INTRODUCTION TO ALUMINIUM - POCKET GUIDE

1. ALUMINIUM SMELTING AND SEMI FABRICATION

Aluminium is categorised into two groups; primary aluminium, derived (smelted) from alumina (Al₂O₃), and derived from previously used aluminium. The primary and secondary smelters produce a range of alloys that are sold to semi-fabricators which convert the basic aluminium forms into flat, shaped and cast products. This in turn becomes the raw material used by the companies that supply a variety of industries.

Aluminium intrinsic and attributive properties of importance to the designer.

The term "Aluminium" includes the aluminium based alloys. Termed "The Magic Metal" or "The Wonder Metal", the reasons for these accolades lie in the very diverse range of physical, chemical and mechanical properties offered by the metal and its alloys in both cast and wrought forms. It is a versatile, highly usable and attractive designers material.

Intrinsic

Bulk Mechanical properties

- Density - A key property is low density. Aluminium, with a density of 2.71 gm/cm³, is only one-third the weight of steel and less than one third the mass of copper or brass.

- High strength to mass ratio - A property that has resulted in extensive use of aluminium in fabricated applications, replacing steel and other materials.

- Strength - Whilst aluminium engineering alloys have similar strength to structural steels, aerospace aluminium alloys are even stronger than steel.

- Ductility - Aluminium is readily formed by a variety of processes (cast, rolled, extruded or forged) and being malleable it is easily worked, formed and machined by the common manufacturing and shaping processes.

- Forms - One of the real strengths of aluminium is in its extruded form. Extrusions are complex hollow and solid shapes that are able to incorporate a variety of features that increase the value of the product by reducing fabricating labour or increasing usability.

- Young's modulus of elasticity - is moderate, being about a third of that of mild steel, requiring stiffer aluminium sections. Aluminium has a relatively high coefficient of linear expansion.

Bulk non mechanical properties

- Electrical Conductivity - Aluminium is a superb conductor of electricity. Mass for mass, aluminium conducts about twice the electric current of copper.

- High Thermal Conductivity - Thermal conductivity is four times that of steel and eight times that of cast iron. This is important in applications that involve either heating or cooling - such as cooking utensils and automotive heat exchangers.

- Non-magnetic - among properties that are invaluable in advanced industries such as electronics, mining, marine or in offshore structures.

- Non-combustible - Aluminium does not burn or sustain combustion.

- Non-sparking.

- Non-toxic and impervious, qualities that have established its use in the food, packaging and pharmaceutical industries since the earliest times. The metal releases no odours or taste impairing substances.

Surface properties

- Corrosion - Aluminium, and most of its alloys, are highly resistant to most forms of corrosion. The metal's natural coating of aluminium oxide provides a highly effective barrier to the ravages of air, temperature, moisture and chemical attack (between the pH range 4.5 to 8.5), making aluminium a useful construction material. It does not rust.

Attributive properties

Production properties

- Joining - Sheets, extrusions, sections and castings are easily joined by welding, brazing, soldering, mechanical fastening and adhesive bonding.

- Temperature - Aluminium can be structurally used between -270 °C and up to 130°C. It does not show a brittle transition. Strength increases towards cryogenic temperatures.

- Totally recyclable / environmentally responsible - with no downgrading of its qualities. Melting recycled aluminium requires requires only 5% of the energy used for primary smelting.
Aesthetic properties

- Reflectivity - Aluminium has high light, radiant heat and radiant energy, and radio wave reflectivity. In terms of reflecting away heat, it has excellent insulation properties.
- Finish - Aluminium looks good in its natural finish that can be soft and lustrous, or bright and shiny. It can be anodised, powder coated, plated and painted. This provides decorative finishes and increased corrosion and wear protection.

Aluminium and the family of alloys clearly have great versatility.

### 2. ALLOY AND TEMPER DESIGNATIONS

The properties listed previously can be found within an impressive array of commercially available alloys tailored to suit specific applications. One of the main modifications is strength. This normally associated with a decrease in ductility. Aluminium can be strengthened in two ways, adding small quantities of other elements or by post cast tempering; hot or cold working.

