

Pulse Anodizing in an Existing Anodizing Line

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1. Abstract

This paper will give a guideline of how to implement pulse anodizing in a conventional, existing anodizing line. The pulse anodizing which will be taken into consideration is the one using slow, square-formed pulses. The paper is part the work to be delivered in the project " Energy optimization in the anodizing process – an electrolytic process" sponsored by the Danish El-distribution(EIFor).

The paper will show which parts should be taken care off when pulse anodizing is used and how it can be installed in an existing anodizing line. The normal process is anodizing 5 –25 μm and usually the aluminum alloy used is a 6063 (AlMgSi1).

The aim, of installing pulse anodizing in this line, has been a wish to decrease the total energy consumption of the process. Therefore some explanations about the consumption of the energy in the existing line will be found and the calculations used to show the theoretical decrease in energy when using pulse anodizing.

There will also be some considerations about the necessary improvements of the exiting line facilities to manage the higher energy input pr. minute.

Different pulse parameters will be tried to gain the optimum pulse pattern for a specific alloy 6063. To gain as much results as possible the Tagushi statistic method is taken into use.

This first paper about the work will give an introduction to the project and the first exciting

results of how to use pulse anodizing in the "real" world.

2. Introduction

The reason for SAPA Profiles, DK to go into this project is to decrease their total energy consumption. For the moment the specific electrical consumption is around 100 kWh/tons aluminum.

Reducing the process time in the anodizing tank by at least 30% changing from conventional anodizing to pulse anodizing would give a large cost reduction.

The long-term aim of the project is to create an operational tool – a calculation model – that optimizes the energy consumption regarding pulse anodizing of aluminum.

2.1 Anodizing in the existing line

The first target of the project was to know the existing conventional line.

Therefore several conventional loads have been carefully followed to have something to compare with when introducing pulse anodizing to the line.

Two of these loads will be used as "dummies" to explain the difference between conventional anodizing and pulse anodizing.

The total surface area (rack and customer parts) was 1970 dm^2 (~ 212 ft^2) and the desired thickness of the layer was 20 μm . The anodizing process is current controlled which is not normal in Denmark. Usually the anodizing process is voltage controlled to avoid the calculation of the

surface area. Processing in the range of 12 – 16 volt. Using the current controlled process will give a shorter process time than for the voltage controlled due to the increase in resistance of the oxide layer.

The aluminum alloy used for the customer parts were the very common 6063-alloy, see table 1.

Table 1, Composition of alloy 6063

	Silicium	Magnesium	Copper	Manganese	Iron
Wt %	0.2 – 0.6	0.45 – 0.9	≤0.1	≤0.1	≤0.35

The pretreatments were the one most commonly used, degreasing, etching and then desmutting. The anodizing followed by a hot sealing process.

Table 2, Some of the conventional anodizing parameters

Total process time	Current density	Aver. thickness
49 min	1.17 A/dm ²	23.2 μm

Table 2 shows the current density and total process time given an average thickness of the oxide layer of 23.2 μm.

2.2 Some considerations before turning to pulse anodizing

Why not use 2 A/dm² (18.58 A/ft²) instead of 1.17 A/dm² (10.86 A/ft²). This could give a theoretically reduction in process time from 49 minutes to 38 minutes, almost 22% using the following rule of thumb (1).

$$(1) \quad h = 0.3 \times i \times t$$

where h is the desired layer thickness, i is the average current density and t the total process time.

One of the reasons for not using this possibility in the existing line was the cooling capacity and the old rectifier. Due to the fact that the current density should be even higher when pulse anodizing, a new cooling system was needed.

At the same time it was found necessary to replace the busbars with larger ones and refresh the contact points between the busbar and flight bar. It was already an expensive improvement even before buying the new pulse rectifier.

Some thoughts about changing the aluminum racks with titanium were also done. It was decided that the aluminum racks should be used.

2.3 The energy calculation

The loads processed with the old rectifier were analyzed regarding the energy consumption.

