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EFFECT OF PULSE FREQUENCY ON PULSE ANODISING OF AA 1100 ALUMINIUM ALLOY IN SULPHAMIC ACID

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Pulse anodising is a recent method for producing better quality of the oxide film on various alloys of aluminium. Various parameters like 'On' and 'Off' time, duty cycle and current density have been already studied using sulphamic acid electrolyte. In order to understand the influence of pulse frequency on the anodic oxide film of AA 1100 aluminium alloy in sulphamic acid, low medium and high frequencies were used. The properties of the pulse anodised oxide coatings were evaluated. The effect of pulse frequency at various current densities and duty cycles on the properties of the oxide film such as thickness, hardness, breakdown voltage has been investigated. All the properties of the oxide film formed by pulse anodising increase with increase of pulse frequency. Better quality of the oxide film is obtained at higher pulse frequencies.

Keywords: Aluminium, pulse frequency, anodising, sulphamic acid.

INTRODUCTION

Anodising is a versatile method for producing thick and hard oxide film with high abrasion, wear, weather and corrosion resistances on metals and alloys. Aluminium and its alloys are anodised generally in sulphuric or oxalic acids [1-2]. Sulphamic acid [3-4] is used as a best electrolyte for producing hard and compact oxide film even at room temperature. Pulse current technique [5-6] is used for anodising even difficult to anodise alloys containing higher percentage of copper and silicon without burning of the oxide film. Pulse current technique can also be used to anodise the alloys which are not easily oxidised to get oxide film of improved physical and chemical properties.

Pulse current produced from zero level with less than 20 pulsed second are used to produce coloured oxide film on aluminium alloys [7]. In our earlier work [8], we reported anodising of aluminium and its alloys using AC superimposed on steady DC to produce better quality of oxide film. Hard anodising of aluminium using microprocessor based pulse current has been also carried out in our earlier work [9]. Effect of pulse parameters such as 'On' and 'Off' time, pulse rate, duty cycle, current density and addition agents on the properties of anodic oxide film formed by pulse anodising was also reported in those papers. In this paper, the effect of pulse frequency on the properties of anodic oxide film such as thickness, hardness, breakdown and coating ratio has been reported with a view to optimise the suitable pulse frequency for producing good quality of the oxide film.

EXPERIMENTAL

The experimental procedure was carried out exactly as described in our earlier report [9-10]. AA 1100 aluminium alloy sheets of size 50 mm x 20 mm x 2 mm were taken for our study. After the conventional pretreatment processes, the samples were anodised in 15% sulphamic acid with 2 gpl magnesium sulphate at two current densities 1 to 3 $A.dm^{-2}$ and at three different duty cycles viz., 40%, 60% and 80%. The pulse frequencies were varied between 0.01 and 100 Hz. The studies were performed at five different frequencies such as 0.01, 0.1, 1, 10 and 100 Hz. On time is varied between 4 ms and 40 s for 40% duty cycle 6 ms and 40 s for 60% duty cycle and 8 ms and 80 s for 80% duty cycle. All the

experiments were carried out at room temperature. The pulse unit employed for carrying out pulse anodising is a PC based pulse console developed at EEI division, CECRI [10]. The method of measurement of the properties of the oxide film such as thickness, hardness, coating ratio and breakdown voltage were reported in our earlier papers [9-10]. The experimental pulse parameters studied are given in Table I.

RESULTS AND DISCUSSIONS

The influence of pulse frequency on the quality of the oxide film formed by pulse anodising of AA 1100 aluminium alloy in sulphamic acid electrolyte at 303 K at two different current densities, three different duty cycles and at five different pulse frequencies has been studied by measuring the properties of the oxide film such as thickness, hardness, coating ratio and breakdown voltage.

The influence of various pulse frequencies on thickness of the oxide film at 1 and 3 $A.dm^{-2}$ are shown in Figs. 1 and 2 respectively. From these figures, it can be seen that the thickness of the oxide film increases with increase of pulse frequency for all duty cycles and current densities.

