100-KW Class Electron Beam Welding Technology (Report I) —Welding Apparatus and Some Aspects as A Heat Source—†

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Abstract

A 100 KW-class electron beam welding apparatus was designed and assembled. Using this apparatus, characteristics of a powerful electron beam up to 120 KW as a heat source and of its bead penetration were both investigated. The possibility of both one-pass welding and cutting thick materials up to 10～20 cm was proposed.

1. Introduction

The heat source of the electron beam gives the deepest weld bead penetration compared with any others as it is well known. Characteristics of the electron beam heat source are that both the power and density become extremely high, moreover, these are controlled easily.

Such characteristics efficiently affect the thick materials as its power becomes much higher. The powerful electron beam of 100 KW-class or above, has the advantage over any other heat source, for the welding ultra high thick materials, 10～20 cm and/or over. From such a view point, the 100 KW-class EB-welder was produced and its capability was tested; moreover, some properties of the poweful electron beam as a heat source were studied. It was then applied to welding and cutting.

2. Characteristics of 100 KW-EBwelder

Fig. 1 and **Photo. 1** show the schematic diagram of the installation and its appearance respectively. Provided that V_b(KV), I_b(mA), and W_b(KW) are taken as beam accelerating voltage, beam current and beam power in the maximum value of a continuous respectively, its capability is as follows.

$$V_b=100,\ I_b=1000,\ W_b=100$$

And it is also possible to utilize it as follows:

$$V_b=200,\ I_b=500,\ W_b=100$$

And this welder was employed up to 120 KW to obtain experimental data although it was for a short interval. The volume of the vacuum work chamber is 1.3 m^3 and the capacity of the exhaust system is 2,000 *l* / min rotary pump, 10,000 *l*/min mechanical booster pump, 360,000 *l*/min diffusion and ejection booster pump respectively. The maximum welding speed is 5 m/min and the cathode material is 3 mmϕ circular type Tungsten.

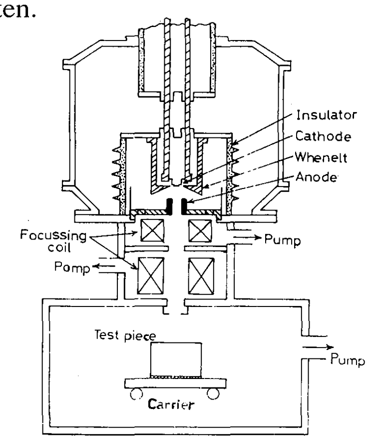

Fig. 1. Schematic diagram of EB-welder.

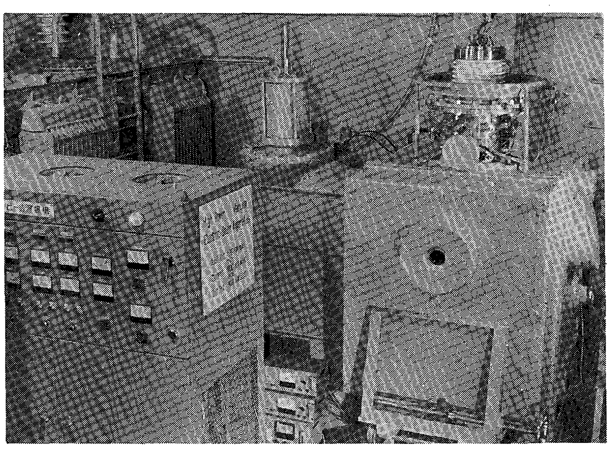

Photo 1. General view of 100 KW-EB welder which was developed by authors.

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3. Some Results and Discussion

The welding bead test was performed using stainless steel SUS304, correspond to AISI304, whoes chemical composition is shown in **Table 1.** The results obtained are shown in **Figs. 2～4** and **Photos 2～5. Photo 2** indicates the typical transverse section of the bead of 50 KW and 100 KW electron beam weldment. **Figure 2** and **Photo 3** show one example of distribution of the vickers hardness and the micro-structure of the bead cross-section respectively.

Figure 3 shows the effect of welding speed on penetration depth at 100 KW, and using this figure, the relation of h_p against $1/\sqrt{v_b}$ (h_p: penetration depth, v_b: welding speed) is obtained as shown in **Fig. 4.** This is in agreement with formula, $h_p \propto I_b V_b^{1.3}/\sqrt{v_b}$, which is given by authors in another report of this JWRI[1].

Table 1. Chemical composition (W_t %) of stainless steel used (SUS304 correspond to SUS27 or AISI304).

