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Author(s)	Kikuchi, Yasushi; Matsuda, Fukuhisa; Ikeda, Hiroki
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Effect of Ar or He Pressure on the Formation of Fine Metal Powder by the MIG Arc Melting Process†

Yasushi KIKUCHI*, Fukuhisa MATSUDA** and Hiroki IKEDA***

Abstract

The formation process of fine metal powder has been studied by means of the arc melting (depositing) process.

The high-pressure arc melting process is a useful process to produce fine metal powder. The MIG arc melting process and a pressurized arc atmosphere are used. The results obtained using the MIG arc process and the effects of Ar and He pressure on the generation of fine metal powder are reported in this paper. He-gas is effective in generating fine powder. The high pressure MIG-He gas process is superior to the high pressure MIG-Ar, high pressure TIG-He and TIG-Ar +H2 mixture gas process for the generation rate of fine powder.

Characterization of the fine metal powders produced is also described.

KEY WORDS: (Fine Powder) (Arc Melting) (High Pressure Arc Welding)

1. Introduction

Production of high purity fine metal powders by means of arc melting is a useful physical process but it is said that production efficiency, such as production rate, of fine powder is not so good.

Improvements to the fine metal powder production process by means of arc melting are required. The previous work has studied the effect of Ar and He arc atmosphere on the formation of fine mild steel powder by means of TIG arc melting method and the results were reported a previous paper.[1] Also, the effects of Ar or He pressure on the formation of fine mild steel powder were discussed.

The present work investigated the production of fine mild steel powder by means of the high pressure MIG arc melting depositing process. The effect of Ar or He pressure on the formation efficiency of fine powder was also estimated.

Characterization of the fine mild steel powder was carried out by X-ray diffraction, SEM and TEM observation. Size distribution of the fine powder was also determined.

In this paper, the results obtained by the MIG arc process and comparative discussions of the results on TIG and MIG processes are reported.

2. Experimental procedures

A welding apparatus[1] designed to maintain a controlled high pressure arc atmosphere was used.

The atmospheric pressure in the chamber can be changed from about 15Pa to 6.5MPa.

Drooping characteristics and electrode positive conditions were used. Bead on plate deposits were prepared with a direct current power source which had OCV of 80V-1000A.

Melting (bead on plate depositing) parameters used in this experiment were as follows: Melting Current, I=300A, base metal travel speed; 0.83mm/S, distance from base metal surface to consumable electrode tip; approximately 15mm.

In order to collect the fine metal powders produced, a stainless steel dish (diameter 150mm) was set to around the welding torch as shown in the previous paper.[1] The weight of the dish was measured before and after MIG

† Received on Nov. 25, 1994
* Associate Professor
** Professor
*** Graduate Student (Presently Sanyo Special Steel Co., Ltd)

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arc deposition and the generation rate of fine metal powder was calculated.

The chamber was evacuated until to about 133Pa and then Ar or He gas was introduced up to the test pressure before the MIG arc was started.

Chemical composition of base metal and electrode (1.6mmϕ) is shown in **Table 1**.

Table 1 Chemical compositions of base metal (SS41) and electrode wire (YM-26, 1.6mmϕ) used (mass%)

Material	C	Si	Mn	P	S
SS41	0.13	0.21	1.13	0.019	0.006
YM-26	0.07	0.81	1.51	0.015	0.008

3. Experimental Results and Discussion

3.1 Formation of fine metal powder by the MIG arc in an Ar atmosphere.

The effect of ambient pressure on the generation rate of fine powder was determined.

The relation between generation rate (G.R.) and ambient pressure of the arc atmosphere is shown in **Figure 1**. OMpa represents atmospheric pressure. The G.R. increases with increasing Ar pressure. The results obtained under low pressure differ from those reported on TIG arc process. An increase[1] in the G.R. of fine powder under vacuum does not observe to MIG arc process.

The G.R. of fine powder by MIG arc process is superior to that by the TIG arc process.