### Table 1: Wrought aluminium alloy - four-digit alloy series designation system (main alloying element(s))

<table>
<thead>
<tr>
<th>Unalloyed</th>
<th>99.5-99.95% Al</th>
<th>1xxx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloyed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(non heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>treatable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Manganese</td>
<td>3xxx</td>
<td></td>
</tr>
<tr>
<td>+ Silicon</td>
<td>4xxx</td>
<td></td>
</tr>
<tr>
<td>+ Magnesium</td>
<td>5xxx</td>
<td></td>
</tr>
<tr>
<td>Alloyed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(heat treatable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Copper</td>
<td>2xxx</td>
<td></td>
</tr>
<tr>
<td>+ Magnesium and Silicon</td>
<td>6xxx</td>
<td></td>
</tr>
<tr>
<td>+ Zinc/magnesium/ copper</td>
<td>7xxx</td>
<td></td>
</tr>
</tbody>
</table>

In high-purity form (99.9% Al) aluminium is soft and ductile. To increase its strength, small quantities of other elements can be added to produce various alloys to perform specific duties or applications. After alloy preparation, the properties may be further enhanced through tempering processes. The opportunity for such treatment is guided by the alloy composition.

Alloys fall into two main groups, non-heat-treatable and heat-treatable alloys. The work-hardening (or non-heat-treatable) alloys achieve strength by the amount of "cold work" applied to the alloy, e.g. by rolling. The heat-treatable or precipitation hardening alloys, achieve strength and properties through a combination of heat treatments of varying complexity sometimes combined with cold work.

The composition logic of the aluminium alloys follows an internationally agreed classifications system for wrought alloys and various nomenclature schemes for the casting alloys, chiefly the American and the European systems.

Thus aluminium alloys are described by two characteristics. The first is the alloy chemical composition and the second, post cast tempering.

### Aluminium Alloys

The wrought alloy system applied in South Africa and internationally uses a four-digit number, while the cast alloy system used in Europe and South Africa is a five-digit number. Table 1 on the next page relates to wrought products.

The first digit of the four-digit system refers to the main alloying element(s), the last two digits to the alloy number and the second digit to the base alloy modification.

### Non-heat-treatable alloys

The non-heat-treatable alloys are those in which the enhanced mechanical properties are determined by the amount of cold work (strain hardening) introduced (e.g. by rolling, drawing etc.). The 1xxx, 3xxx, 4xxx and 5xxx alloys are non-heat-treatable. The 4xxx series is mainly used for casting and for welding filler materials. The properties obtained through cold work are reduced by subsequent heating over 200°C and cannot be restored except by additional cold work.

#### Heat-treatable alloys

The heat-treatable alloys are those in which the mechanical properties may also be improved by the solution heat-treatment process. In contrast to the non-heat-treatable alloys, the increased strength is obtained with little sacrifice of ductility. Heat-treatable alloys have the further advantage that they can be re-heat-treated after annealing to restore the original properties.

### Temper Designations

In order to fully specify a material, the temper designation should be shown as an alpha numeric suffix to the alloy designation, e.g. 1200-H12, 6063 - T6. The symbols are used to designate temper or condition for characteristic structural and mechanical properties produced in an alloy transformation process.

Four letters are used as suffixes. These are O, F, H and T. H and T are followed by numbers giving further process and strength information.