Material \ Composition	C	Mn	Si	Ni	Cr	Cu	Mo	Al	S	P
SUS 304	0.050	1.74	0.74	10.9	19.5	0.12	0.16	0.015	0.010	0.030

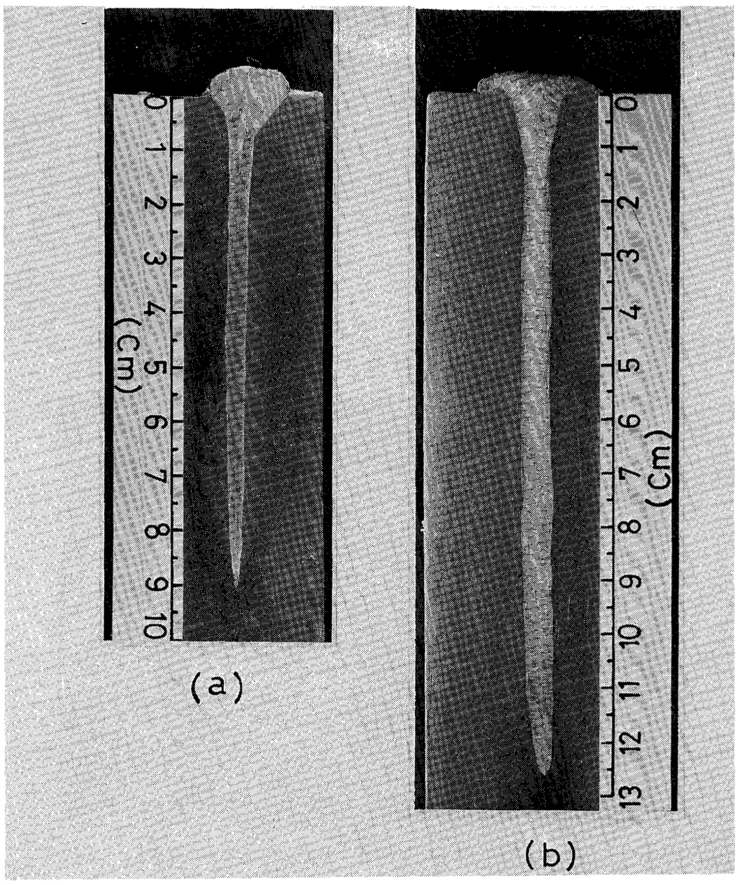

Photo 2. Cross-sectional view of the bead, welded under conditions of v_b=60 cm/min for SUS304,
(a): V_b=100 KV, I_b=500 mA, W_b=50 KW
(b): V_b=100 KV, I_b=1000 mA, W_b=100 KW

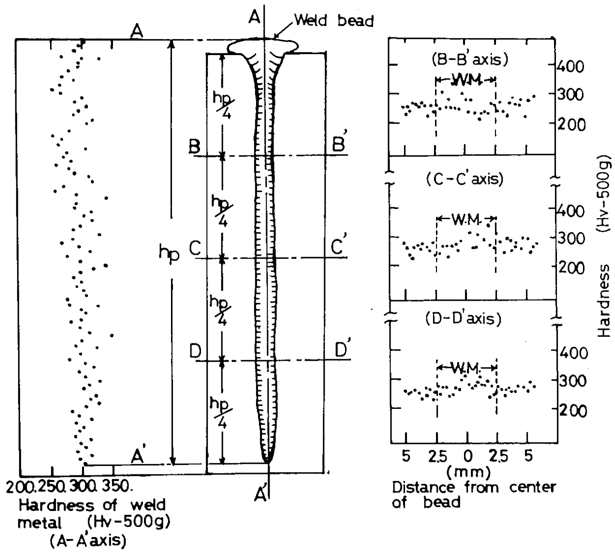

Fig. 2. Hardness distribution in cross-section of welds, (V_b=100 KV, I_b=1000 mA, W_b=100 KW, v_b=60 cm/min, SUS304).

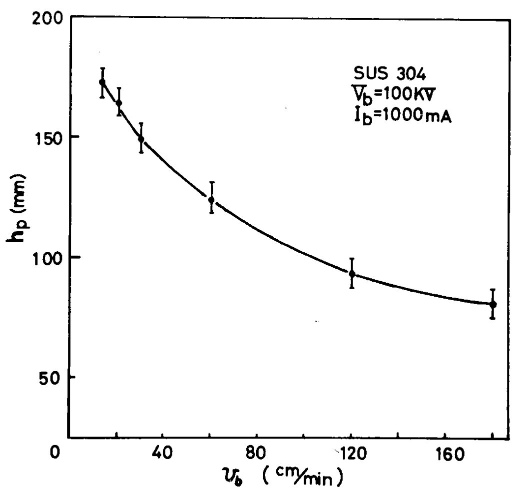

Fig. 3. Relations between v_b and h_p.