TABLE I: Experimental pulse conditions for anodising of aluminium alloys

Duty cycle	Frequency (Hz)	On time	Off time
40%	0.01	40 s	60 s
	0.10	4 s	6 s
	1.00	400 ms	600 ms
	10.00	40 ms	60 ms
	100.00	4 ms	6 ms
60%	0.01	60 s	40 s
	0.10	6 s	4 s
	1.00	600 ms	400 ms
	10.00	60 ms	40 ms
	100.00	6 ms	4 ms
80%	0.01	80 s	20 s
	0.10	8 s	2 s
	1.00	800 ms	200 ms
	10.00	80 ms	20 ms
	100.00	8 ms	2 ms

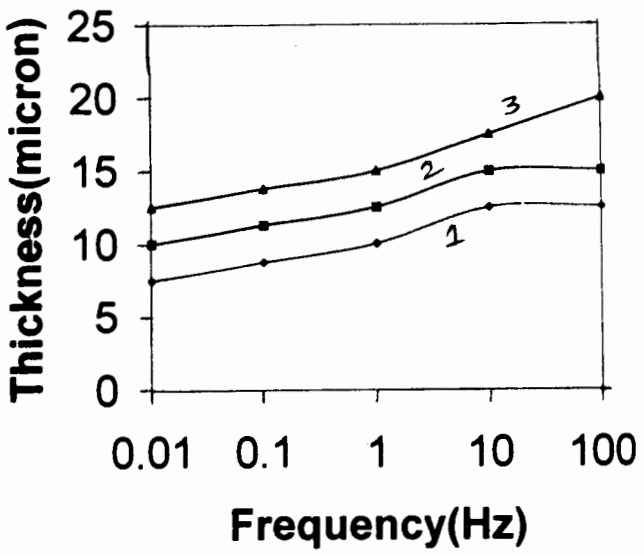

Fig. 1: Effect of pulse frequency on thickness of the oxide film formed at 1 $A.dm^{-2}$
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

The maximum value of thickness is obtained at 100 Hz.

While anodising with DC current, heat is generated continuously in the oxide film throughout the anodising period. So due to the formation of enormous amount of heat, burning of the oxide film has taken place. But no such problem was encountered in anodising of aluminium alloy while applying a pulse current. In the pulse current anodising, the heat formed during the 'on' time period of the pulse may be dissipated to the bulk of the electrolyte during the 'off' time of the pulse. It is already reported that

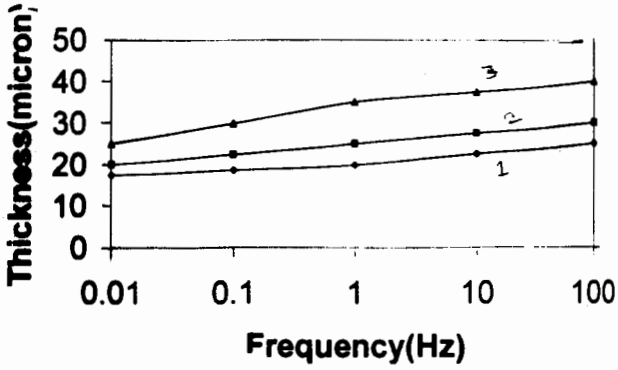

Fig. 2: Effect of pulse frequency on thickness of the oxide film formed at 3 $A.dm^{-2}$
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

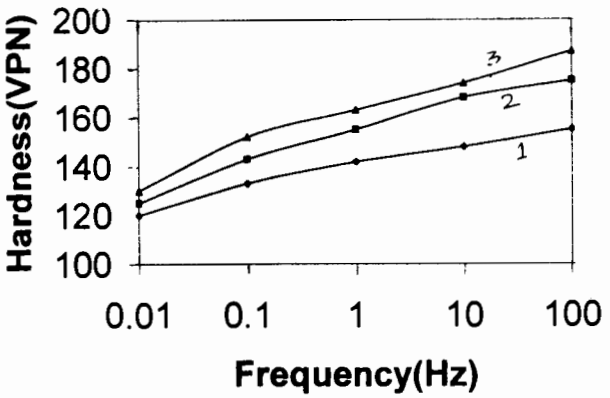

Fig. 3: Effect of pulse frequency on hardness of the oxide film formed at 1 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

75% duty cycle will produce good quality of the oxide film for anodising of aluminium alloy in sulphamic acid using pulse current [10].

