HYDAL
ALUMINIUM
PROFILER

EXTRUSION DESIGN MANUAL

Hydal Aluminium Profiler

From idea to finished component!

Hydal Aluminium Profiler is one of Scandinavia's
leading manufacturers of extruded, machined and surface finished
aluminium extrusions and components.
We supply into most market segments and industries.
Our main markets are Norway and Sweden.

We aim to combine our role of supplier of aluminium
extrusions solutions and machined components with that of an active
partner assisting with the development and design of products.

We intend to support our customers in their work of
creating competitive extrusions that meet all the demands for
function, precision and cost.

From idea to finished component!

Contents

GENERAL OVERWIEV

TECHNICAL DETAILS

Introduction

Our Extrusion Design Manual has been written for you, the professional, who works in any area that touches the development of both existing and new aluminium products.

The book is divided into two parts, first a **general section**, which gives a broad overview of our sphere of activities and products, followed by a **technical section**, which goes into more detail. The latter gives you in-depth information on things like alloys, designing, construction, fabrication and surface treatment to support you in the work of developing your ideas.

The Extrusion Design Manual should be a source of information and inspiration. In it you will find practically all there is to know about aluminium extrusions and the opportunities they offer as a construction material. If you have an idea, then let us help you make this idea a reality.

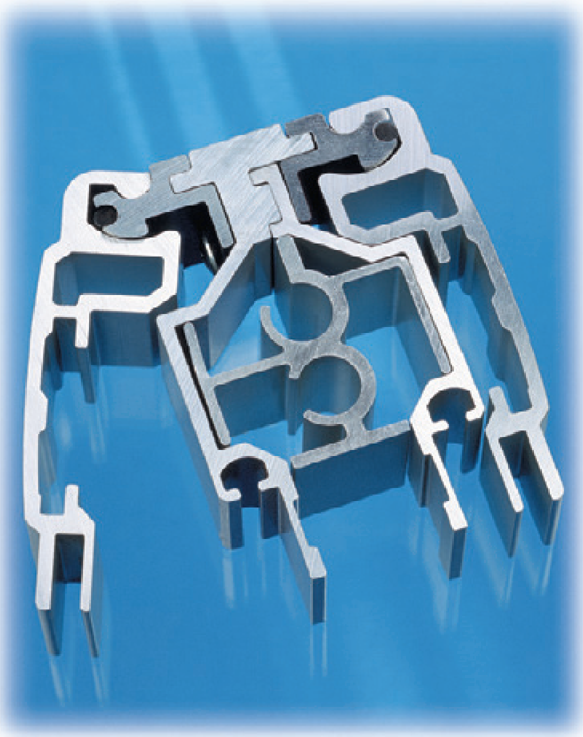
Together we can realize functional, cost-effective and profitable extrusion and product solutions!

Questions? Ideas? Just curious? Contact us - our entire organisation is happy to help you with both service and support.

From the unlikely to the obvious

Aluminium has been correctly described as 'the material of opportunity' and, after steel, is the most widely used metal today. Few other materials exhibit such a unique combination of properties – high strength and low weight, good electrical and thermal conductivity, excellent formability, good resistance to corrosion and attractive surface finish. Best of all, aluminium can be recycled and used time and time again, while expending only a fraction of the energy required for its primary production.

Think freely – think aluminium extrusions!



Creative design
Extrusion is a process that provides virtually unlimited opportunities to adapt the shape of the product as required. Functions can also be built in that cut costs by using fewer components, reducing finishing and simplifying assembly. Aluminium extrusions are a prerequisite for and inspiration to creative designs and technical solutions that improve, simplify and reduce costs.

Extend the limits
The use of aluminium extrusions is increasing rapidly throughout the world and they are continually being used in new applications. As a construction material, aluminium extrusions provide the opportunity to think along completely new lines and to extend the limits of the possible. It was only a couple of decades ago that aluminium ladders were a big innovation. Lorry platforms of aluminium were an impossibility. Construction components such as aluminium windows were virtually unthought of and major load-bearing constructions of extrusions were impracticable.

Today, these products are not just reality. They are a part of everyday life and a necessity for operation, long life, saving energy and good economics. It's no wonder the future looks so bright. The material we produce together lasts forever.

Beyond the limits!
Aluminium extrusions will continue to revolutionise our way of thinking. We hope that this Design Manual will inspire you and we invite you to join us on our journey to go beyond the limits of aluminium extrusions.

Aluminium extrusion applica

Aluminium extrusions are used in practically all businesses, products and environments. A short trip through your daily life provides some interesting examples.

Cars, buses, trains, aircraft, lorries, boats.
The use of aluminium extrusions in the transport sector is increasing rapidly. All the good properties of aluminium will be beneficial in creating strong and light constructions with long working lives and good resistance to corrosion. Every kilogram in weight reduction increases the load capacity and cuts fuel consumption.

Computers, printers, TVs, videos, electronics cabinets.
Facias, frames and heatsinks are often made of aluminium extrusions. Built-in functions in the extrusions that reduce the number of components and simplify assembly and component connections as well as an attractive finish and good thermal conductivity are just some of the strong arguments for using aluminium in these products.

Refrigerators, freezers, electric cookers, kitchen fittings.
Frames, handles, trims and heatsinks are examples of aluminium extrusions in products for the kitchen. Attractive surface finish, easy to keep clean, durable, low weight and high strength are some of the characteristics of aluminium extrusions that are exploited.

Goalposts, tennis rackets, golf trolleys.
Here it is resilience and strength combined with low weight, formability and surface finish that are decisive.

Windows, doors, façades.
Minimal maintenance, strength and low weight, high stability and long service life are the guidelines when choosing aluminium building components. The construction industry

is one of the largest consumers of aluminium extrusions.

Office equipment, fittings, furniture, lighting.
The frame of the board in the conference room, hanging strips, table frames and legs, frames and screens for lighting are examples of fittings made from aluminium extrusions. Strength, low weight, formability and attractive surface finish are the most important characteristics for the choice of aluminium extrusions.

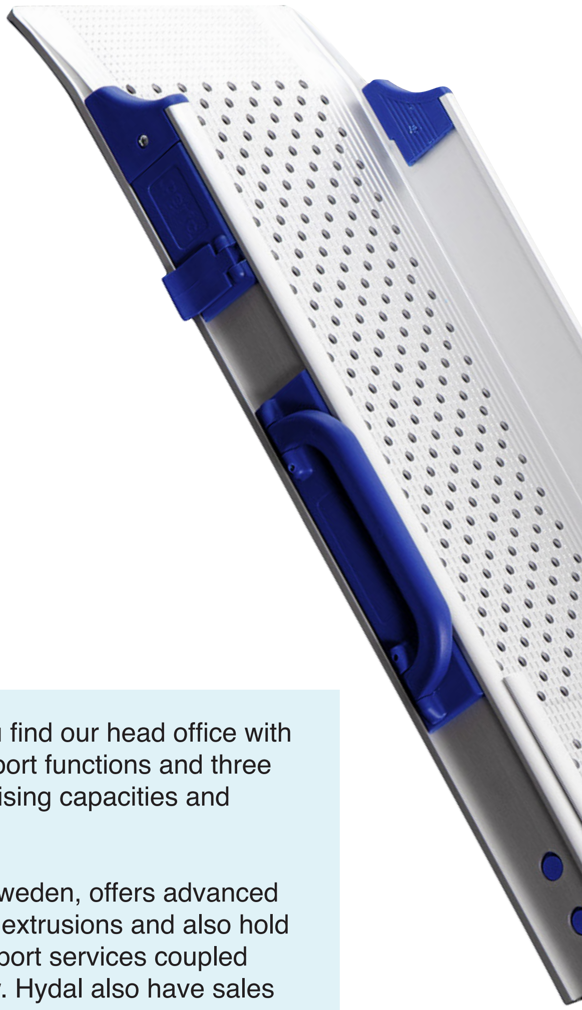
tions

The list is endless... we could have added so many more. Maybe your product will soon be on our list!

Development partner and to

From idea to

Hydal Aluminium Profiler is one of Scandinavia's leading manufacturers of extruded, machined and surface finished aluminium extrusions and components. We supply into most market segments and industries. Our main markets are Norway and Sweden.



We aim to combine our role of supplier of aluminium extrusions solutions and machined components with that of an active partner assisting with the development and design of products. We intend to support our customers in their work of creating competitive extrusions that meet all the demands for function, precision and cost.

Hydal Aluminium Profiler consists of two units, in Norway and Sweden, that collectively have gathered great skills and knowledge in the manufacturing, surface treatment, machining and sales of aluminium extrusions.

We are a small and flexible organisation with long and solid experience of our markets and what our customers expect. We have extensive resources for technical service, extrusion, surface treatment and fabrication.

We pride ourselves on offering swift advice and straightforward communications. Our focus on high quality and delivery performance is part of our core values.

Together we will develop your most competitive product solutions.

From idea to finished component.

In Raufoss; Norway, you find our head office with sales and technical support functions and three extrusion presses, anodising capacities and fabrication resources.

Our plant in Vetlanda, Sweden, offers advanced machining of aluminium extrusions and also hold sales and customer support services coupled with technical know-how. Hydal also have sales office in Karlstad.

- Hydal Aluminium Profiler
- Hydal AS / Hytrans

tal supplier finished component

Hydal Group

Hydal Aluminium Profiler | **Hydal AS** | **Hytrans**

Hydal Aluminium Profiler (Hydal) is part of the Hydal Group with four companies specializing in development, construction and production of extrusions, components and products in aluminium.

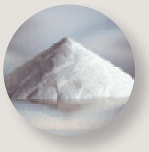
Hydal, Scandinavia´s leading producer of customized aluminium cabinets and Hytrans, leading Nordic supplier of aluminium truck body systems.

Explore our Val

From the mining of bauxite to the production of alumina and primary aluminium. The manufacture of extrusion ingots, the extrsuion process, compo-nent manufacture and recycling. Explore the value chain of aluminium.

Primary Aluminium Production

At the smelter pure aluminium is produced from alumina in electrolytic cells. Carbon cathodes at the bottom of the cells act as electrodes. The anodes, which also consist of carbon, are consumed when the anode reacts with the oxygen in the alumina and forms co_2. Liquid aluminium is tapped from the cells and cast into standard, sheet or extrusion ingot, depending on how it is to be processed further.



a **Alumina**

b **Bauxit**

c **Electrical Power**

The electrolytic process requires significant amounts of electrical power, 13kWh per kg aluminium in most modern reduction plats. More than 2/3 of the electri-cal power our suppliers use when producing aluminium use come from renewable hydroelectric power.

a [Alumina]

Aluminium oxide, or alumina, is produced by refining bauxite and is the most important raw material in the production of aluminium.

b [Bauxit]

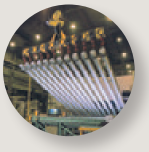
Aluminium is the third most common element in the earth's surface and is found in different minerals, including bauxite. Deposits are mainly located in a broad belt around the equator.

c [Efficient use of resources]

Continuous efforts are made to reduce the effect that primary aluminium production has on the environment and good results have been made. Consumption of resources and energy has decreased. As have emissions from production.

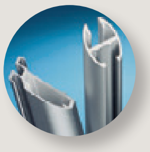
ue Chain

LONDON METAL EXCHANGE (LME)



Enhancing The Metals's Properties

The inherent properties of the metal are adapted for processing and future use by the addition of small amounts of other metals to form alloys. In a casthouse new and remelted aluminium is transformed into extrusion ingot, primary foundry alloys, sheet ingot and standard ingot. The tremendous formability of aluminium, coupled with its low melting point, mean that aluminium products can be shaped, in different ways, to match the design requirements of the end product.

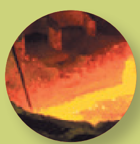


Extruded Profiles

Extruded aluminium products have a wide variety of different uses in areas of application such as the automotive, transport and construction industries.

[High recovery rate]

The remelting of aluminium requires little energy, and less than 2 percent of the metal is lost during the remelt process. And only 5 percent of the energy required to produce primary metal is needed to recycle aluminium.



Remelting

Recycling

Customer → End Users

A complete ecological picture

Aluminium is often called “the green metal”. Aluminium presents the opportunities to creative eco-friendly product solutions that reduce weight and energy consumption, reduces need for maintenance and increases durability. And in addition, aluminium is easy and energy efficient to recover.

Our operations are based on a complete ecological picture that stretches from the mining of bauxite to recycling. This approach characterises the whole production chain and involves responsibility for and commitment to careful raw material production, reduced emission and the efficient use of energy.

Our activities are part of a system that ensures that all the process waste products are sorted, recycled and reused. All scrap metal is remelted and reused in the extrusion process.

By continually improving and increasing efficiency in production processes, minimising emission and focusing clearly and consistently on environmental questions, we have created a good, safe environment in our production plants and their surroundings.

With a complete ecological picture we cooperate with our customers in the work to produce products that minimise the consumption of resources as well as being better, more environmentally friendly and economical.

In a world striving for careful use of resources and increased climate and environmental awareness, our aluminium based products and technique will be important parts of the solution!

The properties of aluminium

Aluminium has a unique and unbeatable combination of properties that makes it into a versatile, highly usable and attractive construction material.

Weight
Aluminium is light with a density one third that of steel, 2.700 kg/m³.

Strength
Aluminium is strong with a tensile strength of 70 to 700 MPa depending on the alloy and manufacturing process. Extrusions of the right alloy and design are as strong as structural steel.

Elasticity
The Young's modulus for aluminium is a third that of steel (E = 70,000 MPa). This means that the moment of inertia has to be three times as great for an aluminium extrusion to achieve the same deflection as a steel profile.

