The University of Osaka
Institutional Knowledge Archive

Title	Dynamic Observation of Beam Hole during Electron Beam Welding in Carbon Steel(Welding Physics, Process & Instrument)
Author(s)	Arata, Yoshiaki; Abe, Nobuyuki; Wang, Hu et al.
Citation	Transactions of JWRI. 1983, 12(1), p. 1-7
Version Type	VoR
URL	https://doi.org/10.18910/7756
rights	
Note	

The University of Osaka Institutional Knowledge Archive : OUKA

https://ir.library.osaka-u.ac.jp/

The University of Osaka

Dynamic Observation of Beam Hole during Electron Beam Welding in Carbon Steel†

Yoshiaki ARATA*, Nobuyuki ABE**, Hu WANG***, Michio TOMIE**** and Eiichi ABE*****

Abstract

The shape and behaviour of beam hole in carbon steel during electron beam welding was observed dynamically. They were filmed by an X-ray image converter and a 16 mm high speed movie camera. These filmes were analysed on shapes of beam hole, its changes and fluctuations.

KEY WORDS: (Dynamic Observation) (Beam Hole) (Electron Beam Welding) (X-rays)

1. Introduction

Dynamic observation of beam hole during electron beam welding is very useful method for clarifying the process of electron beam welding and developing its control process. The authors have been developed the direct observation method using X-ray image converter for the dynamic behaviour of beam hole[1)-5)]. However, most of works were performed on the nonferrous metals or nonmetalic materials.

In the present study, the authors examined the dynamic observation of beam hole in carbon steel by a continuous x-ray and a 16 mm high speed movie of 500 frames per second. From the film analysis of these high speed films, interesting informations for the shape and fluctuation of beam hole in carbon steel are found.

2. Experimental Apparatus

Schematic diagram of the experimental apparatus is shown in **Fig. 1**. X-rays emitted continuously from an X-ray tube pass through a specimen during welding. X-ray images come into the input screen of an X-ray image converter. Visible images can be obtained on the output screen of the converter and filmed by a 16 mm high speed movie camera. The X-ray tube used is an industrial type with maximum continuous output of 4 mA at 160 kVp. Its focusing area is 0.4 mm x 0.4 mm.

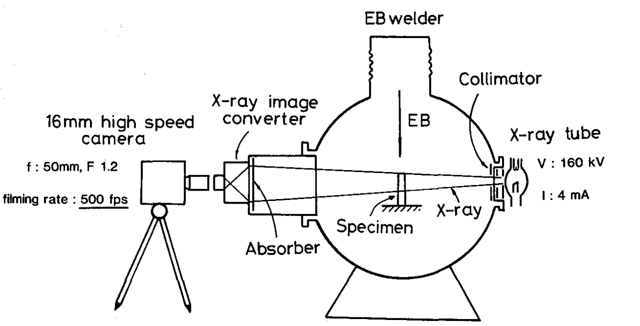


Fig. 1 Experimental apparatus

In order to suppress the x-rays scattered by the specimen, which decrease the sharpness of the image, lead collimeters are inserted between the X-ray tube and the specimen for collimating X-rays only on local part of the specimen where the beam hole is formed.
In addition, a brass foil of 0.7 mm thickness is placed in front of the x-ray image converter as an absorber to avoid the undesired X-rays caused by the interaction

† Received on April 30, 1983
* Professor
** Research Instructor
*** Co-operative Researcher (Welding Research Department of the Beijing Aeronautical Manufacturing Technology Research Institute)
**** Associate professor
***** The Tokyo Metropolitan Research Institute of Industrial Technology

Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

between the electron beam and the specimen, which also decrease the sharpness and contrast of the image.

In order to get fine images, a new model of 4" X-ray image converter (CSII, RTP 7202C) is used, whose special resolution is 50 lp/cm.

The distance between the x-ray tube and the specimen and that of the specimen and the x-ray image converter are about 40 cm. The filming rate of the high speed camera is 500 frames per second. Kodak color negative film (7293) is used. The duration for development is increased into 4 times over the nominal value.