F refers to the as-fabricated form and to no specific defined, controlled treatment.
<table>
<thead>
<tr>
<th>ALLOY</th>
<th>CHEMICAL COMPOSITION (mass %)</th>
<th>TYPICAL TEMPER</th>
<th>2% Proof Stress (MPa)</th>
<th>STOCK RANGE</th>
<th>TYPICAL APPLICATION / USAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1050A</td>
<td>199.5, 0.4, 0.25, 0.05, 0.05, 0.5, 0.7, 0.05</td>
<td>O/Hx4</td>
<td>35/105</td>
<td>Sheet, coil, foil, (0.2 - 6.35 mm)</td>
<td>General sheet work where moderate strength is adequate, packaging for food and chemicals, radiator tubes, insulation foils, automotive trim, light reflectors, architecture.</td>
</tr>
<tr>
<td>1350</td>
<td>99.5, 0.4, 0.10, 0.05, 0.01, 0.03, 0.05, 0.01</td>
<td>O/Hx4</td>
<td>75/110 (UTS)</td>
<td>Extrusions, sheet and plate</td>
<td>Electrical conductors, bussbars, transformer coils.</td>
</tr>
<tr>
<td>2024 AlCu4Mg1</td>
<td>Bal. 0.5, 0.5, 3.8-4.9, 0.3-0.9, 1.2-1.8, 0.25, 0.15, 0.1</td>
<td>T3, T8</td>
<td>340/450</td>
<td>Bar, sheet, Imported</td>
<td>High strength fabricated or machined items. Mechanical joining.</td>
</tr>
<tr>
<td>3003 Special</td>
<td>Bal. 0.15, 0.5, 0.10-0.5, 1.70-2.40</td>
<td>Mill temper only.</td>
<td>On request</td>
<td>Treadbright, 1 - 5 bar sheet &amp; coil</td>
<td>Decorative &amp; architectural, non-slip flooring for boats, vehicles, lifts, offices, factories.</td>
</tr>
<tr>
<td>3004 AlMnMg</td>
<td>Bal. 0.7, 0.3, 0.25, 1.0-1.5, 0.8-1.3, 0.25</td>
<td>O/Hx4/Hx8</td>
<td>75/200/250</td>
<td>Sheet, coil (0.2 - 6.35 mm)</td>
<td>General purpose sheet of high strength used for roofing, cladding, gutters, packaging, containers, transport, architectural, cans.</td>
</tr>
<tr>
<td>4043 AlSi5</td>
<td>Bal. 0.8, 4.5-6.0, 0.3, 0.05, 0.05, 0.10, 0.2</td>
<td>n/a</td>
<td>Wire and rods</td>
<td>Welding filler, commonly used for castings and for welding 1xxx to 5xxx and 6xxx, and 6xxx to 6xxx.</td>
<td></td>
</tr>
<tr>
<td>5083 AlMg4,5 Mn0.7</td>
<td>Bal. 0.4, 0.4, 0.1, 0.4-1.0, 4.0-4.9, 0.25, 0.15, 0.05-0.25</td>
<td>O/Hx2/Hx4</td>
<td>145/240/275</td>
<td>Sheet, plate (0.25 - 6.35 - 150 mm)</td>
<td>Commercial transport, marine plate, structural plate for mining, pressure vessels, chemical plant, storage tanks, tooling plate, railway wagons, general sheet metal, military vehicles, building construction.</td>
</tr>
<tr>
<td>5251 AlMg2Mn</td>
<td>Bal. 0.5, 0.4, 0.15, 0.1-0.5, 1.7-2.4, 0.15, 0.15, 0.15, 0.15</td>
<td>O/Hx2/Hx4</td>
<td>80/165/190</td>
<td>Sheet, plate, coil, bar tread sheet, tube</td>
<td>As for 5083, but a medium to high strength alloy. Also for signs and architectural panels and irrigation equipment.</td>
</tr>
<tr>
<td>5454 AlMg3Mn</td>
<td>Bal. 0.4, 0.25, 0.1, 0.5-1.0, 2.4-3.0, 0.25, 0.20, 0.05-0.2</td>
<td>O/Hx2/Hx4</td>
<td>110/205/235</td>
<td>Sheet, plate.</td>
<td>As for 5083, but good strength in temperature range 65 - 160°C. Chemical and process industries, transportation and building.</td>
</tr>
<tr>
<td>5356 AlMg5</td>
<td>Bal. 0.4, 0.25, 0.1, 0.05-0.20, 4.5-5.5, 0.1, 0.06-0.2, 0.05-0.2</td>
<td>n/a</td>
<td>Wire and rods</td>
<td>Welding filler commonly used for welding 5xxx series to 5xxx and 6xxx series alloys.</td>
<td></td>
</tr>
<tr>
<td>5754</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6061 AlMg5SiCu</td>
<td>Bal. 0.7, 0.4-0.8, 0.15-0.4, 0.15, 0.8-1.2, 0.25, 0.15, 0.04-0.35</td>
<td>O/T4/T6/ sheet T651</td>
<td>55/140/270</td>
<td>Extrusions, bar, plate, sheet.</td>
<td>Heavy duty structural sections, road, rail, marine, bridges, pylons, rivets, hydraulic components.</td>
</tr>
<tr>
<td>6063 AlMg0.7Si</td>
<td>Bal. 0.35, 0.2-0.6, 0.1, 0.1, 0.45-0.90, 0.1, 0.1, 0.1</td>
<td>O/T4/T6</td>
<td>50/90/210</td>
<td>Extrusions - all shapes</td>
<td>Structural, transport, architectural, agricultural, general engineering, tubing, intricate profiles.</td>
</tr>
<tr>
<td>6082 AlSiMnMg</td>
<td>Bal. 0.5, 0.7-1.3, 0.1, 0.4-1.0, 0.6-1.2, 0.2, 0.1, 0.25</td>
<td>O/T4/T6/ sheet T651</td>
<td>60/170/310</td>
<td>Extrusions, sheet, plate.</td>
<td>Stressed and heavy duty structural applications, machinery, towers, roof trusses, cranes, bridge plates.</td>
</tr>
<tr>
<td>6463 AlSiMg</td>
<td>Bal. 0.15, 0.2-0.6, 0.2, 0.05, 0.45-0.90, 0.05</td>
<td>-</td>
<td>T4 / T6</td>
<td>75/160</td>
<td>Extrusions</td>
</tr>
<tr>
<td>7075 AlZnMgCu</td>
<td>Bal. 0.5, 0.4, 1.2-2.0, 0.3, 2.1-2.9, 5.1-6.1, 0.2, 0.18-0.28</td>
<td>T6 sheet &amp; T6 plate</td>
<td>480 &amp; 460</td>
<td>Bar, extrusions, plate, Imported</td>
<td>Very high strength for structural components, machine parts &amp; tools. (Mechanical joining)</td>
</tr>
<tr>
<td>44100 AlSi12</td>
<td>Bal. 0.65, 10.5-13.5, 0.15, 0.55, 0.10, 0.15, 0.2</td>
<td>-</td>
<td>Sand/chill/ die casts</td>
<td>65/75/120</td>
<td>Castings - sand, chill and die.</td>
</tr>
<tr>
<td>46500 AlSi9Cu3</td>
<td>Bal. 1.3, 8-11, 2-4, 0.55, 0.05-0.55, 3.0, 0.25</td>
<td>-</td>
<td>High press. die cast, 'F'</td>
<td>140</td>
<td>High pressure die castings</td>
</tr>
</tbody>
</table>
Typically available in thicknesses down to 0.4 mm.