Among various pulse frequencies studied i.e., 0.01, 0.1, 1, 10 and 100 Hz maximum value of thickness of oxide film is obtained at 100 Hz compared to lower frequencies. This may be explained as follows. When pulse current with high frequency is applied during anodising, current is impressed for very short duration. Because at high frequency, short pulses, i.e. more number of pulse cycles are produced in a second and hence one pulse cycle is executed within a few milli seconds. This results in lesser heat generation and better dissipation of the heat from oxide film to the bulk of the electrolyte. But at low frequencies, longer pulses are produced and so

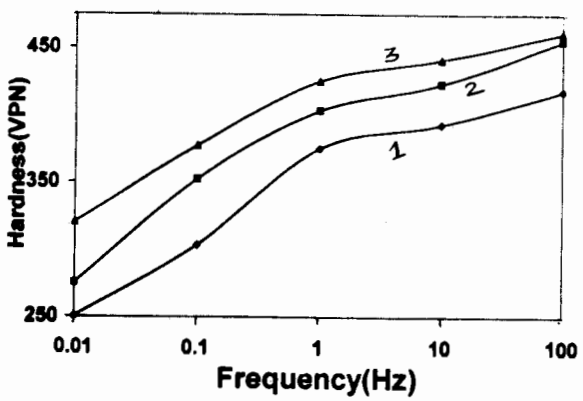

Fig. 4: Effect of pulse frequency on hardness of the oxide film formed at 3 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

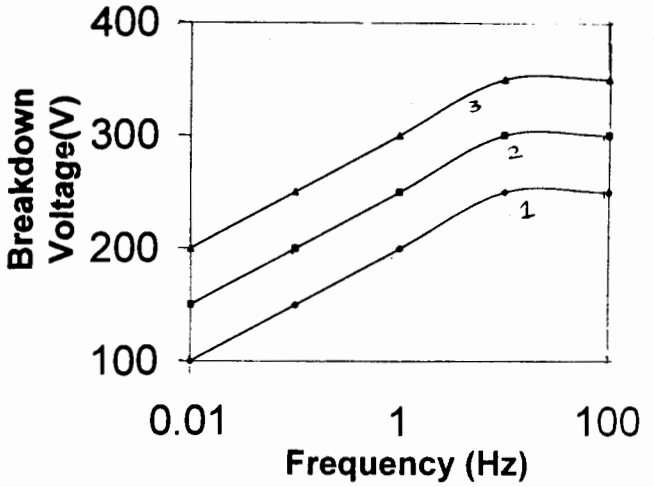

Fig. 5: Effect of pulse frequency on breakdown voltage of the oxide film formed at 1 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

the current is impressed for longer duration since execution of one cycle takes many seconds and hence more amount of heat is produced which may not be removed effectively from the oxide film to the bulk of the electrolyte. As a result of that, a better quality of oxide film may not be produced compared to higher frequency pulse anodising.

The thickness is high at current density 3 A.dm^{-2} than at 1 A.dm^{-2}, because the rate of formation of the oxide film is directly proportional to the applied current density. Also the thickness of the oxide coating increases with increase of duty cycle. This effect of duty cycle on the properties of the oxide film is already reported in our earlier paper [10].

Similarly the effect of pulse frequency on hardness of oxide film formed at 1 and 3 A.dm^{-2} for all the three duty cycles (40%, 60% and 80%) are given in Figs. 3 and 4. Here also, we observe the same trend that hardness of the oxide film increases with increase of pulse frequency and maximum value is obtained at 100 Hz. The reason for this is same as explained for the effect of pulse frequency on thickness of the oxide film.

