ELECTROLYTIC POLISHING OF ALUMINIUM

MOHAMMAD INAM KHOKHAR AND KARIMULLAH

West Regional Laboratories, Pakistan Council of Scientific and Industrial Research, Lahore

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A new electrolyte for electrolytic polishing of aluminium has been developed. The polishing is accomplished under controlled conditions in a mixture of sodium hydroxide, metaphosphoric acid and glycerine. A bright and glazy surface is developed after three to four minutes. Sulphuric acid can be used for subsequent anodizing.

Polishing brings about bright and smooth finish on metal surfaces. Metal surface, which might ordinarily appear even, is not so in actual fact. It consists of depressions and elevations, better known as valleys and hills. The object of polishing is evidently to cut down these hills to the level of valleys.

Three different methods have been and are being practised to achieve this object. The first and the oldest is the mechanical method that involves the cutting of hills of the surface with the help of a bob (fine grinder) revolving at a high speed. On close examination, however, it has been found that the hills are not cut down but are mostly flowed down in the valleys by the high pressure of the bob. Moreover, in mechanical polishing the surface is imbedded with the abrasive particles and acquires a greyish tinge in its appearance. In order to remove these defects, a second method known as chemical polishing was developed. The metal surface is dipped in a chemical or a mixture of chemicals which causes preferential corrosion of the hills of the surface and renders the surface smooth and polished. It is difficult, however, to control the corrosion and carry out the process successfully. This difficulty was overcome by a third method which is known as electrolytic method of polishing. In this method, the surface to be polished is made the anode in a suitable bath. When direct current is passed for a few minutes, the surface becomes bright and smooth.

The preferential attack on the so-called hills has been explained by various workers on the basis of the layer formation theory,[1] although it is not found to be applicable in all cases. Jacquet[2] first developed this process as early as 1935 for the electropolishing of copper using a mixture of acetic anhydride and perchloric acid as the electrolyte. Later on, several new electrolytes[3] were introduced by other workers for a number of metals and alloys like brass, bronze, all types of steel, nickel, nickel-silver alloys, monel metal, nichrome, zinc, magnesium and aluminium.

Electrolytic polishing finds wide application in industry and research. In the early stages, metal surfaces were electropolished mainly for microscopic examination. Such polishing was regarded of much value as it did not disturb the crystalline structure of the metal. Later on, however, electropolishing acquired importance also in case of irregularly shaped articles where mechanical polishing is inapplicable.

When aluminium is exposed to air, a thin film of aluminium oxide is readily formed on the surface which protects further corrosion of the metal. Evidently the degree of protection can be augmented by increasing the thickness of oxide film. The process for increasing the thickness of aluminium oxide layer electrolytically is called anodizing. However, during anodizing, the original shine of aluminium surface is much reduced if the article has already been polished chemically or mechanically. This drawback is overcome to a large extent if the surface is electropolished before anodizing.

Interest in the study of the process was evoked by the fact that aluminium utensils are a common house-hold item in an average Pakistani home. To impart to them a permanent brightness in different shades, increased hardness and other desirable characteristics would certainly add to their persentability and acceptance. The process, in itself, is a general one; aluminium surface, electropolished and anodized, is the pre-requisite in a number of decorative industries where the metal constitutes the main raw material for the finished goods.

It has been observed during the present studies that aluminium articles anodized in sulphuric acid bath under different conditions were not able to maintain the original brightness which had already been obtained mechanically or chemically. The present investigations were also directed towards the elimination of the dullness developed during anodizing.

Experimental

Materials.— 1. Aluminium strips of 99.9% purity. Their surface area varied from 2 sq. inches to 8 sq. inches. They served as anode.

2. Two stainless steel plates, each being 5″×3″. They served as cathode 3. Electropolishing apparatus. (Fig. 1). 4. Commercial grade sodium hydroxide, metaphosphoric acid and glycerine.

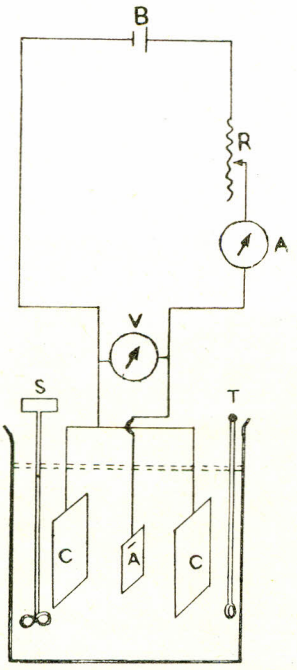

Fig. 1.—B, sources of D.C.; R, External resistance; A, Ammeter; V, Voltmeter; T, Thermometer; S, Stirrer; C, Cathode; A, Anode.

Methods.—For studying the electropolishing effect on aluminium, a solution containing 5 g. of sodium hydroxide per 2 litres was taken initially. The concentration of sodium hydroxide was gradually increased, keeping the other variables like temperature, voltage, current density etc. constant. Observations were taken for each concentration of sodium hydroxide. The operating conditions and results are given in Table 1.

The polishing effect was observed through a magnifying lens (×10)

In the second experiment, the observations were taken by varying the temperature of the bath, keeping the other variables constant. The results are shown in Table 2. Observations due to variations in the voltage are shown in Table 3.

