Hard Anodizing of Pistons for Internal Combustion Engines

International Hard Anodizing Association – 2014

Waldir Delano Abu Gannam
**Copax** is an IHAA member located in Piracaia, São Paulo, Brazil and is in the market since 1996.

The main activity is to produce anodic film by the electro chemical conversion of the aluminum to aluminum oxide.

Our experience cover many different aluminum alloys and also many different production process like extrude profiles, die casting, forging and casting by gravity with permanent mold.
Copax also has an engineering team responsible for technologic innovation:

- **Catalytic -Coating®**

  Consist in apply nanoparticles in the hard anodizing coating (13 ± 5μ coating thickness) on the top and headland on automotive pistons.

  This experiment was made with more than one catalytic element on the same piston.

  The engines was tested with normal calibration by:

  - **VW** Brazil,
  - **GM** Brazil,
  - **Ford** Brazil,
  - **Cummins** Brazil (Diesel).

  The test resultant shows a big potential on fuel consume reduction and emission reduction in all customers, at the moment is not in production (big paradigm)
Piston full anodized®

Main benefits:

- Reduced anodizing device cost
- Don’t need additional anti-friction on the piston surface
- Increase piston ware and scuffing resistances
- Reduce piston friction in the engine
- Increase the service lifetime

Note: in mass production since 2.012 at Ford in Brazil.
With our almost 300 employees we are capable to produce:

- Powder painting
- Hard anodizing
- Low roughness anodizing process (break master cylinder)
- Large anodizing thickness coating (up to 150µ)
- Anodizing from aluminum profiles and others similar with up to eleven meters long.
- Medical and pharmaceutical parts anodizing
- Hard anodizing on pistons for Otto and Diesel cycle around eight million per year.

Incoming inspection as quality support to costumer.

*Note*: Piston is the part with very high complexity to anodize, due to a non-homogeneity micro structure coming from alloy casting process and mechanical damage on the subsurface.

Other relevant point is the quality system structure necessary to maintain the documentation and audits request by automotive costumer.
Object of study

- Hard Anodizing of Pistons for Internal Combustion Engines with Multi-fuel Management System

Pistons diameter 58mm – 106mm
Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

Area with hard anodizing and characteristics:

First Groove

The groove height 1,2mm ±10µm after anodizing (average)

Coating thickness 13µm±5µm, 15µm±5µm and 20µm±10µm

Hardness 300Hv 10 (min)

Roughness 2µm Ra (average)

<table>
<thead>
<tr>
<th>Elements</th>
<th>Alloy A</th>
<th>Alloy B</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI - SILLICON</td>
<td>13%</td>
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<tr>
<td>CU - COPPER(MAX)</td>
<td>1,5%</td>
<td>3,9%</td>
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Object of study

Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

Area with hard anodizing and characteristics:

First Groove and Top

The groove height 1,2mm ±10µm after anodizing (average)

The top can be partial machined or only casted

Coating thickness 13µm±5µm, 15µm±5µm and 20µm±10µm - no additional request to the top.

Hardness 300Hv10

Roughness 2µm Ra (average)

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- Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

Area with hard anodizing and characteristics:

- Coating thickness: 13µm±5µm for all grooves and all functional machined surfaces; 14µm±2µm pin bore
- Hardness: 300Hv10 (min)
- Roughness: 1,5µm Ra (max) grooves and all functional machined surfaces; 1,8µm Ra (max) pin bore

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Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

Area with hard anodizing and characteristics:

Coating thickness: 30-45µm
Hardness: 250HV10 min
Roughness: not specified

Combustion Bowl

<table>
<thead>
<tr>
<th>Elements</th>
<th>Alloy C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si - Silicon</td>
<td>13%</td>
</tr>
<tr>
<td>Cu - Copper</td>
<td>6%</td>
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## The Main Alloy Characteristics

### Materials for piston alloy aluminum in [%] Mass

By Brazilian Standard (ABNT)

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The Main Alloy Characteristics

