Journal of the Korean Society of Marine Engineering, Vol.31, No.7, pp. 852~856, 2007(ISSN 1226-9549)

A Study on the Surface Modification of the Super Alloy by Plasma Transferred Arc Overlay Welding Method

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(Manuscript : Received October 27, 2007 ; Revised November 23, 2007)

Abstract : The Plasma Transferred Arc (PTA) overlay welding method is lately introduced as one of the most useful surface overlay method of the engine component. In this paper, the overlay welding method on the Nimonic super alloy was established by the PTA overlay welding process using the same super alloy powder. The characteristics of the Co-base and Ni-base super alloy overlay layers were investigated through the metallurgical, abrasive and cavitation erosion test. The abrasive and cavitation characteristics were investigated at room and high temperature.

Key words : PTA process, Overlay welding, Stellite, Co base super alloy, Nimonic, Wear, Cavitation erosion.

1. Introduction

The worn surface needs to repair through the overlay welding method. Moreover, even the new manufactured engine component needs surface modification by overlay surface layer in order to extend the using life. However, the Nimonic super alloy is known to be difficult for overlay welding due to its hot cracking sensitivity [1], [2].

In this study, using the PTA process, the overlay on the Nimonic super alloy surface was successfully made without hot cracking through the preheating of the substrate metal. The PTA overlay layers on the Nimonic material were made using Co-base and Ni-base super alloy powder. The effect of high Temperature on the overlay layer was investigated. Moreover, the wear and cavitation characteristics of the super alloy overlay layer were inspected and compared with each other. The wear test was conducted at high temperature which is simulated actual using conditions.

2. Experimental procedure.

The substrate materials are Nimonic 80A which is used in combustion engine valve. The overlay materials are 3 kinds of super alloy powders of Inconel 625, Inconel 718 and Stellite 6.

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Table 1 Chemical composition of the super alloy materials

	Composition (mass %)	Cr	Ni	Co	Mo	W	Nb	Ti	Al	Fe	C	other
Substrate	Nimonic 80A	19.5	73.0	1.0	-	-	-	2.25	1.4	1.5	0.05	0.1
Overlay Materials	Inconel 625	21.5	61.0	-	9.0	-	3.6	0.2	0.2	2.5	0.05	
	Inconel 718	19.0	52.5	-	3.0	-	5.1	0.9	0.5	18.5	0.08	0.15
	Stellite 6	30.0	1.0	61.5	-	4.5	-	-	-	1.0	1.0	-

Table 1 shows the chemical compositions of substrate and overlay materials.

The Pin on Disk type wear test was adopted[3] The Pin materials are Stellite 6 which is used in engine valve seat. The Disks are PTA overlay test specimens. The wear amount was evaluated by the weight loss during the test period. The test was conducted at 400℃ high temperature, 200N operating load, 50rpm, 60,000cycles, and the total friction distance is 8300m. The wear amount at high temperature was compared with that at room temperature of same conditions.

The adopted cavitation erosion test was modified ASTM-G32 mode[4], [5]

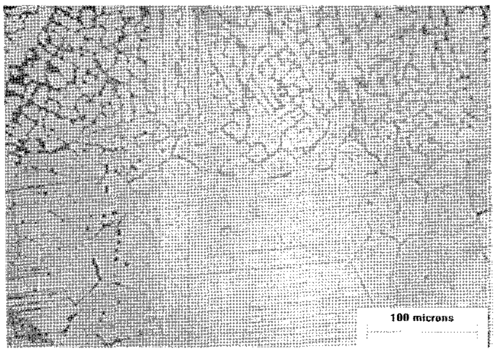
The total test period for each specimen is 48 hr., the amount of cavitation erosion was evaluated from weight loss during the test.

3. Experimental results and discussions

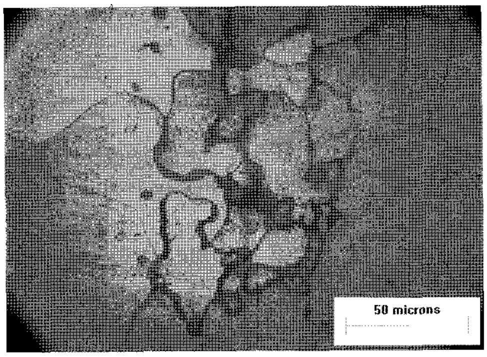
3.1 Hot cracking and its countermeasure.

Fig. 1(a) shows the micro-structure of the overlaid satellite specimen on the Nimonic super alloy surface. The inter-granular micro-cracks appear in the heat affected zone of the Nimonic substrate. These cracks are liquidation cracks induced from heating cycle during the PTA overlay process. This liquidation crack arises due to the composite effect of the thermal stress and segregations of low melting point phases at the grain boundary[6], [7]

For elimination of the segregation at grain boundary, the diffusion heat treatment is needed for the substrate Nimonic materials before PTA overlay

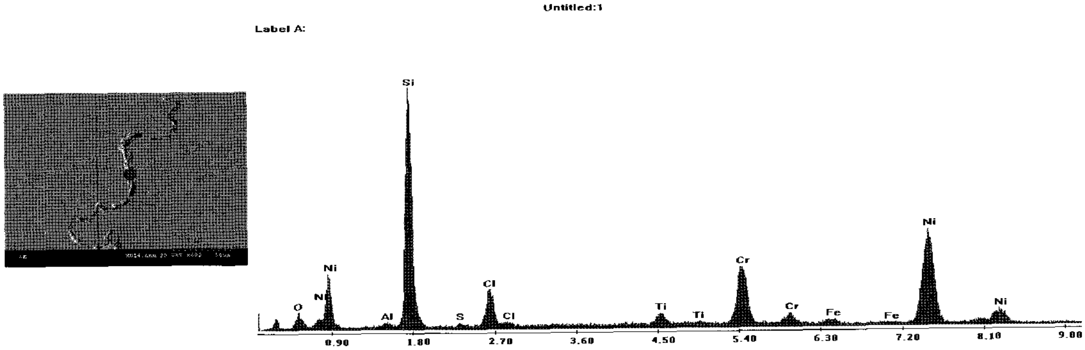


(a)



