IMPROVEMENT OF WEAR RESISTANCE OF ALUMINUM ALLOY BY PTA SURFACING PROCESS

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ABSTRACT The purpose of this study is to clarify the hardness and wear resistance characteristics of surface modified aluminum alloy using Plasma Transferred Arc process, called PTA [1]. The PTA process has been mainly applied to surface modification to steel products [2]. It has some difficulties to apply this PTA process to aluminum products due to its low melting point and high thermal conductivity. It can be possible to make stable surface modification to aluminum alloy optimizing plasma current and powder supply. Niobium carbide composition were varied from 0 to 100 percents to obtain the optimum hardness and wear resistance level during experiments of PTA. As the conclusion, sufficient hardness and wear resistance was archived at the surface modified layer by controlling niobium carbide composition in the deposit. Deposits which have no blowhole and detachment from base metal were obtained in case of more than 60%NbC content of mixture ratio.

Keywords: *PTA surfacing process, Wear resistance characteristic, Niobium carbide (NbC), Volume fraction of NbC (V_{NbC}), Hardness of calculated deposit layer (Hc)*

1. INTRODUCTION

Aluminum and its alloys are extensively used in the manufacturing transport systems, such as motor vehicles, to reduce vehicle weight. However, aluminum and its alloy are suffered from poor mechanical properties, about one-third of steel strength, and from insufficient wear resistance. Their surface modification technologies expected to make them to fit severe operating environments [3]. It might be necessary to form more than 2-3mm thick surface modified layer to improve wear resistance characteristics.

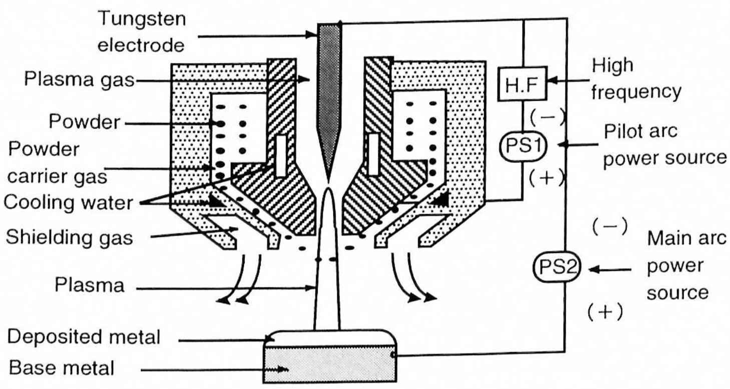

Fig.1 Principle of the PTA system

The PTA process is one of the remarkable surface modification processes. Various heat sources are used to form the thick surface layer in industries. The power density of the plasma arc (50-100kW/cm2) occupies an intermediate position between the arc (<15kW/cm2) and laser/electron beam (>100kW/cm2) [3]. The plasma arc process is also superior to laser and electron beam in terms of operability and initial costs.

Figure 1 shows the principle of PTA surfacing process. In this process, powders supplied by carrier gas forms deposited layer on base metal [4]. A series of preliminary experiments were carried out to evaluate weldability of powder materials. The PTA surface layer was examined those items; the appearance of bead, microstructure, and hardness of the surfaced region. Niobium carbide powder can be applicable as the surfacing materials from these preliminary selection.

2. EXPERIMENTAL PROCEDURES

2.1 PTA SURFACING PROCESS

A5052 aluminum alloy (including 2.5%Mg) plate were prepared as base metal. Aluminum and niobium carbide (NbC) powders were used as surface modification materials. Table 1 is listed the chemical composition and physical properties of NbC powders .

PTA surfacing process were performed at 110-135A current, 4g/min of powder feeding rate and 70mm/min welding speed condition. During the process, the mixture ratio of aluminum and NbC powders were varied from 0% to 100% in every 10% step.

Table 1 Chemical compositions and physical properties of NbC powder

Chemical composition (mass%)				
Nb	Total C	Free C	Fe	O
88.45	11.39	0.04	0.08	0.04

Physical properties			
Melting point (K)	Hardness (Hv)	Spec. gravity (g/cm^3)	Powder size (μm)
4100	2400	7.86	45-75

2.2 Observation of bead appearance

The PTA surfacing specimens were evaluated by visual inspection and conventional metallurgical procedures. X ray diffraction analysis were performed to analyze chemical reaction in weld metal.