Similarly, the influence of pulse frequency of breakdown voltage of the oxide film formed by pulse anodising at 1 and 3 A.dm^{-2} for all duty

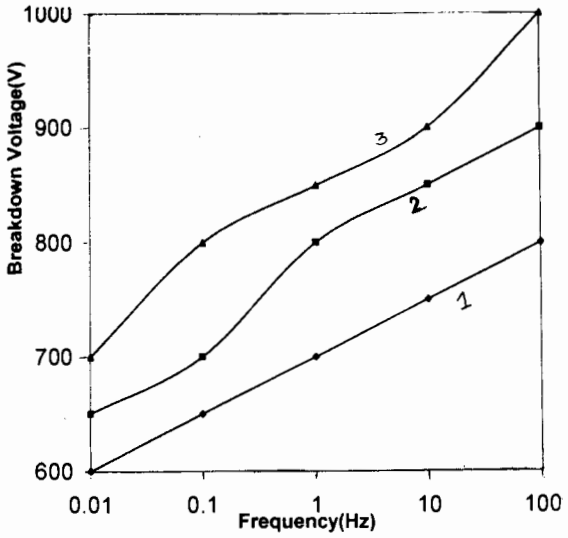

Fig. 6: Effect of pulse frequency on breakdown voltage of the oxide film formed at 3 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

cycles are shown in Figs. 5 and 6 and its effect on coating ratio of the oxide film formed at 1 and 3 A.dm^{-2} for all duty cycles are given in Figs. 7 and 8. Here also, the breakdown voltage and coating ratio of the oxide film increase with increase of pulse frequency and maximum values are obtained at 100 Hz. The reason is same as accounted for the effect of pulse frequency on thickness.

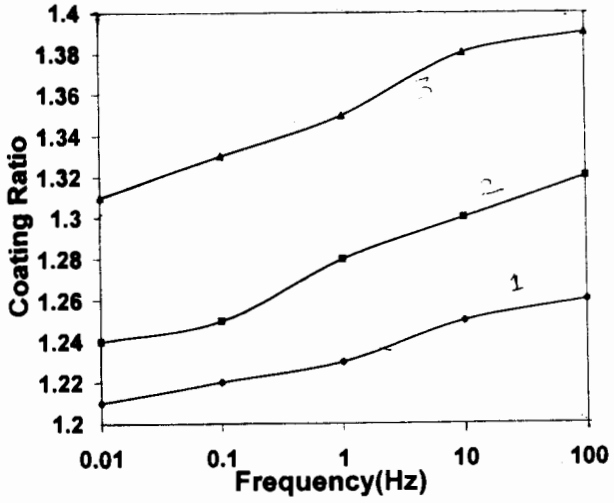

Fig. 7: Effect of pulse frequency on coating ratio of the oxide film formed at 1 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

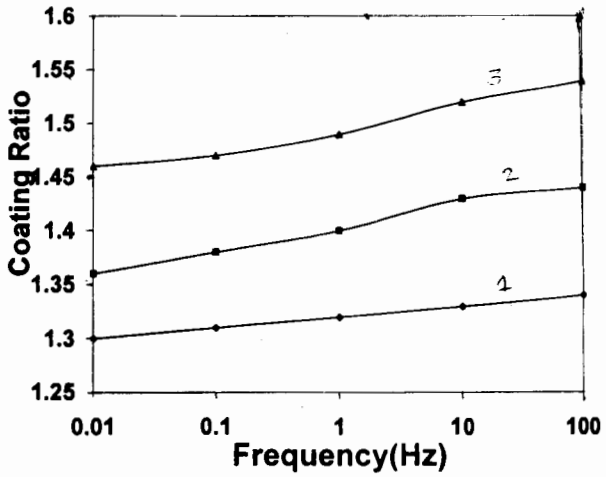

Fig. 8: Effect of pulse frequency on coating ratio of the oxide film formed at 3 A.dm^{-2}
(1) 40% duty cycle (2) 60% duty cycle (3) 80% duty cycle

CONCLUSION

- Thickness, hardness, breakdown voltage and coating ratio of the oxide film increases with pulse frequency.
- Hard and thick film is obtained at 100 Hz.
- Pulse anodising with higher frequency yields better quality of the oxide film than that with lower frequency.

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