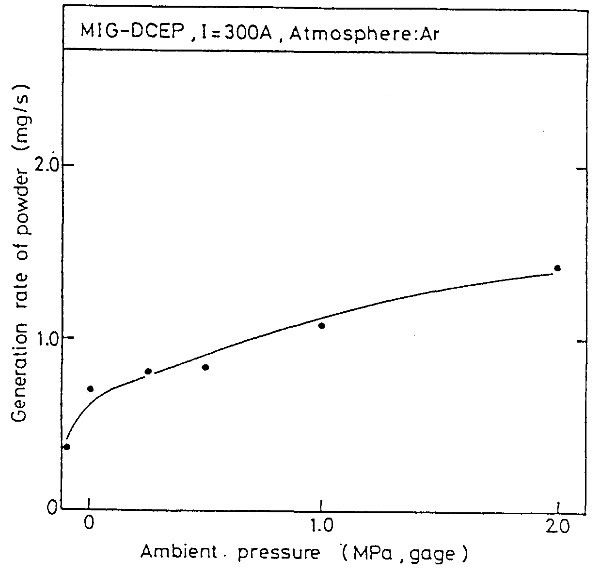

Fig. 1 Effect of ambient pressure on generation rate of powder

Fine powder was analyzed by the X-ray diffraction method. Results are shown in **Figure 2**. and the fine powder was identified as α-iron with iron oxide included.

In order to determine the shape and size distribution of fine powder, transmission electron microscope (TEM) observation was used.

TEM photographs are shown in **Figure 3**. With these conditions the size of fine metal powders were not uniform, diameters distributing between 5~6 nm to several hundreds nm. Spherical and polygon sharp

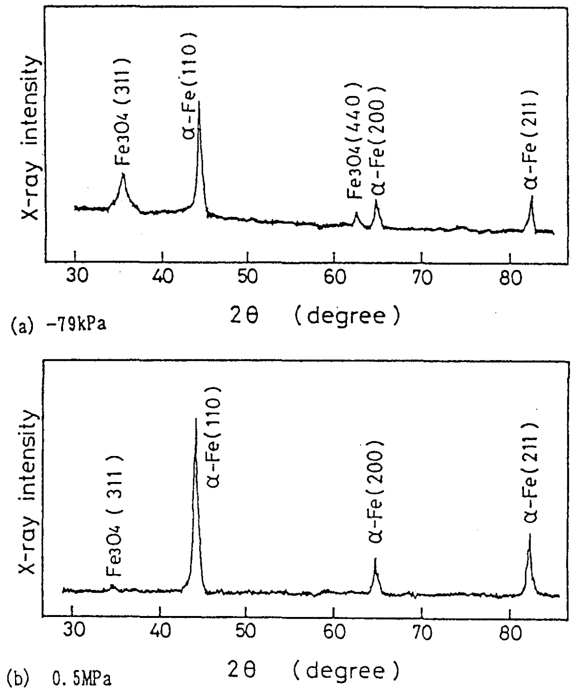

Fig. 2 X-ray diffraction pattern of fine particle (powder)

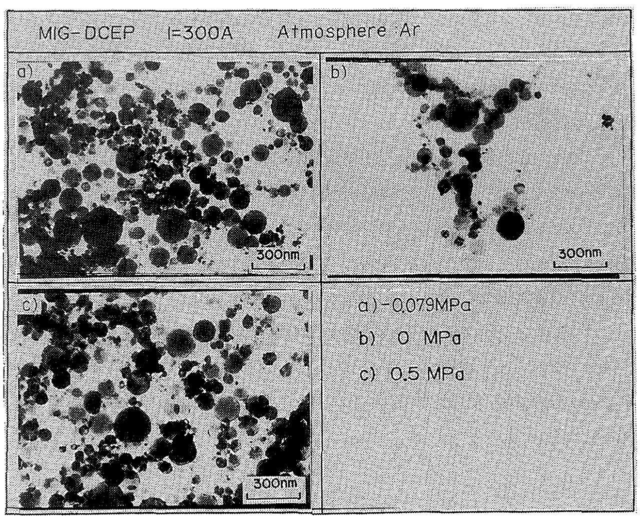

Fig. 3 Morphologies of fine particle (powder) by TEM

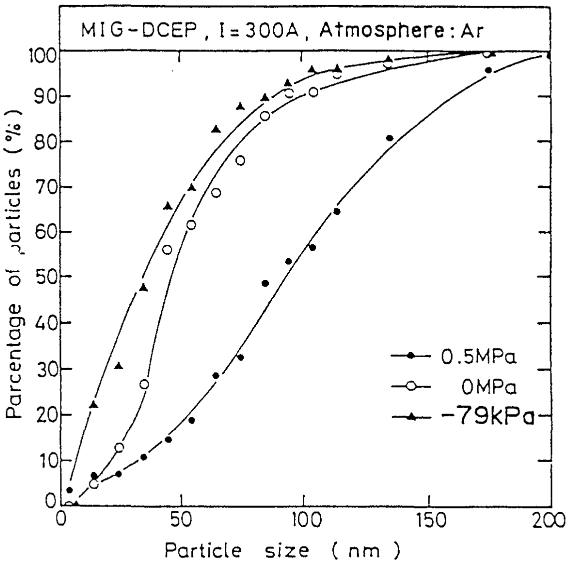

Fig. 4 Cumulative size distribution graph showing comparision of fine particle sizes made by MIG-Ar

