Aluminium Alloy - Fabrication of Aluminium

Aluminium alloys are normally supplied as semi-finished products such as sheet, plate, coil, extrusions, tube or wire. All forms can then be readily fabricated into finished products using a wide range of processes.
A range of cutting and pre-fabrication services are available including coil slitting, cut-to-length and guillotining of sheet and plate, cut lengths of extrusion and tube, polishing, coating, drilling, slotting, bending and weld preparation of edges.

CUTTING

Aluminium can be cut by many different methods depending on the shape and form of the aluminium.
Aluminium plate is cut with various types of saw and also laser, plasma or water jet to produce finished sizes that can have intricate shapes. The advantage of water jet cutting is the lack of heat and therefore no alteration of the properties of the aluminium.
Aluminium extrusion and tube is routinely cut with carbon tipped circular saw blades. Blade cutting can be improved by using a stick wax on the blade to improve lubrication. Other cutting methods include band-sawing and guillotining.
Aalco routinely supply plate cut to size including circles, rings and irregular shapes.

JOINING

The most common way of joining aluminium is welding, Most alloys of aluminium are able to be easily welded once a couple of factors are taken into consideration.
The corrosion resistance of aluminium is due to a tough oxide layer on the surface. This oxide layer has a higher melting point than aluminium and must be removed before welding. It is removed using chemical, mechanical or electrical means and must be prevented from reforming before welding can be completed.
Due to the high thermal conductivity of aluminium, heat needs to be applied at a rate four times that needed for steel. It has a linear expansion coefficient twice that for steel, which must be considered when welding material that has been restrained.
Aluminium has a relatively low melting point and unlike steel, it does not change colour as its melting point is approached.
Consequently, care must be taken not to overheat and/or melt aluminium during joining processes.
Welding tends to reduce the mechanical properties of aluminium in the heat affected zone. This area extends around 25mm from the weld.

GRADES, TEMPERS AND FORMABILITY

When producing an aluminium product the grade selection must be made with consideration given to not only the durability of the alloy when in service, but also if the product can be readily fabricated from that material.
Although the formability of an aluminium alloy relates directly to the type of alloy, the temper of each alloy can change properties in such a way that the same grade maybe perfect for a given application in one temper, but completely unsuited in another.

General fabrication properties of the various alloy series are given in the Table below.

For non-heat treatable alloys additional strength is imparted on the alloy by work hardening. The alloy can then be softened to the desired properties by heating in an annealing stage.
For heat treatable alloys, strength is imparted by heating followed by quenching and ageing. Quenching is a rapid cooling process using air or water.

Alloy	Properties
1XXX	Excellent formability, weldability and corrosion resistance. Low strength
2XXX	Excellent machinability & high strength. Poor formability, weldability & corrosion resistance
3XXX	Formable, corrosion resistant and weldable. Moderate strength
4XXX	Formable, weldable, corrosion resistant
5XXX	Formable, weldable, excellent corrosion resistance
7XXX	Machinable, poor corrosion resistance & weldability. High strength
8XXX	Excellent formability

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DEEP DRAWING

Deep drawing is a common fabrication method for aluminium and is the process used to make one of the world's most common aluminium products; aluminium cans. Deep drawing uses extremely high forces to push a sheet or blank of a relatively soft alloy into a female draw cavity. Several stages are used in the process and appropriate lubrication is required.

Deep drawing is a valued fabrication method as it produces a seamless product. Due to the forming method, products manufactured by deep drawing essentially have a cup like shape. Aluminium alloys used for deep drawing include 3003, 5005, and 5052.

BENDING

Aluminium can be bent using any one of a number of different techniques. The choice of the most appropriate is dictated by factors such as the form and temper of the alloy in question.

The most common form of aluminium that is bent is tubing. When tube is to be bent, drawn tube should be specified as it bends more consistently and to tighter tolerances than extruded tube.

Four main methods are used for bending aluminium:

~ Three roll bending
~ Three point bending
~ Wrap and mandrel bending
~ Stretch forming

Three Roll Bending

Three roll benders use a central roller that is moveable and is gradually depressed on the work piece until the desired radius is achieved.

Three Point Bending

Similar to three roll bending, the three point bender can apply a load via an impact or gradually. Both three roll and three point bending are used on strong sections.

Wrap and Mandrel Bending

Wrap and mandrel benders use formers and support tools to bend the aluminium to tight radii while minimising buckling. In wrap bending the former moves around the section. Mandrel bending differs in that the section moves around the former.