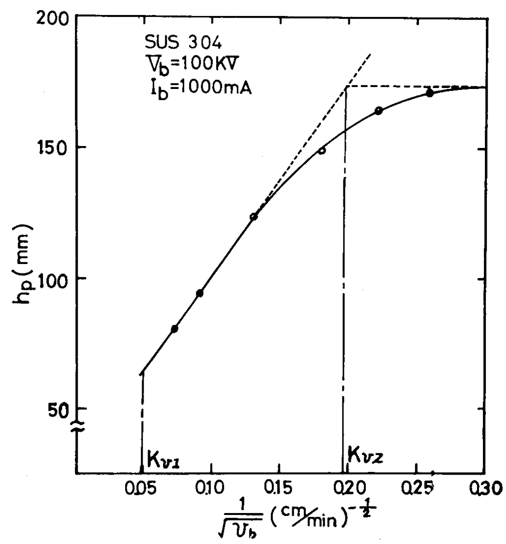

Fig. 4. Relations between h_p and $1/\sqrt{v_b}$.

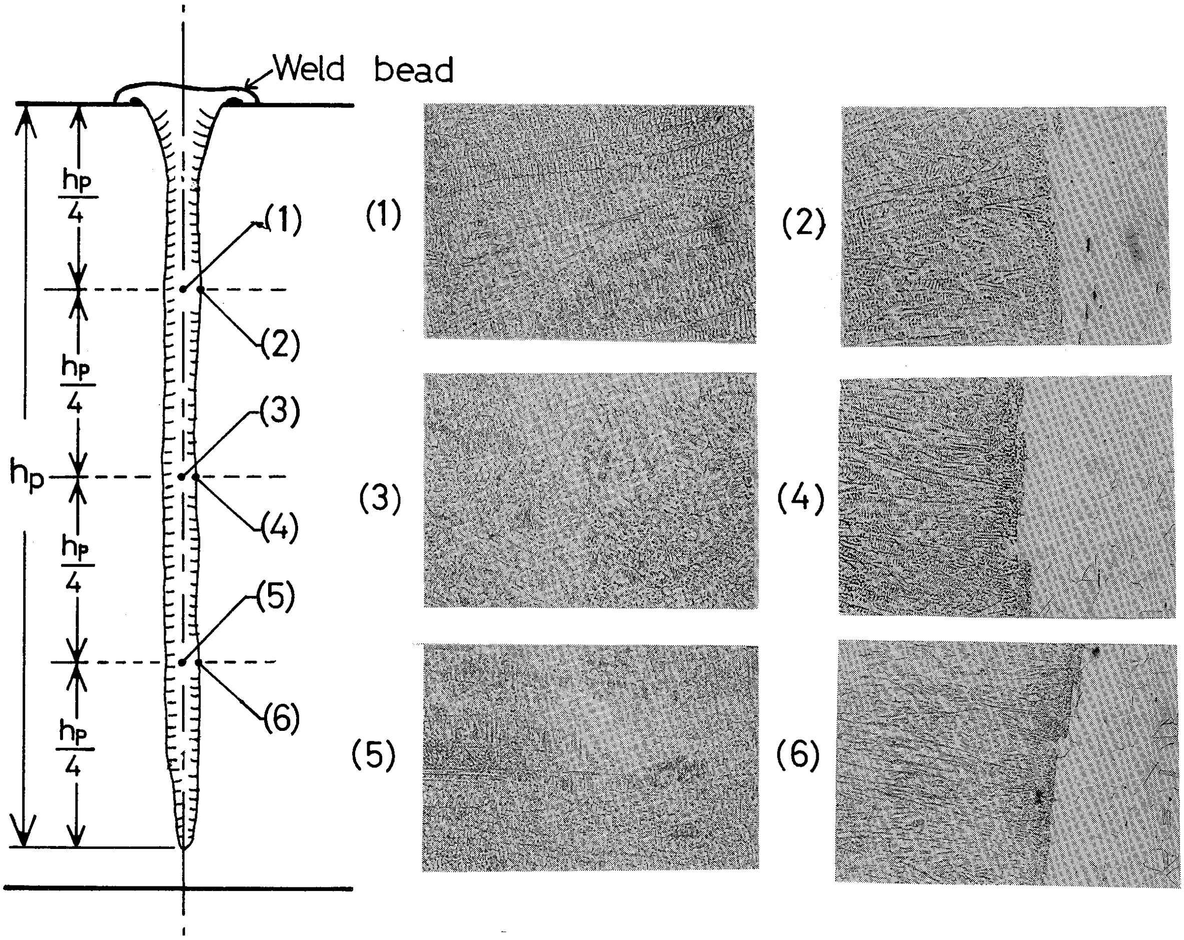

Photo 3. Microstructure at various positions in weld bead, (V_b=100 KV, I_b=1000 mA, W_b=100 KW, v_b=60 cm/min, SUS304).

