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SA 508 Low Alloy Steel for Reactor Pressure Vessel via Powder Metallurgy

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1. Introduction

As one of the alternate manufacturing routes of the small modular reactor (SMR) vessels powder metallurgy (PM) is reckoned one effective fabrication method. Powder metallurgy followed by hot isostatic pressing (HIP) is the main fabrication process in this route, and this is widely understood as an effective and time saving fabrication method. PM parts are widely known as more uniform in microstructure and consequently in various properties, i.e. these parts show isotropic behavior in tensile, fracture or fatigue mode. Although PM route may not be very beneficial to mass production compared with the conventional one including ingot casting, hot forging and rolling, it seems more relevant and effective way for manufacturing the SMR vessels and the like.

In this study a preliminary experiment has been done using some archive materials of SA 508 low alloy steel. SA 508 Gr. 3 low alloy steel powders was prepared by utilizing the backup material for the intermediate shell of a domestic PWR vessel. Samples were prepared by HIP process following two different powder preparation methods, respectively. Pore fraction of samples were estimated, and the macro- and micro-structure are investigated.

2. Methods and Results

Two SA 508 low alloy steels of which the chemical composition is shown in Table I, were exploited in this study; one was Gr. 3 steel from the backup material for the intermediate shell of a domestic PWR vessel that had been kindly provided by Doosan Heavy Industries, and the other was an experimental Gr. 4 forged steel bar prepared by the laboratory. These two steels were re-melted and atomized to produce the steel powders, respectively and the samples were prepared by HIP process.

2.1 Preparation of Steel Powders and HIP Process

Low alloy steel powders were prepared by the vacuum induction melting (VIM) inert gas atomization method and electrode induction gas atomization (EIGA), respectively. Round rod electrodes of low alloy steel with 30 mm of diameter were used for the EIGA process. This technique is expected to produce cleaner steel powders because the crucible which is one major source of contamination during melting is inherently eliminated during the process. An example of SEM observation of Gr 3 steel powders by EIGA process is illustrated in Fig. 1 which shows most powders are in spherical shape.

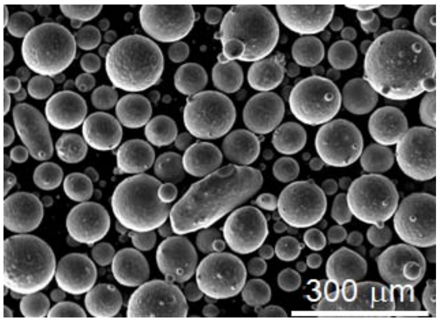

Fig. 1 SEM Micrograph of SA 508 Gr. 3 Steel Powders by EIGA Process (DAT Advanced Materials Co. Ltd.)

The steel powders under 200 micrometers in diameter were collected by sieving, and used for the further sample preparation procedures. Steel powders were HIP processed at 1050°C under the pressure of 105 MPa following the canning and degassing. HIP samples from Gr. 3 and Gr. 4 steel powders by using two separate powder preparation methods are as follows;

	Gr. 3	Gr. 4
Atomization	A	B
EIGA	E	F

2.2 Pore Evaluation and Microstructure Investigation

Round rods with 1.5 mm in diameter were sampled at the center portion in height and in diameter of the cylinder-shaped HIP samples, and the pore distribution within the rod specimens were evaluated by 3D X-ray Tomography Microscope System (Zeiss, Xradia 620 Versa). The volume fraction (%) of each specimen was as follows:

A	0.031	B	0.012
E	0.006	F	0.006

The volume fractions of pores in HIP samples from EIGA powders appear significantly lower than those from gas atomization powders. The effect of additional HIP at a higher temperature is being pursued.

Table I: Chemical Composition of Two SA 508 Low Alloy Steels (wt%)

	C	Mn	Ni	Cr	Mo	Si	P	S	V	Cu	Fe
Gr. 3	0.20	1.34	0.89	0.20	0.50	0.20	0.007	0.002	0.002	0.02	Bal.
Gr. 4	0.18	0.33	3.44	1.80	0.49	0.21	0.003	0.002	0.003	0.01	Bal.

3. Summaries

SA508 Gr.3 and Gr. 4 low alloy steel samples were fabricated through the route of powder metallurgy including HIP of gas atomization powders and EIGA powders, respectively. Round rod specimen with 1.5 mm diameter was taken out at around the center of each cylindrical HIP sample, and the porosity was measured by 3D x-ray tomography technique. HIP samples from EIGA steel powders showed significantly lower porosity than those from the gas atomization steel powders, and demonstrated its potential for the better mechanical properties.

REFERENCES

[1] D. Gandy and M. Albert, Program on Technology Innovation: Small Modular Reactor Vessel Manufacture and Fabrication, Phase 1 - Progress (Year 3), Electric Power Research Institute, Inc., 2021.
[2] M.C. Kim, J.H. Yoon, K.J. Choi, J.M. Kim, and J.H. Hong, Development of High Strength Low Alloy Steel for Nuclear Reactor Vessel, KAERI/RR-3646/2012.