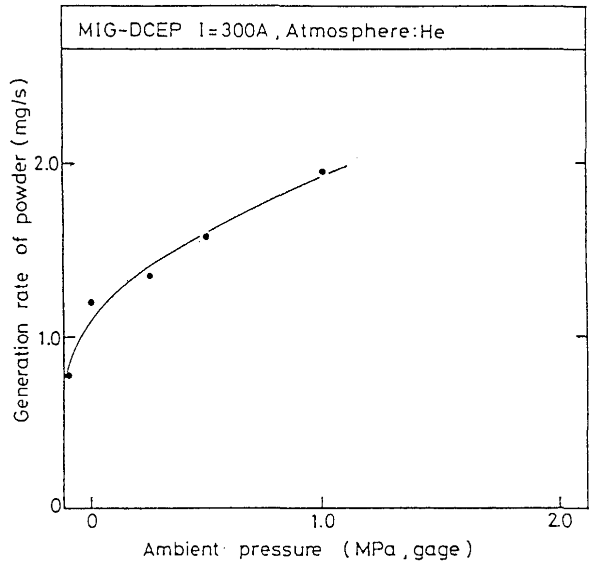

Fig. 5 Effect of ambient pressure on generation rate of powder

powder were observed. The fine powder had a magnetic nature with particles adhering to each other in chains.

Based on the TEM results, the relation between cumulative size distribution and ambient pressure was considered. **Figure 4** shows a comparison of cumulative percentage of particles and particle size. The distribution of particle size has a wide range from several nm to hundreds of nm in diameter. With increasing pressure, the diameter of particles became slightly bigger.

3.2 Formation of fine metal powder by the MIG arc in a He atmosphere

The effect of He on the formation of fine metal powder was investigated. Helium is an inert gas like argon and it is expected to increase the temperature of the MIG arc.

The relation between generation rate (G.R.) and ambient pressure is shown in **Figure 5**. Depositing conditions are the same as for Ar the atmosphere. A similar increase with pressure seen in Ar is also observed but in He, G.R. is more than double that in Ar at 1MPa.

X-ray diffraction was used for analysing the powder component obtained in a He atmosphere. **Figure 6** shows the analytical result which reveals α-iron and iron oxide.

Figure 7 shows the TEM photographs where the size of fine particles is distributed non-uniformly from several

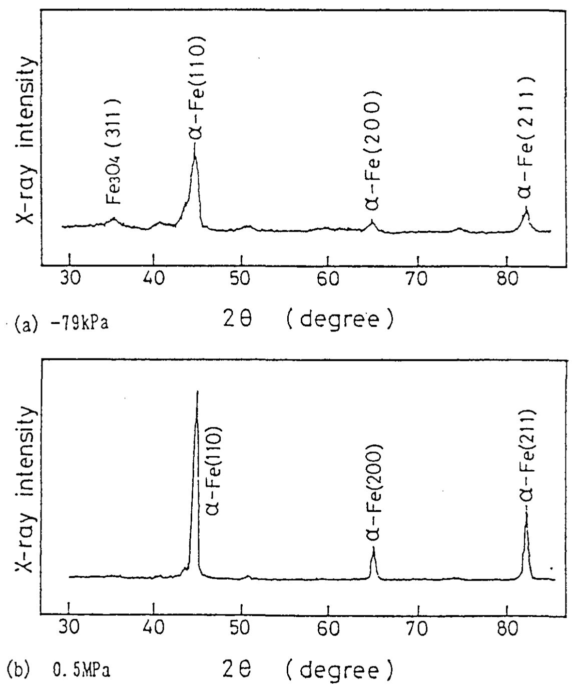

Fig. 6 X-ray diffraction pattern of fine particle (powder)

