Electron Beam Welding of Zirconium Plate†

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KEY WORDS : (Zirconium) (Electron Beam Welding) (Chemical Process Industries)

Zirconium had been used primarily as fuel rod for nuclear reactors since its thermal-neutron absorption cross section is low, but in these years it is becoming useful for chemical process industries as well due to its excellent corrosion resistance. Zirconium exhibits excellent corrosion resistance in concentrations below 70 percent sulfuric acid, and in hydrochloric acid, phosphoric acid, nitric acid, and alkaline solutions. Thus, the application as corrosion resisting material intended for chemical industrial service will be promising for the future.

Zirconium is a very active metal at high temperature and prone to reaction to the atmosphere to thereby form brittle oxides or nitrides. For such reason, it is necessary in welding of zirconium to shield the weld metal and the heat affected zone completely by use of inert gas. Therefore, the electron beam welding may be very convenient for welding of such chemically active and atmospheric gas absorbing material as zirconium because this welding is performed in vacuum.

This report describes the bead characteristics of a pure zirconium plate weld by electron beam. The chemical composition of a pure zirconium plate (ASTM Gr R60702) with 8 mm thickness used in this experiment is given in **Table 1**. When the electron beam welding is used in manufacturing of a pressure vessel, the minimum required bead to be welded in production is 3mm from the top to the bottom of the bead, because some root gap between the welded surfaces is anticipated in large scale production welds.

Table 1 Chemical composition of a pure zirconium plate used in this experiment

(wt %)

Analyzed Location	Zr+Hf	Hf	Fe+Cr	O	C	H	N
Top	>99.2	<1.0	0.090	0.112	0.0058	<0.0003	0.0026
Bottom	>99.2	<1.0	0.081	0.129	0.0054	<0.0003	0.0021

Accelerating voltage of the electron beam used in this experiment was set at 70kV constant, and beam current, a_b values and welding speed were varied, and a bead-on weld was made in flat position, of which the cross section and the surface appearance were analyzed.

When the full penetration welding was made at flat posision, burn through and under-fill occurred, and therefore a backing strip (^{t}8 mm)of same material was adopted to prevent burn through. **Figure 1** is the relation between beam current I_b and bead width d_B at a_b values 0.9, 1.0, 1.1 and 1.2 when welding speed v_b is 100 cm/min. At any a_b value, as the beam current I_b is increased, the bead width tends to be greater, although in small increments, but when the beam current I_b is

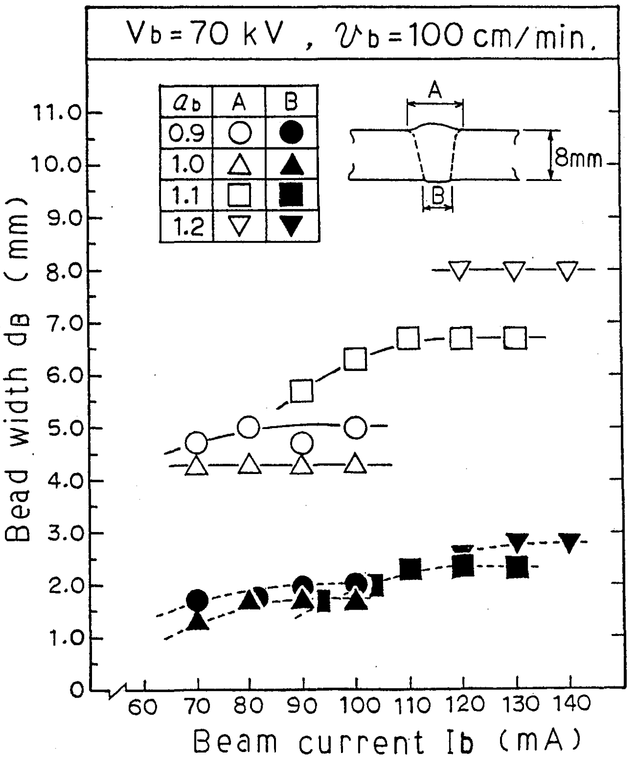

Fig. 1 Relation between beam current I_b and bead width d_B.