Stretch Forming

Stretch formers work with the section in tension being wrapped around a former. With the section in tension, compression failure is minimised.

Bend Radii

To avoid cracking when bending aluminium, the bend radius must be considered.

Minimum allowable bend radii are functions of the alloy, temper, cross sectional dimensions, mandrel use and the required surface finish. It is therefore not possible to give strict rules to the bend radii for all instances. Published bend radii tables should be consulted before bending and practical trials done before bending the work-piece.

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SOLDERING & BRAZING

Soldering

The oxide coating on aluminium and it’s high thermal conductivity makes soldering difficult. The larger the part being soldered, the more evident this becomes. A small part can be held at soldering temperature but a large part can become distorted as one section might be hot while another remains cold.
Fluxes used to remove the oxide layer can be corrosive and must be removed after soldering. To solder without flux the surface needs to be covered in molten flux and the surface below the liquid flux abraded before the two surfaces are joined.

Brazing

Aluminium can be brazed by torch, dip or furnace processes as long as close temperature control is maintained.

WELDABILITY

Fusion Welding

For economic and quality reasons, MIG and TIG welding are the recommended methods for welding aluminium.

TIG and MIG Welding

TIG welding is suited to joining of lighter gauge materials with section thicknesses from about 0.8 to 12.5mm. It is also suited to the joining of pipes, ducting and intricate welds. Joints can be butts, lap welds, edge welds and fillets.
MIG welding allows for a high current density with deep penetration and welding speeds higher than for TIG. This means less total heat input and less chance of distortion. The process of TIG and MIG welding automatically removes the oxide layer electronically.
During the positive cycle of AC current, aluminium oxide particles are stripped from the weld pool allowing the fusion of oxide free metal in the next cycle.
Some pre-cleaning of the joint for welding is still required to ensure the weld is completely free of oxide.

Filler Alloys

Filler wires for MIG and TIG welding are restricted to pure aluminium, Al-Mg and Al-Si alloys.

Resistance Welding

For aluminium alloys, spot, seam, wire and flash welding are the most common types of resistance welding.
They all result in excellent joints, particularly with high-strength heat-treatable alloys. Resistance welding can be more economical than fusion welding but is not suited to all applications.

Friction Welding

It is not uncommon for a brittle zone to be created when aluminium is fusion welded to dissimilar metals. Friction welding can be used to overcome this problem. Processes such as friction stir welding have been found to be suited to the joining of aluminium alloys.

Welding to Dissimilar Metals

Large differences in properties such as melting point, thermal conductivity and thermal expansion mean welding aluminium to dissimilar metals such as steel is extremely difficult and often impossible in extreme environments such as ship repair and offshore oil rigs.
In these instances explosion bonded transition joints are used. Structural Transition Joints (STJ) are bimetallic strips of material with a cross section that

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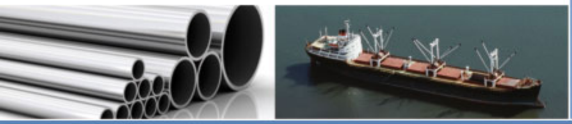

has an appropriate aluminium alloy on one side and a dissimilar material like steel on the other. The STJ is used to form a filler bridge between the dissimilar metals with each metal welded directly to the corresponding metal on the STJ.

MECHANICAL JOINTS

From small aluminium boats to aircraft, riveting is still used to make joins. Riveting, screwing and bolting can produce high strength joins without distortion or strength loss and requires less skill than for other joining methods.
Aluminium alloys used for rivets include 2017A, 2024, 5056, 5052, 5754, 6061, 6082 and 7075.

ADHESIVE BONDING

As welding tends to reduce properties in the heat affected zone, aluminium parts are being increasingly joined with adhesives. Adhesives are now used for joining aluminium in structural applications such as aircraft flooring, vehicle body panels and even attaching street light poles to their bases.
The adhesive bonding of aluminium has grown in importance since the 1930's when it was observed that hot curing wood adhesives also worked extremely well on the surfaces of some metals. New technologies in the area of synthetic adhesives promise to further increase the importance of adhesive bonding for aluminium.
When adhesive bonding is used with aluminium, it is generally found that no bonding occurs between the adhesive and the aluminium metal. Rather the adhesive bonds to the aluminium oxide layer. Acid etching can be used as a surface preparation to create a bond directly to the aluminium. Surface preparation is dependant upon the type of adhesive being used and should be done in accordance with manufacturers recommendations.
It is also not adequate to simply use adhesive on a join that would otherwise be welded or mechanically fastened. Joint design for adhesive bonding should allow for maximum surface contact between the adhesive and the aluminium. The joint design should also consider the loading forces that the joint will endure. Adhesive bonding performs best when the forces are predominantly pure shear, tension or compression. The use of lap joints is common as they have a large joint surface area, load predominantly in tension and avoid cleaving or peeling forces.