The engineering, marine and transport sectors mainly use 5xxx series alloys. These are rarely available less than 4.5mm thick. The size of sheet produced is up to some 1500mm wide and 7000mm long.

Stress relieved sheet or plate is advised if the product is to be cut. Stress relieving ensures that the plate / sheet remains flat if cut. The need for stress relieving relates to the effects of internal stresses in the plate as a result of the rolling process. A flat sheet which has not been stress relieved may well move when cut. The equal and opposite forces which held it flat when uncut have been unbalanced and this can lead to twisting. Stress relieving is designed to remove the internal stresses that may affect the product and then a flat product remains flat when cut.

### Semi fabricated forms: extruded shapes

Extrusions are one of the characteristics of aluminium that separate aluminium from other metals. Aluminium’s ability to be forced through a die, rather like icing sugar through a range of possible nozzles, offers great opportunity. Extrusions can be tailored to offer products that can better achieve the function required, that save on labour during assembly or deliver accuracy in fabrication.

Unlike steel, where the range of shapes is limited, the range in aluminium is effectively limitless. One can put metal where it is required, build in features that hold bolts or screws (or anything else), develop hinges, clip or roll fits, provide assembly lines or weld preparation angles or back plates and more. The possibilities are almost endless.

Extrusions may be hollow (like a pipe) or solid (such as an angle or a bar).

### Table 3: Aluminium sheet / plate minimum bending radii for 90° cold bends

Note: It is suggested that a test bend is done to ensure a clean bend with no fractures.

<table>
<thead>
<tr>
<th>Alloy/ Temper</th>
<th>Plate and Sheet Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>3003 H12</td>
<td></td>
</tr>
<tr>
<td>4017 H12</td>
<td></td>
</tr>
<tr>
<td>5052</td>
<td></td>
</tr>
<tr>
<td>H32</td>
<td>0.5t</td>
</tr>
<tr>
<td>H34</td>
<td>0.5t</td>
</tr>
<tr>
<td>5083</td>
<td></td>
</tr>
<tr>
<td>H32</td>
<td>X</td>
</tr>
<tr>
<td>H32</td>
<td>X</td>
</tr>
<tr>
<td>H34</td>
<td>X</td>
</tr>
<tr>
<td>H0/111</td>
<td>X</td>
</tr>
<tr>
<td>H116</td>
<td>X</td>
</tr>
<tr>
<td>5182 (T500) H111</td>
<td>X</td>
</tr>
<tr>
<td>H32</td>
<td>X</td>
</tr>
<tr>
<td>H34</td>
<td>X</td>
</tr>
<tr>
<td>5754</td>
<td></td>
</tr>
<tr>
<td>0/H111</td>
<td>0.5t</td>
</tr>
<tr>
<td>H22/32</td>
<td>0.5t</td>
</tr>
<tr>
<td>H24/34</td>
<td>1.0t</td>
</tr>
<tr>
<td>H26/36</td>
<td>1.5t</td>
</tr>
</tbody>
</table>
Two processes are used to produce hollow extrusions.

The more common is one where the extrusion billet from which the extrusion is formed is divided into streams by a fixed mandrel to form the hollow. The edges are fused together under heat and pressure as the outer shape is formed. The seams formed in this manner are not visible to the eye and do not generally affect local properties. However the internal weld is a reality.

