

Manufacturing – Surface finishing

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4 Surface finishing

4.1 Scope of contents

In this chapter, the surface finishing of aluminium for auto applications is considered in 2 parts:

1. Pre-conditioning of aluminium forms.

This covers the range of surface conditioning treatments applied by the Al-industry to semi-fabricated forms

- ⤴ sheets / strip / blanks,
- ⤴ extrusions,
- ⤴ castings and wrought parts

before supply to the auto-manufacturer.

2. Finishing of BIW & assemblies.

This covers the surface conditioning treatments typically applied by the auto-manufacturer after assembly of the BIW or sub-assemblies:

- ⤴ Phosphating
- ⤴ Electro-coating

In addition, a few comments on emerging technologies are included.

4.2 Pre-conditioning of Al-forms

This section describes the main surface conditioning processes applied by the aluminium supply industry:

- ⤴ sheet products (coil or blanks)
- ⤴ extruded products
- ⤴ cast & wrought products



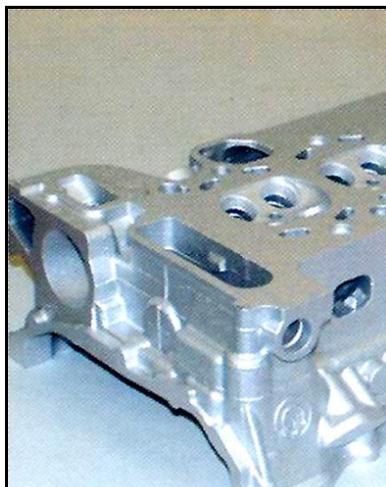
Coils products

Source: Alcan



Examples of extruded products

Source: Hydro



Example of a cast engine block

4.2.1 Sheet / strips

Surface conditioning of sheet & strip

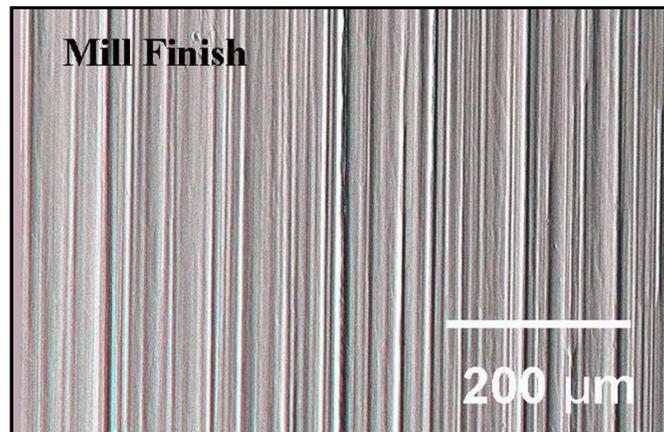
This section describes the main surface conditioning technologies which are typically applied to **aluminium auto-sheet** prior to supply to the auto manufacturer (as coil or blanks).

- ⤴ **Surface texturing** (to produce increased roughness and a more isotropic surface)
- ⤴ **Cleaning** of aluminium sheet & strip (to remove process oils, contamination etc)
- ⤴ **Coil pre-treatment** (examples of anodising and chemical conversion options are described)
- ⤴ **Lubrication** of the surface (for enhanced formability of press-shop blanks)
- ⤴ **Pre-Primed & Coated sheet** (selected examples are described).

Surface texturing (EDT & Mill Finish)

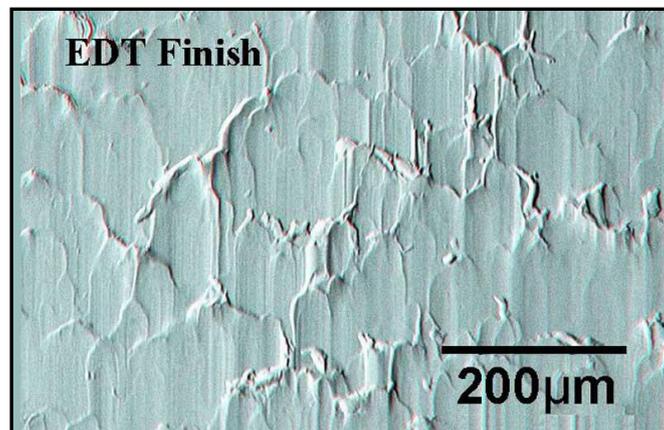
Background:

- ⤴ The established surface topographies for Al auto-sheet are Mill-finish and EDT (electric discharge texturing).
- ⤴ Mill-finish is the standard surface used in N. America.
- ⤴ Although Mill-finish is used in Europe, EDT is more common (particularly for outer panels).



SEM image of a conventional mill-finish surface on AA6016 sheet

Source: Alcan



SEM image of an EDT surface on AA6016 sheet

Source: Alcan

EDT surface texturing is produced by applying an additional cold rolling pass on coil products using specially textured work rolls (EDT). This is typically <4% cold reduction and is applied as the final pass to the desired sheet gauge.

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Advantages of EDT over Mill-Finish

Literature:

- ⤴ Lahaye, C.T.W., Emmens, W.C., Bottema, J., Schoepen, F., Verhoeven, G.: Influence of substrate texture on forming and paint appearance of aluminium sheet material. Proc. IBEC'97, (1997)

Claimed advantages of EDT surface texture over Mill-Finish:

- ⤴ **isotropic structure** (no directional influence on the forming behaviour)
- ⤴ **lubrication pockets lead to build up of hydrostatic pressure**
 - low and regular friction coefficient
 - better formability than with millfinish surfaces
 - improves press-shop handling (de-stacking of blanks etc)
 - less pick-up of work piece material on the tool surface
 - more consistent press parameters
- ⤴ **improved lacquer appearance and panel matching** (irrespective of orientation)

NOTE: The acknowledged disadvantage of EDT texturing is the cost of applying an additional cold rolling pass to final gauge.

Cleaning of coil / sheet products

Background:

For most auto-sheet products, coil cleaning is generally the first surface conditioning treatment applied by the aluminium producer. For European products, the application of a controlled surface texture (via EDT cold rolling) can precede cleaning.

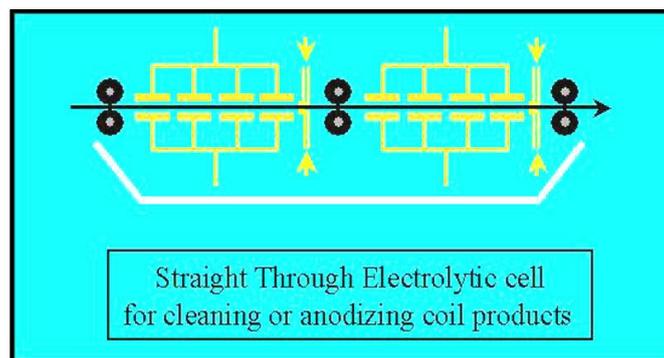
Purpose of Coil Cleaning:

- ⤴ Cleaning is widely considered to be an important process in the establishment of key properties (e.g. adhesion & corrosion resistance).
- ⤴ Coil Cleaning methods vary, but as a minimum, they all remove process contaminants (mill oils, fines etc).
- ⤴ Certain auto-products require greater levels of cleaning to remove disturbed oxides & surface layers. This depends upon subsequent processing & the requirements in end use.

Typical coil cleaning processes:

- ⤴ **Mixed Acids:** This is the most commonly used coil cleaning process for auto-sheet. Typical formulations are combinations of sulphuric and/or phosphoric acid with small additions of hydrofluoric acid and operate at ~50 to 70°C. Processing can be by spray (recirculation) but is more typically by passage of the strip through a bath. Acid concentrations are usually << 5%.
- ⤴ **Electrolytic cleaning:** In Europe, high speed, electrolytic cleaning is becoming increasingly established. This involves the counter flow of phosphoric acid (~20%) at ~80 to 90°C in recirculating, "straight through" cells (see opposite). The moving strip is connected (via liquid coupling) to an AC-power source which forces a controlled level of dissolution.