Formability
Aluminium has a good formability, a characteristic that is fully utilized in extruding. Aluminium can also be cast, drawn and milled.

Machining
Aluminium is very easy to machine. Ordinary machining equipment can be used such as saws and drills. Aluminium is also suitable for forming in both the hot and the cold condition.

Joining
Aluminium can be joined using all the normal methods available such as welding, soldering, adhesive bonding and riveting.

Corrosion resistance
A thin layer of oxide is formed in contact with air, which provides very good protection against corrosion even in corrosive environments. This layer can be further strengthened by surface treatments such as anodising or powder coating.

Conductivity
The thermal and electrical conductivities are very good even when compared with copper. Furthermore, an aluminium conductor has only half the weight of an equivalent copper conductor.

Linear expansion
Aluminium has a relatively high coefficient of linear expansion compared to other metals. This should be taken into account at the design stage to compensate for differences in expansion.

Non-toxic
Aluminium is not poisonous and is therefore highly suitable for the preparation and storage of food.

Reflectivity
Aluminium is a good reflector of both light and heat.

Aluminium's physical properties compared to other common construction materials

	Aluminium	Copper	Steel 371	Plastic
Strength/Breaking strength N/mm²	250	250	400	50
Ductility/Expansion %	15	25	20	25
Elasticity E, Young's module MPa	70.000	125.000	210.000	3.000
Density kg/m³	2.700	8.900	7.800	1.400
Melting point °C	660	1080	1500	80
Working temperature range °C	-250–150	-200–300	-50–500	-50–80
Electrical conductivity m/Ohm-mm²	29	55	7	-
Heat conductivity W/m °C	200	400	76	0,15
Coefficient of linear expansion $x10^{-6}$/°C	24	17	12	60-100
Non-magnetic	Yes	Yes	No	Yes
Weldable	Yes	Yes	Yes	Yes

Extrusion manufactu

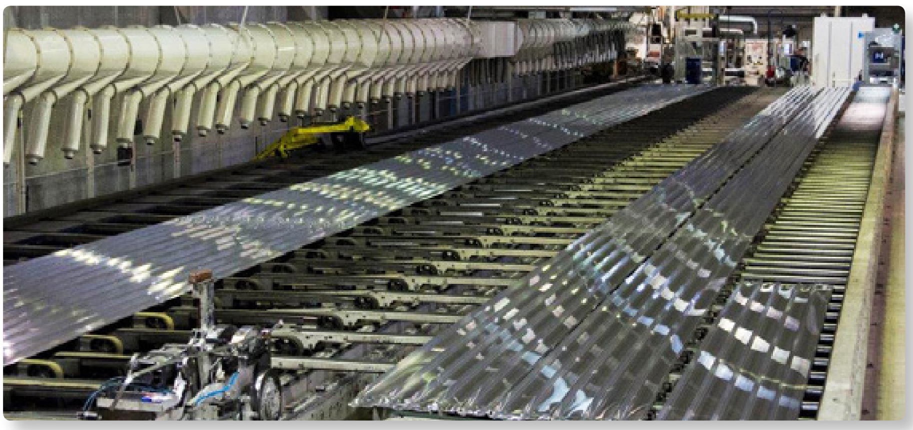
Design and construction

The whole manufacturing and production process starts on the drawing board. It is here that the extrusion takes shape and features are built in for easier connection, minimal finishing work and simpler assembly. Here we can take advantage of all the benefits of aluminium and the extrusion process in order to make a product with optimal functions, attractive appearance and the best cost effectiveness.

We have the resources to help you at the design and development stages. Our departments for technical service, product development and industrial design contribute with extrusion design as well as by making adaptations for functional features and environmentally friendly solutions.

We can create exactly the solution you require, test machining steps and evaluate connection ideas using our advanced CAD systems. All without the need to produce a single die or prototype extrusion.

Extrusion process



The extrusion moves onto a cooling table.

Aluminium ingot

The starting material for making aluminium extrusions is an aluminium ingot that is either made of primary aluminium or recycled, secondary aluminium. The extrusion ingot is made by casting lengths of up to 7 m and is available in a wide variety of alloys and dimensions to suit specific needs and requirements. The ingot is cut into shorter billets depending on the capacity of the press and the length of the finished extrusion.

Extrusion

Extrusion involves pressing a preheated aluminium billet (450-500°C) under high pressure (1200-7000 tons depending on the size of the press) through a die the opening of which corresponds to the cross-section of the extrusion. The extrusion press speed (normally 5-50 m/min) depends on the alloy and the complexity of the die's opening.

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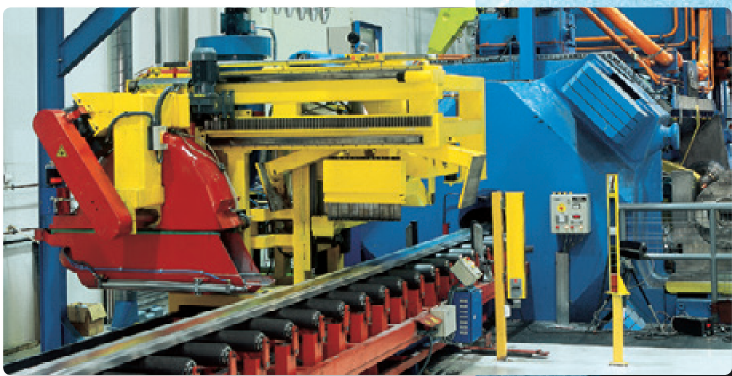


Extrusion process employs high pressure, 1200 – 7000 tons depending on the size of the press.

Cooling and stretching

The main parts of the press are the container where the extrusion billet is placed under pressure, the main cylinder with piston that presses the material through the container and the die and die holder. The extrusion principle is shown in the diagram below. When the extrusion leaves the press it moves onto a table where it is cooled with air or water depending on its size, shape, the alloy involved and required properties. To get straight extrusions and eliminate any stresses in the material, they are stretched. After this they are cut into suitable lengths and artificially aged to achieve the right strength. Ageing takes place in ovens at about 190°C for 4 to 8 hours. This is followed by a final check and the extrusion is ready for machining or delivery to the customer.

A heated aluminium billet is pressed through a die the opening of which corresponds to the cross-section of the extrusion.

Hollow dies or solid dies

The dies are divided into two groups, those for solid extrusions and those for hollow extrusions. The dies for solid extrusions consist of a flat plate which forms the external shape of the extrusion. The dies for hollow extrusions consist of two parts where the aluminium flows through the ports and then rewelds as it flows over the mandrel during pressing. The other die part creates the extrusion's outside surface.

Up to eight extrusions – depending on the size – can be pressed in multi-cavity dies.

The dies are made of high temperature resistant steel and the die's opening is made by wire erosion in CNC controlled machines.

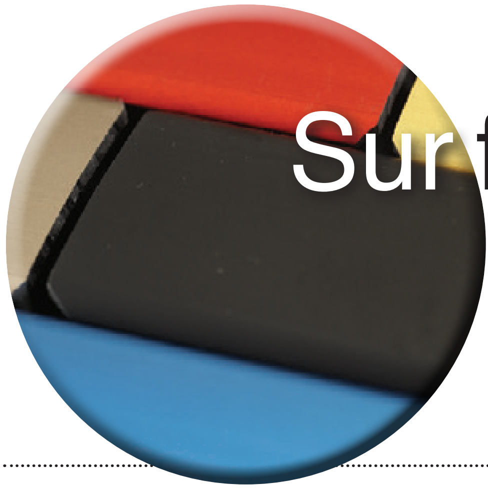
Occasionally open extrusions have a design that makes the use of a flat die inappropriate. A die with a deep tongue and a narrow gap will not withstand the extrusion pressure. Therefore the die can be designed with a mandrel to support the tongue even though the extrusion is open. Sometimes this concept is denominated a 'semi-hollow' die.

Low costs

The cost of dies is significantly lower than the tools used for many other materials and methods of production. The costs vary with the size and type of extrusion. Low die costs also make the extrusion technique interesting for the production of trials and prototypes.

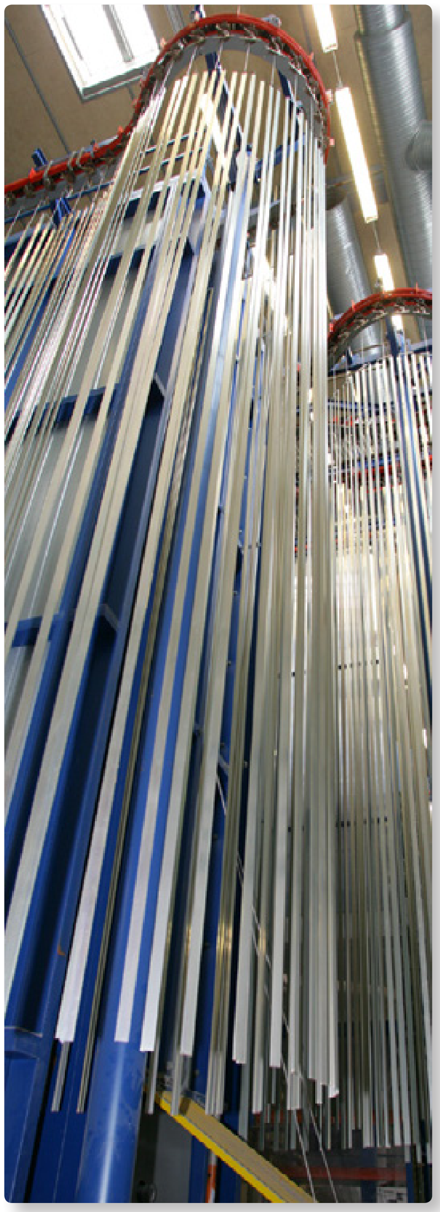
Dies for hollow extrusion.

Solid extrusion.



Surface treatment

In its natural state, Aluminium has a clean and attractive surface with good corrosion resistance. There are a number of surface treatment types that improve resistance to corrosion and mechanical wear. They can also provide a decorative appearance or in other ways alter the properties of the surface.



Surface treatments include:

- Anodising
- Powder coating
- Mechanical surface treatment

Anodising

Anodising is an electrochemical process where the oxide film on the aluminium surface is made thicker artificially. The process involves lowering the extrusion into an electrolytic bath where a DC current is connected to the extrusion, which acts as the anode in the circuit. While the natural oxide film is only 0.02 μm, anodising increases the oxide layer to between 5 and 25 μm depending on the product characteristics required. With the anodising process, aluminium's natural colour (naturally anodised) can be retained or a colour from a wide range of alternatives can be chosen.

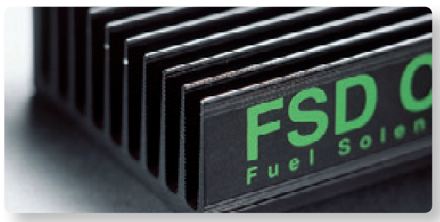
Powder coating

Powder coating offers a virtually unlimited choice of colours and is very durable.

Other methods of surface treatment

Other methods of surface treatment include screen printing and the use of protective foils.

Grinding, polishing and barrel processing are examples of mechanical surface treatments.



Fabrication

It is possible at the design stage to construct an extrusion that minimises the need for further work and makes fitting and assembly more efficient. However, some form of fabrication is often required.

Because of their ductility, aluminium and aluminium extrusions are highly suitable for all types of fabrication. The bulk of the extrusions we deliver go through some form of fabrication such as surface treatment or machining.

Our complete programme of fabrication, using our own or outside resources, includes:

Machining
- sawing
- deburring
- drilling
- turning
- milling
- tapping
- die cutting

Joining
- welding
- adhesive bonding
- bolting
- riveting
- clinching

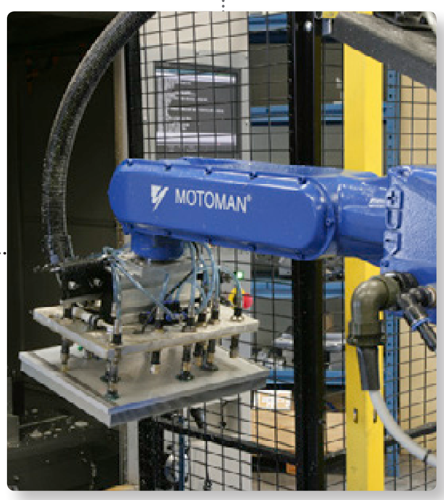
Plastic forming
- bending

Hydal – a powerful resource for your business!

We have modern and advanced machines incl. CNC-controlled, multiaxle and multioperation machines, also for long length machining. These are highly specialised machines that offers possibilities for rational fabrication within tight tolerances.

We have all the resources required to deliver your extrusion in exactly the right design, shape and size for your finished product.

Read more about the possibilities and technology under Fabrication in the Technical Section, page 48.



Packaging
and transport

We use a wide range of different packaging methods. Together we can come to an agreement that best suits your extrusions and requirements. In this way we avoid unnecessary handling and ensure that the goods are delivered safe and undamaged. Examples of common methods of packaging are:

- **bundled**
- **on a pallet**
- **in a carton**
- **with or without polythene wrap**
- **with or without interleaving**

Recycling

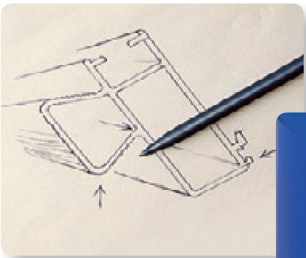
Aluminium is easy to recycle and can be remelted using only a fraction of the energy required to make primary aluminium.

In analysing a product´s life cycle this gives positive results and contributes to reduced negative environmental effects.

At Hydal all scrap aluminium is recycled in our production. We can assist you in developing your own recycling system.

