Application of the Surface Technology to the Elucidation of Various Welding Defects†

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Abstract

In welding, the chemical reaction in molten pool is mainly influenced by light elements. The ion probe microanalyzer (IMA) is a useful device for the determination of light elements such as hydrogen, carbon, nitrogen, phosphorus and sulfur. IMA was applied to clarify a bright band formed in flash welding and the behaviour of carbon in the case of gouging with carbon electrode. Carbon behaviour obtained with IMA was in a good agreement with that obtained with EPMA.

1. Introduction

When ion beams (primary ion) bombard solid materials, the atoms situated near a surface of the material are sputtered and some of them are ionized (secondary ion). The ion probe microanalyzer (IMA) is composed of the following operations, that is, it can ejects secondary ions from a surface of solid sample by argon ion source and analyze them through a mass spectrometer. IMA is a useful device for the chemical analysis of solid samples, surface analysis including thin-film, depth analysis, isotope analysis and it has high sensitivity as for determination of ppb impurities.

In welding, the chemical reaction in molten pool is mainly influenced by light elements. If the quantitative analysis of various elements is established by using IMA, the behaviours of them in the weld metal will be clarified. Especially, this means has advantage to clalify the determination of light elements such as hydrogen, carbon, nitrogen, phosphorus and sulfur.

In this paper, we have carried out the clarification of a bright band formed in flash welding with IMA. In addition, it was applied to investigate the behaviour of carbon in the case of gouging with carbon electrode. From the quantitative point of view, the results obtained with electron probe microanalyzer (EPMA) was compared with the results from IMA.

2. Decarburization in flash-butt welding

The decarburization at welded joints in flash-butt welding is a common phenomena. At present, there is no recognized opinion regarding the mechanism of bright band formation. Okada, Kihara, Onimaru and Wakabayashi[1] have compared the results obtained from the flash-butt welding in the atmosphere of argon or oxygen. They concluded that the influence of oxygen should be considered as a cause of decarburization, and the decarburization can be prevented by welding in oil. Forostovets[2] has summarized previous opinions regarding bright band formation as follows:

1) The bright band consists of ferrite.
2) According to spectroscopic analysis, the bright band has less carbon content than bulk material. This phenomena becomes remarkable when high carbon steel is used.
3) The bright band is brittle.

Andou, Nakata and Fukui[3] have obtained similar results from the measurement of EPMA and metallographic examination. They have concluded that the bright band is formed from the decarburization, but there still exist many unresolved problems in the bright band formation. Žák and Ryš[4] pointed out that there are three groups of bright band formation mechanism until now.

1) Ferrite layer increases owing to oxidation of carbon by oxygen in air or oxidized layer. However, from the fact that there appear decarburization region in the periphery of the welded zone, it is unable to interplet from the following thought that decarburization can be controlled by diffusion process only, because there exists unsufficient time for diffusion.
2) Zatinsky has showed the bright band is not by decarburization but a carbon content becomes higher than bulk material because of overheating and a

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thermal gradient existing in the weld area. He supposes that the ferrite at the weld line can be oversaturated by carbon as the result of the perfect homogenization of austenite at high overheating temperature and quick cooling.

3) The weld zone is really decarburized as a result of the liquid extrusion from the contact area to the fin.

In order to clarify what thoughts above described are reasonable, the interesting examination was performed. They indicated that bright band does not appear without pressure. Appearance of bright band is independent on the existence of slag or oxide. However, they described that it is impossible to explain bright band structure with only decarburization.

3. Experimental procedures and results

3.1 Flush-butt weld

1) sample: flash-butt welded steel "SS41" grade with bright band[3].
2) operating conditions of IMA
   primary ion beam diameter: 300 μm
   ion source: Ar^+

In order to eliminate any possible surface contamination effects, at first time, the sample is bombared for 7~15 minutes by argon ion beam of 1 mm diameter.

Measurement is performed with small beam (300 $\mu m\phi$) and for about one minute the sample is sputtered by large beam (1 $mm\phi$) to avoid the influence of crater shape. To check reproducibility, the procedures above described are repeated ten times. The ratio of the output intensity of each secondary ion to Fe^+ is shown in **Fig. 1.** Carbon in the bright band decreases compared with HAZ. There are no apparent differences about Mn, H and N. The EPMA result is shown in **Fig. 2.** It gives same result with IMA.