NOTE: Alkali etching is also used in the cleaning of aluminium, however it is generally restricted to batch type processes (e.g. extruded products) or to non-auto products (e.g. foil).



Schematic design of the straight through cell arrangement for the electrolytic cleaning or anodizing of coil products

Source: Alcan

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| METHOD | ADVANTAGES | DISADVANTAGES |
|-----------------------|--|--|
| Mixed acid cleaning | <ul style="list-style-type: none">• Relatively simple & well established process requiring no external power source. | <ul style="list-style-type: none">• Level of clean can vary with alloy, line speed, gauge etc.• Lower line speeds required for deep cleaning. |
| Electrolytic cleaning | <ul style="list-style-type: none">• Higher levels of clean are possible.• Can apply a consistent level of cleaning irrespective of alloy, line speed, gauge etc.• Improved process monitoring. | <ul style="list-style-type: none">• Cost of equipment and power. |

NOTE: The effectiveness of subsequent processes are very dependent on adequate cleaning. An inadequately cleaned surface is likely to result in poor product performance (adhesion/corrosion) irrespective of the quality of pre-treatment or coating.

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Pre-treatment of coil / sheet products

Literature:

- ▲ Lahaye, C.T.W., Bleeker, R., Vrenken, J., Heyvaert, S., Verboom, E.: Importance of pre-treatment of aluminium sheet for automotive applications. Proc. IBEC2002, SAE Technical papers series 2002-01-2090, (2002)

| Pretreated products fall into two categories | Pretreatment requirements |
|---|--|
| Temporary surface products. The most common type of auto-sheet. Typical surfaces are cleaned, pretreated & lubricated. Surface combinations provide a balance of manufacturing requirements (forming, bonding, welding etc). After final assembly (BIW), they are removed & replaced in the auto-paint line. | <ul style="list-style-type: none">• Stability in storage / transit• Improved durability of adhesive bonds• Removeability in cleaning system prior to phosphating |
| Permanent surface products. There is growing interest in pre-coated products (mainly in Europe). Typical surfaces are cleaned, pretreated & coated (various types including conventional or electrically conducting primers). These are described in more detail in later pages on pre-coated sheet. | <ul style="list-style-type: none">• Good adhesion to organic coatings• Under film corrosion resistance |

Pre-treatment options

Chemical Conversion Coatings

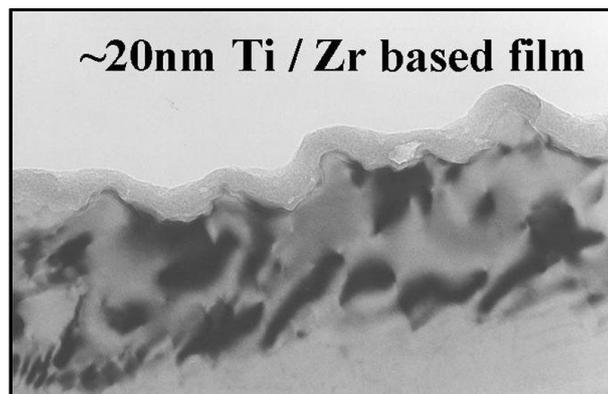
A very wide variety of chemical conversion coatings are commercially available for coil products. For automotive applications, they can generally be considered in 3 groups:

- ⤴ **Cr-based:** These have excellent properties but are now largely phased-out (toxicity)
- ⤴ **Ti / Zr based (Cr-free):** are becoming increasingly favoured as stabilizing treatments for inners & outers (particularly in Europe).
- ⤴ **Si-based (silanes, silanols):** Less commonly used, but are being exploited for applications requiring full structural adhesive bonding.

Anodizing

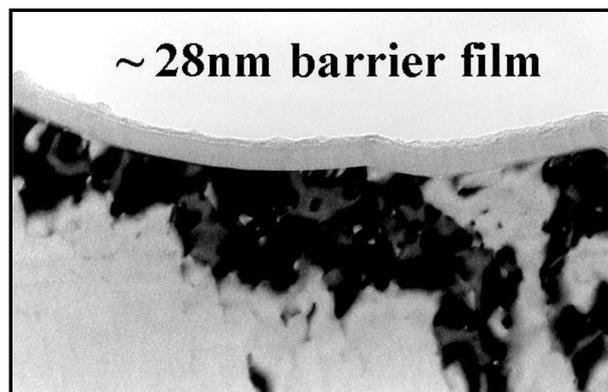
This form of surface pre-treatment is of increasing interest (particularly in Europe). A wide spectrum of film types are possible, but they can be summarised in 2 general groups:

- ⤴ **Thin barrier:** These are equivalent to thin, chemical stabilizing pre-treatment, such as the Ti / Zr type films. They are sufficiently conductive to allow resistance spot welding.
- ⤴ **Thicker barrier +/- porous layer:** More advanced films which provide enhanced bond durability for temporary surface products, or organic adhesion for pre-coated products.



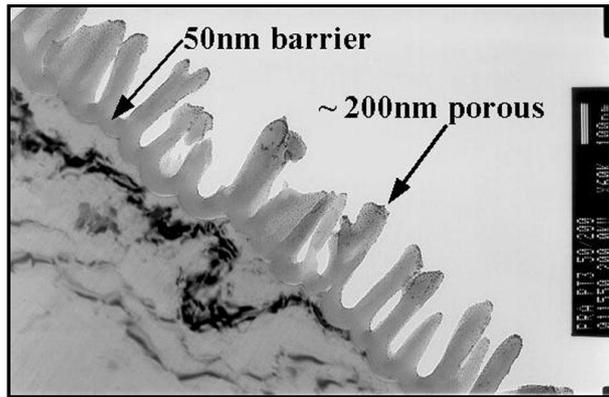
TEM cross section of a Ti / Zr chemically stabilized surface

Source: Alcan



TEM cross section of a barrier anodized surface

Source: Alcan



TEM cross section of an anodised surface with both barrier and porous film structure

Source: Alcan

Lubrication of coil products

Literature:

- ⤴ Lahaye C.T.W., Janson, I., Olofsson, A., Maurus, N.: Influence of the application of dry-lubricant on the production route for aluminium hang-on parts at Volvo. Proc. IBEC98, 982304, (1998)

Background:

- ⤴ Almost all flat sheet products are press-formed to create useful 3-dimensional parts for auto-manufacturer. Hence, all sheet products are used in a pre-lubricated form, (occasionally they are lubricated as discrete blanks before pressing).
- ⤴ The press-forming of parts is usually the first stage in auto-manufacture (it precedes assembly/joining and BIW painting).
- ⤴ Irrespective of the inherent formability of the sheet alloy, inadequate lubrication can lead to failures in the press-shop.
- ⤴ **For all of these reasons, lubrication of sheet products is a crucial part of the surface conditioning sequence.**

Lubricant Options:

There are a very wide variety of lubricants available for press-forming applications. These can be summarised in 2 groups:

- ⤴ **Oils:** Usually mineral oils, these are the most common type of lubricants employed in North America for thinner gauge closure applications (inners / outers). They are typically used in combination with a mill-finish surface.
- ⤴ **Dry-Films:** These wax type lubricants are increasingly favoured in Europe. They are almost always used in combination with a roughened isotropic surface texture, such as EDT (see earlier section).

A further category of dry-lubricants is based on acrylate films. These are not yet widely used and are generally considered as development products.