Working with Hydal

We are here to realise the exact extrusion solution that meets your demands for performance, quality, precision and economy. The earlier we can take part in the development process, the better. This will allow you to access all our experience, skills, know-how and resources. Here is a short guide to make your extrusion planning and your first contact with us at Hydal easy and pleasant.



Sales and customer service
Reaching our sales and customer service organisation is quick and simple. You will find our contact details on the inside front cover of this manual or just visit **www.hap.hydal.com** for more information about Hydal and our customer service organisation.

Can a boat hook be extruded?
Can my product be made in aluminium? Can a boat hook be extruded? Obviously we are only too pleased to answer your questions about aluminium and aluminium extrusions at the earliest opportunity. We can then put you on the right track from the very beginning. We look forward to hearing from you!

Need help with drawings, product development, design, construction?
You have an idea? A rough sketch but you're not sure where to go from here? Or maybe you have a drawing that needs to be optimised. Contact us and we'll get things moving!

What does it cost?
We can give you a good idea of the costs involved for dies and production, fabrication and surface treatment at the idea stage. Phone us and we can tell you more.

Draw up a check list!
The more prepared you are when you contact us, the better. This will help us give you qualified answers efficiently. Make yourself a check-list and be sure to include the following points:

Area of application
(indoors or outdoors)

Function
(how is it going to be used)

Material properties (large or small, solid or hollow extrusion)

Design (visible or concealed)

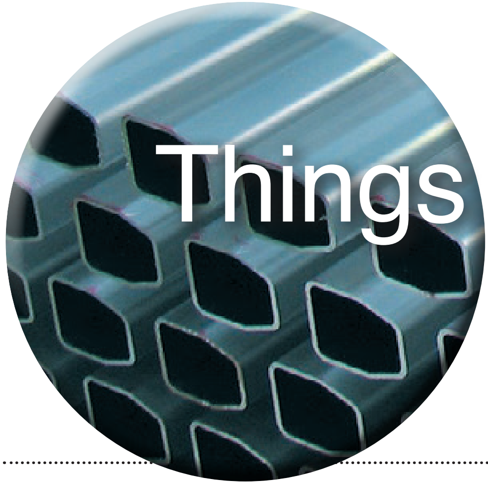
Surface treatment requirements (anodized or painted)

Tolerances

Packing (how you want your product delivered)

Depending on your project, there will be other points you could consider. Go through this manual for more ideas and call us so we can help you put it all together.

Good relationships
Good and lasting relationships with our customers are the very foundation of our business. By getting to know you, your requirements and your product well, we increase the possibilities of achieving our common goals.



Things to remember when ordering extrusions

Our Extrusion Design Manual provides you with a range of variables to take into account when drafting and designing aluminium extrusions. All are important for both performance and economy.

Technical cooperation
At Hydal we can combine the roles of extrusion supplier and development partner. Feel free to contact us at the initial stage so we can produce an extrusion that offers the best performance and economy together.

One-stop shop
Taking advantage of Hydal's special skills releases the resources in your company. Through Hydal you gain access to a partner who takes total responsibility for solving your fabrication and surface treatment requirements. Rational, time saving and economical.

Alloys
Choose the right alloy to meet the required characteristics and performance of the product. High-grade aluminium alloys are more expensive and difficult to press.

Optimal design
Study the advice and tips in the Manual. Creative extrusion design with built-in functions simplifies the next stage and cuts costs.

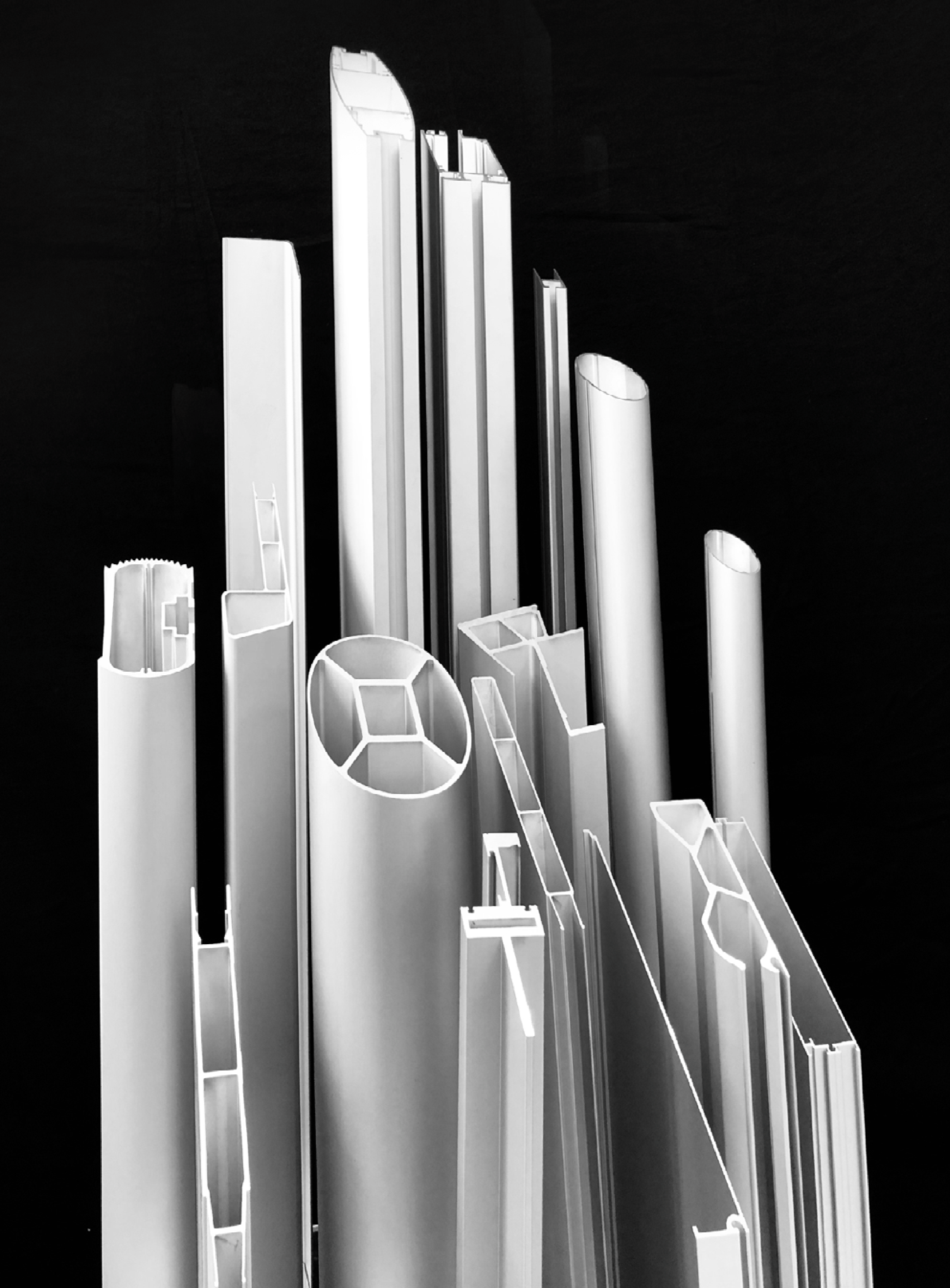
Optimising materials
Materials can be optimised using creative design even in extrusions with requirements for high strength. Put the material where it is needed and do not make the extrusion heavier and more expensive than is necessary!

Surface requirements
Not all of the extrusion's surfaces need to be of the highest quality. There is no doubt the surface demands for an extrusion built into a truck are different from those that is part of the front panel of a hi-fi facia panel. The right finish for the right application saves money!

Fabrication
An increasing number of extrusions are machined after pressing into finished components. The need for fabrication can be minimised even in the early design stage. In the same way, extrusions can also be designed, adapted and prepared bearing fabrication in mind. All for rational and cost-effective production.

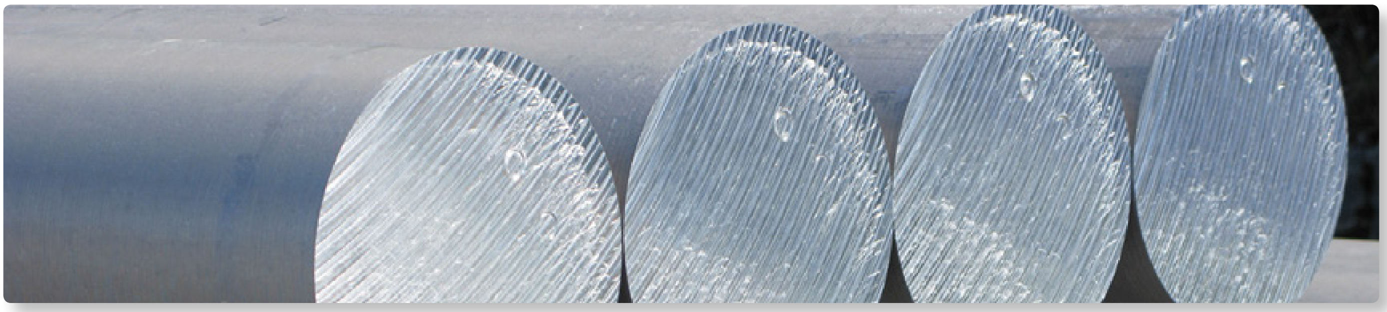
Correct quantity
Optimise your orders/extrusion deliveries. Small volumes mean higher delivery costs.

Recycling
Aluminium is a valuable raw material and we recycle all waste from production. We can also take your production waste and recycle it effectively.

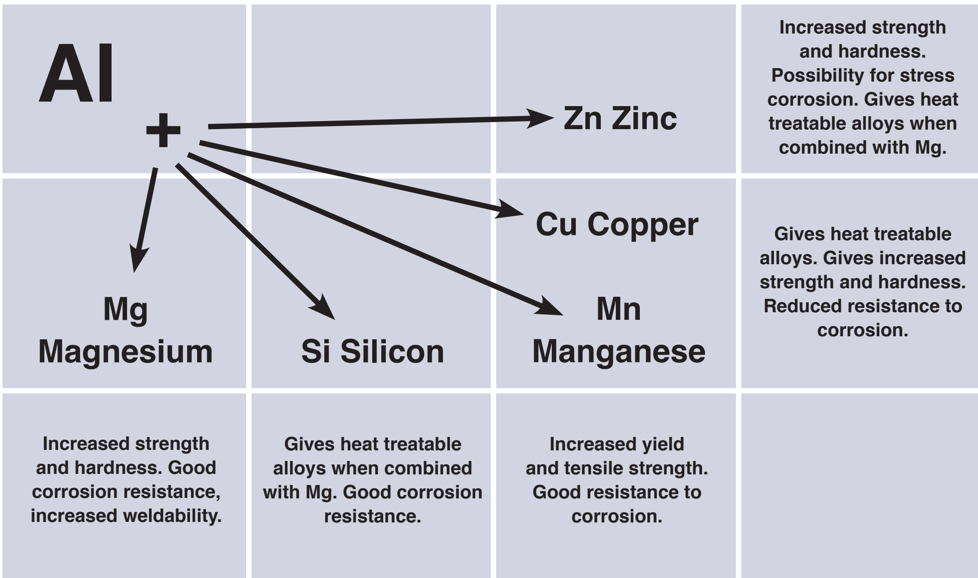


Technical Section

Alloys



The choice of material is a critical decision in all product development. Aluminium makes it possible to give the product suitable physical and mechanical properties at the same time as achieving an aesthetically attractive appearance. Furthermore, the extrusion technique, combined with the right alloy and proper thermal treatment, offers an infinite number of application opportunities. It also forms the basis for product improvement. Pure aluminium is only used in a limited way commercially. The majority of extrusions are made from aluminium alloyed with other metals. The most common elements used are magnesium (Mg), silicon (Si), manganese (Mn), zinc (Zn) and copper (Cu). They form between 0.2 and 7.0 per cent of the alloys.



Properties that can be achieved when alloying with other metals.

Aluminium for extrusion is mostly alloys with the following serial numbers:

1000 series – Al

6000 series – Al + Mg + Si

7000 series – Al + Zn + Mg

The 1000 series is non heat treatable. These alloys are often chosen in products where high thermal and electrical conductivity are desired. They have low strength.

The 6000 and 7000 series are heat treatable. They are the most commonly used extrusion alloys and have a wide range of applications.

The 6000 series has good extrudability and can be solution heat treated at the extrusion temperature. Furthermore, these alloys have medium to high strength, are easy to weld and offer good resistance to corrosion, even in marine environments. The bulk of the extruded material for load bearing constructions is made from these qualities. They are used for load bearing constructions both on land and at sea.

The 6060 alloy offers medium strength and is easy to extrude even for complicated cross-sections. This alloy is the most used extrusion alloy. It has good formability during bending in the non heat treated condition. Typical applications are extrusions for windows and doors, lighting, awnings, handrails and furniture. This material is highly suitable for anodising, both for decorative and protective reasons.

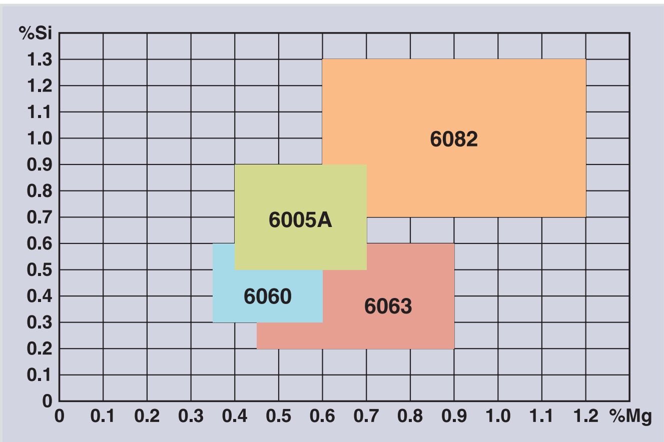
The 6063 alloy has slightly higher strength than 6060, but is also marginally more difficult to extrude, especially if the cross-section is complicated. Applications are for the most part the same as for 6060. This material is well suited for anodising, both for decorative and protective purposes.