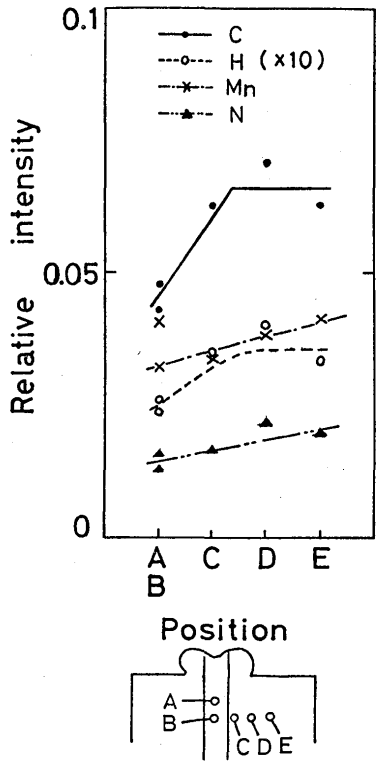

Fig. 1. Output intensity of each secondary ion to Fe^+, flash-butt welded steel. (IMA)

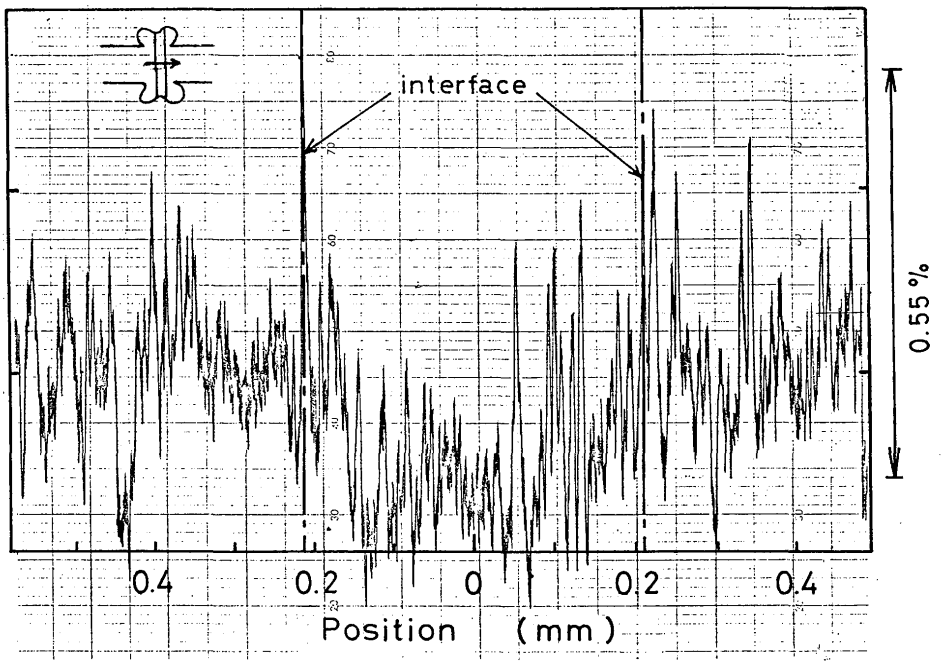

Fig. 2. Carbon distribution in flash-butt welded steel. (EPMA)

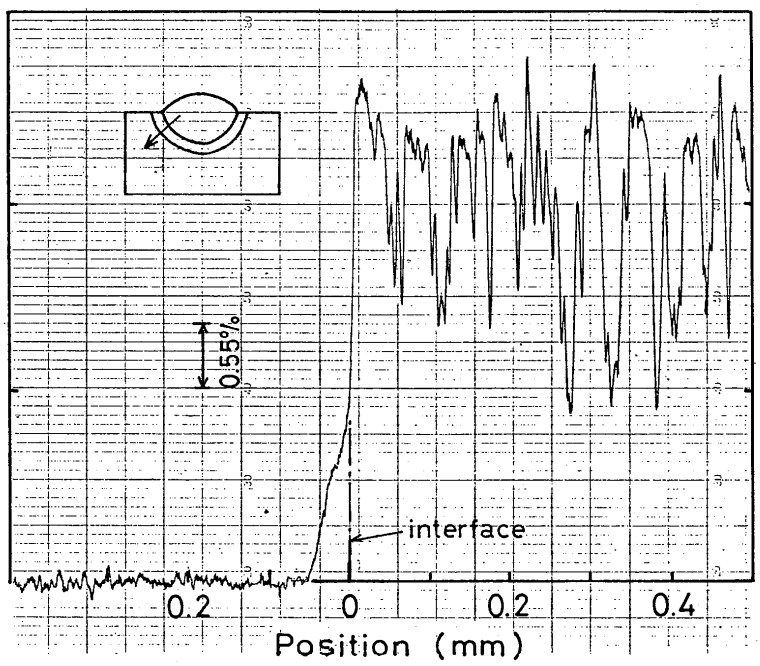

Fig. 3. Carbon distribution in the case of gouging with carbon electrode. (EPMA)

In EPMA measurement, iron intensity remain constant in every regions, but IMA measurement showed the variation of iron intensity in bright zone and HAZ.