Lubricant Requirements:

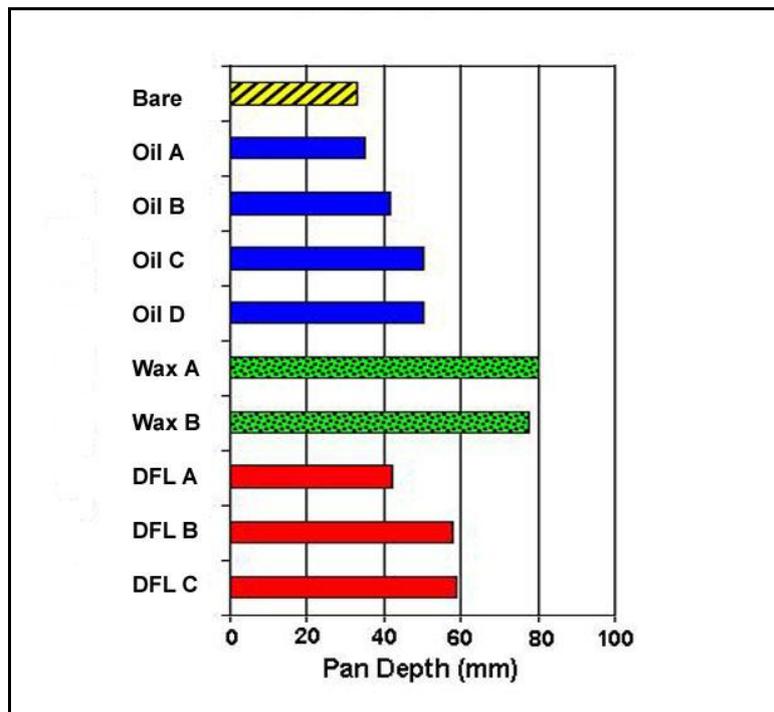
- ⤴ **Formability:** The first & most fundamental requirement is the ability to form the part. Sheet stocks of standard gauges are required to form a variety of parts. (i.e. the level / quality of lubrication must be adequate for the most difficult to form parts).
- ⤴ **Stability in Storage / Transit:** Lubricants are always applied at a specified coat weight (usually defined by forming needs). It is important that the originally applied coat weight is maintained during storage / transit of either coils, or stacks of blanks. It is also essential that lubricants are stable over a range of ambient conditions (temperature & humidity).
- ⤴ **Handling & runnability:** Most sheet products are supplied as stacks of pre-lubricated blanks. Hence, ease of de-stacking is a key handling requirement in the press-shop. Also, most modern press-shops are highly automated. Hence, it is essential that lubricants are compatible with all handling equipment.
- ⤴ **Compatibility:** Lubricants must be compatible with other stages of the auto-manufacturing sequence. It is unusual for press-formed parts to be cleaned prior to joining & assembly. Hence lubricants usually need to be compatible with processes such as adhesive bonding, mechanical fastening or resistance spot welding. Lubricants are generally removed from sheet surfaces during the first cleaning stages

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of the BIW during painting. "Remove-ability" is, therefore, a further essential requirement.

ADVANTAGES of dry, wax type lubricants

- ⤴ Increased deep drawing capability. The less widely used acrylate type dry-film-lubricants (DFL) can also provide some formability advantage (see opposite).
- ⤴ For more difficult parts, higher lubricant coat weights can be applied / maintained.
- ⤴ Dry lubricants are generally more stable in storage / transit.
- ⤴ De-stacking can be easier since surface tension effects from liquid surfaces are avoided (however, it is essential to avoid melting of the wax under hot ambient conditions as this can cause blanks to stick together).
- ⤴ Compatibility with joining and paint shop processes is generally equivalent to oils.



Comparison of deep drawing capability of lubricants on a common AA6016 substrate

Source: Alcan

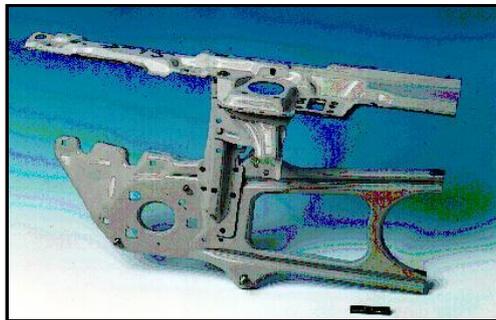
DISADVANTAGES :

- ⤴ Die sets need to be set up differently for dry type lubes than mineral oils (this can sometimes cause problems during "change-over" periods).
- ⤴ Depending upon the nature of the forming process and the lube coat weight, wax can accumulate in die sets (requiring occasional cleaning).
- ⤴ Wax type lubes can be more difficult to spot weld (this is more of a problem in North America where spot welding is more widely used).

Pre-coated sheet

Pre-coated aluminium sheet has been increasingly used in Europe in recent years (it is uncommon in North America). There are essentially 3 types of pre-coated sheet:

- ⤴ **Electrically conducting, pre-primed types:** These single coat products are the most commonly used in Europe and are usually used for non-cosmetic applications within the BIW (they are compatible with established E-coat processes).
- ⤴ **Non-electrically conducting pre-primed types:** Usually based on polyurethane primers. Because these are not currently considered to be compatible with E-coating they are less widely used.
- ⤴ **Fully painted sheet:** This is an emerging area of aluminium sheet usage. Selected outer panel applications exist for sheets with multiple coatings, (including cosmetic finishes).



An example of an auto sub-assembly manufactured using pre-primed sheet, adhesive bonding and mechanical fastening

Significant progress has been made in establishing suitable joining methods for all forms of pre-coated sheet. The main joining options include adhesive bonding and/or mechanical fastening. Strength / durability and fatigue properties have been demonstrated to be generally equivalent to conventional, uncoated sheet.

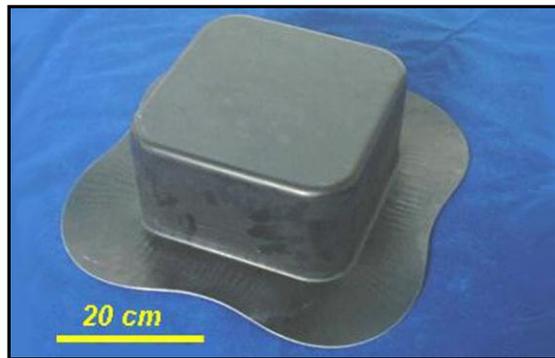
Main advantages of pre-coated sheet:

- ⤴ **Formability :** Up to 30% improvement in draw capability is possible compared to conventional bare/ lubricated sheet (see comparison below). This can be exploited to form more difficult parts, to use less lubricant, or to exploit lower grade metal.
- ⤴ **Corrosion Resistance:** Pre-coated sheet has excellent corrosion resistance. This can be exploited for parts/assemblies which are added to the BIW after the paint line, or for repair/replacement parts.
- ⤴ **Paint-line:** Minimise Al build up in paint line processes, e.g. phosphating.



Square pan pressing of an uncoated blank using ~1.5g/m² of wax lubricant

Source: Alcan



Square pan pressing of a pre-primed blank using $\sim 1.5\text{g/m}^2$ of wax lubricant

Source: Alcan

The main disadvantages of pre-coated sheet options are cost and that, with few exceptions, they cannot be spot welded.