In the next two experiments metaphosphoric acid was used and the observations were noted by varying the concentration of metaphosphoric

TABLE 1.

NaOH g./2 litres	Polishing Effect*
2	N
4	P
6	P+B
8	C+B
10	S+B
12	O+B
14	O+B
16	O+B
18	C+B
20	C+B
25	C+B
30	P+B
35	E
40	E
45	E
50	E

Voltage, 18-25 volts; Current density goes on increasing with increase of NaOH; Temperature, 80-85°C. Time, ½ minute.

*N, No polishing; P, Partial polishing; B, Black layer formation, O, Optimal polishing; C, Complete and smooth polishing without shine; E, Electricity S, Smooth polishing with shine.

TABLE 2.

Voltage (in volts)	Polishing Effect*
5	P
7	P
9	P+B
11	P+B
13	P+B
15	C+B
17	S+B
20	O+B
25	O+B
30	S+B

NaOH, 12 g.; Water, 2 litres; Temperature, 75-85°C.; Current density, 150-300 asf; Time, ½ minute.

* See foot note of Table 1.

acid and voltage of the bath. The results of these experiments are given in Tables 4 and 5.

Lastly, various concentrations of glycerine were tried to study its effect on glaze and shine of the surface.

Discussion

Some workers have reported the use of sodium hydroxide in combination with various inorganic salts and acids for electropolishing of aluminium and its alloys.[4,5] These auxiliary salts and acids include neither metaphosphoric acid nor glycerine. In the present investigations, electropolishing of aluminium and its alloys has been studied in a bath containing metaphosphoric acid and glycerine along with sodium hydroxide.

The polishing effect due to sodium hydroxide alone was studied first and conditions approaching the optimum were achieved. It was found that sodium hydroxide was capable of giving good polish under the following conditions: sodium hydroxide, 6 g.; Water, 1 litre; Temperature, 75–85°C.; Voltage, 15–25 volts; Current density, 150–300 asf; Time, 30 seconds.

TABLE 3.

Time (minutes)	Temperature °C.	Polishing Effect*
2.0	40	C
2.0	45	C
1.5	50	C
1.5	55	C+B
1.5	60	C+B
1.0	65	S+B
1.0	70	S+B
0.5	75	O+B
0.5	80	O+B
0.5	85	S+B
0.5	90	E
0.5	95	E

NaOH, 12 g.; Water, 2 litres; Voltage, 18-25 volts; Current density goes on increasing with increase of temperature.

* See foot note of Table 1.

TABLE 4.

NaOH g./2 litres	HPO_3 g./2 litres	Polishing Effect*
12.25	0.5	C+B
12.50	1.0	S+B
13.0	2.0	S
13.5	3.0	S
14.0	4.0	S
14.5	5.0	S
15.0	6.0	O
16.0	8.0	O
17.0	10.0	S
18.0	12.0	S
19.5	15.0	S
22.0	20.0	C
24.5	25.0	C

Current density, 150-300 asf; Voltage, 18-25 volts; Temperature 75-85°C; Time, 3-4 minutes.

* See foot note of Table 1.

TABLE 5.

Voltage (volts)	Polishing Effect*
4	N
6	P
8	P
10	P
15	S
20	O
25	O
30	S

NaOH, 15 g.; HPO_3, 6 g.; H_2O, 2 litres; Current density, 150-300 asf; Temperature 75-85°C.; Time, 3-4 minutes.

*See foot note of Table 1.

It was noticed, however, that when the aluminium article was kept in the polishing bath of above composition for more than thirty seconds a uniform and thin layer of a black precipitate began to appear on the surface, the thickness of which went on increasing, upto a certain limit of course, with the passage of time. Due to the formation of this black precipitate, polishing could not be carried out successfully. This defect was totally removed by the addition of certain compounds like phosphates. These salts did not allow the formation of black precipitate. They also increased the smoothness and brightness of the surface. The compounds of phosphorus investigated in this connection included tribasic sodium phosphate, dibasic sodium phosphate, monobasic sodium phosphate, sodium pyrophosphate, sodium glycerophosphate, di-potassium hydrogen phosphate, diammonium hydrogen phosphate, orthophosphoric acid, hypophosphorus acid, metaphosphoric acid and polyphosphoric acid. Some of these compounds (hypophosphorus and polyphosphoric acid) were not successful at all while others like sodium glycerophosphate, and diammonium hydrogen phosphate gave poor results. Among those which gave satisfactory results metaphosphoric acid proved to be the best. Various concentrations of this acid (along with extra sodium hydroxide to keep the pH of the bath constant) were studied along with 6 g./litre of sodium hydroxide and the following optitmum conditions were established. NaOH, 7.5g.; HPO_3, 3 g.; Water, 1 litre; Temperature, 75–85°C.; Voltage, 20–30 volts; Current density, 150–300 asf; Time, 3–4 minutes.

The smoothness of the surface was further enhanced when 5 ml. of glycerine was added to the above composition. Variations in the amount of glycerine used in the batch showed no difference in the final results. Effect of current density on polishing was also studied. It was observed that increase in current density by introducing external resistance always caused decrease in the shine and smoothness. The aluminium articles polished in a bath having above composition could be anodized in sulphuric acid (10% by volume) and coloured subsequently in various shades according to one's taste.

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