To gain a large amount of information about the energy consumption several measuring points were placed around the load, see figure 1.

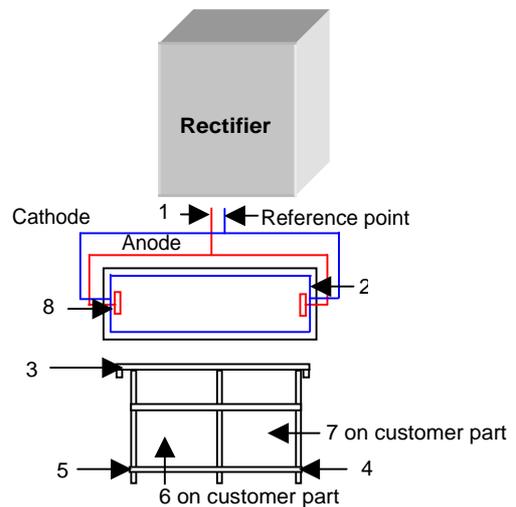


Figure 1, Schematic drawing of the measuring points

For the moment an analysis is carried out of the losing components and contact points in the anodizing process.

The same information should be measured for the pulse anodizing process. Giving clear information about the reduction in energy.

3. The pulse anodizing parameters

The whole idea of using pulse anodizing is to have a higher average current density and hereby reducing the process time^{1,2,3}.

Pulsing between two values of direct current instead of using the same value during the whole process gives several possibilities for individual process conditions.

When the high voltage E_1 is applied, the current will reach a steady level i_1 , stage 1 in figure 9. In this period the barrier layer will reach a thickness

d_1 corresponding to the forming voltage E_1 . The structure of the cells will also be controlled by E_1 .

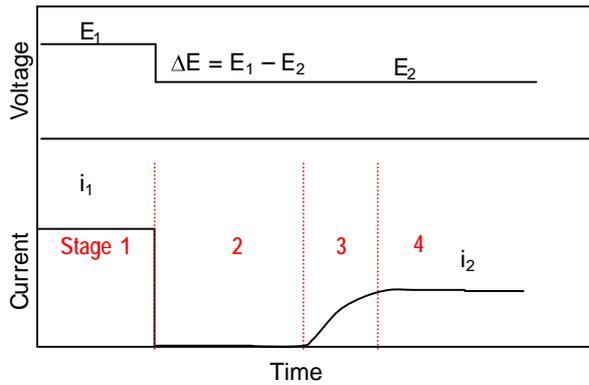


Figure 2, The recovery effect¹

When the voltage is suddenly lowered to E_2 the current density will decrease drastically to a very small value as seen in stage 2. This small current density with values in the range of μA , corresponds to the very high resistance in the barrier layer d_1 . The electrical field across the barrier layer in this period is very low. Hence the formation of oxide is almost zero and the field assisted dissolution also very slow. The main reaction in this period will be the chemical dissolution of oxide, reaction (2). This period is called the recovery period.

After a certain time, dependent on many factors such as alloying elements, concentration of the electrolyte, temperature and the value of ΔE , the thickness of the barrier layer has become thinner hereby increasing the electrical field across the barrier layer. Now the field-assisted dissolution and formation will take place increasing the total dissolution rate as seen by the steep increase in current density during stage 3, due to a less resistance in the reduced thickness of the oxide layer.

After a while the current density will reach a steady level corresponding to the value of E_2 , see stage 4. Now the barrier layer thickness has reached the value d_2 (less than d_1) that corresponds to the voltage E_2 . The oxide will also adopt another dimension with smaller cells corresponding to E_2 and appearing beneath the oxide layer formed at E_1 .

This kind of pulsating process between a low and a high value of either current or voltage will be used in this investigation.

4. The first experiments

The first experiments done with the new pulse rectifier were one with pulsating current and one with pulsating voltage.