4.2.2 Extrusions

Surface Treatment – Reasons and methods

Reasons for controlled surfaces:

- ⤴ Aesthetic and decorative reasons
- ⤴ Improved corrosion resistance
- ⤴ Improved mechanical and/or physical properties
- ⤴ Improved soldering and/or brazing
- ⤴ Creation of durable inter-phases for painting and adhesive bonding

Methods of surface finishing:

- ⤴ Mechanical surface treatment
- ⤴ Electrolytic and chemical polishing
- ⤴ Etching and conversion coatings
- ⤴ Anodising
- ⤴ Organic coating (powder coating, wet painting, foiling and screen printing)
- ⤴ Metal plating

Electrolytic and chemical polishing

General Notes:

- ⤴ The 2 polishing methods are often used prior to anodising to obtain a bright surface. In this case the process is called bright anodising.
- ⤴ Chemical polishing is used more often than electrolytic polishing (examples are Acid-cleaning, Glossing, buffing, Chromating & Phosphatising).
- ⤴ The methods are suitable for profile geometries where mechanical polishing is difficult.
- ⤴ Sometimes mechanical polishing is used prior to electrolytic / chemical polishing when a mirror / gloss appearance is required.

Electrolytic polishing:

- ⤴ Electrolytic polishing is carried out by means of an applied current, special chemicals and elevated temperature.
- ⤴ The "Brytal" process is one of the commercial electrolytic polishing processes. With this process it is possible to obtain mirror finishes on large flat areas. The profiles should be carefully polished by mechanical means before treatment.

Chemical polishing:

- ⤴ Chemical polishing is carried out by means of special chemicals (e.g. Phosphoric Acid, Nitric Acid and Sulphuric Acid) and elevated temperature.
- ⤴ Mirror-like surfaces are generally produced in mixtures of Phosphoric and Nitric Acids to which numerous other additions can be made to secure a higher levelling action.
- ⤴ Sulphuric Acid is very often added to the mixture to remove or minimise the die lines.

Etching and conversion coatings

General Notes:

- ⤴ In the as-rolled, or as-extruded condition, Al surfaces often exhibit a corrosion susceptible "Near Surface Active Region (NSAR)." This region is typically ~1µm in thickness. The nature of the NSAR is a consequence of the thermo-mechanical history of the aluminium surface (extrusion, hot rolling, cold rolling, etc.).
- ⤴ In the case of painting and adhesive bonding, the passivation or removal of this reactive region can improve the corrosion resistance of the system. Established alkaline or acid etch cleaning (i.e. prior to pre-treatment) generally provides the necessary passivation for good corrosion resistance.
- ⤴ The surface must be further stabilised by a conversion coating or by anodising to withstand the degrading effects of water. Water will attack the oxide, the oxide/polymer interface and the polymer. Therefore, retention of wet adhesion, especially under stress, is a determining factor.

Some examples of conversion coatings include:

Chromating:

Chromating usually shows excellent durability behaviour, but due to environmental reasons, chrome pre-treatment are no longer accepted for automotive applications.

Titanium (Ti) and/or Zirconium (Zr) based coatings:

These are increasingly used in automotive applications. Originally developed to prevent further oxide growth to maintain stable welding conditions. For bonding and painting, they provide excellent environmental durability.

Alternative coatings:

The search for further Cr-free alternatives is ongoing. Strong candidates include silanes, and permanganates.

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Anodising – Overview

- ⤴ Anodising is an artificial re-growth of the oxide layer by use of current and an electrolyte (normally Sulphuric Acid).
- ⤴ The thickness of the layer is dependant on the service-conditions. For indoor use, the thickness is typically from 3-15 μm , and for outdoor use the layer should be between 15-20 μm (or even thicker depending on required service life).
- ⤴ Anodic oxide films improve some major properties of aluminium.



Examples of extrusions

Source: Hydro

Anodising – Properties and process

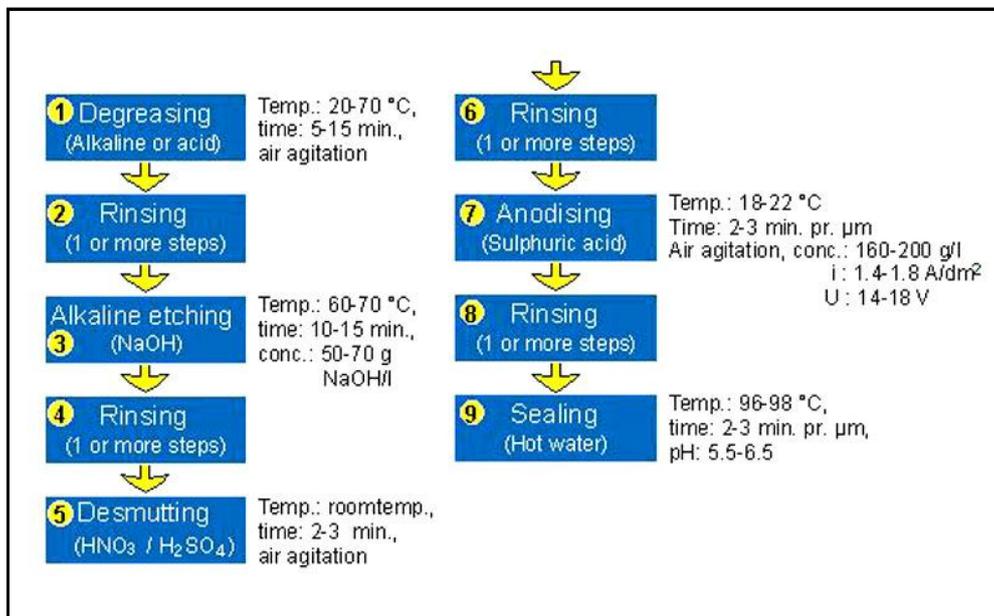
Response to colouring. Many colours available for indoor use. Mainly brown colours for outdoor use (fading is a concern for most colours).

Corrosion resistance. A low porosity oxide film has a good resistance against pitting corrosion. Chloride ions have little effect on a uniform layer.

Wear resistance. Anodising improves wear resistance. "Hard anodising" increases abrasion properties (normal architectural anodising also gives better wear resistance).

Surface hardness. Normal architectural anodising significantly increases the surface hardness.

Electrical resistance. The anodic oxide layer has high electrical resistance. Anodised aluminium is suitable for electrical components, e.g. transformers and capacitors.



Usual process order for architectural colour anodising

Source: Hydro

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Anodising parameters

For high standards of surface finish, the following parameters need to be controlled:

- ▲ surface finish and metallurgical structure of Al- alloys used for anodising.
- ▲ pre-treatment, anodising &, when required, colouring and sealing of the coating.

Pre-treatment (prior to anodising) are available that can mask, or eliminate many of the surface irregularities of Al-alloys, but the metallurgical condition of the alloy cannot be controlled by the anodiser & depends on the processing at the casting and extrusion stages of fabrication.

NOTE: The list of alloys below includes all extrusion alloys. Automotive extrusions are generally limited to 6xxx alloys.

| Alloys (AAXXX) | Protective anodising | Anodising and dyeing | Bright anodising | Hard anodising | Electro- plating |
|-------------------|-------------------------|-------------------------|---------------------|-------------------|---------------------|
| 1080 | E | E | E | E | - |
| 1060 | E | VG | VG | E | VG |
| 1200 | VG | VG | VG | E | VG |
| 2011 | M-G | M-G* | U | G | - |
| 2014 | M | M* | U | G | VG |
| 2031 | M | M* | U | G | VG |
| 3103 | G | G | M | G | G |
| 3105 | G | G | M | G | - |
| 4043 | G | M* | U | G | X |
| 5005 | E | VG | G | E | - |
| 5056 | G | G | M | E | X |
| 5083 | G | G | M | G | X |
| 5154 | VG | VG | G | E | X |
| 5251 | VG | VG | G | E | X |
| 5454 | VG | VG | G | E | - |
| 6061 | VG | G | M | VG | X |
| 6063 | E | VG | G | E | X |
| 6082 | G | G | M | G | X |
| 6463 | VG | VG | VG | VG | - |
| 7020 | G | G | M | G | - |

Anodising parameters

Source: Hydro

Legend:

E = Excellent
 VG = Very Good
 G = Good
 M = Moderate
 U = unsuitable

* = Only suitable for dark colours

X = A modified etching technique prior to plating is essential

Organic coating – Overview

Overview:

- ⤴ Organic coatings are mainly powder coatings and wet painting.
- ⤴ Powder coating is applied either by electrostatic or tribostatic charging of the powder particles.
- ⤴ Wet painting is applied by spray (incl. electrostatic spraying) or electrophoretic painting.