3.2 Gouging

1) sample: SS41
2) operating conditions of IMA are same with Section 3.1.

Photo. 1 shows melted area and HAZ. Martensite appears in the boundary between melted area and HAZ. The melted area has more than 1.5 pct carbon from the EPMA result (**Fig. 3**). The result using IMA is shown in **Fig. 4.** The tendency of variation of carbon content is same as the result by EPMA. Other elements tend to decrease in melted area. On the other hand, there are a few voids in melted area. The change of relative intensity of carbon and oxygen on the surface of the void with the change of the sputtering time is shown in **Fig. 5.** The peculiar behaviours are observed. It is caused by poor flatness of the crater at the surface of void. Alder, Kennedy and Satkiewicz[5] have obtained a similar result about hydrogen distribution in the vicinity of the void in the titan specimen electron beam welded. However, we can not agree their

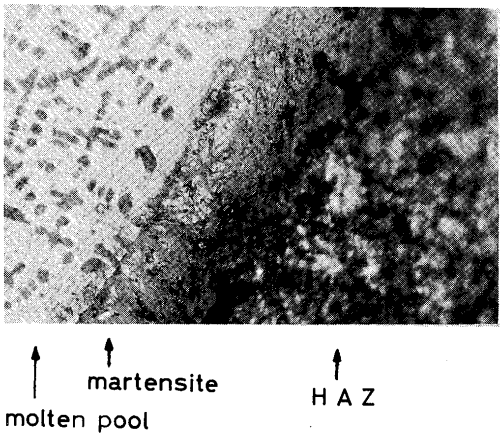

Photo. 1. Melted area and HAZ (×400)

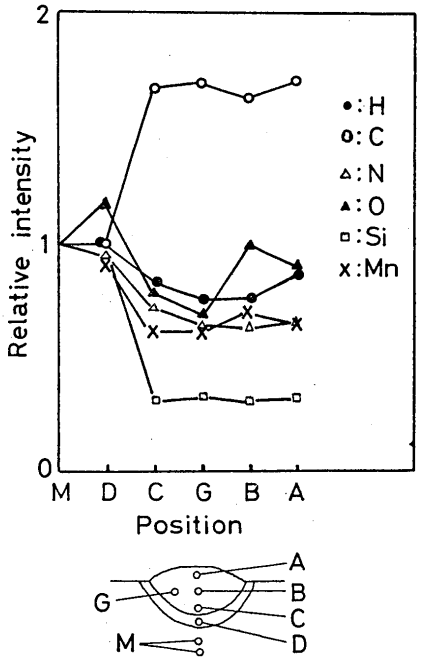

Fig. 4. Output intensity of each secondary ion to Fe^+ in the case of gouging with carbon electrode. (IMA)

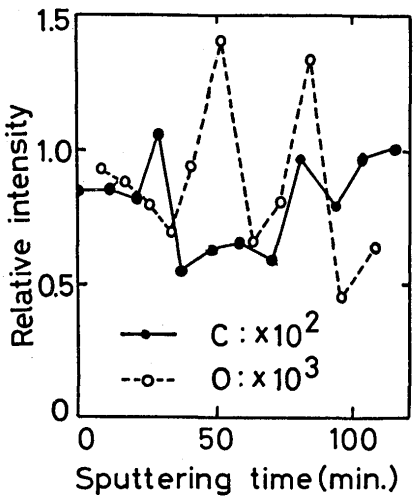

Fig. 5. Change of relative intensity of carbon and oxygen to iron on the surface of the void vs. the sputtering time.

explanation of extraordinarily behaviour of hydrogen in voids.

4. Conclusions

In this paper, we have focussed to the solution about carbon behaviours in flash-butt welding and partially melted steel plate from the gouging by carbon electrode.

The result of carbon behaviour obtained with IMA is in a good agreement with that obtained with EPMA. In IMA method, secondary ion intensity depends on the vacuum in the analyzer and shape of crater. Therefore, careful attention must be paid to obtain quantitative analysis.

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References

1) M. Okada, H. Kihara, S. Onimaru and R. Wakabayashi: J. Japan Welding Society, **19** (1950) p. 90. (in Japanese)
2) B. A. Forostovets: automatic W., (1968) p. 18.
3) K. Andou, S. Nakata and I. Fukui: J. Japan Welding Society, **40** (1971) p. 137. (in Japanese)
4) J. Žák and P. Ryš: Welding J. Supplement, **51** (1972) p. 272-s.
5) P. N. Alder, J. Kennedy and F. G. Satkiewicz: ibid., **52** (1973) p. 180-s.