The 6005 alloy has higher strength than 6063 but is slightly harder to extrude. The material withstands comparatively little elongation before there is permanent deformation in the heat treated condition. This alloy can be exposed to greater inter-crystalline corrosion than 6060, 6063 and 6082. It is suitable for anodising for protective purposes but the quality of the surface makes decorative finishing more difficult.

The 6082 alloy has high strength and is suitable for extrusion of cross-sections that are not too complicated. Typical applications are load carrying structures in the ship-, offshore-, transport-, and building industry such as platforms, bridges, stairs, scaffolds and handrails. The material is suitable for anodising for protective purposes.

The 7000 series has the highest strength of the most used construction alloys. They have good weldability and obtain lower reduction of strength in heat affected zones than the 6000 series. Their corrosion resistance and formability are, however, not as good as those in the 6000 series. But by adding small amounts of Zr, Cr or Mn this can be improved. Typical applications are automotive parts, aircraft containers, bicycle frames and high speed boats.

The 7108 alloy has high strength and good fatigue strength, but has a limited extrudability and formability.



The magnesium and silicon contents of various 6000 alloys can overlap in certain cases (see diagram above). Alloys can therefore be made up with the focus on optimal function adaptation and the ability to produce them. This process takes place continuously and today we have a number of variants of the alloy types above that have been adapted to suit specific conditions.

Condition on delivery

F	**Extruded and air cooled**
O	**Softened, annealed at 350-500°C, for 1-5 hours**
T4	**Solution heat treated and naturally aged at 20°C, for 5-10 days**
T6	**Solution heat treated, artificially aged**

Special material properties can be achieved with special thermal hardening. With, for example, extended heating (i.e. thermal hardening longer than the optimal time), lower strength is achieved but in return the alloy becomes tougher and in certain cases has greater resistance to corrosion.

The alloy is susceptible to stress corrosion in areas with high stresses.
The resistance to stress corrosion is slightly increased with overageing. Welding should only be carried out in areas where the loading is lower. Typical applications are structures for building and transport applications where high strength is required. The material is suitable for anodising for protective purposes.

Temperature – Mechanical properties

Care should be taken when using aluminium at high temperatures. Mechanical properties could significantly be reduced at temperatures above 100°C, especially if the material has been thermally hardened or cold worked.

In general the 6060, 6063, 6005 and 6082 alloys should not be used in structures at temperatures above 100°C. The tensile strength decreases as the temperature increases while elongation on fracturing usually increase. It should be noted that the characteristics are dependent of alloy, temperature and time. If the designer is unfamiliar with the exact temperature characteristics for a given alloy, it can be assumed as a starting point that properties such as tension, shear and fatigue strength vary in proportion to the tensile strength.

Low temperature properties

In contrast to steel, aluminium alloys do not become brittle at low temperatures. In fact aluminium alloys increase in strength and ductility whilst impact strength remain unchanged. As the temperature decreases, below 0°C, the yield strength and tensile strength of aluminium alloys increase.

Alloys

EN 755-2 (European standard)							Physical properties						
Hydal	**Alloy**	**Temper**	**Wall thickness mm**	**$Rp_{0,2}$ (Mpa)**	**R_m (Mpa)**	**A_{50mm} (%) min.**	**Brinell hardness HB**	**Density**	**Young's modulus (GPa)**	**Coeffecient of expansion (1/K)**	**Thermal conduc-tivity**	**Electrical conduc-tivity**	**Melting point**
1050 F	EN AW-1050A [Al 99,5]	F	All	20	60	23	20	2700	69	$24\ 10^{-6}$	229	62	645–658
6060 T4	EN AW-6060 [Al MgSi]	T4	All	60	120	14	38						
	EN AW-6060 [Al MgSi]	T6	t≤3 3<t≤25	150 140	190 170	6 6	57 54	2700	69	$23\ 10^{-6}$	200	52	600–655
6060 T6	EN AW-6060 [Al MgSi]	T66	t<3 3<t≤25	160 150	215 195	6 6	60 57						
6063 T4	EN AW-6063 [Al Mg0,7Si]	T4	≤25	65	130	12	47						
	EN AW-6063 [Al Mg0,7Si]	T6	t≤10 10<t≤25	170 160	215 195	6 6	64 60	2700	69	$23\ 10^{-6}$	200	52	600–655
6063 T6	EN AW-6063 [Al Mg0,7Si]	T66	t≤10 10<t≤25	200 180	245 225	6 6	76 68						
6005 T6	EN AW-6005A [Al SiMg(A)] Solid extrusion	T6	t≤5 5<t≤10 10<t≤25	225 215 200	270 260 250	6 6 6	85 81 76	2705	69	$23\ 10^{-6}$	200	52	615–655
	EN AW-6005A [Al SiMg(A)] Hollow extrusion	T6	t≤5 5<t≤15	215 200	255 250	6 6	78 76						
6082 T4	EN AW-6082 [Al Si1MgMn]	T4	≤25	110	205	12	60	2710	69	$23\ 10^{-6}$	180	46	580–650
6082 T6	EN AW-6082 [Al Si1MgMn]	T6	t≤5 <5<t≤25	250 260	290 310	6 8	95 98						
7003 T6	EN AW-7003 [Al Zn6Mg0,8Zr]	T6	≤10 <10<t<25	290 280	350 340	8 8	105	2780	72	$23\ 10^{-6}$	175	45	615–650
7108.50T6	EN AW-7108 [Al Zn5Mg1Zr]	T6	≤10	320	350	12	105	2780	72	$23\ 10^{-6}$	175	45	615–650

$Rp_{0,2}$ – Yield strength **A_{50mm} – Elongation (EN 755)** **R_m – Tensile strength**

*** equivalent to Swedish standard SS EN 755-2**
**** Hydal has no own designation but can deliver in accordance with EN 755**

The relationship between some accepted methods for measuring hardness.

Brinell	45	50	55	60	65	70	75	80	85	90	95	100	105	110
Vickers	46	51	56	61	66	71	76	82	87	92	98	103	109	115
Rockwell 'F'	36	46	54	61	67	71	76	79	82	85	87	89	91	–
Rockwell 'E'	47	55	62	68	72	77	80	83	86	88	90	92	94	96
Rockwell 'B'	–	–	–	–	12	23	32	39	45	50	55	60	63	66
Rockwell 'K'	–	15	25	34	41	48	53	58	62	66	70	73	76	78
Webster	5	7	9	10	11	12	13	13-14	14-15	15	15-16	16	16-17	17

Hardness number

Corrosion resistance

One of the principal reasons for choosing aluminium and its alloys for construction applications is their high corrosion resistance. Although aluminium is a chemically very active metal, its behaviour is stabilised by the formation of a protective film of oxide on the surface. Generally, this film is stable in aqueous solutions with pH 4.5-8.5. Further considerations need to be made if the pH exceeds these limits or the environment contains chloride.

Although being in general very stable, the most common types of corrosion which can occur on aluminium alloys are summarized below:

Uniform attack

The corrosion proceeds homogeneously over the whole surface of the metal. With aluminium and its alloys this type of corrosion is mainly seen in very alkaline or acid environments where the solubility of the natural oxide film is high.

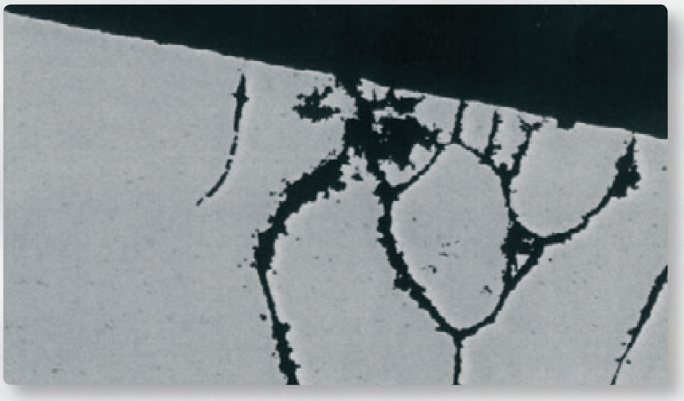
Pitting corrosion

Pitting corrosion is the most common type of corrosive phenomena with light alloys, and is characterised by local discontinuities in the oxide film, i.e. locally reduced film thickness, rupture, localised concentrations of impurities/alloying elements, etc. Aluminium is sensitive to pitting when chloride ions are present (e.g. sea water). Pits develop at weak spots in the surface films and at sites where the oxide film is mechanically damaged.

Correct choice of alloy and surface treatment (e.g. anodising, powder coating, coating with an anodic (Zn), cathodic protection with sacrificial anodes or applied current, or by use of inhibitors, are methods which can be used to limit or prevent pitting corrosion. Frequent cleaning, as well as ventilation of dense constructions and a profile design avoiding accumulation of stagnant water, are recommended.

Intergranular corrosion (IGC)

IGC is a selective corrosion around the grains and in the adjacent zones without any appreciable attack on the grain itself. The reason for the IGC is a difference in corrosion potential between grain boundaries and the bulk of the immediately adjacent grains. The difference in potential may be caused by the difference in chemical composition between the two zones.



Due to the low metal consumption, intercrystalline corrosion is difficult to detect visually and even more difficult by measurements of weight loss. However, if the corrosion is permitted to propagate into the metal, the mechanical properties of the material will be severely deteriorated.

Alloys in 6000 series are normally resistant against IGC, however, this is dependent on the chemical composition. Recrystallised structures in addition to high content of Si or Cu, may give corrosion of this type. Addition of Mn/Cr will prevent or minimise recrystallisation.

IGC of alloys in 7000 series is linked to MgZn precipitates, which are very anodic compared to aluminium.

One action to prevent IGC is correct choice of alloy. In addition, see actions mentioned under “Pitting corrosion”.

Crevice corrosion

Crevice corrosion may occur in narrow, crevices filled with liquid (e.g. water). Use of sealant prior to joining may prevent penetration of moisture. By use of correct profile design, it is possible to minimise the risk of crevice corrosion.

Water staining is a type of crevice corrosion and is caused by water or moisture entrapped between e.g. dense stacked profiles. Water staining is a very common corrosion type.

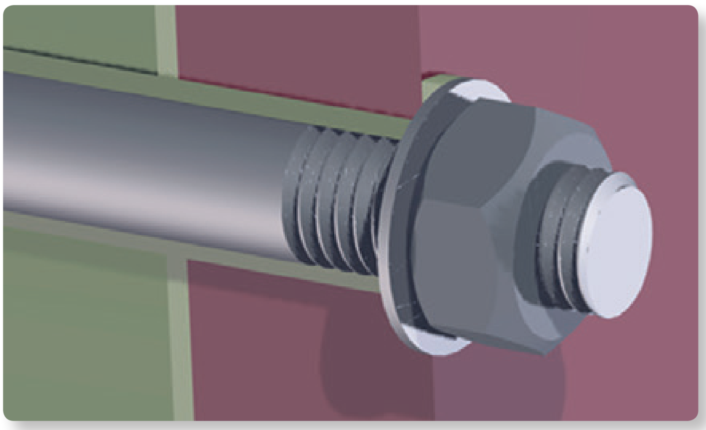
The appearance varies from iridescent in mild cases, to white, grey or black in more severe instances. Water staining on profiles is normally removed by grinding or powder coating.

Profiles without any surface treatment should never be stored outdoors, even though plastic wrapping is used, because of risk of condensation. Storing should be carried out in places with a relative humidity of max. RH 45%, and a max. temperature variation of +/-5 °C. During transportation from a cold to a warmer area, the temperature should be increased gradually to avoid condensation.

Galvanic corrosion

Galvanic corrosion is the increase in corrosion that occurs when two metallic materials are in contact in the presence of an electrolyte. Corrosion will increase on the least noble material (the anode) and decrease on the noblest (the cathode). Since aluminium is less noble than most commonly used construction materials, with the exception of zinc, magnesium and cadmium, this can be a serious form of corrosion with aluminium.

The protective effect from the oxide layer can be seriously deteriorated by the coupling to a more noble material. This is especially dangerous in atmospheres or water with high concentrations of chlorides or other aggressive corrosives.



Most types of aluminium corrosion can be related to some kind of galvanic coupling with a dissimilar material.

Galvanic corrosion can be avoided or minimised by means of the following actions:

If possible, avoid use of materials far from each other in the galvanic potential difference series of the actual environment (stainless steel not included). However, if that is not a practical solution, the different material qualities have to be properly electrically insulated. It is very important to use insulation material of proper electrical resistance and to avoid metallic contact in the entire construction. This can be checked by resistant measurements (using multimeter).

Aluminium may be protected by means of sacrificial anodes.

The most noble material can be surface treated with a metallic coating (Al, Zn), organic coating, (lacquer, paint, plastic, rubber) or a special coating for screws and bolts. The surface treatment has to be carried out correctly; surface treatment shall not be done only on the less noble material. As a consequence, a defect in the surface coating may generate a very unfavourable cathode/anode ratio (a big cathode area in relation to a small anode area gives considerable corrosion).