2.3 Wear resistance test

The wear resistance of the deposits was evaluated using an Ohgoshi type test machine. The load (Pf), which increases gradually as wear progresses, had a final value of 3.2kgf, and friction speeds used was 1.32m/min. The friction distance (L) varied 100m, 200m and 400m. The wear resistance was evaluated by measuring the width of wear mark under specified test conditions and the relative wear rate (Ws) was calculated by equation (1) [5].

$$Ws=B \cdot b_0^3/8 \cdot r \cdot Pf \cdot L \qquad (1)$$

3. RESULTS AND DISCUSSION

3.1 Metallurgical analysis

The deposits of the PTA surfacing process shows relatively sound appearances, and no detachment from base metal. Figure 2 shows microstructures of deposits with NbC addition. At lower NbC contents (0-50%NbC), blowholes were observed at middle and top layer in the deposits shown in Fig.2(a) and (b). Increasing NbC content, less blowholes were formed. More than 60%NbC content, no blowhole was observed, and NbC particles were uniformly distributed in deposits.

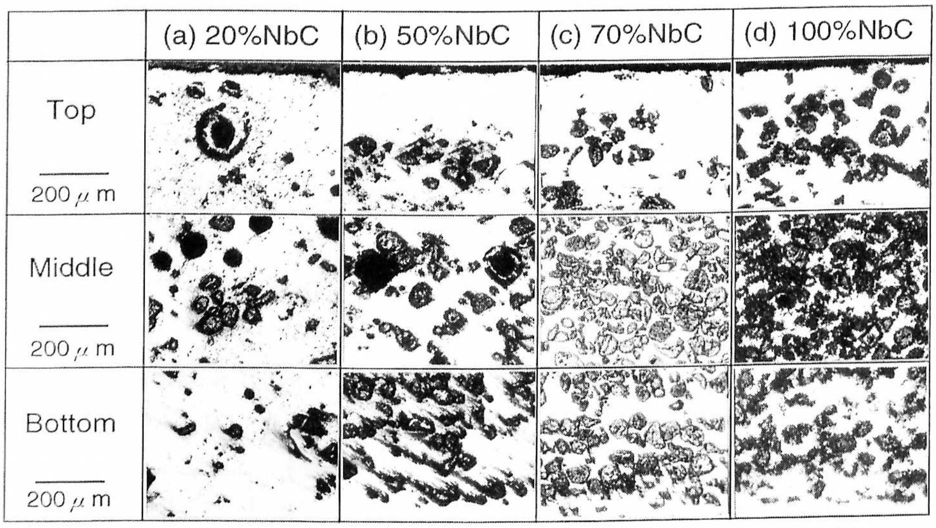

Fig.2 Microstructure of niobium carbide and aluminum deposited layer

Figure 3 shows relationship between the nominal mixture ratio of NbC to aluminum powder and observed volume fraction in PTA weld metal, which is defined as V_{NbC}. V_{NbC} of each deposits were measured using projector and image processing. The straight line means the predicted V_{NbC} values when the supplied powders and base metal were form their deposits under specific dilution. It was drawn by connection of two V_{NbC} values of 0% and 100%NbC. In case of 100%NbC, V_{NbC} was about 50%. PTA process is considered 50% dilution ratio to base metal. Observed V_{NbC} values were a little higher than expected one. Decreasing NbC mixture ratio, the discrepancies between observed V_{NbC} value and expected one were increased. In case of 20% NbC mixture ratio, observed V_{NbC} value was double of expected one. It seems to be increment of Al composition at supplied powder. Larger Al powder volume resulted decreasing temperature of weld pool. It decreases the amount of melted base metal in deposit, increasing the observed V_{NbC} value than expected one.

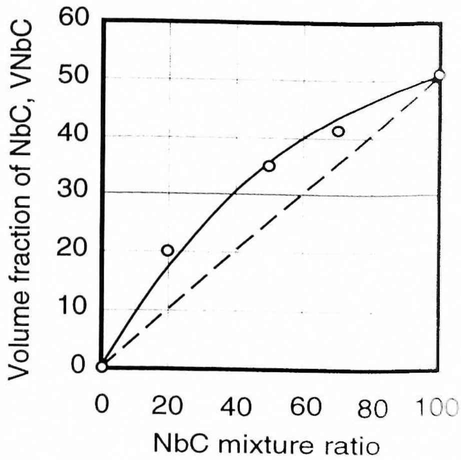

Fig.3 Relationship between NbC mixture ratio to aluminum and observed volume fraction of NbC in PTA deposits

3.2 Hardness test

The hardness distribution of the PTA deposits were measured and results were shown in Fig.4. The NbC particles were quite effective to hardness increment. Hardness at 100%NbC deposit was 8 times that of 0%NbC, reached about 160 Hv. The hardness of the deposit increases with the increasing NbC content. Hardness of the deposits were lower than that of base metal (about 55 Hv) in case of lower NbC content (0-40%NbC). It is due to low hardness of pure aluminum powder addition (about 30 Hv) and NbC content is too small to improve low matrix hardness. In case of 50-100%NbC content, the hardness of the deposits were higher than that of base metal. Increasing NbC composition, hardness of deposits increased.

