High Speed Welding of Thin Stainless Steel Plates by Tandem Electron Beam

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Electron beams, which have both high energy density and high power, enable high speed welding of thin plates of a few mm in thickness which is a difficult task for conventional welding methods such as arc welding. However, this high energy density also causes special welding defects such as humping, undercut or overlap in high speed welding. For stainless steel of 2mm in thickness, below a welding speed of 0.05m/sec (3m/min), a sound bead is obtained even by a single electron beam. As welding speed increases, undercut and humping phenomena occur. However, these defects were successfully suppressed by Tandem Electron Beam (TEB) welding up to a welding speed of 0.1m/sec (6m/min)[1]. Up to a welding speed of 0.25m/sec (15m/min) for 3mm thick stainless steel plates, sound beads also have been obtained by TEB welding[2].

Above a welding speed of 0.3m/sec, overlapping occurs very violently, as shown in **Fig.1**. Molten metal is blown away from the beam hole and solidifies very quickly at the surface of the specimen. Consequently, a deep groove remains in the bead and a large overlap bead is formed on the surface. When the beam power is too high, the molten metal also spatters from the bottom of the specimen, resulting in cutting phenomenon. In this report, such a violent overlap phenomenon is suppressed by Tandem Electron Beam welding in high speed welding of stainless steel plates of 3mm thickness at a welding speed of 0.35m/sec (21m/min).

From observing the welding phenomena with a high speed camera, the molten metal seems to blow out from both sides of the beam hole opposite to the welding direction. It was thought that as the moving speed of the electron beam was too high to drill the front wall perpendicularly, the front wall angle of the beam hole decreased with increasing welding speed, especially over a

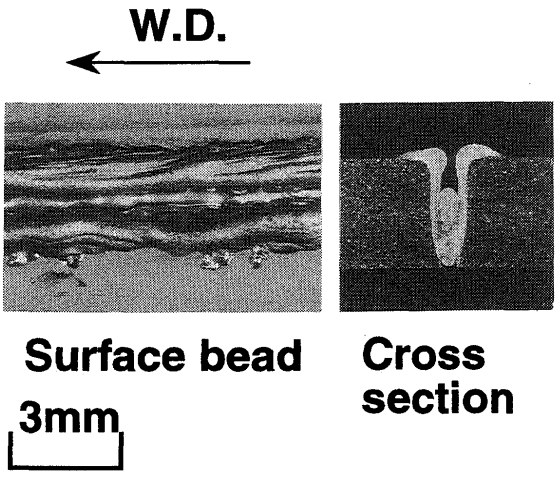

Fig.1 Overlap defect occurs in high speed welding of thin plates.

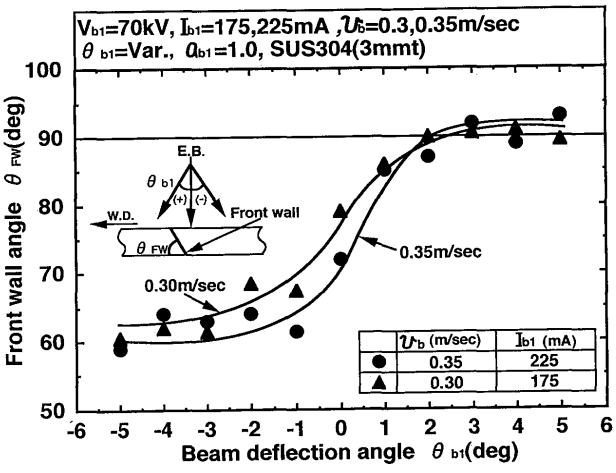

Fig.2 Effect of beam deflection on the front wall angle of the beam hole at a welding speed of 0.3 and 0.35m/sec.

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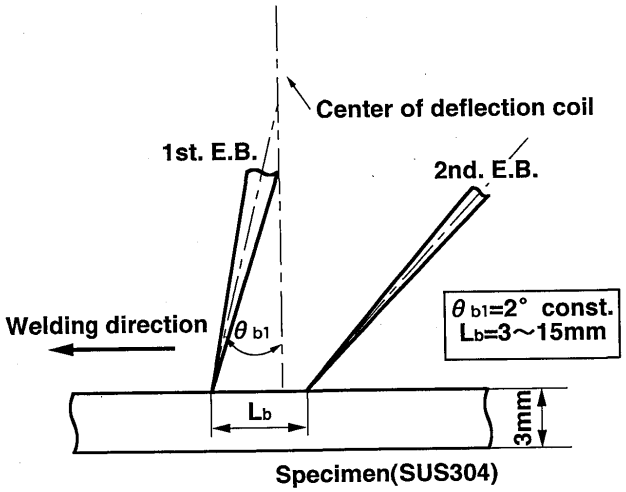