† Received on May 7, 1990
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Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

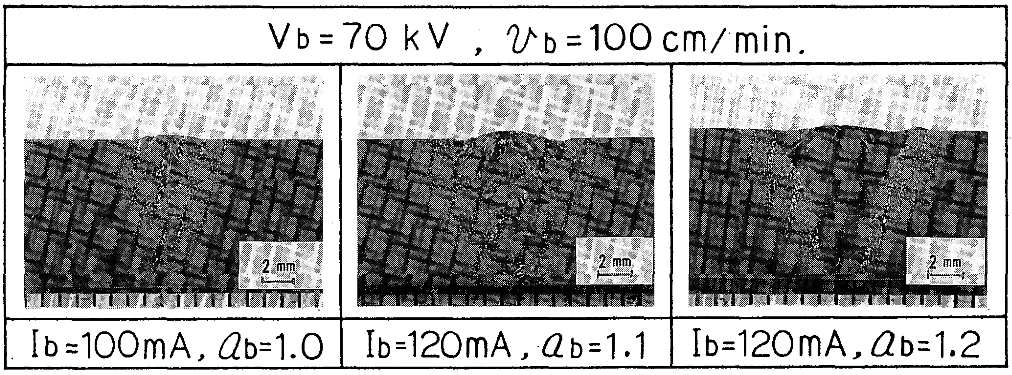

Fig. 2 Cross sections of beads at various a_b values.

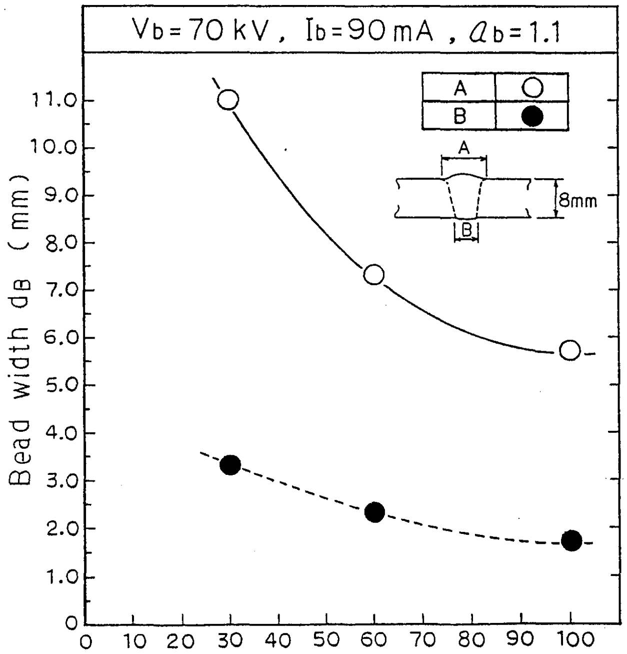

Fig. 3 Relation between welding speed v_b and bead width d_B.

increased to a certain point and higher, the bead width becomes substantially constant. The typical cross sections of beads at a_b values 1.0, 1.1 and 1.2 are shown in **Fig. 2**. The bead at a_b value 1.2 forms a wine-cup profile having a greater surface bead width, but at a_b value 1.0 it is becoming a wedge profile. Thus, the bead width is sufficiently large on the face side but less than 3 mm on the root side, which will not be applicable on actual production. Shown in **Fig. 3** is the relation between welding speed v_b and bead width d_B when the beam current I_b is constant at 90 mA and a_b value is constant at 1.1. In correspondence with the decreasing welding speed v_b, the bead width is in tendency of being greater significantly. In addition, as the welding speed v_b is down, the bead surface becomes flat, as shown in **Fig. 4**, and the width of the heat affected zone greater.

Based on the present experiment, in order to obtain 3 mm bead width on the back side, it is necessary to reduce the welding speed, in which case however it was found difficult to secure the parallel beads. In the future, we will attempt to obtain parallel beads by oscillation of the beam, while studying on the feed of filler wire.

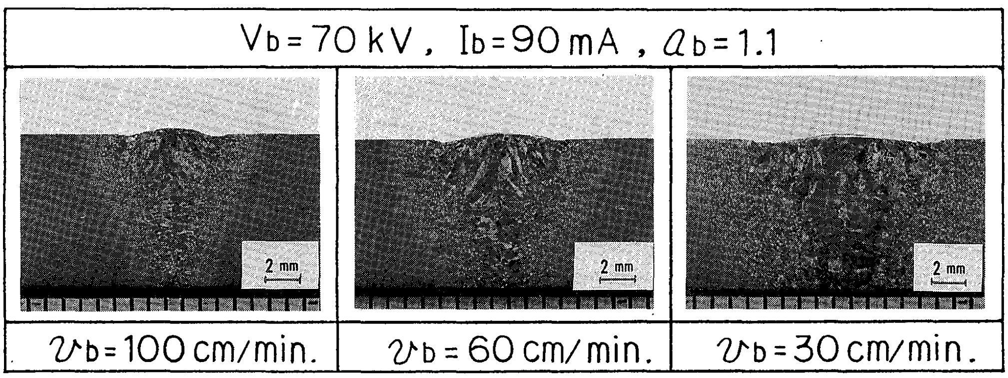

Fig. 4 Cross sections of beads at various welding speed v_b.