The chosen parameters were:

Current controlled exp.

$$i_1 = 4 \text{ A/dm}^2 \text{ (36 A/ft}^2\text{)} \quad i_2 = 1 \text{ A/dm}^2 \text{ (9 A/ft}^2\text{)}$$

$$t_1 = 120 \text{ sec.} \quad t_2 = 30 \text{ sec.}$$

Voltage controlled parameters were:

$$E_1 = 23 \text{ V} \quad E_2 = 12 \text{ V}$$

$$t_1 = 120 \text{ sec.} \quad t_2 = 30 \text{ sec.}$$

Figure 3 shows the current controlled experiment. After 400 seconds a burning was started and the experiment had to be stopped.

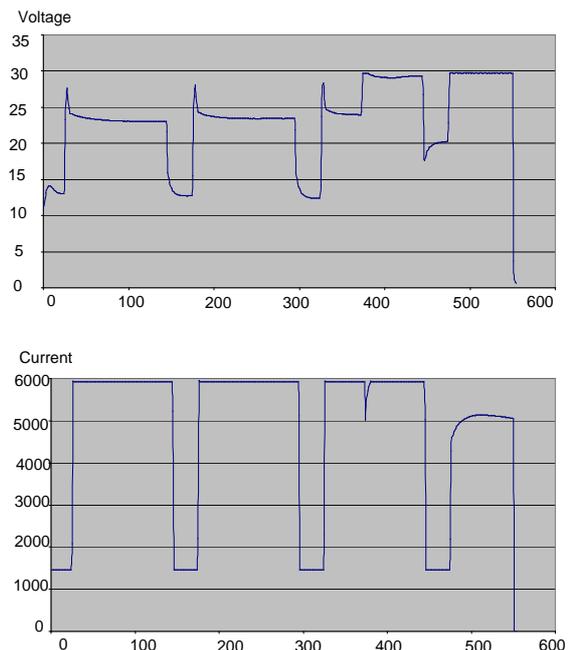


Figure 3, Current controlled anodizing process

Looking at the load about 30 % of the aluminum parts were burning at the clamps or in corners of the profile.

The voltage controlled experiment can be found in figure 4. This time the process was able to proceed the total process time of 20 minutes. The average thickness of the load was 20 μm which corresponds to 1min/ μm . The process time is reduced to 1/3 of the process time used before introducing the new rectifier.

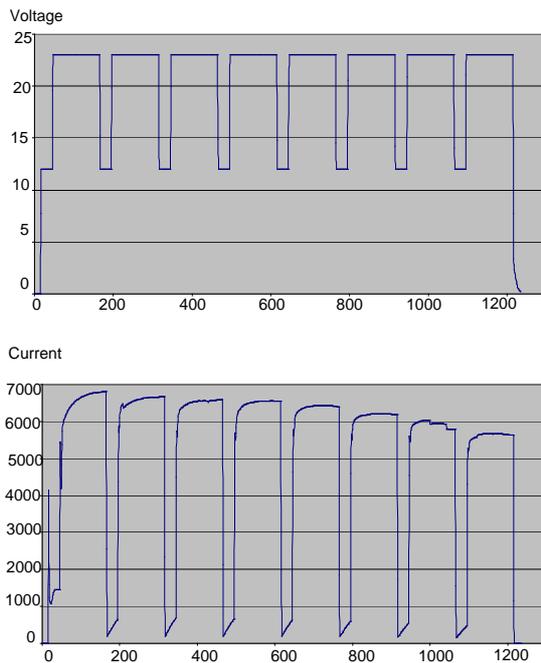


Figure 4, Voltage controlled anodising process

5. Future works

A lot of other experiments will be done in the next year given a more precise indication of the various process parameters for pulse anodizing. The final result should give an optimal process for different alloys and customer parts.

There will also be a lot more energy measurements and calculations to verify the first indications of the energy loss, mostly found at the busbar and contact point. These energy measurements will show how much the cost reduction is by introducing pulse anodizing in an existing anodizing line.

6. Acknowledgement

To the Danish Eldistribution, ELFOR, Jørn Borup Jensen.

7. References

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