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Title	Narrow Gap High Energy Density Beam Welding (1) : Principle
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Citation	Transactions of JWRI. 1973, 2(1), p. 119-120
Version Type	VoR
URL	https://doi.org/10.18910/5403
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Narrow Gap High Energy Density Beam Welding (1)†
—Principle—

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It is considered that the narrow gap welding is an excellent welding process for the thick plate.

As a typical example, the narrow gap welding in which arc heat source is used to perform the multi-pass welding of the square groove zone with about 5 ~10 mm wide gap and over several to ten cm depth, has been developed recently and its research for the industrial application progresses in some countries. In this process, the core wire, shielding gas and their guides are inserted into the narrow gap zone and travel there, so the automatic control is necessary essentially because manual handling is very difficult.

The accurate automatic control of the arc behaviour and the operation of these tools in the narrow gap are complicate in general. Moreover the narrower width of the gap, the more difficult it becomes.

Therefore, from now on the development of the new control technique is necessary in this process.

On the other hand, in the narrow gap welding proposed in this paper, the fine beam with the high energy density such as the electron beam or the laser beam is passed into the narrow gap zone using the method shown in **Fig. 1,** and due to their energy, the adequate filler or insert metal wire plate or powder is melted, and the narrow gap zone is welded[1].

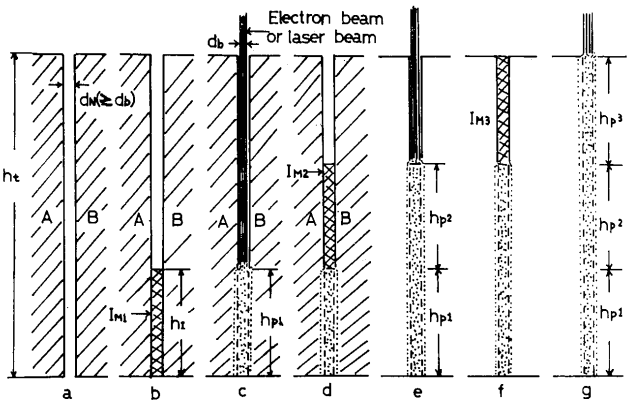

Fig. 1. Schematic illustration of narrow gap high energy density beam welding (NG-EBW, NG-LBW)
A, B: thick material to be joined, I_{M1}, I_{M2}, I_{M3} -----: insert metal, h_{p1}, h_{p2}, h_{p3}, ----: melted zone, d_N: narrow gap between A and B, d_b: electron or laser beam diameter.

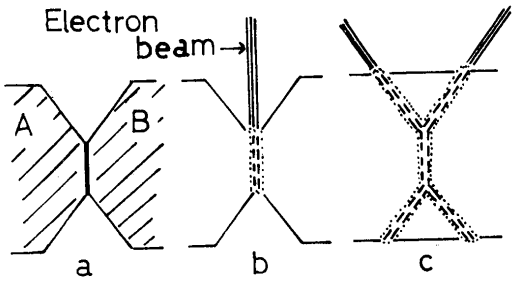

Fig. 2. Joining method given maximum thickness.

It is well known that the fundamental difference between the high energy density beam heat source and the arc heat source come out in their penetration depth. In the welding availing oneself of such beam to produce a deep penetration (the maximum penetration depth: h_p), the maximum plate thickness to be possibly jointed is smaller than 3 h_p as shown in **Fig. 2.** In the weld joint penetrated from both sides of it, the maximum plate thickness is smaller than 2 h_p.

On the contrary, in the narrow gap welding process proposed in **Fig. 1,** we may suppose the possibility to be jointed even the ultra thick plate with several ten cm thickness. As shown in **Fig. 3,** it is well known that if the angle, θ_b with which the electron beam or the laser beam run against the material's wall is smaller than the certain angle, the beam is reflected efficiently on the wall surface, and the reflected beam energy becomes extremely larger than the absorbed beam energy on it. Therefore, adapting this principle to the narrow gap welding, the beam energy can be transported up to the very deep zone and distributed wide range. Namely, because the phenomenon such that the beam doesn't scatter but is focused with the wall, take place as mentioned above, it is to be called the "wall-focusing".

