APPLICATION OF AUSTENITIC STAINLESS STEELS FOR LIQUID HYDROGEN VESSELS

Motonori Tamura
The Japan Research and Development Center for Metals,
1-5-11 Nishishinbashi, Minato-ku, Tokyo 105-0003, Japan

Introduction

Liquid hydrogen has been expected to be the most effective energy carrier and storage medium. Cryogenic materials working group was organized in 1993 to pick up and solve the issues of the materials to be used for the liquid hydrogen vessels [1, 2]. Austenitic stainless steels of type 304L and 316L have been considered as the most promising candidates because of those good strength and toughness. But the conventional welded joints of those materials still require high toughness at cryogenic temperature. In the present paper, some new welding methods are applied to improve the mechanical properties of their welded joints. And effect of hydrogen doping and hydrogen environmental embrittlement of stainless steels is also studied.

Results and discussion

Table 1 shows the chemical compositions of the candidate materials.

Figure 1 shows the effect of test temperature on Charpy absorbed energy of base metal and weld metals of type 316L stainless steel. Charpy absorbed energy of the conventional (TIG, SAW and MIG) weld metals at the temperatures below 77K were much lower than those of the base metals. But this was greatly improved by applying reduced pressure electron beam (RPEB) welding, which was recently conducted at TWI, UK. RPEB welding is considered one of the optimum welding procedure.

The mechanical tests for the hydrogen doped stainless steels were also conducted. About 10ppm of hydrogen was charged by exposing the materials to the high pressure (9.8MPa) hydrogen gas atmosphere at 573K for 100h. It was recognized that the influence of hydrogen doping of this level against mechanical properties of the doped materials was very small. But further investigation of the relation between doping level and mechanical properties would be necessary.

Some kinds of stainless steels are known to show the hydrogen embrittlement in gaseous hydrogen. Since the ceilings and the walls on upper portion of the actual liquid hydrogen vessels may be exposed to the environment with which the embrittlement occurs, it is an important subject to be examined for stainless steels.

Figure 2 shows the effect of test temperature on the relative reduction of area ($\varphi_{Hydrogen}/\varphi_{Helium}$) of the type 304 and 316 stainless steels in hydrogen and helium gases of 1.1MPa. The degree of HEE can be estimated from the decrease in the relative reduction of area. It is shown that HEE tends to increase (decrease in the relative reduction of area) with decrease in temperature and reaches to the maximum at about 200K.

HEE in type 304 steels is remarkably observed than in type 316L steels, and HEE behavior varies according with the difference in chemical compositions in the case of type 316 steels. On the other hand, HEE is slightly observed in type 316L and no HEE is found in type 316LN. These are considered to be caused by the difference in the tendency to form strain-induced martensite.

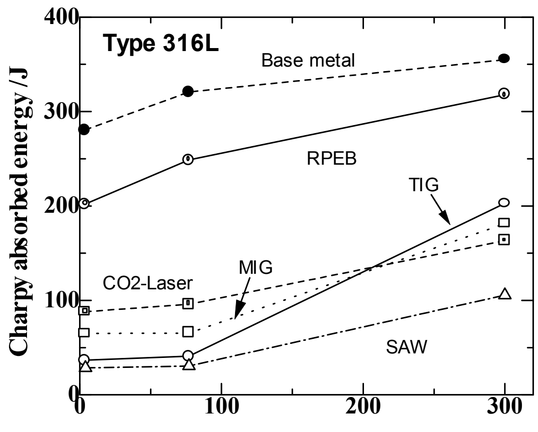

Fig. 1 Effect of temperature on Charpy absorbed energy of base metal and weld metals of type 316L steel

Table 1 Chemical composition of test materials (mass%)

	C	Si	Mn	P	Ni	Cr	Mo	Cu	N	O
Type304L	0.02	0.44	0.84	0.03	9.18	18.27	0.13	0.27	0.27	0.004
316L	0.02	0.53	0.85	0.02	12.19	17.44	2.09	0.21	0.21	0.002
316LN	0.01	0.46	1.27	0.02	10.50	17.50	2.83	0.21	0.13	0.002

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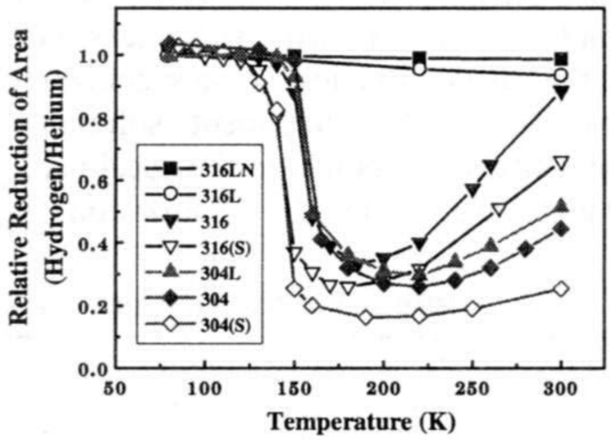

Fig. 2 Effect of temperature and chemical composition on the relative reduction of area in 1.1MPa H_2 and He

Conclusions

Mechanical properties of base metals and welded joints of type 304L and 316L austenitic stainless steels were examined at the temperatures between 4K and ambient temperature including 20K, liquid hydrogen temperature. It was found that fracture toughness of the weld metals at cryogenic temperatures was remarkably improved by using RPEB welding. HEE in type 304 steels is remarkedly observed than in type 316L steels.

References

1. T. Horiya, et al. : Proc. of Hydrogen ' 96, Stuttgart, (1996) p.2267
2. S. Okaguchi, et al. : Proc. of 14th World Hydrogen Energy Conference, (2002)