Figure 4 also shows good agreement between measured hardness values (Hm) and calculated hardness values (Hc). Hc are predict hardness values when the supplied powders and base metal were form their deposits under specified dilution ratio. It was calculated from equation (2) [3] defined as volume fraction of hardened material to matrix materials:

$$Hc = \frac{H_B Vp + Hp\,(Vp + 1)}{Hp\,(1 - Vp) + H_B\,(Vp + 1)}\, H_B \qquad (2)$$

Where, Hc is hardness of calculated deposit layer, H_B is hardness of base metal, Vp (V_{NbC}+V_{Al}) is volume fraction of used powder and Hp is hardness of supplied powder which is calculated by equation (3) defined as volume fraction of mixed powder materials:

$$Hp = \frac{H_{Al} V_{NbC} + H_{NbC}\,(V_{NbC} + 1)}{H_{NbC}\,(1 - V_{NbC}) + H_{Al}\,(V_{NbC} + 1)}\, H_{Al} \qquad (3)$$

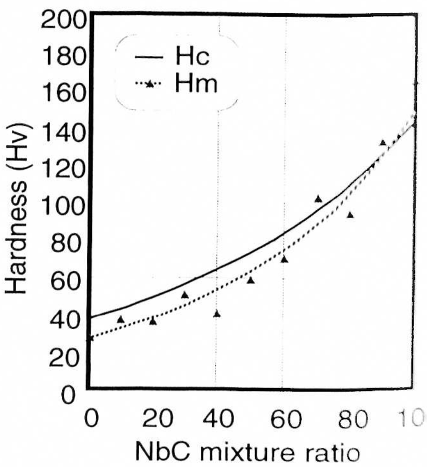

Fig.4 Vickers hardness test results

Where, H_{Al} is hardness of Al powders, V_{NbC} is volume fraction NbC powder and H_{NbC} is hardness of NbC powder.

3.3 Wear resistance

Wear resistance test results were shown in Fig.5. The improvement of wear resistance was achieved in case of more than 50%NbC addition, here wear resistance was calculated by equation (1) as relative wear rate, Ws. But no proportional relationship was achieved between NbC addition and wear resistance characteristic. Wear resistance characteristic was maintained almost constant from 50% to 100% NbC case and the best one was attained at 70%NbC addition case.

Figure 6 shows relationship between hardness and wear resistance characteristics. Increment of hardness improved wear resistance characteristics. The minimized wear rate was observed at Hv 100.

Figure 7 shows variation of NbC volume fraction (V_{NbC}) measured from the interface of the deposit to the surface. In this figure, a line at 1.5 mm