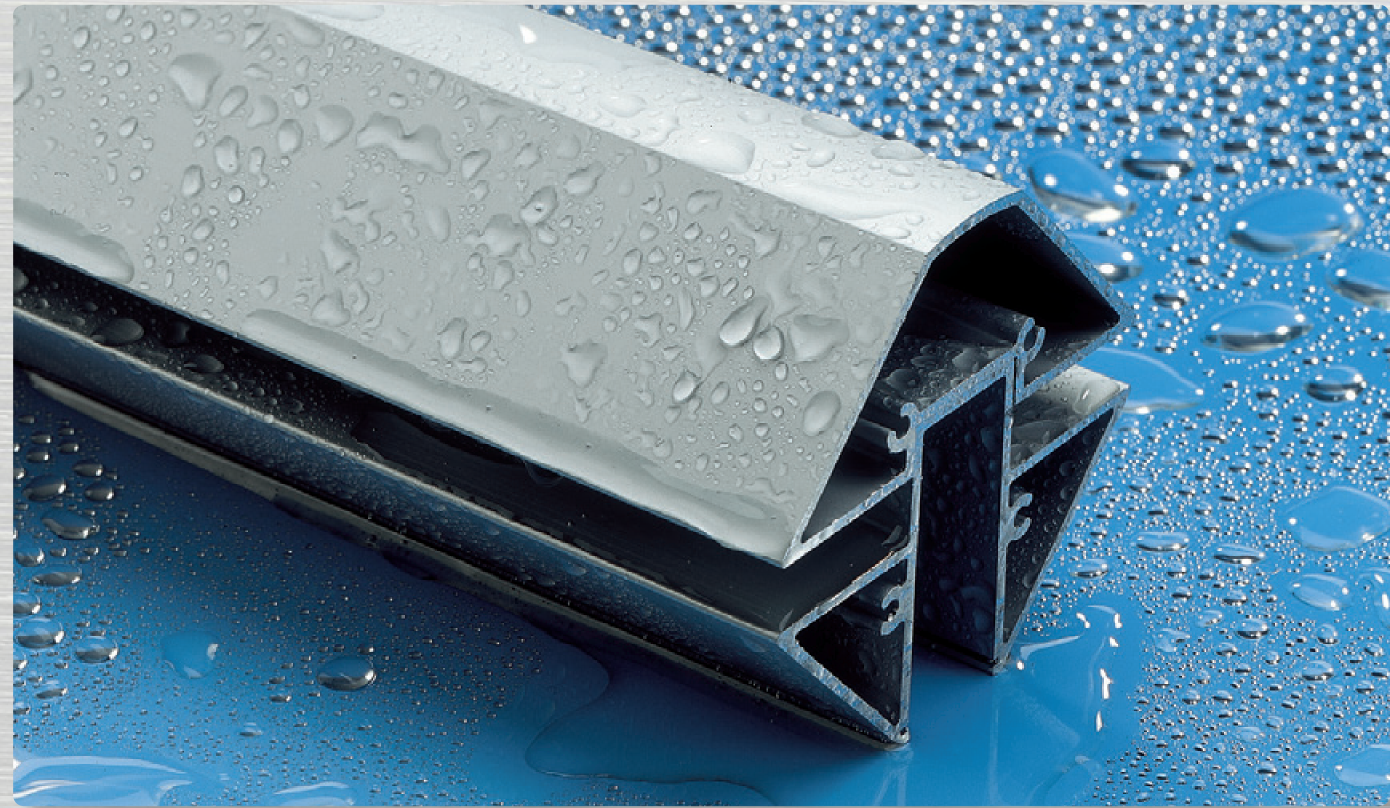
Galvanic corrosion in combination with crevice corrosion may give concentrated attacks. Based on that, it is important to avoid entrapment of liquid/water in crevices between materials of various nobleness.

Filiform corrosion (FFC)

Filiform corrosion on passivated surfaces exhibits itself as thin, threadlike and shallow attacks progressing below surface layers such as paint. The corrosion normally starts in coating defects (e.g. on mitres) and follows certain directions, like for example the extrusion direction. The front of the attack is supported by moisture which penetrates the surface layer and becomes depleted of oxygen making the area anodic.

FFC is mainly an aesthetic problem, but corrosion products may cause deformation in narrow crevices or delamination of surface treatment. It is proven that sufficient metal removal of aluminium 2 g/m^2 by chemical etching prior to properly performed chromating is required. Providing this is done properly, aluminium extrusions in 6060/6063 will exhibit high FFC resistance.

Corrosion resistance in different environments



The atmosphere
Corrosion is insignificant in the general outdoors. Aluminium does not corrode where there are high levels of sulphur dioxide but can under certain circumstances become dark or matt in appearance.

Water
Pitting can occur in stagnant water. The composition of the water is the important factor as the presence of copper, calcium, chloride and bicarbonate ions increase the risk significantly. This can be prevented however by regular cleaning and drying. In this way, aluminium is highly suitable for making saucepans for example.

Seawater
Alloys containing silicon, magnesium and manganese show good resistance to corrosion in seawater. Copper alloys, on the other hand, should be avoided.

Soil
The resistance to corrosion is to a great degree dependent on the moisture in the soil and its pH. Aluminium surfaces in contact with the soil are best treated with a thick layer of bitumen or a powder coating.

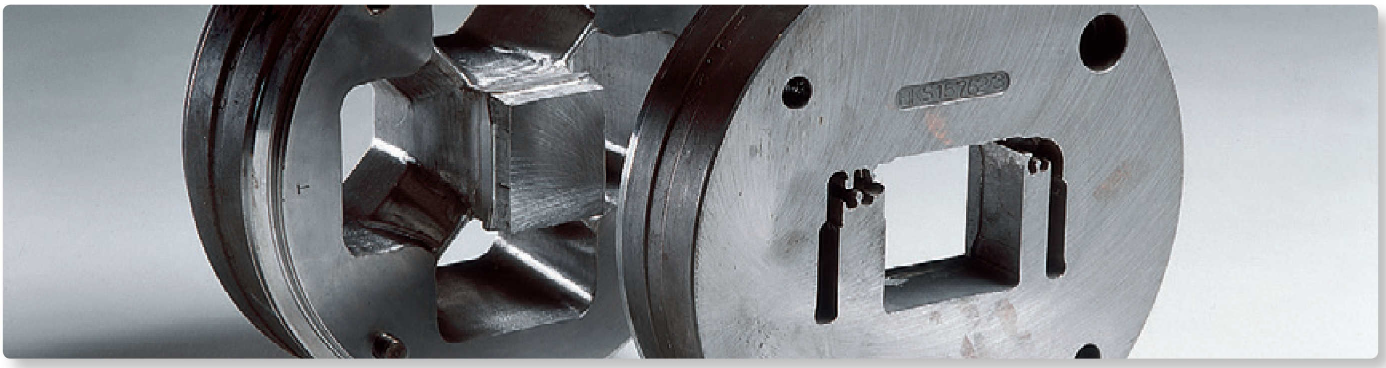
Acids
The majority of inorganic acids have a very corrosive effect on aluminium – except nitric acid. High temperature, high acid concentrations and high levels of impurities in the aluminium increase the rate of corrosion significantly.

Alkalis
Strong alkalis are very corrosive. Sodium hydroxide reacts violently with aluminium. The rate of corrosion can be reduced in environments where the pH is between 9 and 11 by using silicates. Wet cement has a high pH and therefore corrodes aluminium alloys.

Organic compounds
Aluminium is highly resistant to the majority of organic compounds. Corrosion can occur however with certain anhydrous liquids.

Other materials
In practice the corrosion problem caused by contact with other materials is for the most part small. The natural oxide layer provides good protection.

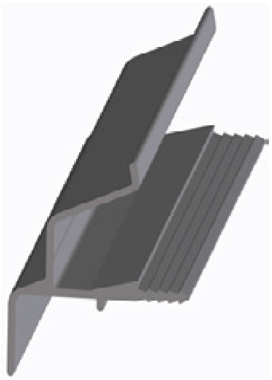
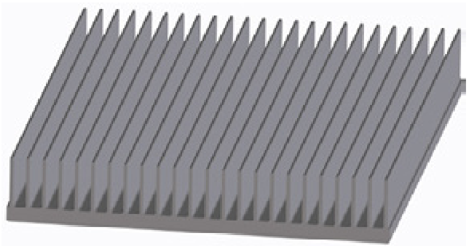
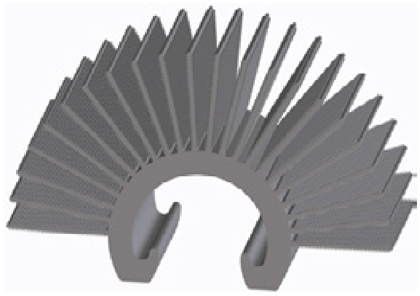
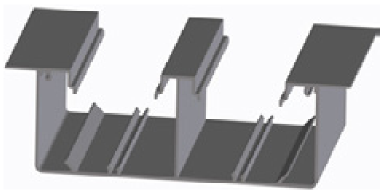
Types of extrusions



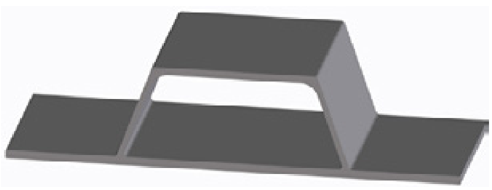
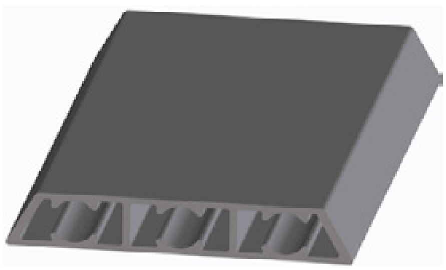
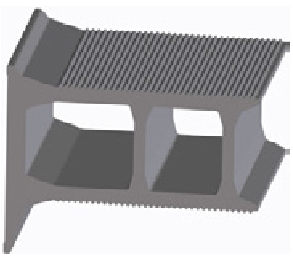
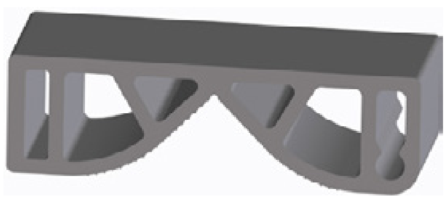
There are 2 types of extrusions;

- Solid extrusions
- Hollow extrusions

Solid

Hollow

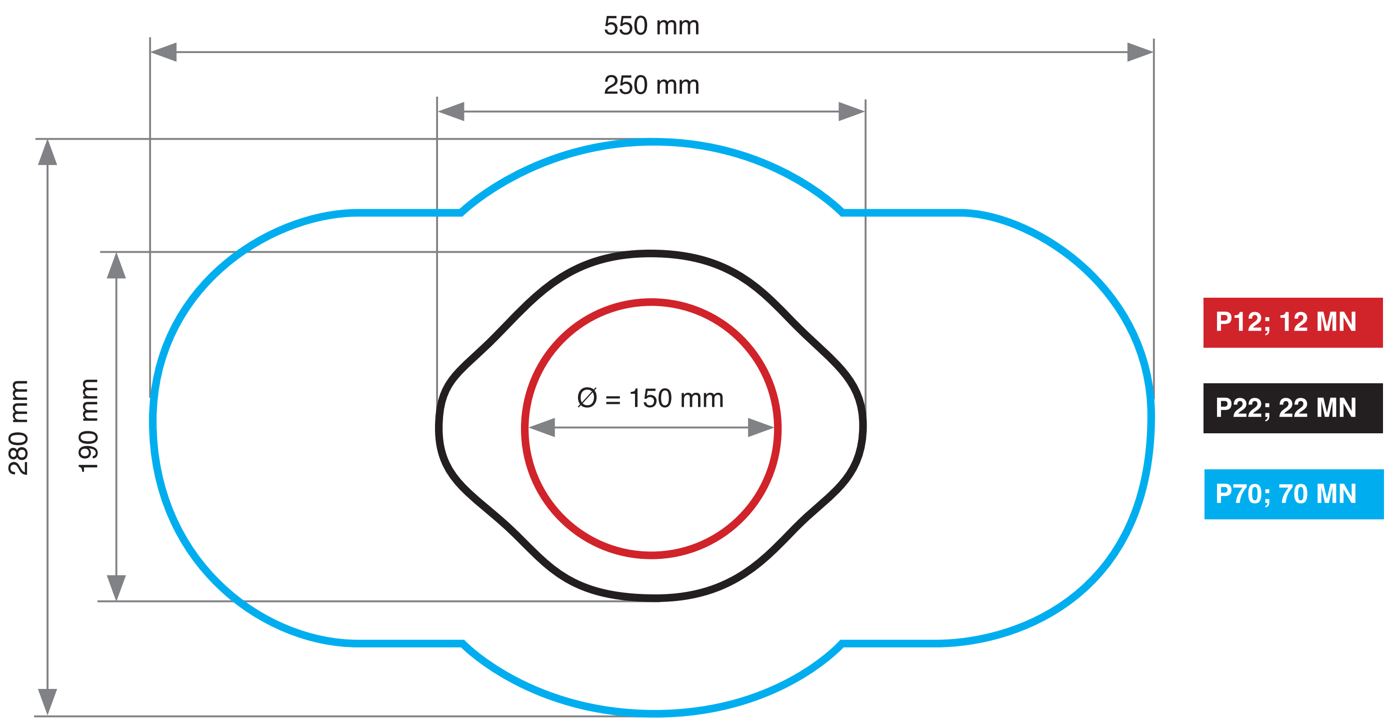
Extrusion dimensions

The diameter of the circumscribing circle (DCC) is a measure of the extrusion's size and therefore determines the material thickness, tolerances and price.

Below are the measurement limits within which Hydal can supply aluminium extrusions based on the DCC.