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<th>Alloy C</th>
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<tr>
<td>SI – SILICON</td>
<td>8,5 – 10,5</td>
<td>11,0 – 13,5</td>
<td>10,0 – 13,5</td>
</tr>
<tr>
<td>CU – COBRE</td>
<td>2,0 – 4,0</td>
<td>0,8 – 1,5</td>
<td>2,5 – 6,0</td>
</tr>
<tr>
<td>MG – MAGNÉSIO</td>
<td>0,5 – 1,5</td>
<td>0,7 – 1,5</td>
<td>1,5 MÁX</td>
</tr>
<tr>
<td>NI – NIQUEL</td>
<td>0,5 MÁX</td>
<td>0,7 – 1,4</td>
<td>1,0 – 3,5</td>
</tr>
<tr>
<td>FE – FERRO</td>
<td>1,2 MÁX</td>
<td>0,7 MÁX</td>
<td>0,7 MÁX</td>
</tr>
<tr>
<td>MN – MANGANÊS</td>
<td>0,5 MÁX</td>
<td>0,35 MÁX</td>
<td>0,4 MÁX</td>
</tr>
<tr>
<td>ZN – ZINCO</td>
<td>1,5 MÁX</td>
<td>0,3 MÁX</td>
<td>0,3 MÁX</td>
</tr>
<tr>
<td>PB – CHUMBO</td>
<td>–</td>
<td>0,05 MÁX</td>
<td>0,05 MÁX</td>
</tr>
<tr>
<td>SN – ESTANHO</td>
<td>–</td>
<td>0,05 MÁX</td>
<td>0,05 MÁX</td>
</tr>
<tr>
<td>OUTROS</td>
<td>0,5 MÁX</td>
<td>0,15 MÁX</td>
<td>0,15 MÁX</td>
</tr>
<tr>
<td>AL – ALUMÍNIO</td>
<td>RESTANTE</td>
<td>RESTANTE</td>
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**A** LIGA AL-SI EUTÉTICA NÃO MODIFICADA COM SILÍCIO PRIMÁRIO ISOLADO. TAMANHO DE GRÃO DE SILÍCIO – 100 µM MÁXIMO PERMITIDO.
Microstructure Characteristic Before Anodizing

- Grooves microstructure Mechanical Damage

500 x ~6 µm
Microstructure Characteristic Before Anodizing

- Combustion bowl microstructure Mechanical Damage
Typical Si segregation coming from refined alloy casted by gravity in permanent mold
Typical Si grain size coming from refined alloy casted by gravity in permanent mold
Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

- Typical hard anodizing coming from a normal microstructure.
Microstructure Characteristic After Anodizing

- Influence of microstructure in aluminum alloys in the formation of hard anodic coating.
  - Typical hard anodizing coating under influence of microstructure.
Influence of microstructure in aluminum alloys in the formation of hard anodic coating.

- Typical hard anodizing coating under influence of microstructure.
Microstructure Characteristic After Anodizing

- Influence of microstructure in aluminum alloys in the formation of hard anodic coating.
  - Typical hard anodizing coating under influence of microstructure and mechanical damage.
First groove coating thickness, how to evaluate?

**Conventional method**

Destructive analyses supported by probes and microscope.

**Optional method**

No destructive analyses by Eddy current / Copax special device

Main advantages:
- Low cost
- High accuracy
- No scrap
- Fast analyze
- Results on-line, integrated with Quality System
- More checked points increase the decision quality robustness
Special dedicated device to measuring thickness, integrated with quality system.

1. Positioning Device
2. Probe
3. Measuring Device
4. Data Control Screen
5. Interface charts with quality system
Steps to Setup

- Similar piston without coating (necessary to minimize the diameter effect in relation to the eddy current sensor)
- Calibration master plate
- Anodized piston to be evaluated
Setup and start evaluation procedure
Poka-yoke samples to verify eddy-current result.
Data Evaluation

- Data comparison between coating thickness on the groove evaluated by conventional method (lab with probe) versus Evaluation with the same 360 samples measured on the head-land with Copax Eddy-current method.

Head-land (by eddy-current)

First groove (by lab)
Even considering all variables coming from influence of microstructure and process, we can decide the groove coating thickness using the data coming from head-land always we support by statistical analysis.