Phot 4 indicates one example of 100 KW electron beam cutting, which demonstrates the usefulness of the powerful beam for cutting ultra thick materials. **Photo 5** shows the profile of the very long molten pool over 10 cm waved strongly during 100 KW-class beam welding, and its aspect was that of molten metal poured into the long narrow beam cutting zone which was similar to a deep narrow gap. Such a powerful beam looks like it causes severe gaps compared with a relatively low power beam such as the 50 KW-class beam or below, especially the evaporation due to violent boiling during welding.

Such "welding vapor" emitted violently from the molten pool near the beam, heavily contaminates both space and wall surface of the beam channel and the beam accelerating chamber, and it leads to fluent arcing in the electron gun.

Consideration for its prevention is as follows.

1) To make each slit or nozzle of the beam channel as small or long as possible.
2) To make the beam axis shift with each other inside accelerating chamber, the beam channel and the work chamber.
3) To make a relative high pressure gas layer in a

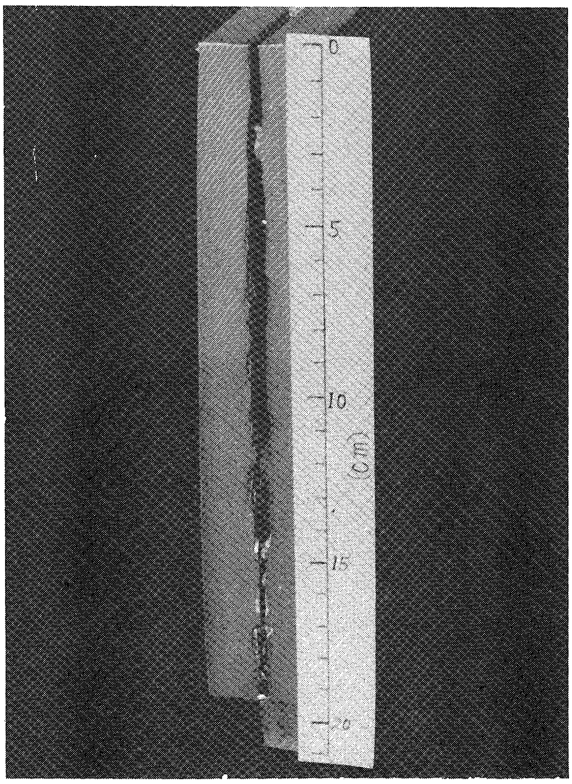

Photo 4. One example of beam cutting (V_b=100 KV, I_b=1000 mA, W_b=100 KW, v_b=20 cm/min, SUS304).

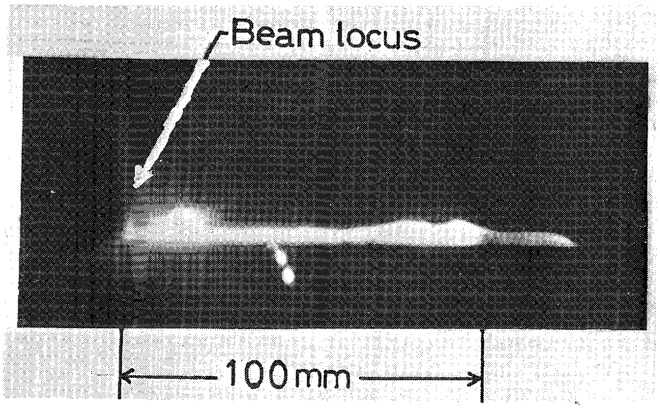

Photo 5. Typical appearance of molten pool in 100 KW beam welding (v_b=30 cm/min, SUS304).

region between the beam channel and the work chamber, and have its pressure much higher than that of the either.

4) It seems that the beam of higher voltage and lower current is better than the diametrically opposed beam to decrease welding vapor, in the case of the high power welder with the same power.

4. Conclusion

The 100 KW-class EB-welder (120 KW in a short time) was designed and installed. The possibility of one-pass welding and cutting for the ultra thick material was proved. A scheme to decrease the damage due to the violent welding vapor was given.

Acknowledgment

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Reference

1) Y. Arata, M. Tomie and Y. Kato: "Some Properties of 30 KW-class Electron Beam for Welding", Trans. JWRI Vol. 1, No. 2 (1973).