Fig.3 Tandem Electron Beam welding condition for high speed welding.

welding speed of 0.3m/sec. Therefore, the molten metal was blow onto the surface of the specimen violently. In order to change the front angle of the beam hole, the electron beam was deflected from the vertical line to the front or back against the welding direction. **Figure 2** shows the effect of deflection of the beam on the front wall angle. It is found that a deflection angle of 2 degrees increases the front wall angle to 90 degrees again. However, although underfill and overlap defects were decreased by beam deflection, porosities remained in the welded bead.

In order to heat the molten metal again and to delay the solidification of the molten metal, which fills the groove and suppresses the porosities, the second electron beam was impinged behind the first beam as shown in **Fig.3**. The relationship between the second electron beam current and the porosity ratio is shown in **Fig.4**. The first beam current is 225mA, which is the penetration current of the specimen at a welding speed of 0.35m/sec and the beam deflection angle is 2 degrees. The a_b value of the second beam is 1.0 and the Tandem Gap is 9 mm. Over a second beam current of 50mA, porosities are suppressed completely. Thus, as shown in **Fig.5**, Tandem Electron Beam welding can suppress the special defects in ultra high speed welding of thin stainless steel plates of 3mm in thickness at a welding speed of 0.35m/sec -- a feat ordinary single electron beam welding cannot achieve. In order to reveal the production mechanism of violent overlap phenomenon in ultra high speed welding and the suppression mechanism by Tandem Electron Beam, further research is planned using high speed observation methods with a high speed camera.

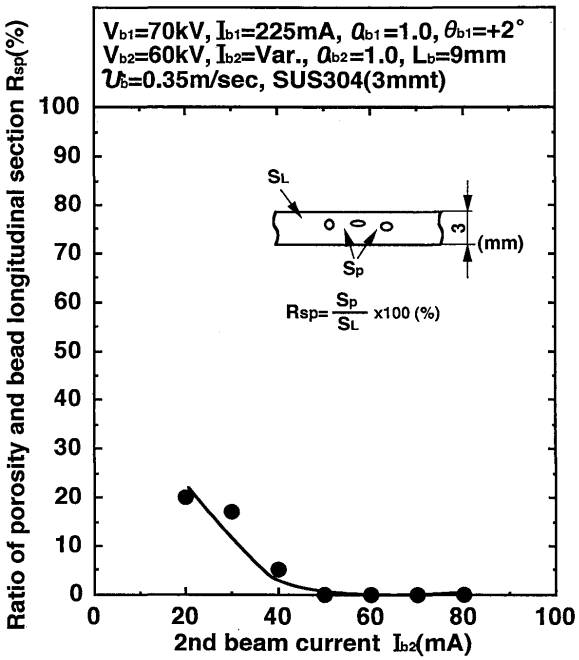

Fig.4 Relationship between the second electron beam current and the porosity ratio.

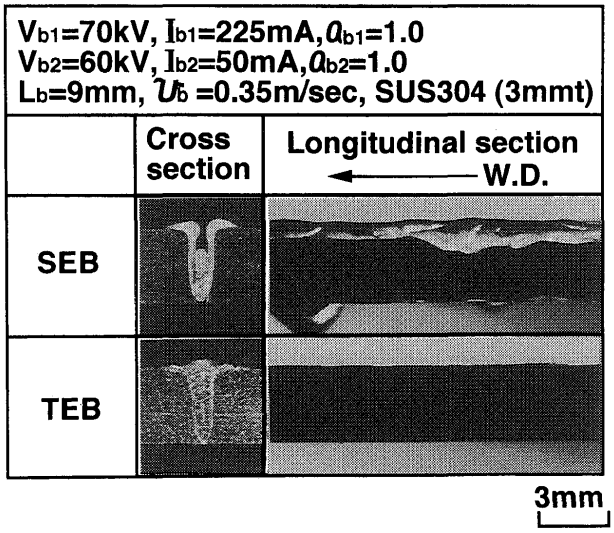

Fig.5 Comparison of cross and longitudinal sections of bead by SEB and TEB welding.

References

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2) M. Tomie, N. Abe and Y. Arata; Tandem Electron Beam Welding (Report IX), Trans. of JWRI, 18(2)1989, 13