In the narrow gap welding proposed here, putting the wall-focusing to practical usage, most of the beam energy is concentrated upon the filler or the insert metal, and they are melted with the basemetal. In such case the multipass welding is usually used. The number of the pass-layers depend on the beam output, which can determine the adaptable one-pass maximum

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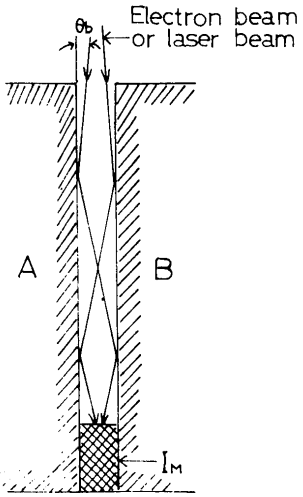

Fig. 3. Schematic illustration of "wall focusing".

penetration depth (h_p). Moreover, such one-pass maximum penetration depth corresponding to hight of each layer or the number of it often, is decided due to the metallurgical characteristics of the weld zone. **Figure 4** is one example obtained experimentally, using this process. In this case, the welding depth of each layer is 2 cm and also the welding joint with 10 cm thickness has been welded with five layers. Because the electron beam has been used as the heat source, this welding process as shown in **Fig. 4** is called "Narrow gap electron beam welding" (NG-EBW). And in a similar manner, the laser beam can be used, and so it is called "Narrow gap-laser beam welding" (NG-LBW).

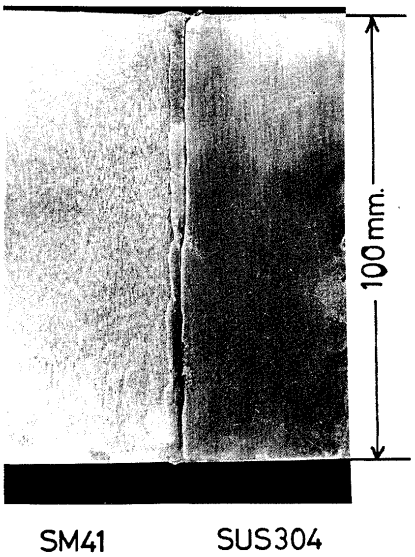

Fig. 4. One example of NG-EBW (thickness; 10 cm, dissimilar metals; SM41 and SUS304, number of multipasses; 5).

SM41: plane carbon steel (0.15 % C)
SUS304: correspond to AISI304

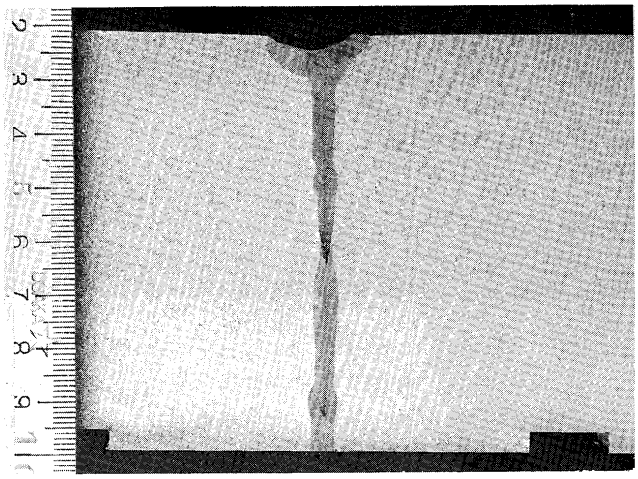

Fig. 5. Another example of NG-EBW (thickness; 8 cm, materials; SUS304, number of multipasses; 4).

The merits of these welding process are as follows.

1) In case the ultra thick plate is welded with one-pass, the high energy density beam with the very large output is needed. But the narrow gap welding proposed here, becomes possible to joint the ultra thick plate without a very high power level of beam output as mentioned above. Moreover, in comparison with the narrow gap arc welding process, this process fully displaies the narrow gap welding process's real ability. For example, we may expect that the width of the narrow gap is usually about 2～3 mm and its depth become possible even several ten cm.

2) The welding of the dissimilar materials become easer than other process. **Fig, 4** and **Fig. 5** are examples of the NG-EBW. But in the welding of the very thick materials, the ploblems such as the cracking and the joining difficulties on the metallurgical properties, often may occur.

In such case, it may be needed that the properties of the welded joint is improved by unifying the deposited metal with not the one pass but the multipass narrow gap welding.

Acknowledgment

The author thanks the electron beam groop of JWRI, Kawasaki Heavy Industry Co. and Japan Electron Optics Industy Co. Ltd., for their effort in the experiment.

Reference

1) Y. Arata: A Special Lecture in a Symposium of Vacuum Metallurgy in the Iron and Steel Institute of Japan, and the Japan Institute of Metals, November (1972).