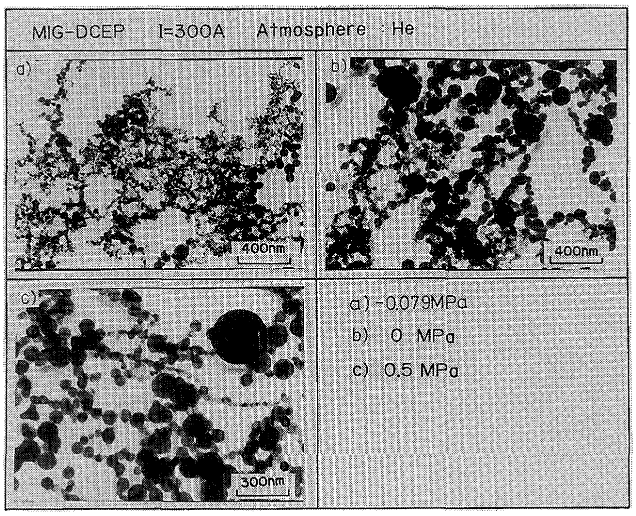

Fig. 7 Morphologies of fine particle (powder) by TEM

nm to hundreds of nm. Particle size also became slightly bigger with increasing ambient pressure. By analysis the electron diffraction pattern for iron oxide is confirmed.

The relation between size, cumulative distribution and ambient pressure was considered. **Figure 8** shows a comparison of cumulative percentage of particle and particle size. A growth in particle size was also observed when the ambient pressure was raised.

As for the Ar atmosphere, arc voltage rose when ambient pressure was increased but by a larger amount in the case of He.

Figure 9 shows the comparison of He and Ar atmosphere heat input change curves as a function of pressure. Heat input was calculated by equation previously reported.[1] It was found that the calculated heat input in the He atmosphere was higher than that of the Ar atmosphere.

Arc temperature is an important factor in the formation of fine metal powder by the arc melting process.

It is reported that the temperature of arc column in a He atmosphere is higher than that of an Ar atmosphere.[2]

For these reasons, it can be proposed that MIG arc process in a He atmosphere is superior for the generation of fine metal powder.

The effects of gas type and melting process on the generation rate of fine metal powder as a function of ambient pressure are summarized in **Figure 10**.

From this figure, the MIG-He process appears superior for the generation of fine powder compared with a number of other types of process.

The size distribution of fine particles from the MIG-He arc process and from the gas evaporation method[3] are compared in **Fig. 11**, which shows that at OMPa the

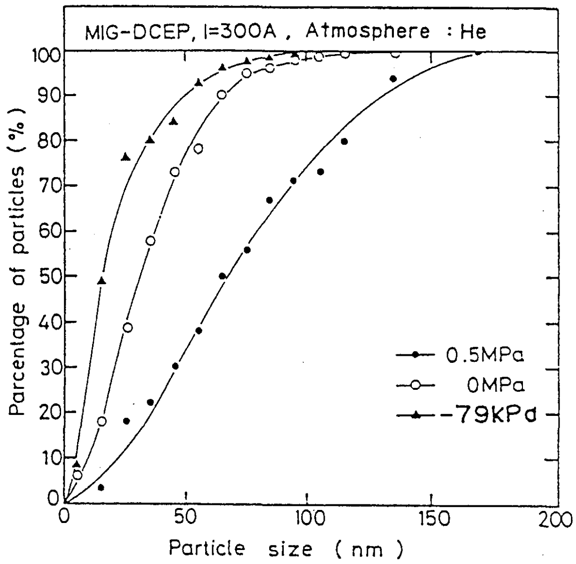

Fig. 8 Cumulative size distribution graph showing comparision of fine particle sizes made by MIG-Ar

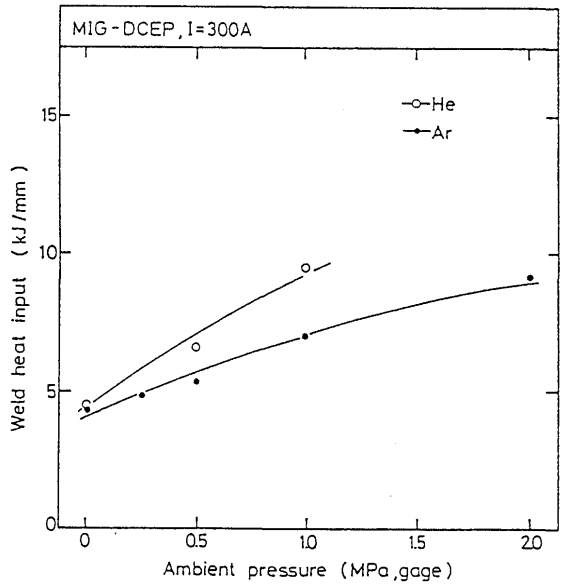

Fig. 9 Relationship between ambient pressure and weld heat input

methods are similar.