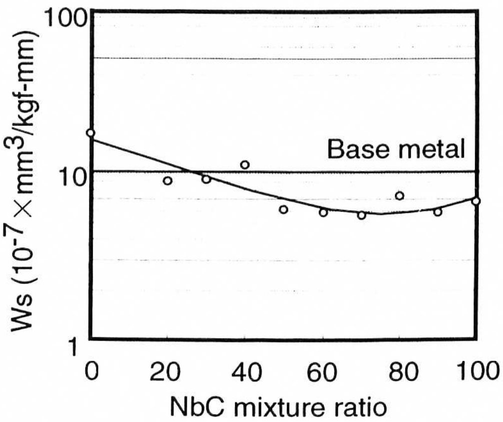

Fig.5 Effect of NbC addition on wear resistance characteristics

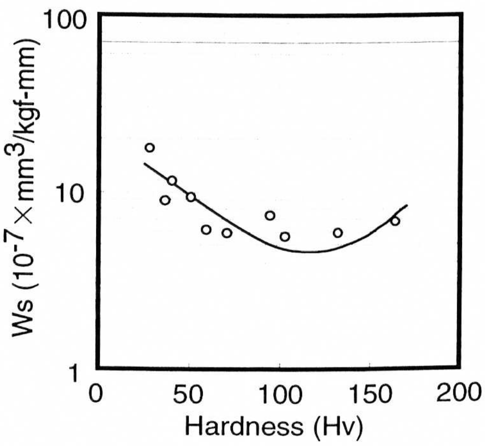

Fig. 6 Relationship between hardness and wear resistance characteristics

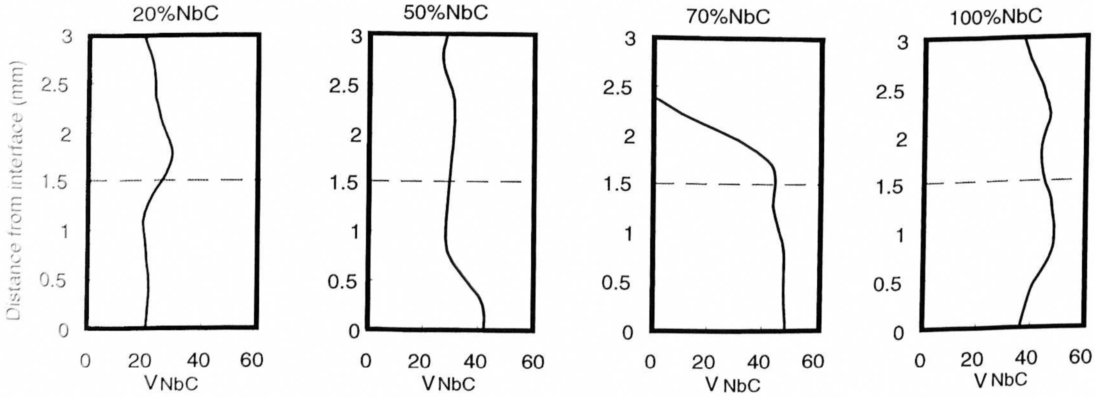

Fig.7 Relationship between nominal NbC addition and observed NbC volume fraction in weld metal

is shown at the level where wear resistance test was performed. It is confirmed NbC parti- uniformly distribute in aluminum matrix, and the V_{NbC} was not scattered with distance fr interface, except 70% NbC addition.

The V_{NbC} increased with NbC addition. In case of 20%NbC, V_{NbC} was below 30% through the deposit and it seems to be insufficient to improve wear resistance characteristic. 50%Nb powder addition was resulted between 25% and 40% V_{NbC} in weld metal which is reflect effective improvement of wear resistance characteristic.

In case of 70%NbC, V_{NbC} in weld metal shows more than 40%V_{NbC} except near surface reg. V_{NbC} at the location where wear resistance test performed shows about 45% volume fraction seems to be sufficient improvement for wear resistance characteristic to70% NbC addition.

Photo 1 shows the microstructure of wear tested region. At low NbC additions (Photo 1 (a)) very rough wear mark were obtained. Increment of NbC resulted in smooth wear mark (Photo 1 (b)) but matrix near large NbC particles were considerably worn (Photo 1 (c)). It seems to be uniform distribution of NbC particles is a very important factor for wear resistance characteristics.

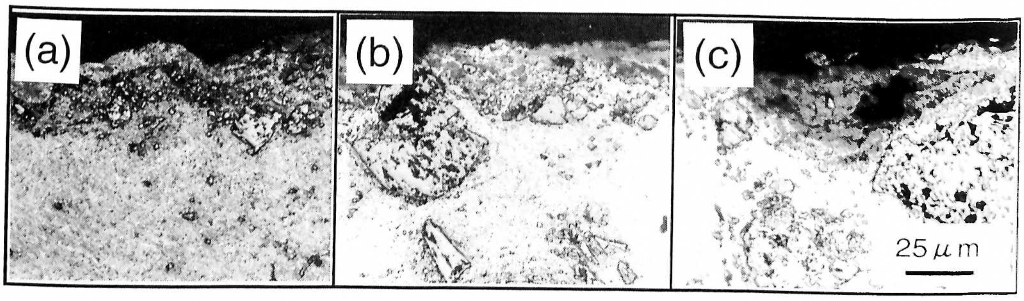

Photo 1 Microstructure of wear tested region
(a) 20%NbC-80%Al (b) 70%NbC-30%Al (c) 100%NbC

4. Conclusions

This paper purposed to improve hardness and wear resistance characteristic of A5052 aluminum alloy by PTA process with NbC powder addition. The results of this experiment are as follows:

(1) Deposits without blowhole and detachment from base metal were obtained in case of more than 60%NbC addition to aluminum powder in PTA process.

(2) The hardness of the deposits was increased with NbC addition and resulted in better wear resistance characteristicres of deposits.

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