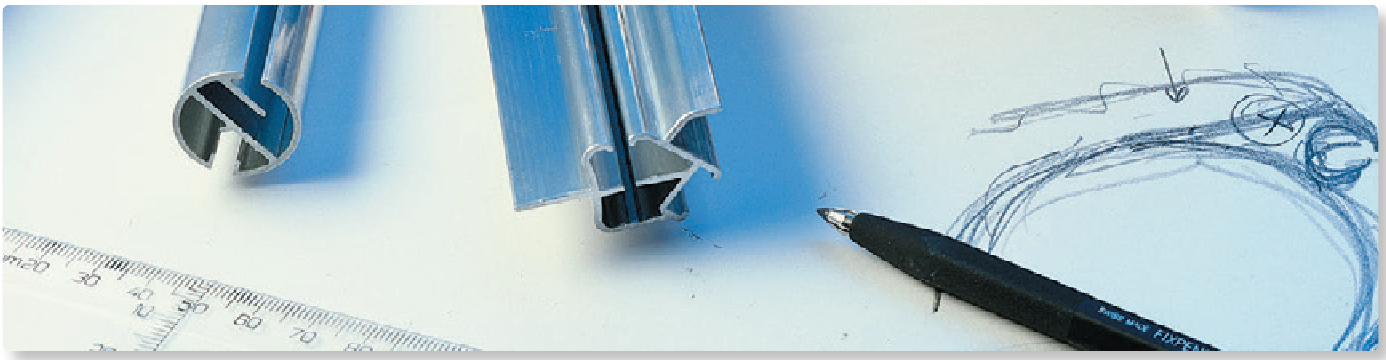
The diagram shows the maximum dimensions for extrusions that can be produced on our three extrusion presses with capacity 1.200, 2.200 and 7.000 tonnes.

Hydal produces extrusions weighing from 80 g/m up to 30 kg/m.



The maximum sizes can vary depending on the alloy, material thickness, complexity and tolerances.
Please contact us for defined limits.

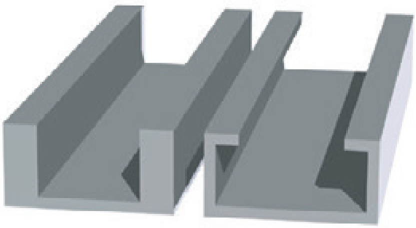
Design & Construction



If you work with the development and improvement of both existing and new products, using aluminium as a construction material gives virtually unlimited design opportunities.
To achieve a succesful design of a product, some design guidelines for extrusion design will be very helpful. These guidelines will help the designer to achieve extrusions with better functionality and extrudability and, consequently, lower production costs and better allround economy.

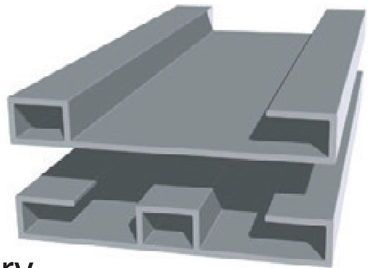
The following pages provide information to help with your design work.

Contact us if you need any more help.



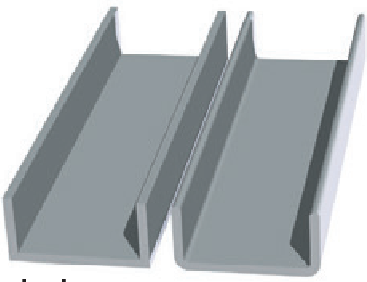
Uniform wall thickness

Uniform wall thickness within a section reduces the loading on the die and therefore minimises the risk of it being damaged. Big differences in wall thicknesses within a section should also be avoided in order to minimise differences in surface appereance after anodising. Uniform wall thickness is obtained by changing the shape of the extrusion and putting the material where it is most needed.



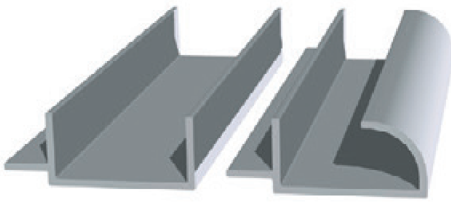
Symmetry

With symmetrical extrusion designs, a balanced flow of material through the die is achieved at the same time as the load on the die is evenly distributed. The extrusion shape is more accurate at the same time as the risk for broken dies is significantly reduced.



Rounded shapes

As a rule all corners should be rounded. Normal radi are 0.4 to 1.0 mm. If the design requires sharper edges and corners, a radius of 0.2 mm is the smallest that can be produced.

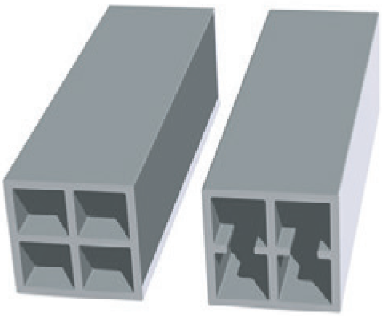


The diameter of the circumscribing circle

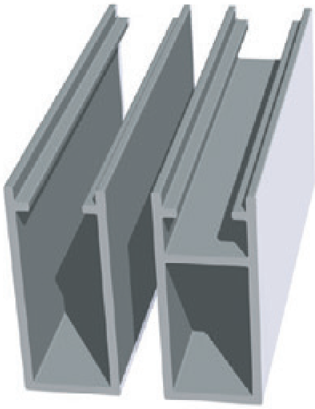
Always try to reduce the circle circumscribed around the extrusion. Apart from making it easier to press the extrusion, it also helps keep die and production costs down.

Simplify and facilitate

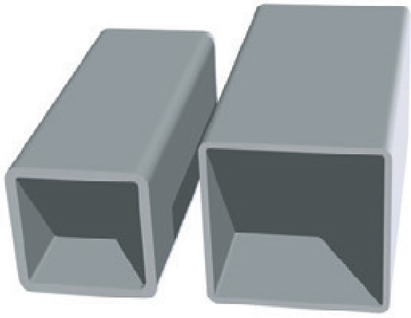
A change that has no effect on the functional appearance of the extrusion but which simplifies and facilitates production means lower production costs and better economics. Here are some examples.



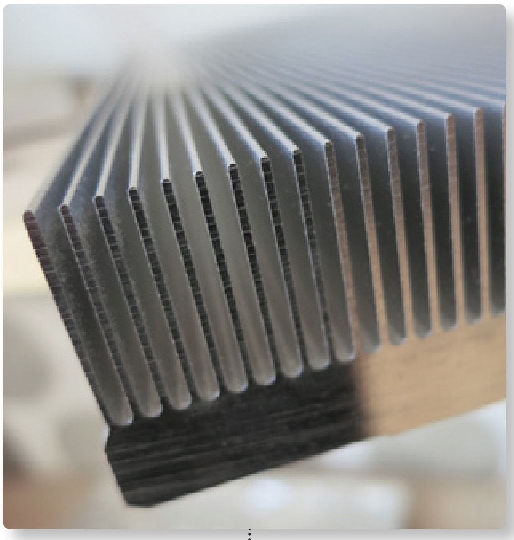
Fewer cavities cut costs.

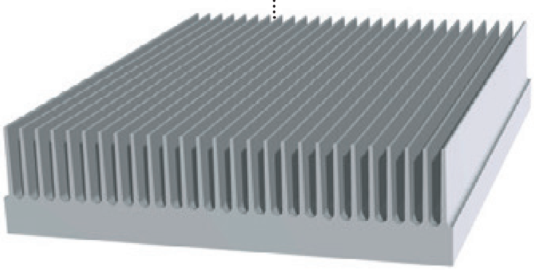


A move towards a hollow extrusion gives better dimensional control.



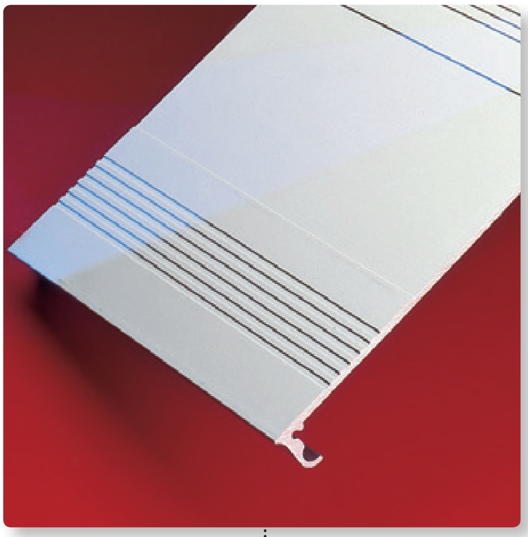
Increased size can cut the weight and increase the rigidity.

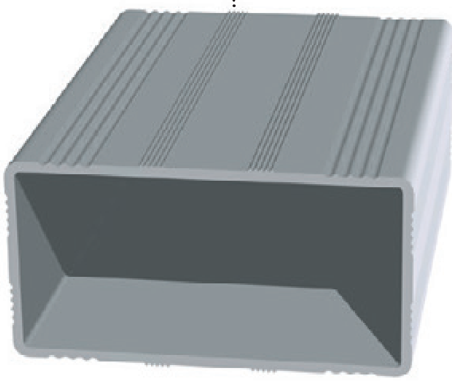




Heatsinks

The design of the flanges increases the surface of the extrusion and improves thermal conductivity.

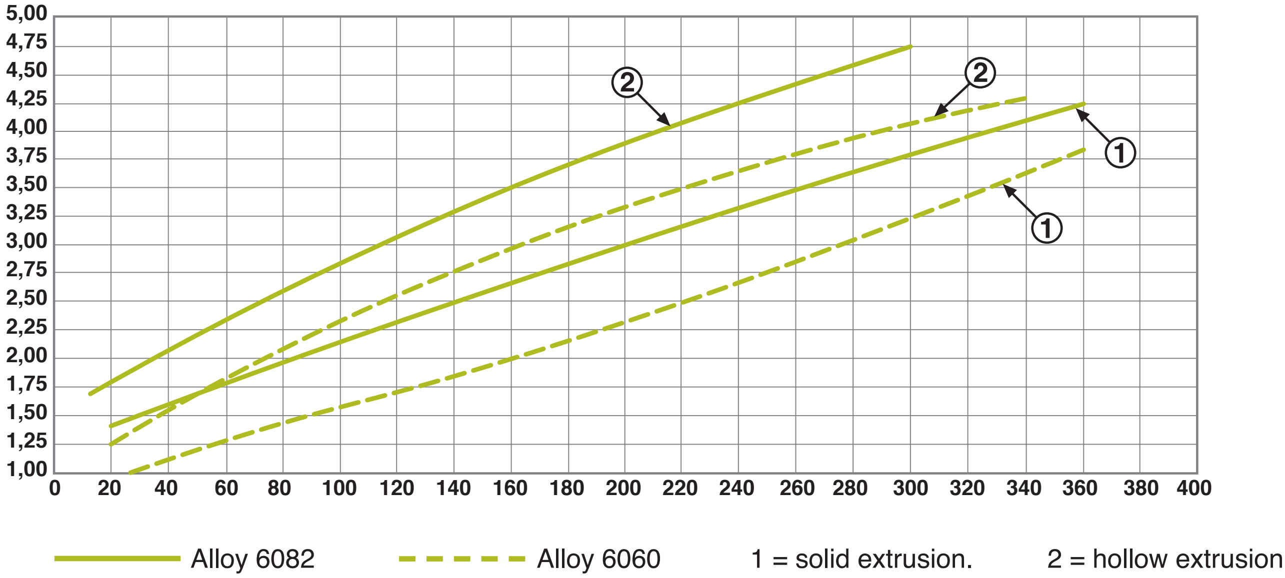




Decorative lines

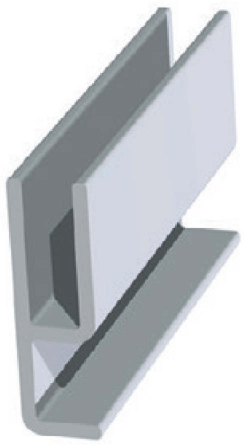
Decorative lines in an extrusion can conceal irregularities as well as protect against damage during handling and fabrication.

Minimum material thickness

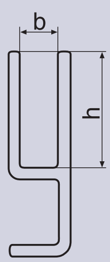


Recommended minimum material thickness (mm) in relation to the circumscribing circle diameter.

Gap depth – gap width

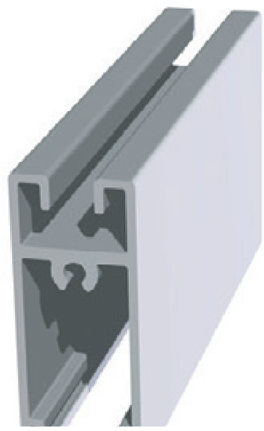


Gap width b	Ratio h:b
-1	1,0
1-2	2,0
2-3	2,5
3-4	3,0
4-5	3,5
5-15	4,0
15-30	3,5
30-50	3,0
50-80	2,5
80-120	2,0
120-	1,5

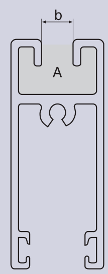


The recommended ratio between the gap depth (h) and the gap width (b) in solid extrusions.

Surface – gap width

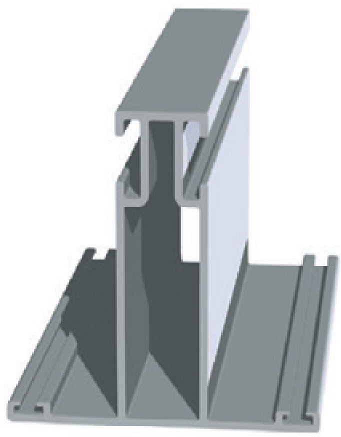


Gap width b	Surface ratio A:b2
2-3	2,0
3-5	3,0
5-50	3,5
50-80	3,0
80-120	2,0
120-	1,5

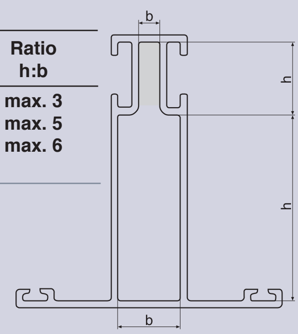


The recommended ratio surface – gap width.