MACHINABILITY

Although readily machinable, aluminium has a high coefficient of friction and high thermal coefficient of expansion. This means a special approach is required including the use of polished tools with different tool geometry and good lubrication to avoid thermal stress.
Aluminium alloy 2011 is referred to as a free machining alloy (FMA) due to it's excellent machining properties. 2011 has poor corrosion resistance and which leads to 6262 T9 being used when greater corrosion resistance is required but the alloy still must have excellent machining properties.
Both 2011 and 6262 are commonly supplied in bar form. When machining of plate aluminium is required, the grade selected is 6082. Alloy 6082 machines very well and produces tight coils of swarf when chip breakers are used.

FILING AND GRINDING

Normal files and grinding wheels become clogged with aluminium filings. When rough filing aluminium the file should have deeply cut curved teeth with only around 4 teeth per centimetre. A long angle lathe file with 6 to 8 teeth per centimetre can be used for finer work and should be cleaned with a wire brush.
Chalk can be rubbed into the file to reduce clogging and immersion in a 20% caustic soda solution will dissolve the aluminium and clean the teeth.
For grinding, specialist wheels can be used. For coarse grinding use felt, leather or rubber covered discs with 60 to 120 grit emery or corundum abrasive and a paraffin lubricant. For fine grinding use 160 to 320 grit emery abrasive and small amounts of lubricant.

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FINISHING

Aluminium can be finished using mechanical, chemical, anodising and organic processes. Aalco has extensive polishing facilities to provide a range of finishes to meet every application.

Mechanical Finishing

Mechanical finishing most commonly involves grinding and polishing.
Grinding utilises an abrasive wheel attached to a rotary grinder. The preferred method is low speed grinding with aluminium oxide to avoid surface overheating.
Polishing uses wheels or belts with abrasives bonded to them. A buffing step can be included to remove any emery marks. Buffing wheels are usually made of muslin discs sewn together.

Chemical Finishing

Chemical finishes react with the metal surface to alter its form. They include conversion coatings and etching.
Conversion coatings thicken the natural oxide coating and allow for better bonding with paints, lacquers and other coatings. Chemical conversion films are thinner and cheaper than those produced by anodising.
Etching uses a chemical to attack and roughen the metal surface. Etching media can be either acid or alkaline. Alkaline etchants are cheaper and easier to handle, therefore more common. The most widely used is a solution of caustic soda in water. As etching removes the protective oxide layer another step is required to restore it.
As chemical finishing involves the removal of metal to create a pattern or polish, it does result in an minor overall reduction in metal thickness.

Anodising

Anodising is an electrolytic process that is used to increase the thickness of the surface oxide films on aluminium. The resultant films are hard, durable and inert and have better corrosion resistance and strength compared to finishes produced by chemical processes. The anodic films are normally between 5 and 25 microns thick depending on the end use, in particular how aggressive the end-use environment. Anodic films can also be used as a base for dyes of any colour.

Chromate Conversion Coatings

Chromate conversion coating or chromating, is a process that coats aluminium with an extremely thin chemical coating. This coating can be used to impart enhanced corrosion resistance, conductivity and bonding ability to the aluminium substrate.
Chromating uses an aqueous solution containing chromates and certain activator ions to dissolve some of the base metal. This metal enters the solution as metal ions where it combines with the chromate ions and reforms on the metal surface as an adherent coating.
The advantage of chromating over anodising includes it not being an electrical process. This means electrical contact does not need to be made with the part and coating can be done on a bulk scale. This makes chromating generally faster, easier and therefore cheaper.
Two categories of chromates are used for aluminium:
~ Chrome phosphates are primarily used on architectural aluminium extrusions to provide a paint-bonding coat.
~ Chrome oxides are used on almost every type of aluminium including sheet, coil, castings and stampings. They are used to increase corrosion resistance and to enhance paint bonding.

Organic Coatings

Organic coatings include paint systems such as alkyd, acrylic, vinyl and epoxy coatings.
Organic coatings are commonly employed on aluminium for siding, awnings and aluminium cans.
They are typically applied using continuous processes while the aluminium sheet is still in coil form. Such coatings can be applied to one or both sides and more than one coat can be applied per side.

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