True seamless extrusions are sometimes specified for critical applications such as the aluminium used on aircraft. They are more limited in availability and shape than the conventional process. Seamless extrusions are formed by piercing an extrusion billet in an initiating operation to provide a hollow. A floating mandrel (one not retained in vertical or horizontal orientation) is fitted which guides the formation of the inner part of the required extrusion. As the mandrel is floating, wall thickness is more difficult to control. There is however, no fusion seam.

Extrusions allow the designer the unique opportunity to design sections to meet the load and design criteria. With the standard shapes and sections available from steel mills, designers are limited to the commercially available range. It results in selecting sections that exceed requirement, wasting metal and resources.

A key approach in aluminium extrusion design is to envisage how few parts can be used to manufacture the required product - as distinct from limiting shape opportunity to the standard shapes and joining methods used - as is the case with hot or cold rolled sections.

Tolerances

The hot process involved in the extrusion process results in reasonable, but not exact, precision. While this is not normally a concern there are occasions where sliding fits or interconnected sections, such as corner cleats, do need to address the limitations of tolerances. The extrusion industry standard on size, twist and straightness tolerances is available in the current edition of BS EN 755:1998.

Tolerances cover:
- diameter and wall thickness for round tube
- hollow rectangular width, depth and width across flats
- wall thickness other than for round tube
- cross sectional dimensions
- straightness and twist tolerances
- convexity and concavity across sections, and
- angularity tolerances for right angles

Should different tolerances to the standard be required these need to be discussed early in the design process as this may influence the manufacturing process.

Technical Grade Materials

Some critical applications require evidence of the conformance of aluminium to given specifications. This can be obtained by specifying 'Technical Grade'. In this instance, certification covering composition properties and trace-ability will be supplied.

Note: Most of the stockholding is not technical grade as it is generally not required for common usage.

4. FABRICATION OF ALUMINIUM

Generally, while aluminium requires sharper tools and larger rake angles, common metal working tools can be used. Sometimes, where aluminium grains stick between teeth, the coarser pitches of hard
wood tools perform well. Softer alloys, such as the 1xxx series, are easier to form but more difficult to machine and cut as the soft alloys clog the tools.

An important difference between machine work on steel and machine work on aluminium is the need to keep the work piece cool in aluminium. To achieve this one uses a cooling fluid aimed at the work piece (as opposed to a cutting fluid for steel).

For occasional work, while threading-tools suited to steel may be used, specific threading tools have been developed for aluminium. In particular, these cut round (as distinct from sharp) edged threads.

When machining, some alloys are better suited to this purpose than others. These are the machining alloys, (such as 2024 - T8 and 7075 - T6) which are sold as machine bar or plate. They are characterised by the ability of the metal to form chips as distinct from long shards. The difficulty with the shards is that they can be heated to such an extent that they can fold back onto the work and self weld onto the machined surface even if the work is kept cooled.

Note: More comprehensive information on the use of aluminium can be obtained from Aluminium Stockist technical staff and from AFSA staff.

Marking out on aluminium with scribes is very poor practice as it leads to stress raisers in the metal surface. Use permanent markers.

Bending Data

A guide for the minimum recommended radii for 90° cold bends in aluminium sheet and tube is provided in Table 3. The radii given in bending tables Tables 3 and 4 are based on normal workshop practice and assume lubricated bending. Minimum possible radii should be determined by forming a sample of the sheet or plate in actual use.

As the stress-strain relationship of aluminium includes an elastic zone followed by elasto-plastic and plastic-elastic zones, the metal tends to spring back after bending. This implies a need for over-bending that must be considered in bending tool design. This is due to the elastic deformation that occurs in addition to the normal plastic deformation of the material. It is most marked in hard material of high yield strength, but negligible with dead soft tempers. The need for over-bending also increases with decreasing metal thickness.

Punching and shearing are best carried out on materials in the hard condition. Soft material tends to drag. Alloys in an intermediate or hard-rolled temper give cleaner edges and are not as prone to distortion and bending under the punch.

Joining Aluminium

While structural integrity is best achieved without joints, in most cases a fabrication requires a joint of one type or another. These joints may be required to simply connect components that are too large to produce as a unit, to hold a specific configuration but to allow movement in some directions (such as hinges), to allow for maintenance, and the like.

In general terms, joints are a natural weak link from a structural point of view. If they cannot be avoided, they are best placed in low stress regions and if this is not possible, design should take this into consideration.