Reasons for using organic coating :

Aesthetic and decorative purposes: a wide range of colours are available and coatings will mask irregularities in the pre-treatment (conversion coating).

Weather resistance: most of the organic coatings for outdoor use have a very good gloss and color stability. However, epoxy coatings are not suitable for exterior architectural use. The epoxy resin is broken down by the UV-light.

Wear resistance: some special powder coatings (polyamides) have a superior abrasion resistance. Tests have shown that abrasion results are 600 times greater than the results of conventional powder coatings.

Friction: some special powder coatings (polyamides) have a low friction coefficient relative to conventional powder coatings.

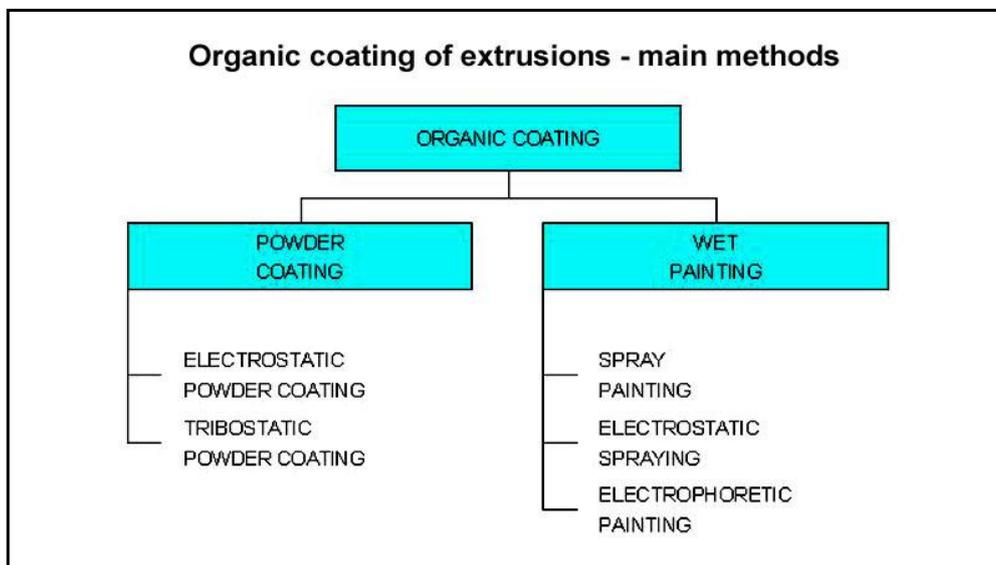
NOTE: Most of the above noted comments are relevant to architectural applications. There are currently few automotive applications for coated extruded sections.

Organic coating – Method



Powder coating of Al extruded profiles

Source: Hydro



Main methods of organic coating

Source: Hydro Aluminium

Metal Plating

Metal plating involves the deposition of a metal layer on another metal or polymer substrate. The deposition usually occurs from a solution which contains ions of the metal used for the coating. Plating can either be carried out by means of electro deposition, electroless deposition or mechanical deposition.

The main reasons for plating on aluminium are:

- ⤴ Formation of an attractive finish
- ⤴ Increased corrosion resistance
- ⤴ Increased surface hardness
- ⤴ Increased solder ability / braze ability

Comparison of finishing options

| METHOD | ADVANTAGES | DISADVANTAGES |
|-----------------|---|--|
| Anodising | Retention of metallic appearance Good weather and corrosion resistance | White colour of oxide layer not possible Possibility for uneven colour Reveals material and process defects |
| Organic Coating | Wide range of colours available Gives good weather & corrosion resistance Masks irregularities in the material | The metallic Al appearance is hidden |
| Metal Plating | Compared to bare metal: Improvement of decorative appearance Improvement of wear, corrosion resistance and hardness Improvement of solderability/brazability | More expensive than organic coating and anodising Most metal plated coatings are cathodic compared to aluminium |

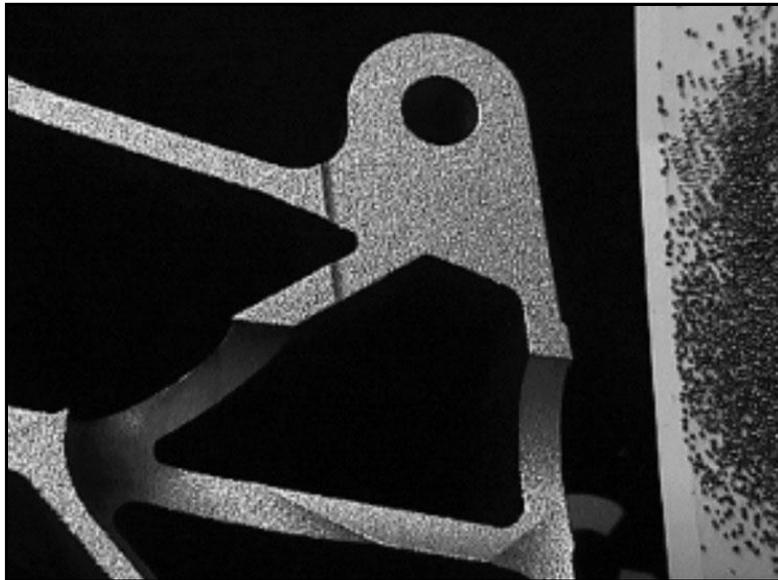
4.2.3 Castings and wrought parts

Mechanical surface treatment – General

Mechanical surface treatment is a term that covers a number of methods used to change the surface of an aluminium component.

The reason for using such methods may be for esthetical reasons, to round off sharp edges, i.e. deburring, prepare the surface for some other operation, e.g. coating, or to enhance mechanical properties in critical areas.

Some methods of mechanical surface treatment are suitable to combine with other types of treatment, e.g. anodising.



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Mechanical surface treatment – Polishing

Polishing is used to provide a smooth surface, eliminating any marks or stripes after extrusion. Surface quality and gloss are usually produced to customers' requirements.

Gloss is determined by polishing equipment and alloy.

Polished surfaces are often anodised. For a surface with a bright finish, anodising is done after polishing.



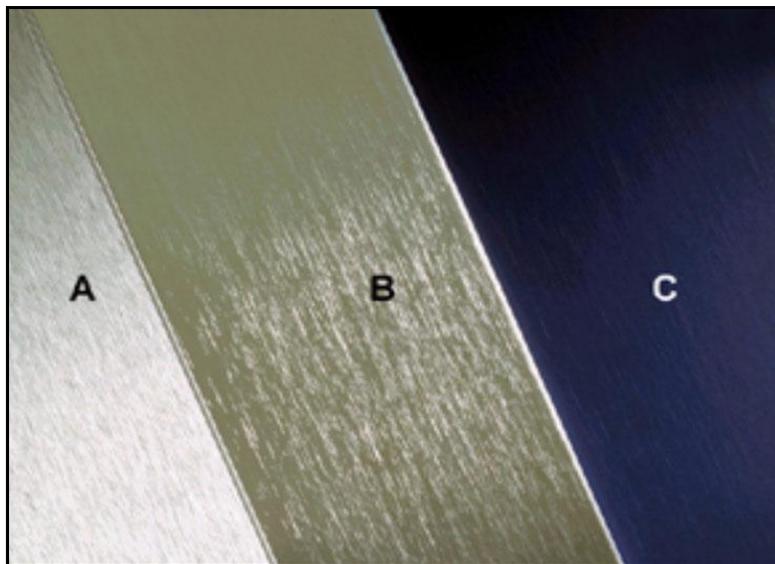
Mechanical surface treatment – Brushing and grinding

Brushing

Brushing is used to enhance surface quality for aesthetic reasons, to remove oxide prior to other operations i.e. welding, or for deburring cut edges. In the first case this treatment gives a scratched surface where the scratches are mostly of uniform size and lie parallel. The depth and width of the scratches are determined by the equipment, typically to the customers' requirements. Brushed extrusions are commonly anodised to provide a stable surface quality.

