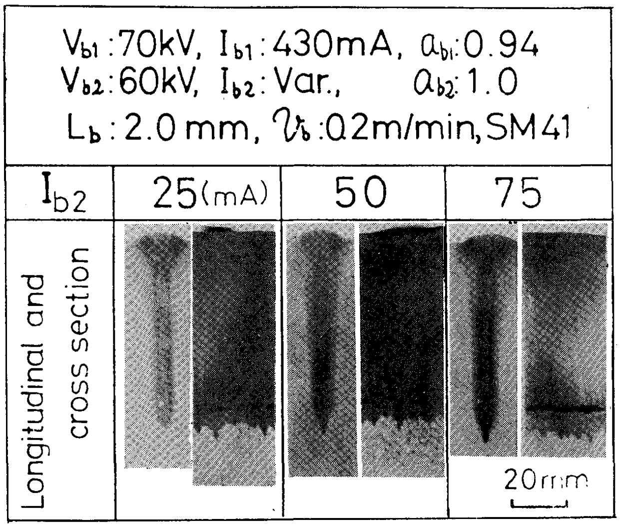

Fig. 9 Example of transverse and cross sections of beads by retreating angle TEB welding.

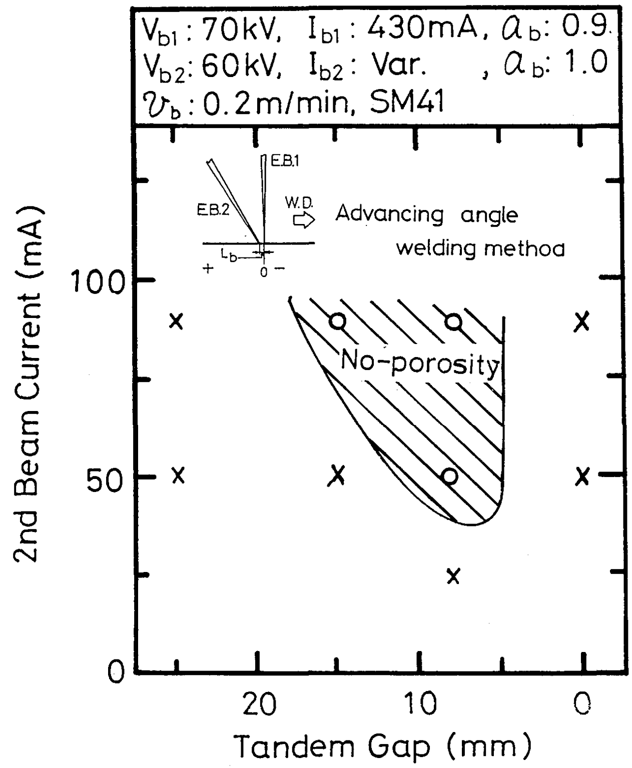

Fig. 10 Suppression of porosities by advancing angle TEB welding.

completely. The area of Tandem Gap which suppresses the porosities is enlarged with increasing second beam power. Furthermore, even outside of non-porosity area, A-porosity is completely suppressed and the area ratio of R-porosity is reduced to below 0.05%. Bead sections of TEB and SEB welding are compared in **Fig. 11**.

5. Suppression Mechanism of Porosity by TEB Welding Method

In order to reveal suppression mechanism of porosity

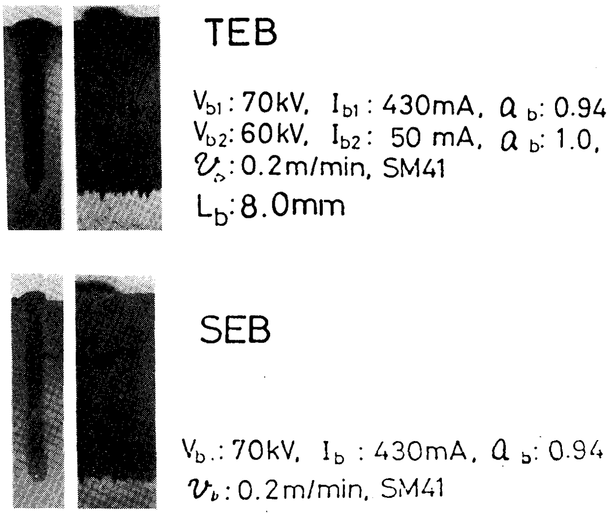

Fig. 11 Comparison of bead sections between advancing angle TEB welding and SEB welding.

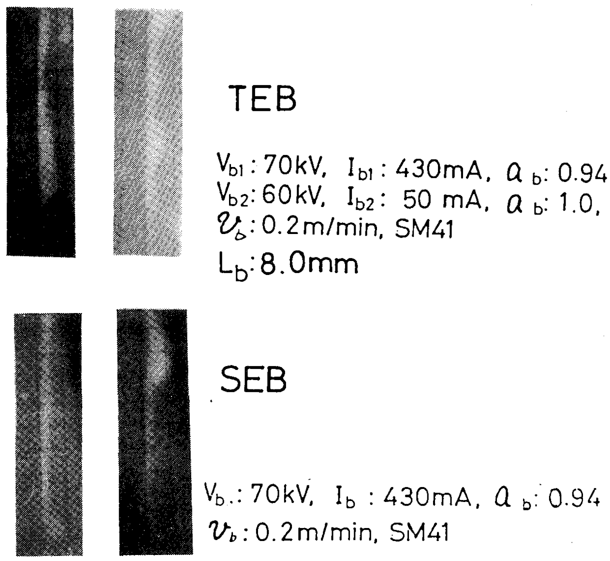

Fig. 12 Comparison of beam hole shapes between advancing angle TEB welding and SEB welding.

by TEB welding method, the behavior of beam hole was observed by transmission X-ray method. **Figure 12** shows the typical shape of beam hole in SEB and TEB welding. In SEB welding, beam hole was compressed just above the expanded part where porosities are formed. In TEB welding, the compression of the beam hole is suppressed and the width of the beam hole is enlarged from top to bottom uniformly. Incident angle of 25° and Tandem Gap of around 8 mm bring the second beam to the compressed part of the beam hole. The second beam of optimum power ratio enlarges the neck of the beam hole and make the flow of molten metal smoothly.

6. Conclusion

Formation mechanism of porosities which are frequently seen in deep penetration welding was analyzed by transmission X-ray method. When porosity is formed, beam hole is not uniform and steady. Beam hole is frequently compressed at peculiar depth, which causes the stagnation of molten metal flow and formation of porosity. Based on this results, TEB welding method was applied to suppress these porosities. Advancing angle TEB welding could suppress porosities completely with the power ratio of over 10%.

References

1) Y. Arata, N. Abe and S. Yamamoto: "Tandem Electron Beam Welding (Report III)", Trans. of JWRI, Vol. 9 (1980), No. 1, 1–10.

2) Y. Arata, M. Tomie, N. Abe and E. Abe: "Tandem Electron Beam Welding (Report VI)", Trans. of JWRI, Vol. 15 (1986), No. 1, 21–25.

3) Y. Arata, N. Abe and E. Abe: "Tandem Electron Beam Welding (report IV)", Trans. of JWRI, Vol. 11 (1982), No. 1, 1–5.

4) Y. Arata, N. Abe, H. Wang, and E. Abe: "Tandem Electron Beam Welding (Report V)", Trans. of JWRI, Vol. 11 (1982), No. 2, 1–6.