A wide range of choice is available:

- Extrusions can be designed to include joints or joint assistance features as previously described.
- Many cleats are extruded and connected either mechanically (through local plastic deformation) or using screw ports.
- Castings are a useful method of accommodating three-dimensional structures that need to transmit forces. While the castings themselves will need to be connected, they provide a method of stress accommodation in high stress areas and reduce stress in the joints themselves.
- Flexible adhesives can be an attractive method of joining. They require application to a clean, prepared surface and need to be applied in the correct thickness to enable them to function properly. Often the affected components need to be held in place to allow the adhesives to cure.
- Mechanical fasteners such as bolts, screws and solid and pop rivets are frequently used. Access is important and may be required from either one or two sides.

Rivets and bolts (as distinct from set screws - bolts threaded the full depth of the shank) should be fitted into holes that are originally drilled undersize and reamed to the bolt shank dimension. (This is very different from the steel practice of over-drilling bolt holes to accommodate tolerances).

Swage lock bolts (Huck bolts) are often used when vibration that could lead to the loosening of the bolt is possible. In this case the "nut" is plastically deformed around parallel threads on the shank of the bolt. Variations of these bolts can also be fixed from one side only (blind) - as is the case with pop rivets.

Screws - a wide range of screws is available. Screws have the advantage of being fixed from one side. Self-drilling screws are also available. As aluminium screws are difficult or almost impossible to get, the preferred connector material is austenitic stainless steel (3xxx series) because it acts neutrally towards aluminium regarding corrosion. Both are (galvanically) passivated by oxide skins that form rapidly on exposure to oxygen. All stainless steel screws and bolts are made from austenitic stainless steel.

"Pop" rivets (to be used particularly outside in corrosive atmospheres) should be aluminium with an aluminium shank, not aluminium with a steel shank (it is easy to check which is which - apart from the mass, steel is magnetic, aluminium is not).

Fusion welding. All aluminium alloys, other than those containing more than 0,5% copper in the 2xxx and 7xxx series, can be welded. Welding is commonly used in engineering and transport applications. The 5xxx (Mg) and 6xxx (Si, Mg) series are frequently welded, as are castings such as CEN42000 (LM25) and CEN44100 (LM6).

Further Information on fusion welding can be obtained from AFSA.

5. SURFACE FINISHING OF ALUMINIUM

Surface finishing: How can the surface be altered to suit the user's purposes?

There are two sets of surface finishing of interest - aesthetic and functional. As correct pre-treatment is essential to success, it is recommended that buyers of coated aluminium insist that surface finishing companies work to an appropriate code of practice or standard.

Aluminium is supplied in a range of rolled and extruded surface finishes. Aluminium distributors stock a full range of aluminium products featuring surfaces suited to a variety of applications - from engineering tread plate to various aesthetic embossed and rolled finishes.

Aluminium may be decorated in a number of ways. These include mechanical and chemical polishing, mechanical brushing and/or surface treatments such as anodising and powder coating.

Aesthetic finishes are normally factory applied and include decorative anodising, powder coating and other organic finishes, mechanical polishing and electroplating.
Decorative Anodising - external exposures

Anodising is a process that electro-chemically thickens the oxide layer that naturally forms on the surface of aluminium.

A range of colours from natural through bronzes to black are offered. These colours are deposited at the base of micro-pores generated in the metal during the electro-chemical process and are resistant to the elements. Correct sealing of the pores is essential.

One other advantage of anodising surfaces is that the slight self-sealing, pitting corrosion of exposed aluminium is prevented. This pitting corrosion is not structurally significant so it can be ignored other than where aesthetic finishes are concerned.

The recommended anodising micron thickness for external applications is normally between 15 and 25 micron. This thickness is related to exposure conditions. With the exception of coastal areas where 25 micron is recommended, 15 micron will suffice.

Decorative anodising - internal exposures

A wide range of metallic colours from natural to reds, to blues and greens and black are offered. These colours are deposited at the top of the micro-pores generated in the metal during the electro-chemical process and are less resistant to the elements than the more restricted range of external colours.

If the metal is chemically polished before anodising, a reflective surface can be achieved.

Organic Finishes

Two types of finish are available, wet coating and powder coating. Both are factory processes.

Wet coating is normally factory applied to flat products prior to coiling and forming into products such as caravan sides, roof and side cladding and gutter products.

While some products are designed for life and cannot be over coated, other coatings can be over coated to facilitate changes in colour preferences.

Powder coating is a factory applied system, applying electrostatically charged, thermosetting powders. A wide range of colours is available. Guidance on powder coating pre-treatment, powder selection and film thickness suited to specific application circumstances is available from manufacturers and approved applicators. Different powders are used externally and internally. Marine environments require different approaches.