The welding conditions are follows; acceleration voltage: 56 kV, beam current: 140 mA, welding speed: 36 cm/min. 0.3% carbon steel of 300 mm length, 10 mm width and 30 mm thickness is used as base metal. Its chemical composition is given in **Table 1**.

Table 1 Chemical composition of material

Element / Mark	C	Si	Mn	P	S	Sol. Al
EB	0.31	<0.01	0.50	0.004	0.005	<0.001

Chemical composition of material wt(%)
Size: 300l X 10w X 30t (mm)

3. Results and Discussion

Many bubble formation are observed on high speed film frequently. Three typical series of high speed movie photographs of beam hole in carbon steel during electron beam welding of 56 kV, 140 mA, 36 cm/min are shown in **Figs. 2, 3** and **4**.

Figure 2 shows the case of no bubble formation. The white part of the center of photograph is the image of beam hole. The upper white part is a space above the surface of specimen. The welding direction is from the left to the right. Therefore, the right of the image is the front wall while the left of the image is the rear wall of beam hole. The depth of beam hole is about 21 mm. The numericals show frame numbers.

It can be recognized that the shape of beam hole changes with time. The front wall of beam hole generally keeps straight shape. As already reported[3], it seems that there is little molten metal on front wall to make large fluctuation. On the other hand, the behaviour of the rear wall is somewhat different from that of the front wall. The "bulge" often occurs at the rear wall. One or two bulges grow up gradually in length and width. After the shape of beam hole becomes uniformly thick, its width decreases again.

Figure 3 shows the case of bubble formation in molten pool of very near surface. Except for the upper part of beam hole, change of beam hole is nearly the same as Fig. 2. Figure 4 shows the case of bubble formation in deep part of molten pool (middle depth of beam hole). In this case, fluctuation of beam hole seems to be somewhat suppressed till the bubble reaches to the beam hole. It is very interesting that the depth of bubble does not change till it is absorbed in beam hole.

In order to understand the fluctuation of beam hole more clearly, film analysis are performed for 200 frames in Fig. 2. **Figure 5** shows the fluctuation of depth of beam hole with time. Average depth is 21.6 mm. Two holizontal lines around average value show the standard deviation. It seems that the process in which the beam hole becomes deep is fast but the process in which the beam hole becomes shallow is slow.

On the other hand, average values and standard deviations of the length of beam hole are plotted in **Fig. 6** against the depth of beam hole. The abscissa is positions of beam hole as depth. The left ordinate is average value and the right ordinate is standard deviation. As clearly seen in Fig. 6, length of opening of beam hole has the maximum value for both parameters. That for middle depth has also large value for both parameters. More notable fact is that the length of beam hole 2 mm under surface has smallest fluctuation and seems the "neck". The results of film analysis on these three positions are shown in **Fig. 7**. The top figure shows the fluctuation on surface, the middle shows that on the position of 2 mm under surface and the bottom shows that on the position of 8 mm under surface. It seems that large fluctuation occurs periodically on surface and middle depth, while

