§1. Fabrication and Properties of V-Cr-Ti-Si-Al-Y Alloys by Levitation Melting

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Vanadium alloys, e.g. V-(4-5)Cr-(4-5)Ti type alloys, are considered as promising candidate structural materials for fusion reactor components because of their several preferable characteristics. Modified V-Cr-Ti alloy series containing Si, Al and Y have been developed for oxidation resistance, and these alloys show relatively good tensile properties after neutron irradiation even below 400°C. However, this alloy series was obtained only at laboratory scale, and it is necessary to produce relatively large-scale ingots more than several 10 kg in order to investigate various baseline properties of the alloys including mechanical properties.

The purpose of this study is to establish the fabrication method of high-purity large ingots of V-Cr-Ti-Si-Al-Y type alloys, especially reducing interstitial impurity levels, such as oxygen, nitrogen and carbon.

Three alloys of V-Cr-Ti-Si-Al-Y type were produced by 2.5kg scale levitation melting. Microstructural observations of the resulting ingots were carried out. Three type of blocks, (1) as-melted condition, (2) hot isostatic pressing (HIP) treatment (1200°C, 150MPa, 2hr) following levitation, (3) arc melting following levitation were cold-rolled or warm-rolled.

Table I shows the chemical composition at various position of the 2.5kg ingots produced by levitation melting. Oxygen contents decreased with increasing yttrium contents and were kept below ~180 weight ppm (wppm) over wide region in the ingots. Nitrogen contents in the V-Cr-Ti-Si-Al-Y type alloys were about 100 wppm and carbon contents in all ingots were below 80 wppm, which were as low as those in the starting materials.

On the other hand, inhomogeneous distribution of alloying elements was observed in the ingots, especially for Al and Si in alloy (a). However, this problem of the segregation of Al and Si was solved as shown in alloy (c) by melting in the sequence; Si → Al → Cr → Ti → Y. Because Cr and Ti contents were somewhat higher than the intended composition, except for Cr in alloy (b), it is necessary to further optimize the melting conditions and nominal composition of these alloying elements.

The results of rolling are summarized in Table II. Each alloy is designated by alphabetical symbol ((a)-(c)) corresponding to table I for simplification.

Only the alloy (c) could be cold-rolled even as-melted condition. Because large yttrium inclusions with several μm in diameter were observed at grain boundary in the alloy (a) and (b) which contain about 0.5 wt.% Y, it is necessary to optimize yttrium contents to avoid inclusions and to obtain good workability.

The specimens after HIP treatment (Levi + HIP) could be warm-rolled with smaller aspect ratio. Because of the high cooling rate, it is considered that micro cracks were formed around the inclusions and this led to degradation of workability.

The arc-melted button after levitation melting (Levi + Arc) could be cold-rolled, although chemical composition of the button was almost the same as that of the levitation-melted ingot, which could not be cold-rolled. Large inclusions were observed uniformly distributing in the arc-melted button. In the case of the alloy containing relatively large amount of yttrium, dispersing fine inclusions is considered to be effective in obtaining good workability.

The details of this work will be published in journal of the Japan Institute of Metals, (2000).

Table I Chemical composition of 2.5kg V-Cr-Ti-Si-Al-Y ingots produced by levitation melting in the present study. (Cr, Ti, Si, Al, Y: wt.%, C, O, N: wppm)

Element	Cr	Ti	Si	Al	Y	C	O	N
(a) V-4Cr-4Ti-0.5Si-0.5Al-0.5Y								
Top D/4	4.41	4.73	0.79	0.85	0.49	73	47	112
Mid D/4	4.45	4.35	0.37	0.01	0.36	44	54	97
Bot D/4	4.42	4.39	0.02	0.01	0.39	73	74	104
(b) V-4Cr-4Ti-0.5Y								
Top D/4	3.97	4.49			0.32	72	54	388
Mid D/4	3.96	4.38			0.30	74	56	402
Bot D/4	3.87	3.74			0.20	66	42	378
(c) V-4Cr-4Ti-0.1Si-0.1Al-0.1Y								
Top D/4	4.64	4.98	0.14	0.17	0.02	80	184	108
Mid D/4	4.63	4.84	0.14	0.17	0.02	70	167	102
Bot D/4	4.48	3.95	0.11	0.16	0.04	50	695	102

Top, Mid, Bot: 44, 30, 16 mm from the bottom surface
D/4: ~25 mm from the peripheral surface

Table II Workability of the V-4Cr-4Ti-Si-Al-Y type alloys at ambient temperature or 200°C.

	As-melted			Levi + HIP				Levi + Arc	
Aspect Ratio	1	0.5	0.3	1		0.5		*	
Temp. (℃)	RT			RT	200	RT	200	RT	200
(a)	×		×		×			○	
(b)	×			×			○		
(c)		○							

*Button: 30mmϕ x 8mmt