Mechanical Polishing

Aluminium can be polished using a polishing compound and suitable rotary mechanical brushes. Rotary brushes can be used to provide a decorative finish. These finishes can be further protected with clear lacquers.

Functional surface treatments

Chemical polishing and milling, corrosion protection.

Chemical treatments can be used to polish, etch or mill a surface. The purposes are similar in principle with the degree of surface attack successively greater. A number of internationally tested formulations exist that are different in composition for each process.

Chemical polishing is intended to remove the discontinuities on the surface to provide a generally flat surface.

Etching is used to attack the surface in order to provide a key for surface treatment. The process attacks surface oxides and grain boundaries to produce a matt surface with a higher surface ratio, i.e. more wetting surface over the same area.

Chemical milling is an alternative to mechanical milling. The purpose is to aggressively attack the grain surfaces and to erode these without affecting grain boundaries below the general level required.

Surface Hardening

It is important to note that surface hardening provides resistance to abrasion, which is a sideways movement seeking to remove surface particles. It does not provide resistance to impact, which is a downward movement displacing the surface.

Engineering (hard) Anodising - Engineering anodising is different to decorative anodising. While the principle of enhancing the natural oxide layer is the same as decorative anodising, the process is different because the intent is to provide a non-hydrated oxide skin thicker than what can be achieved using the decorative process. Thickness varies with the alloy between 30 and 300 microns, but for normal engineering use 80 microns is sufficient. These films are not decorated.

Aluminium oxide is the essential ingredient of corundum, second only to diamonds in terms of hardness. It is this hardness that provides abrasion resistance.

Metal Surfacing

Electrolytic or electroless deposition of a range of metals can be used to provide surface hardness.

Electroplating of aluminium is possible and is typically used for, but not limited to, the medals given at sports meetings.

6. CORROSION

Aluminium does not corrode significantly under normal atmospheres. Aluminium does not rust. Oxygen reacts with aluminium to
form a hard, tenacious surface which inhibits corrosion where the oxide surface is able to rebuild.

There are however, two sets of circumstances where aluminium may corrode and may even corrode quickly.

The first is galvanic corrosion.

Galvanic corrosion is related to the elemental stability of specific metals. Less stable electron fields involving one metal offer the possibility of movement into more stable electron fields of another metal. Thus some metals are typified as galvanically active (less noble - more likely to corrode), with aluminium amongst these, and some more noble like gold - hence the name. The more active material forms the anode (or donor); the less active, the cathode (or receiver) material. Thus (relatively) anodic metals will protect relatively cathodic metals. As an example, galvanised steel works on exactly this principle.

Zinc is the most active metal. As is commonly observed, a zinc carbon battery produces about 1.5v. Consider a lighted torch. Switch it on. In due course the battery stops working; the light is no longer lit. What has happened? The Zinc has an electro-galvanic potential of -1.03v, the carbon +0.47. While the two are connected, zinc electrons flow through an electrolyte towards the carbon until they are exhausted and the zinc has been corroded away. Note that if the torch is not switched on, and there is no connection between the zinc and carbon, the battery does not deplete. The zinc does not corrode (in practice batteries have a finite shelf life because moisture in the atmosphere provides a limited linkage).

Aluminium is also an active metal. Therefore when aluminium is galvanically connected to a more noble metal or carbon, the aluminium will corrode. The speed of corrosion will depend on the relative areas of the corrosion. A relatively small anode will corrode rapidly while a relatively large anode will corrode more slowly.

Where aluminium is used in conjunction with other metals it is important to avoid galvanic connection and to avoid the presence of a connecting electrolyte such as moisture. This can be done by insulating one from the other. The area of galvanic throw, the area affected beyond direct contact is however limited.

The second aspect relates to anaerobic circumstances, the most common of which is crevice corrosion.

As previously noted, the corrosion resistance of aluminium relates to the aluminium oxide film that tenaciously adheres to the surface. It rebuilds rapidly when exposed to oxygen.

However, if the oxide surface is attacked and not allowed to rebuild, the aluminium will corrode. (This is why aluminium, stainless steel and galvanised products are best stored vertically, allowing for a free flow of air).

The most important aspect of preventing crevice corrosion is to keep the surfaces dry. The surface tension of water will pull water into crevices less than 0.5mm wide and hold it there - preventing access to oxygen.