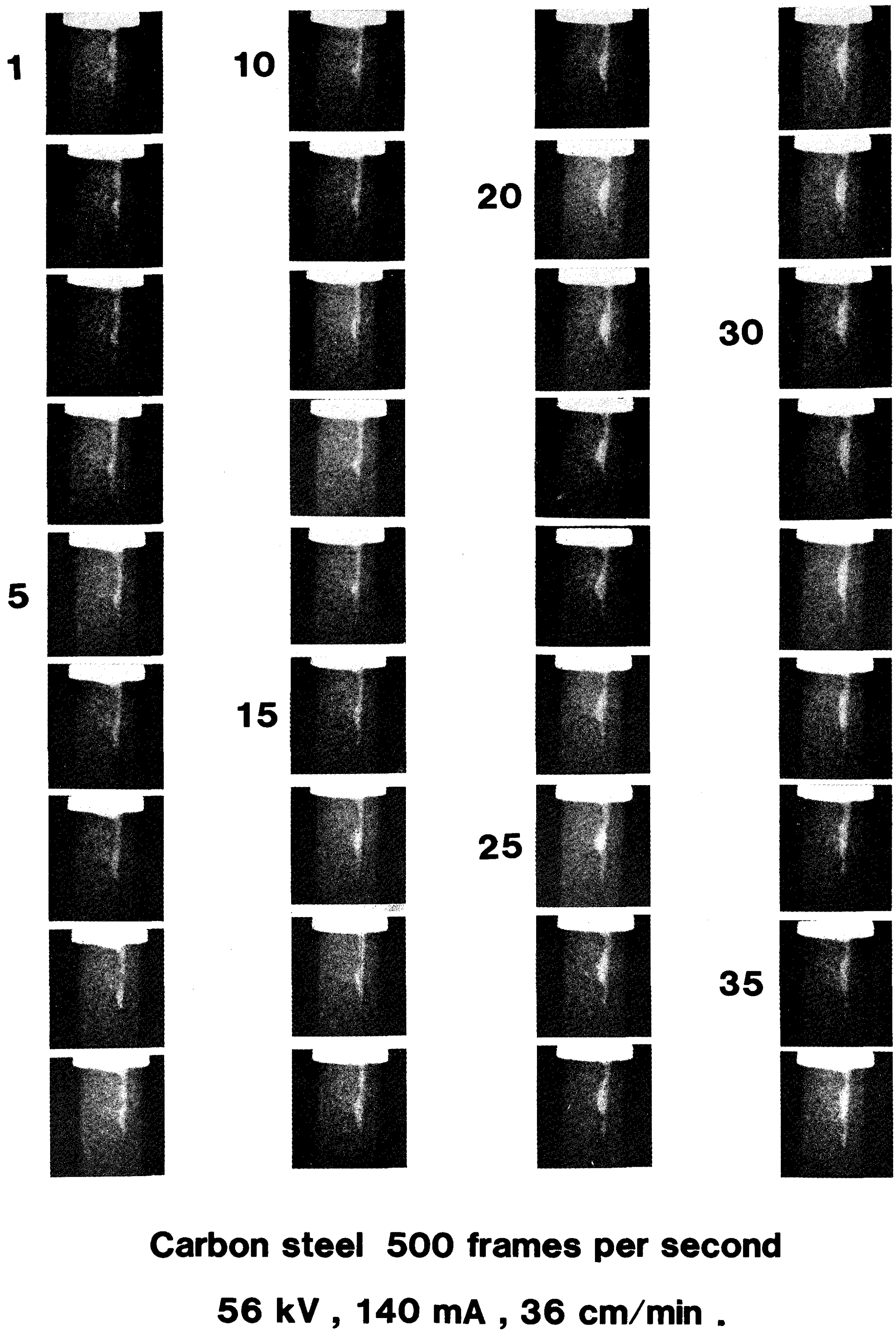


Fig. 2 High speed photographs of beam hole (a)