The generation rates of fine metal powder by the MIG-He process and other gas evaporation methods [3)-4)] are compared in **Figure 12**. Uda[3] and Okada[4] have reported on the TIG-Ar+H2 mixture gas method and their results are included.

It can be seen from this Figure, that the MIG-He process is almost equal to others at ambient pressure of 0.5MPa. By increasing the ambient pressure, the MIG-He process becomes superior to most other processes for the generation of fine powder.

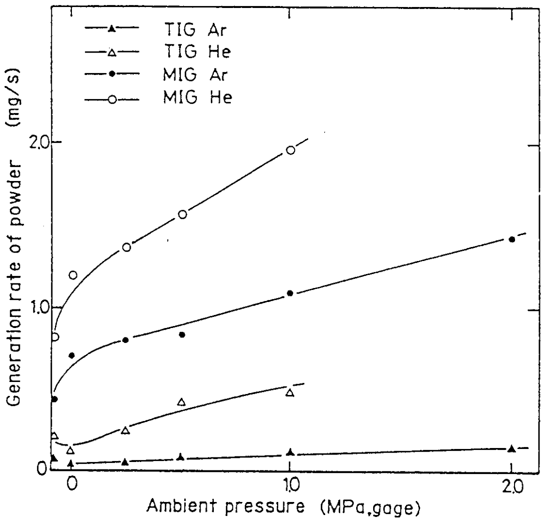

Fig. 10 Effect of ambient pressure on generation rate of powder

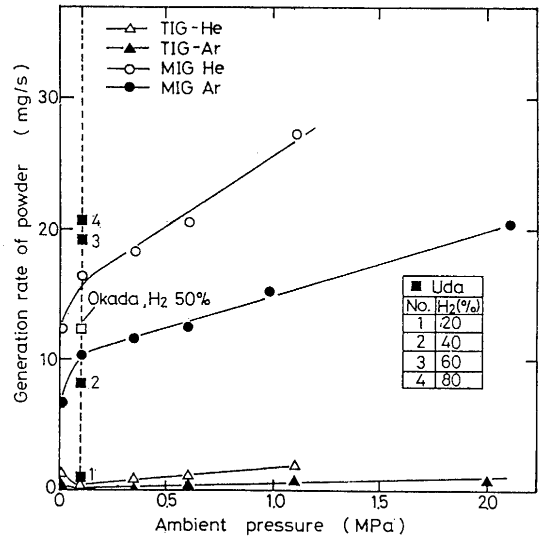

Fig. 12 Comparision of generation rate of fine metal powder made by MIG, TIG process and other gas evaporation method

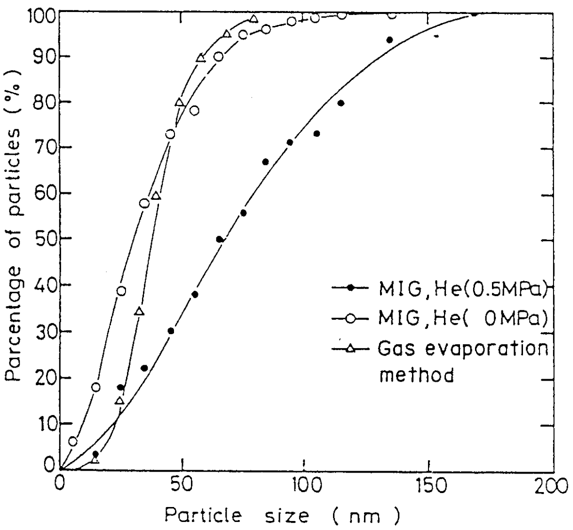

Fig. 11 Cumulative size distribution graph showing comparision of fine particle sizes made by MIG-He and gas evaporation method

4. Conclusions

The main results obtained in this study are summarized as follows:

(1) The MIG-He gas atmosphere is more effective in forming fine metal powder compared to the MIG-Ar gas atmosphere and the generation rate of fine metal powder in both gases increases with increasing pressure.

(2) Fine powder is identified as α-iron with iron oxide (Fe_3O_4)

(3) The distribution of particle size has a wide range from several nm to hundreds of nm in diameter.

(4) With increasing pressure particle diameters become slightly larger.

(5) With ambient pressure >0.5MPa, the MIG-He process has superior generation rate of fine powder than MIG-Ar or other evaporation methods.

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