Height – width

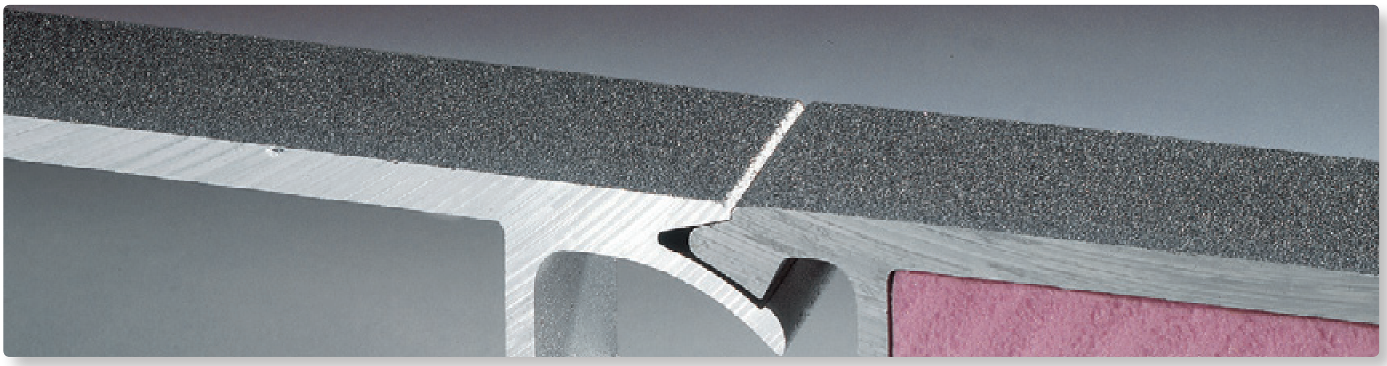


Gap width b	Ratio h:b
6-10	max. 3
10-20	max. 5
20-30	max. 6
30-	



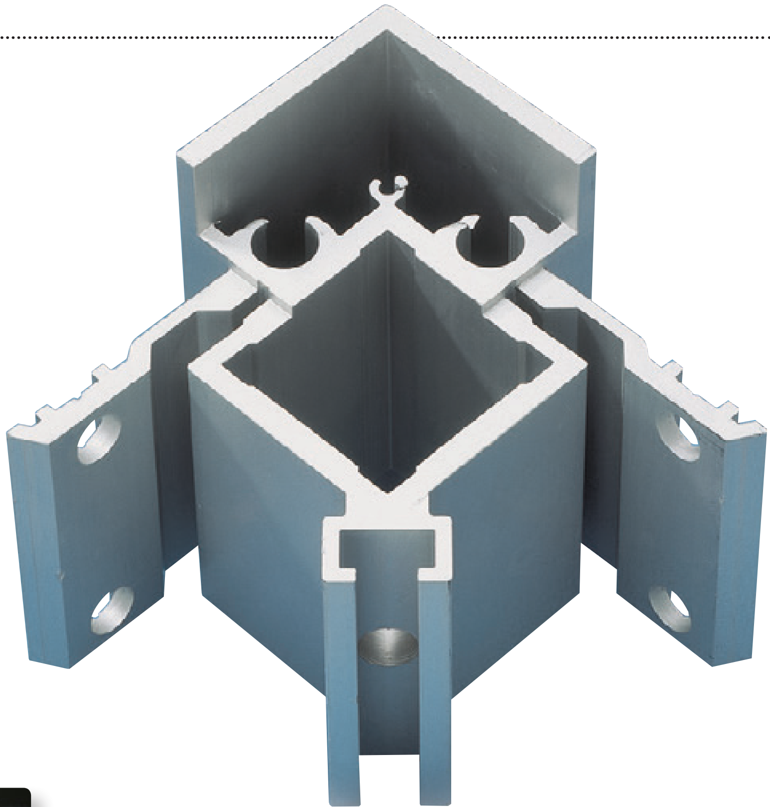
Height – width ratio for hollow extrusions.

Joining



Using the opportunities provided by the extrusion process for creative designs gives strong, stable, rapid and effective joints.

Whether it is for joining one extrusion to another or for joining an extrusion to another material.



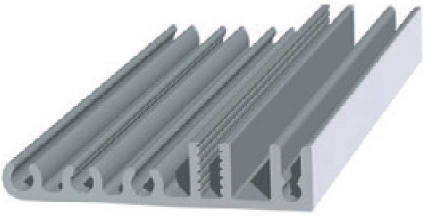
There are many advantages to be obtained by joining several smaller extrusions to a larger unit. Handling is easier. Pressing, surface treatment and a large amount of the machining can be done on a more rational basis. Smaller extrusions can be produced with less material thickness, better accuracy and in many cases lower die costs.

The following examples show a wide range of joining methods. We hope this will inspire the extrusion designer to create better solutions.

Screw grooves

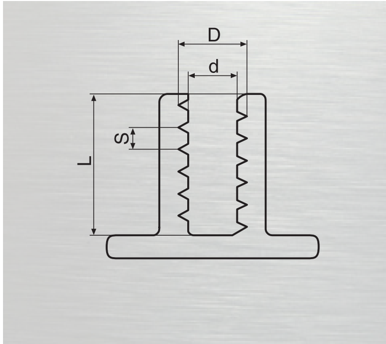
With edge joints, assembly of covers, etc, in mind, aluminium extrusions can be designed and pressed with screw grooves for self-tapping screws or plastic screws. The material consumption of the screw grooves is insignificant, but the fabrication costs will be significantly lower compared with the conventional way of drilling and threading screw holes. Obviously screw grooves for machine screws can be threaded in the normal way.

Longitudinal screw grooves

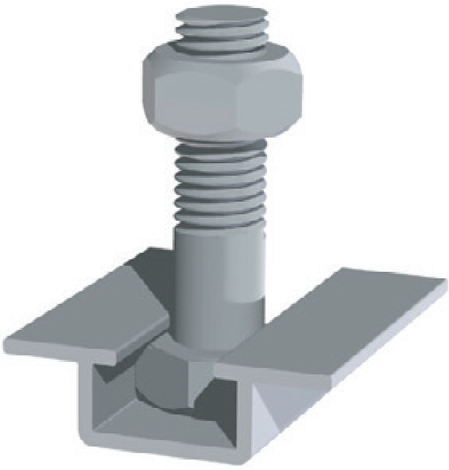


Screw no	Thread diameter D	Core diameter d	Screw pitch S	Length L
2	2,2	1,6	0,79	5
4	2,9	2,0	1,06	6
6	3,5	2,6	1,27	7
7	3,9	2,9	1,34	9
8	4,3(4,2)	3,1	1,69(1,41)	9
10	4,9(4,8)	3,4(3,6)	2,12(1,59)	13
12	5,6(5,5)	4,1(4,2)	2,31(1,81)	16
14	6,5(6,3)	4,7(4,9)	2,54(1,81)	16
5/16”	8,0	6,2	2,12	
3/8”	9,6	7,8	2,12	

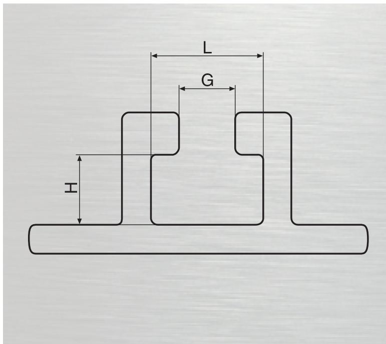
( ) screws with a narrow thread.



Channel dimensions for bolt heads/nuts

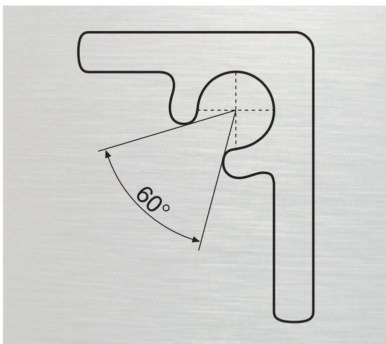


Size	Length L	Height H	Gap dimension G
M4	7,4	4,0	4,5
M5	8,4	4,5	5,5
M6	10,5	5,0	6,5
M7	11,5	6,0	7,5
M8	13,5	7,0	8,5
M10	17,5	8,5	11,0
M12	19,5	9,5	13,0
M14	22,6	10,5	15,0
M16	24,6	11,5	17,0
1/4”	11,8	5,0	7,0
5/16”	13,2	6,0	8,5
3/8”	15,0	7,0	10,2
7/16”	16,5	8,0	12,0
1/2”	19,7	9,5	13,5
9/16”	21,3	10,5	15,2
5/8”	24,5	11,5	17,0

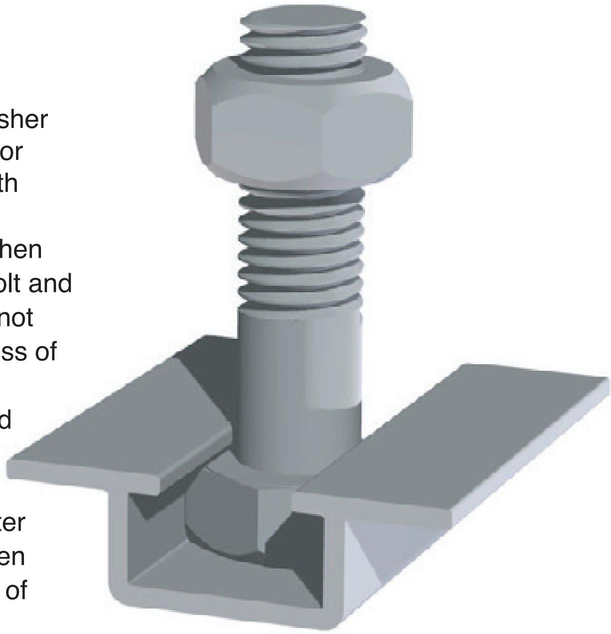


Hole diameters for self-tapping screws

Screw no	Hole diameter	Thread diameter	Tolerance (±)
2	1,8	2,2	0,15
4	2,5	2,9	0,15
6	3,0	3,5	0,15
7	3,5	3,9	0,15
8	3,8	4,2	0,15
10	4,3	4,8	0,15
12	4,8	5,5	0,15
14	5,5	6,3	0,15
5/16	7,0	8,0	0,15
3/8	8,5	9,6	0,15



Bolting

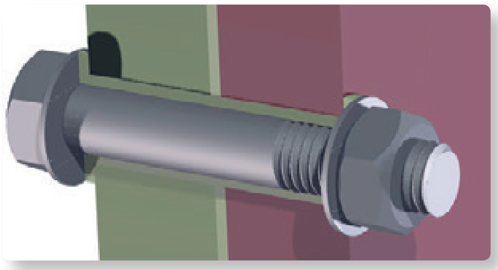


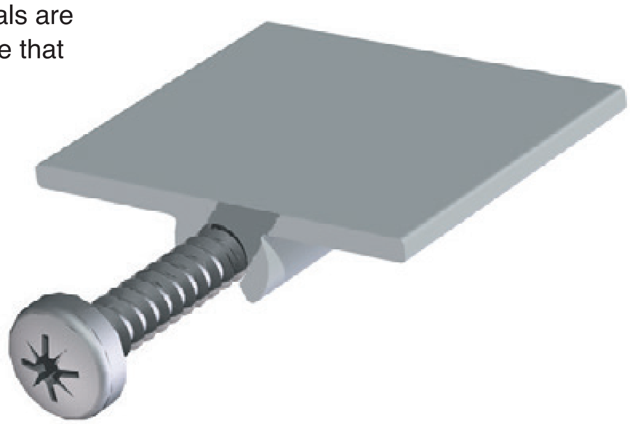
Should it be necessary to dismantle a construction, a bolt with a washer and nut is the best way to join things together. Normally galvanised or stainless steel bolts are used. Painting or coating of the surfaces with available coating systems can be a good way of stopping corrosion.

To assemble a corner joint correctly, drill and ream the hole and then use a bolt with a close fit. The difference in diameter between the bolt and the hole can be up to 1 mm. In simpler joints, reaming the edges is not necessary but then the bearing stress in the hole and the shear stress of the bolt should be lower than the recommended.

For bolted joints with heavy loads, the hole should be reamed and the difference in diameter between the hole and the bolt should be 0.15 mm at the most. If hot-dip galvanised bolts are used, the difference in diameter should be about 0.3 mm based on the diameter of the bolt before galvanising. The length of the bolt should be chosen so that the cylindrical unthreaded section passes through the whole of the reamed hole.

Steel bolts should be insulated from the aluminium structures in strongly corrosive environments. The most usual insulation materials are neoprene and nylon. When neoprene is used, it should be of a type that does not contain carbon as an additive.





The table below gives the measures that should be taken when stainless steel and hot-dip galvanised screws and bolts are used in aluminium structures in various environments.