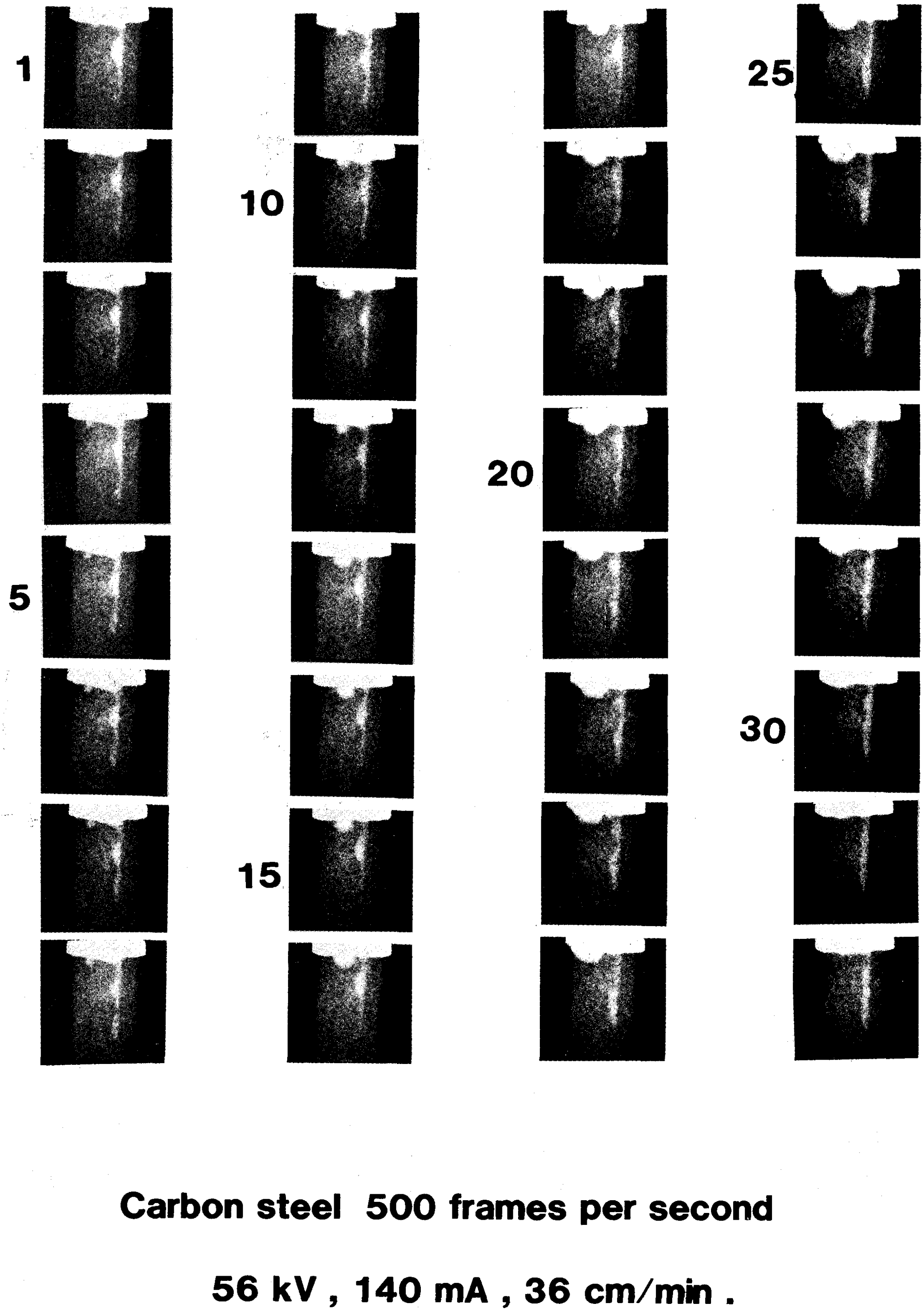


Fig. 3 High speed photographs of beam hole (b)