Grinding

Grinding is quite similar to brushing. It is used mostly for aesthetic reasons. This is typically done in a machine where the work piece, often a full length extrusion, is fixed, ground and cut afterwards. The surface structure may vary from fine to very coarse depending on the customers requirements, and is often anodised afterwards.



Examples of ground surfaces:

A = fine surface

B = coarse surface

C = surface anodised after grinding

Mechanical surface treatment – Tumbling

Tumbling is a method used to deburr or round off sharp edges on short parts, usually after cutting and milling.

It is suitable for parts having complex geometry where other methods, i.e. brushing, are not practical.

There are different ways of tumbling. In the simplest case, the parts are tumbled in a barrel and the edges rounded off by abrasion. In other cases the parts are tumbled in a barrel that is also vibrated along with abrasive pellets.

Various types of abrasive pellets are used, sometimes in combination with other materials i.e. sawdust. In other cases water is added during the process.



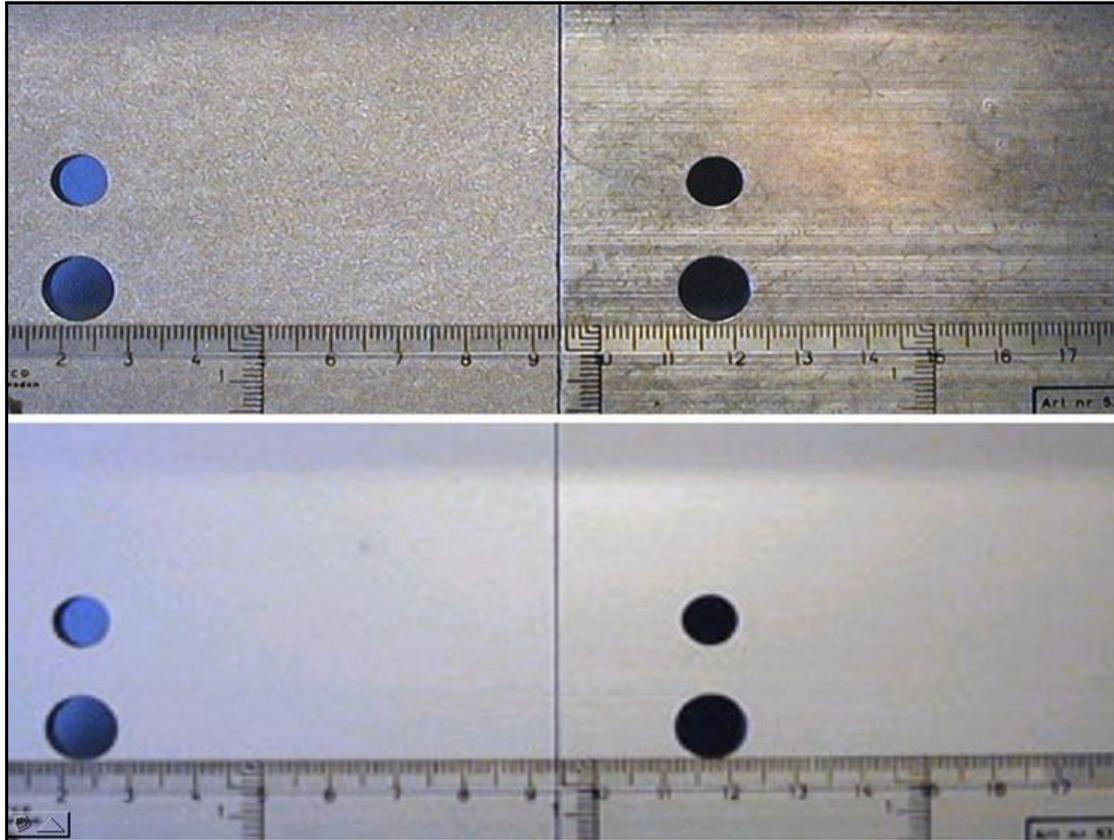
Tumbling with abrasive pellets

Mechanical Surface Treatment – Shot Blasting / Sand Blasting

Shot blasting

(s. figure below)

Shot blasting is conducted by hitting the surface with metal shot at high velocity. The type of shot, e.g. stainless steel, may vary in size and the velocity upon impact may vary as well. The surface is fairly coarse depending on the length of time the work piece is subjected to treatment and the size of the shot. Shot blasting is used to remove sharp edges and to produce a nice, uniform surface.



Top: Shot blasted (left) as compared to "as pressed" surface (right)

Bottom: Same as top, after anodising

Sand blasting

Sand blasting is similar to shot blasting, but where sand is used instead of shot. Various types of sand are used i.e. olivine, and even sand like materials i.e. aluminium oxide. Sand blasting is used to prepare the surface for other types of treatment i.e. coating, or to enhance surface roughness before joining.

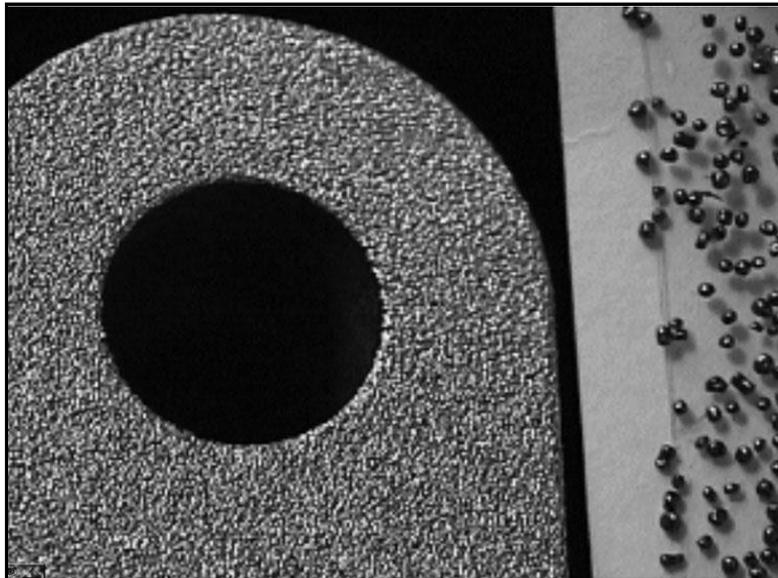
Mechanical surface treatment – Peening

Peening covers a number of methods used to create compression stresses on the surface of a metal part, and thereby enhancing fatigue strength. There are several peening methods available:

Shot peening is closely related to shot blasting but the shot is applied very locally, i.e. often on weld seams.

Hammer peening is a method where a hammer driven by compressed air is used to treat the surface. The hammer has a typical frequency of 50-100 hits per second and is quite noisy. Also it calls for sturdy fixtures to keep the hammer in position.