Also where poulite (gathered residues) can gather, for instance in corners and other traps, the oxygen will be occluded. Consequently, where these traps cannot be designed out, it is important to fill the gap with for instance, an impermeable gasket, wet organic coatings immediately before bolt up, or silicones, and the like.

Corrosion Protection

Many surface pipelines and chemical plants include areas or circumstances of high corrosion where any material is attacked. Underground pipelines are subject to anaerobic conditions. The treatments available to protect materials are related to their performance in corrosive conditions, quite different from decorative finishes where the main concern is aesthetic.

Quite apart from designing to avoid or minimise corrosion, surface treatments including wraps and specialised corrosion protection systems that are commercially available. Many are not aesthetically attractive - but that is not their function.

The important aspect is to focus on the corrosion circumstances.

7. STORAGE AND CARE OF ALUMINIUM

Time and money can be lost unless the manufacturer and user adopt a few simple procedures to protect the aluminium finish during processing, handling, storage and construction / fabrication.

Unloading and Handling

Aluminium commodities are supplied as a finished or semi finished product. In many cases they have a highly polished surface. Care is therefore needed in handling. The following simple precautions should be observed:

- Do not drag or throw parts to the ground, rather lift and carry.
- Avoid parts scraping each other or against other hard or sharp surfaces.
- When hoisting, use slings to evenly distribute lifting stress; as this will avoid distortion.

- Do not permit slings, wires or other handling equipment to damage the aluminium surface.

Storage in the Factory or On Site

To maintain the best possible surface condition over long periods aluminium needs to be stored under cover out of the weather.

Upon receiving aluminium components any paper or plastic wrapper should be removed as soon as practicable and within seven days of delivery. If the aluminium is protected by a strippable coat, this should be left in place. It should however, be inspected to ensure that there are no breaks or gaps. It is important to maintain a free flow of oxygen in the atmospheres over surfaces.

Good practice includes:

- oil the surface, and store in a vertical position to allow unrestricted circulation of air over all surfaces (take care not to damage edges)
- store in an enclosed area
- store away from direct air draughts
- store under conditions of controlled humidity and temperature
- store with air filtration to eliminate chemically contaminated and dust laden air
- store away from contact with other materials

Care in Working Procedures

Stubborn stains on aluminium surfaces are often caused by splashing, spattering and run-down of cement, mortar, etc. These etch unprotected surfaces.

To avoid this it is recommended that:

- aluminium surfaces are protected through the application of a proprietary strippable coating or oil prior to delivery on site.
- aluminium installation work be delayed as late as possible.
- all accidental splashing of mortar, plaster, concrete, paint or other wet preparations be wiped from the aluminium surfaces before they dry. (Particular care should be taken where acid solutions are used to clean brick-work and masonry as these will attack the aluminium).
- if the metal or its protective coating is spattered with acid, rinse all surfaces and hose out cracks and crevices thoroughly with water.
Note
When removing spatters of mortar and plaster, these should only be chipped off with a wooden or plastic scraper. Use of metal tools is likely to damage the finished aluminium surface.

8. TYPICAL QUESTIONS TO CONSIDER WHEN SELECTING ALUMINIUM AS AN APPROPRIATE SOLUTION

One of the dilemmas of serving the customer is the need to understand the problem statement. It is important to decide if the choice of aluminium alloy will meet the customer's needs and that it represents the best value for money. Sometimes customers are sure of what they are trying to achieve and of what they need, while at other times it is necessary to understand the intended use before selecting the appropriate alloy.

Typical questions intended to help the selection process include (this list is incomplete and may also include facets outside specific interest):

- What is the component/product intended to achieve?
- At what temperature range will it be used?
- What is the physical size?
- Where will it be used/installed now and in the future?
- What sector or type of industry is involved in its use?
- What type of attack will it be subjected to in use - e.g. chemical, abrasion, high impact loading, atmospheric?
- How will the component be used/supported?
- What strength is required to withstand operating conditions?
- Is there any limit to permissible deflection that affects choice?
- How will it be fabricated - does it need to be machined, joined (or welded), formed or bent?
- Are the skills available to achieve the ends sought?
- For extrusions: Can the extrusion be developed to meet a range of ancillary needs?
- Is its purpose mainly functional or mainly aesthetic?
- Is surface finishing required to protect the surface, to decorate the surface, to aid marketing?
- What life is expected of the product?
- How will it be maintained?
- How will it be disposed of?
- What alloy, temper and form are suited to the fabrication and end uses intended?

At no time should a stockist just sell aluminium - they should sell a solution and be a solution provider.

To do this effectively requires knowledge - that can be learnt or obtained from various sources including the Aluminium Federation of South Africa (AFSA).