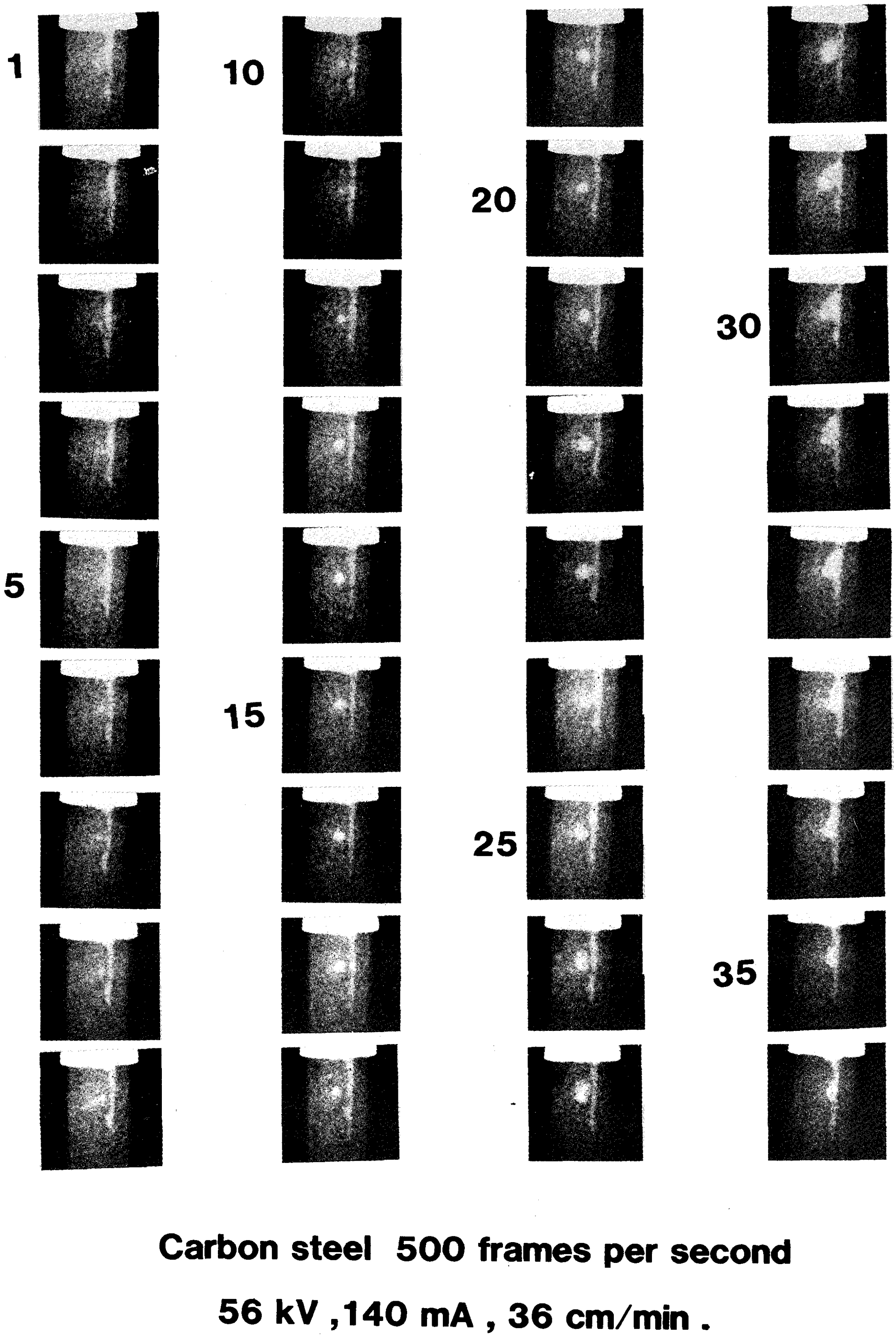


Fig. 4 High speed photographs of beam hole (c)