Ultrasonic peening is a new method where the hammer is driven by an electromagnetic device. The frequency of the hammer is about 27 kHz. The noise is fairly low and the fixing forces are considerably lower than for hammer peening.



4.3 Finishing of BIW and assemblies

4.3.1 Introduction

This short section provides general information about the most commonly applied surface finishing technologies for body structures which incorporate aluminium.

It is very important to note that most BIW assemblies are not exclusively constructed of any one metal. Even aluminium intensive vehicles contain steel, or galvanised steel (e.g. mechanical fasteners). Hence, the auto paint process must be compatible with the painting of a mixed metal assembly typically containing aluminium, steel and zinc (often also includes non-metals).

The two most important stages in the finishing of the BIW are **Phosphating** and **Electro-coating** and these are described in subsequent pages.

4.3.2 Phosphating

Phosphating of aluminium

See also:

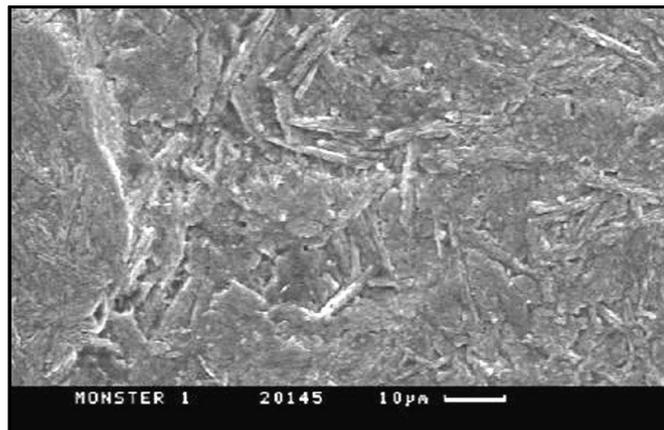
- ⤴ AAM – Manufacturing – 4 Surface finishing > Finishing of BIW and assemblies > New / emerging technologies

Literature:

- ⤴ Hunter J. A., Butler C., Hirth S. et al.: Balancing conflicting property requirements in the development of high performance AA6016 automotive closure sheet. Proc. 2nd Int'l Symp. on Aluminium Science & Technology, UMIST, 21 - 25 May 2000.

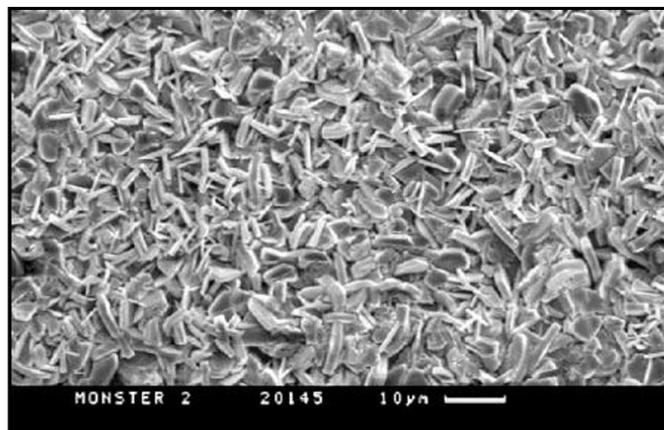
Introduction:

- ⤴ Phosphating is the most common form of pre-treatment in auto-manufacture. It provides excellent adhesion for subsequent coatings (E-coat) and long term corrosion resistance for the auto-body.
- ⤴ Two examples of phosphated aluminium are shown.



Non-layer forming Phosphate on AA6016 Sheet Surface (SEM image)

Source: Corus



Layer forming Phosphate on AA6016 Sheet Surface (SEM image)

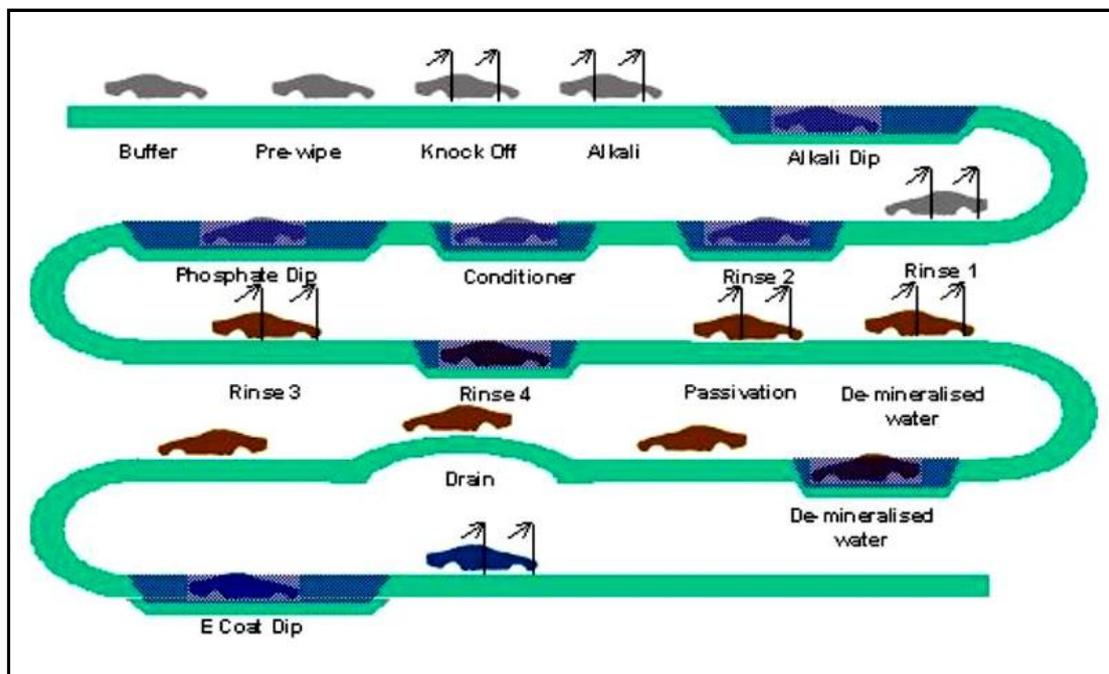
Source: Corus

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The phosphate response of an Al surface depends on several factors. One of the most important is the cleanliness of the starting surface. Cleaning processes for BIW vary, but usually involve a mild alkali or acid spray sequence (to remove lubricants etc) followed by a thorough rinse.

General Notes:

- ⤴ The most common method of pretreating a BIW is based on Zinc-Phosphate chemistry. Although processes vary between manufacturers, Tri-cation phosphating (based on mixed phosphates of Zinc, Manganese & Nickel) has become established as the most common form of auto-body pretreatment.
- ⤴ This can be applied by spraying, or immersion of the BIW. The objective is to create a dense network of phosphate crystals which provide good coatings adhesion and corrosion inhibition for all the metallic components of the BIW (steel, galvanised steel (Zn) and aluminium).



An example of an auto paint line sequence

Source: Alcan

Mixed Metal Assemblies & Paint Lines:

- ⤴ It is very important to note that BIW are not exclusively constructed of any one metal. Even aluminium intensive vehicles (AIVs) contain steel, or galvanised steel (e.g. mechanical fasteners). In addition, manufacturers of AIVs frequently need to process conventional steel vehicles on the same paint line.
- ⤴ Hence it is unusual for a phosphating process to be optimised for Al alone. Processing conditions are generally a compromise to provide adequate pre-treatment for all parts of the BIW assembly.
- ⤴ New Al-paint line technologies are now emerging, particularly with those manufacturers having a high proportion of Al usage.