(b)

Fig. 1 Hot cracking(a) and perfect section(b) in HAZ of the Stellite 6



Elem	O	Al	Si	S	Co	Ti	Cr	Fe	Ni	Total
mass%	3.47	0.65	27.26	0.35	4.50	1.98	13.68	1.05	47.07	100

Fig. 2 Chemical composition by EDX analysis of liquidation cracking part

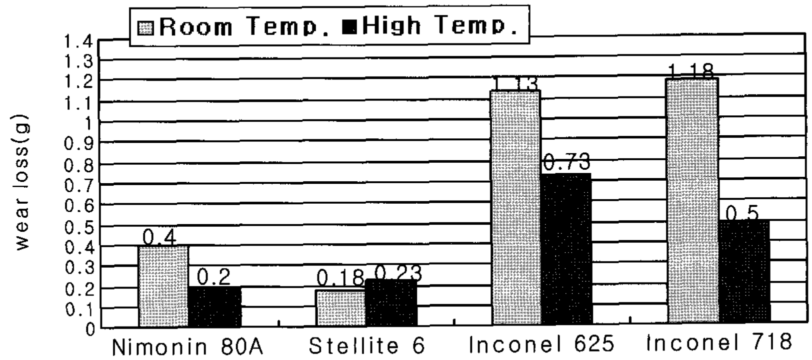


Fig. 3 Comparison of wear amount of each overlaid layer at room and high temperature.

process.

Fig.1(b) shows the improved overlay section without liquidation crack by the diffusion heat treatment for the substrate. The diffusion pre-heat treatment was conducted at 1080℃ for 5hr followed by air cooling. Moreover, Fig.1(b) shows that the overlay layer has dendrite structure developed from epitaxial structure at fusion line. This structure is quite different from general plasma metal spray structure.

Fig. 2 shows the results of EDX analysis of the overlaid specimen at the liquidation cracking area. This figure shows the Si segregation at grain boundary.

From this result, it can be seen that the liquidation crack can be removed through the removal of the Si segregation by the pre-heat treatment.

3.2 The wear characteristics at high temperature

The wear characteristics of super alloy are more important at high temperature than that at room temperature. The wear amounts of each overlaid layer at room and 400℃ high temperature are shown in Fig. 3.

From this figure, the wear resistance at high temperature appears to be better in Nimonic and Stellite than that in Inconel 625 and 718.

The Nimonic and Stellite have about same wear resistance, and follow them in order of Inconel 718 and Inconel 625

Fig.3 shows that the wear amount is down at high temperature except Stellite 6. The Stellite 6 overlaid layer increases its abrasion at high temperature. The lowering of wear amount of the layer at high temperature is contrary to decreasing of hardness at high temperature. This result is considered to be caused by the difference of wear mode between at room temperature and high temperature.

3.3 The Cavitation characteristics after high temperature exposure.

The cavitation erosion tests were conducted for the Nimonic substrate and the 3 kinds of layer after high temperature exposure at 400C, 48hr.

Fig. 4 shows the result of the cavitation test.

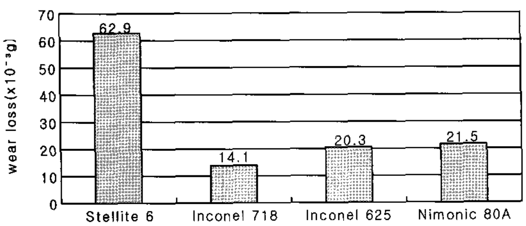


Fig.4 Result of the cavitation test

This figure shows that the Stellite 6 layer has the most cavitation erosion amount and follows it in order of Nimonic substrate, Inconel 625 and Inconel 718.

These results indicate that Co-base super alloy, Stellite 6 layer is not appropriate for cavitation erosion conditions in spite of its high hardness. The Inconel 718 layer is the most adequate among the 4 kinds of super alloy layer.

4. Conclusions

The 3 kinds of super alloy overlaid layer of Stellite 6, Inconel 625, and Inconel 718 were made on the Nimonic substrate surface using the PTA (Plasma Transferred Arc) process. The wear and cavitation erosion tests were conducted at high temperature and after high temperature exposure simulating the actual using conditions of the super alloys. Main results obtained are summarized as follows.

1. The PTA overlay welding on the Nimonic super alloy was possible without hot cracking through pre-heating of substrate.

2. The wear amount of Ni-base, Inconel layer decreases in the 400 C high temperature more than in room temperature while the Co-base, Stellite 6 layer increases its wear amount in high temperature.

3. The cavitation erosion characteristics are the most inferior in the Co-base Stellite 6 overlaid layer and it was better in order of Inconel 718, 625 and Nimonic super alloy.

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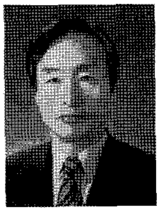

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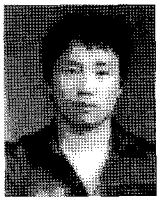

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