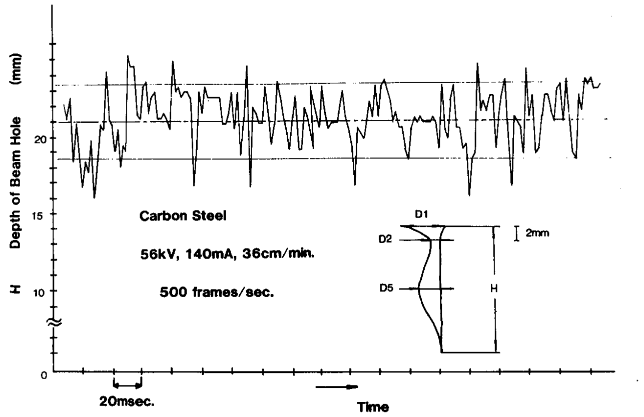


Fig. 5 Film analysis on depth of beam hole

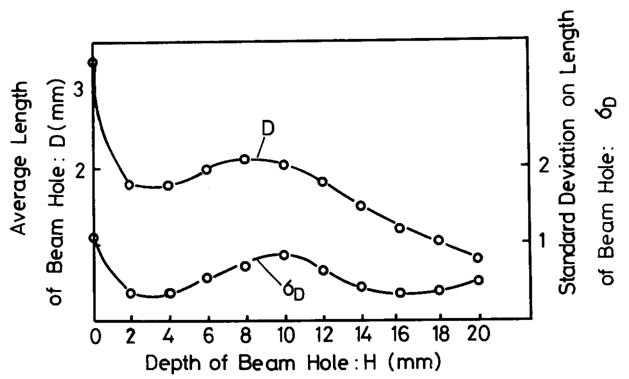


Fig. 6 Average value and standard deviation for length of beam hole

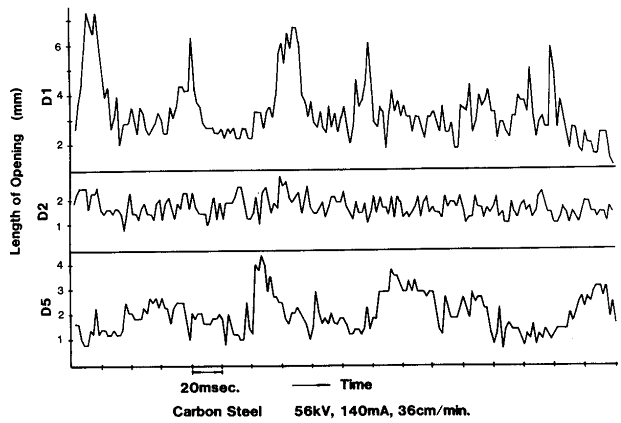


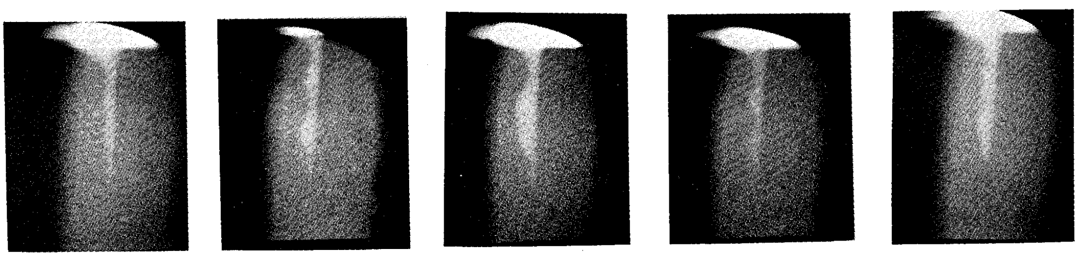
Fig. 7 Film analysis on length of beam hole

(2) occurrence of bulge in bottom or middle of beam hole
(3) growth of bulge
(3') split of bulge
(4) uniformly thick beam hole

Photographs corresponding these stages are shown in **Fig. 8**.

4. Conclusion

The behaviour of beam hole in carbon steel can be observed dynamically by transmission x-rays and high speed movie.



(1) (2) (3) (3') (4)

Fig. 8 Typical shapes of beam hole

there is small fluctuation on the position of 2 mm under surface. Furthermore, the phase between on surface and on middle depth is different. After the growth of the bulge on middle depth, length of beam hole on surface increases.

Summing up these facts, following process may be proposed.

(1) uniform and thin beam hole

Many bubbles are seen in molten pool. The "bulge" frequently ocurres on rear wall of beam hole. It grows gradually in size and shape and then beam hole becomes uniformly thick. These process brought about periodically.

References

1) Y. Arata, E. Abe and M. Fujisawa: A Study on Dynamic Behaviour of Electron Beam Welding (Report I)-The Observation by a Fluoroscopic Method–: Trans. JWRI, Vol. 5 (1976), No. 1, p. 1-9.
2) Y. Arata: What Happens in High Energy Density Beam Welding and Cutting: 1980.
3) Y. Arata, N. Abe and S. Yamamoto: Tandem Electron Beam Welding (Report III): Trans. JWRI, Vol. 9 (1980), No. 1, p.p. 1-10.
4) Y. Arata, N. Abe and E. Abe: Tandem Electron Beam Welding (Report IV): Trans. JWRI, Vol. 11 (1982), No. 1, p. 1-5.
5) Y. Arata, N. Abe, H. Wang and E. Abe: Tandem Electron Beam Wedling (Report V): Trans. JWRI, Vol. 11 (1982), No. 2, p. 1-6.