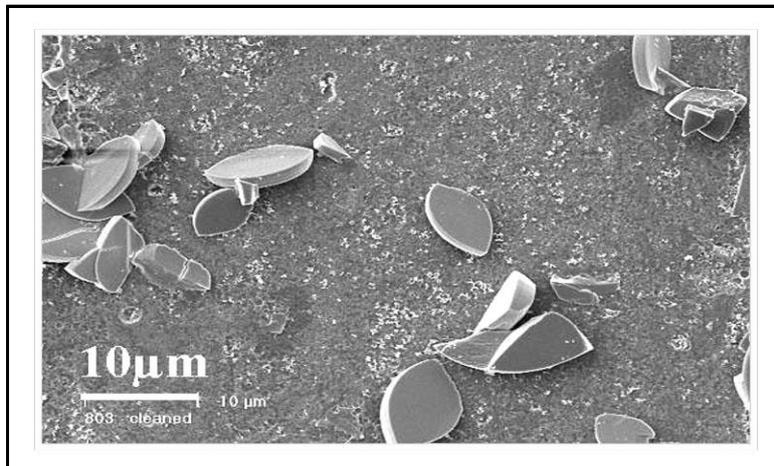
Process Options for the Phosphating of Aluminium:

- ⤴ Optimum phosphating of Al requires free fluoride in the phosphate system (typically >100 mg/litre). This aids the removal of process oxide and contamination by etching the surface. Fluoride also acts as a complexing agent to create a phosphate layer of acceptable quality (1.0 to 1.5 g/m²) [1-3]. It is also recognised that complex fluorides generally perform better than simple fluorides [3,5].
- ⤴ One problem with higher fluoride levels is that they can increase the formation of sludge (cryolite, elpasolite) and this can limit the amount of aluminium that can pass through a conventional, mixed metal paint line. Various strategies are available to counter this problem:
 - Spray rather than dip processing can increase the tolerance to aluminium,
 - Subsequent chemical treatments can allow the use of lower Fluoride levels.

Achieving Optimal Phosphate Response:

The phosphate response of aluminium forms can be significantly influenced by the starting surface:

- ⤴ The presence of a pre-treatment for storage stability or to enhance bonding properties can impair the phosphate response.
- ⤴ If certain chemical species (Ti, Zr etc) are present at > ~10mg/m² they can build up and poison the phosphate bath.
- ⤴ Certain lubricants can be more difficult to remove in the cleaning section prior to phosphating (e.g. acrylate films).
- ⤴ Lubricants applied at too high coat weight can take longer to remove and consequently reduce the phosphate response (see example shown below).



Example of poor phosphate response caused by the presence of too much lubricant

4.3.3 Electro-coating

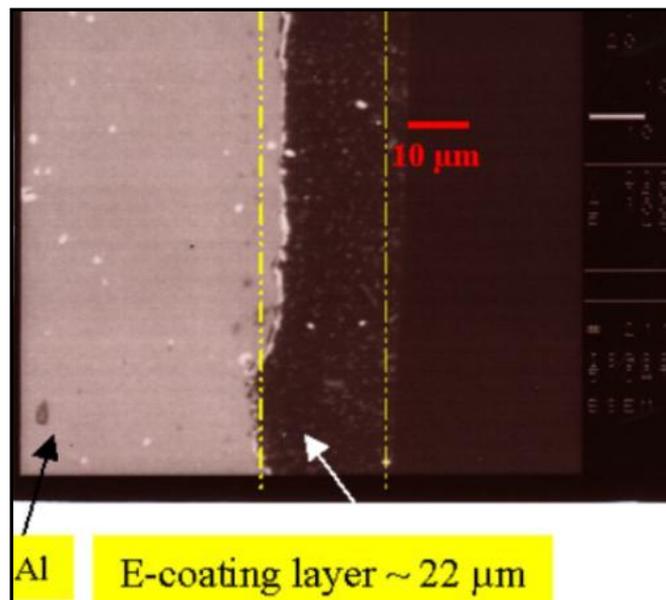
Process description

See also:

- ⤴ AAM – Manufacturing – 4 Surface finishing > Finishing of BIW and assemblies > Phosphating

Description:

- ⤴ Electro-coating is a "electrophoretic" paint process and is commonly used as the first primer coating of the Body-In-White (BIW). It is applied after phosphating or pre-treatment of the auto-body. The BIW is immersed in a tank of E-coat paint and electrically connected to a series of inert electrodes arranged around the periphery of the tank. During processing, the E-coat paint is attracted to all conducting surfaces resulting in a continuous, corrosion protective layer over the entire body structure (including inner/box surfaces).
- ⤴ E-coat also provides good adhesion between metal / phosphated surfaces and subsequently applied primers & paints.



E-coat section

Source: Pechiney

Cathodic E-coating is the most commonly used anti-corrosion primer system for Body-in-white painting.

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Principles & Chemistry

Principles of the Process:

Electrophoresis is the result of particle displacement in an electrical field (can be an anodic or cathodic process).

Some paint constituents have ionisable terminal groups in aqueous solution. Ions migrate under polarisation to form an organic film on the metallic surface (usually epoxy based).

The Chemistry of Deposition:

ANODIC PROCESS:

Metal surface anodic (+): -----> anaphoretic film



CATHODIC PROCESS:

Metal surface cathodic (-): -----> cataphoretic film



Electro-coating is an auto-limiting process. As the E-coat builds up in one area, the electrical resistance increases, progressively slowing the deposition. This allows deposition in other, relatively shielded regions of the structure to progress to an acceptable level.

Aluminium & mixed material assemblies

Mixed Metal Assemblies:

The Cathodic E-coating process is the most commonly used in the auto industry.

One set of operating conditions provides excellent coverage & protection for aluminium, steel & galvanised steel, or for mixed metal assemblies (BIW). For best coverage and protection, it is essential that the BIW is well cleaned to remove lubricants or contamination.

Typical Process Conditions:

Voltage: 150 to 300 volts

Coating Thickness:

- ⤴ exterior parts: 20 to 30 μm
- ⤴ interior parts: 10 to 20 μm
- ⤴ box (shielded) parts: 8 to 10 μm

Curing conditions:

- ⤴ 140 to 190°C for 20 to 30 minutes

Non-phosphated areas tend to develop thicker E-coat films and so good phosphate uniformity is important (particularly for cosmetic parts such as body panels).

4.3.4 New / emerging technologies

Alternatives to Zn-phosphating before E-coating

See also:

- ⤴ AAM – Manufacturing – 4 Surface finishing > Finishing of BIW and assemblies > Phosphating

Background :

- ⤴ The chemical treatment of Al auto-bodies before E-coating can be carried out by means of Tri-cationic phosphating (usually with fluoride addition). However, it is often necessary to modify existing phosphate conditions in order to treat higher levels of Al (see phosphating section).
- ⤴ If the amount of aluminium passing through a conventional dip-phosphating process exceeds ~ 20 to 30% (by area), problems can arise, e.g. generation of cryolite sludge. This can cause a variety of problems (control of bath chemistry, surface defects etc).
- ⤴ Zn-phosphating by means of a spray process can be carried out up to ~ 80% Aluminium percentage.

ALTERNATIVE PROCESSING:

- ⤴ New processes for the treatment of Al intensive vehicles are now emerging.
- ⤴ One approach utilizes a conversion treatment which forms a thin film of Ti or Ti/Zr complex (+/- polymer additives).

The new process forms a pre-treatment film on Aluminium and Magnesium. **It offers the following advantages:**

- ⤴ tailor made for Al and the process has no Zn, Ni or Cr
- ⤴ almost no sludge formation
- ⤴ cost saving in investment and line operation:
 - short line design
 - reduced energy consumption
 - less consumption of chemicals
 - reduced maintenance
- ⤴ excellent paint adhesion, improved corrosion resistance of the finished panels compared to conventionally processed panels (i.e. via the established Zn-phosphate method).