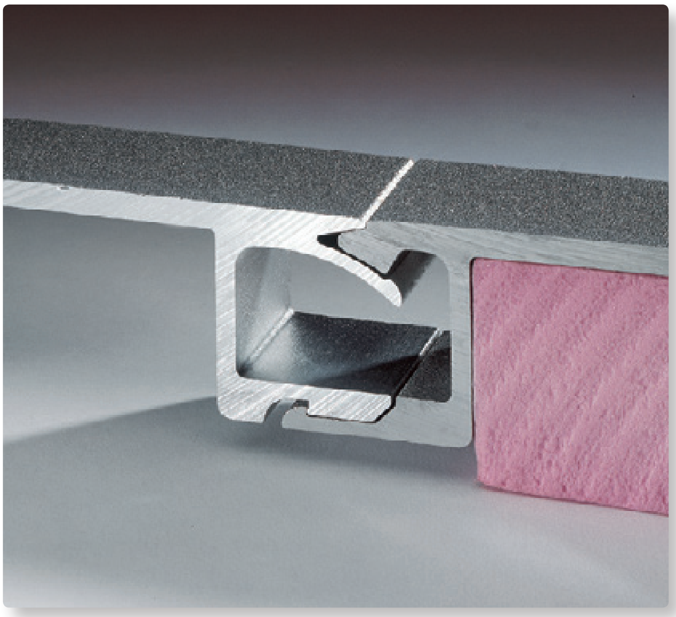
	Stainless steel		Hot-dip galvanised steel	
Environment	**Insulation necessary**	**Alternative methods**	**Insulation necessary**	**Alternative methods**
Immersed in seawater	No [1]	Paint contact faces Sealing compound Cathodic protection	No [1] [2]	Cathodic protection
Immersed in soft freshwater	No [1]	Spacer	No [1] [2]	Spacer
Immersed in hard freshwater	No	Paint contact faces Sealing compound Spacer	No [2]	Spacer (insulation)
Inland climate	No	None	No	None
Moderate marine environments	No [1]	Paint contact faces Sealing compound Spacer	No [1] [2]	Spacer (insulation)
Aggressive marine environments	Yes	Paint contact faces Sealing compound Spacer	Yes [2]	Spacer

[1] Without insulation, one or more of the corrosion inhibiting measures should be used.
[2] Zinc coating has a limited life even if insulation is used.

Clip joints

The elasticity of aluminium makes it ideal for clipped joints. This is an effective way of joining two extrusions with many advantages. The greatest is that the two parts can quickly be separated to give access to internal constructions.

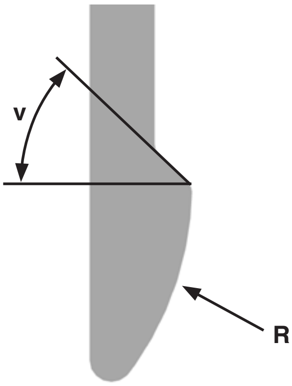
Designed in the right way, this joining technique is ideal for many applications. For example, many extrusions can be clipped together to create a whole panel. Extrusions that cannot be produced as a single unit can be made as two parts and then clipped together. The risk of permanent changes in shape through the material losing its elasticity should be taken into account when designing snap connections. This applies especially to connections that are often joined and separated. In such cases plastic clips, steel springs or similar should be used for the spring function.



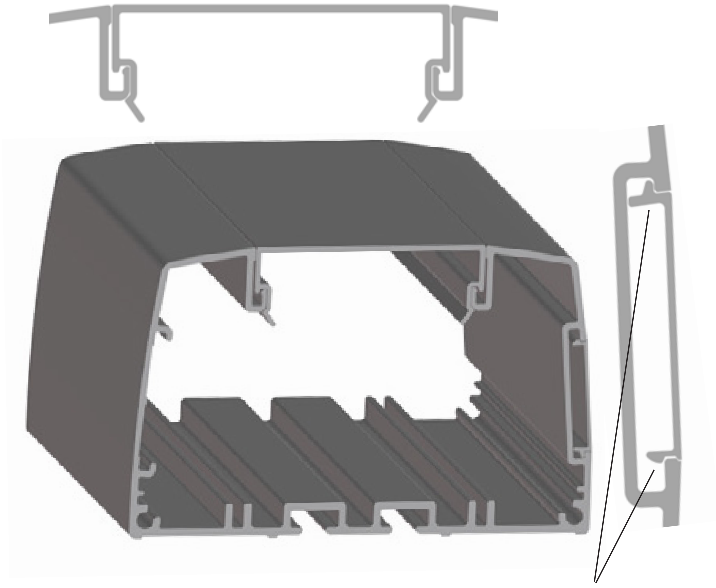
Clip arms are designed with a radius that reduces the friction between the extrusions and facilitates joining.

If it is necessary to separate clip arms they are designed with a clearance angle, left a suitable angle is between 45° and 60°.

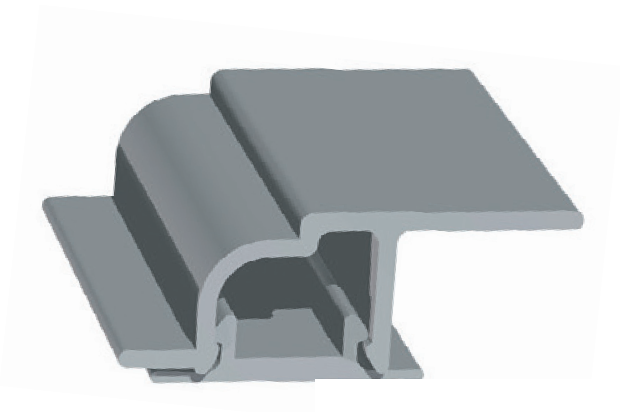
Permanent clip joints that are not meant to be opened are designed with a 0° or negative angle.

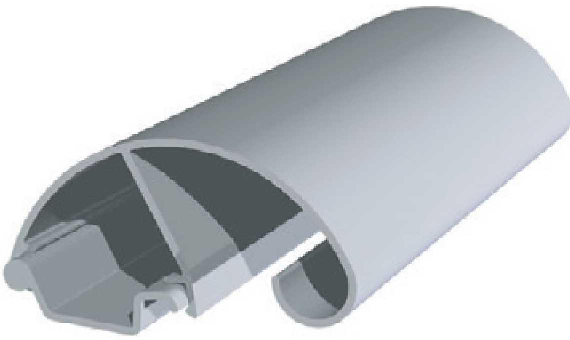


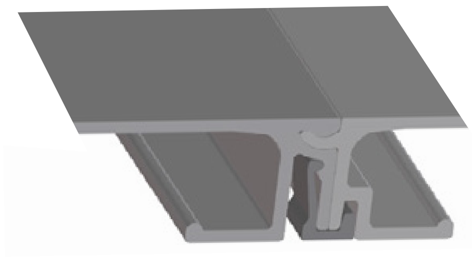
The clip height should be designed according to this example for clip joints that should sit tightly and that are accessible for clipping together properly. Generally speaking the clip arm should not be shorter than 15 mm.



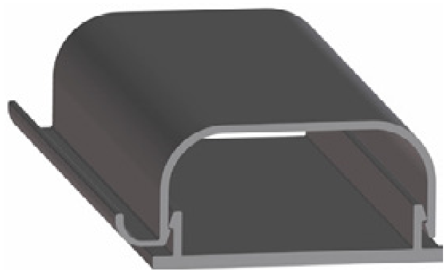
The most suitable design for a clip joint is with a catch or abutment on one side and a clip arm on the other.







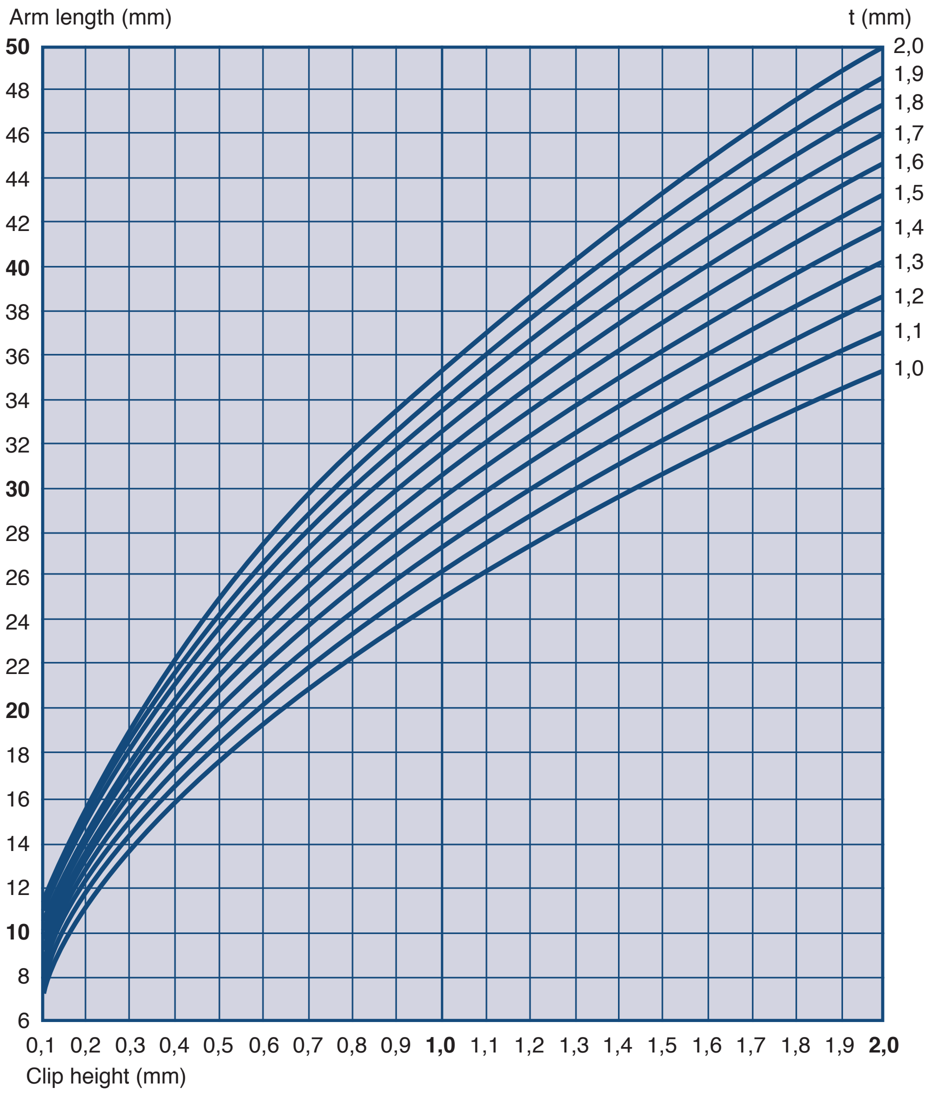
A clip extrusion can be used for both parts where an extrusion is to be fitted to itself. It is cut into suitable lengths.

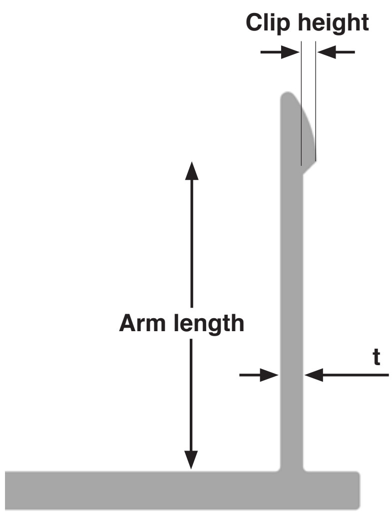


For clip joints that are meant to be opened, the extrusions are produced with flanges so they can be disconnected with the fingers, a screwdriver or something similar.

Designing the clip arm

Below are guideline values for designing clip arms taking into account the arm length, the clip height and the thickness (t).



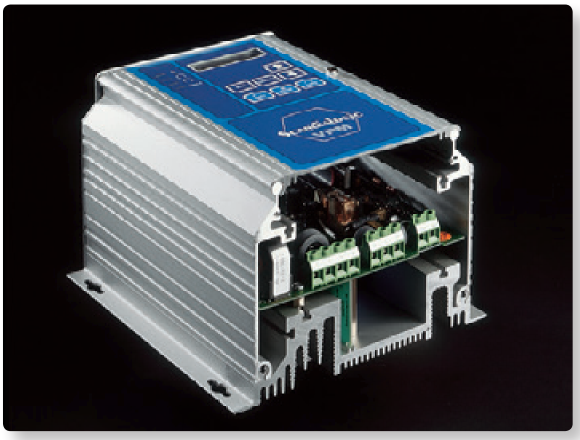


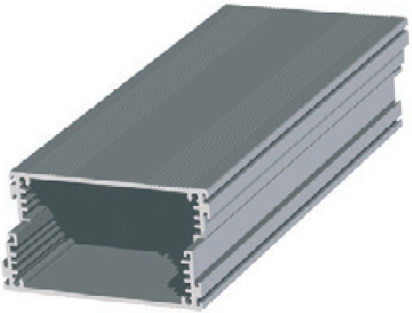
Extrusions in extrusions

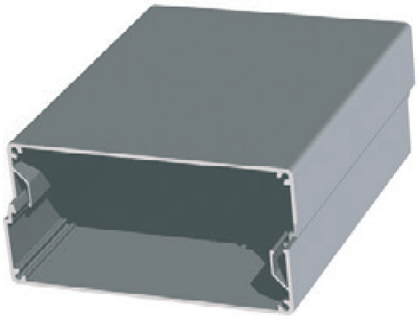
When joining one extrusion to another, they can either be slid together longitudinally in specially designed tracks or snapped together. Locking can either be by specially designed deformations, screws or cylindrical plugs.

Cabinets are often built by sawing an extrusion and then joining the two halves together. They are locked together by fitting a cover. This technique makes for easier assembly of the electronic components as well as reducing die costs by replacing a relatively expensive hollow extrusion with a solid aluminium extrusion.

This is easier to extrude and thus cheaper to produce.

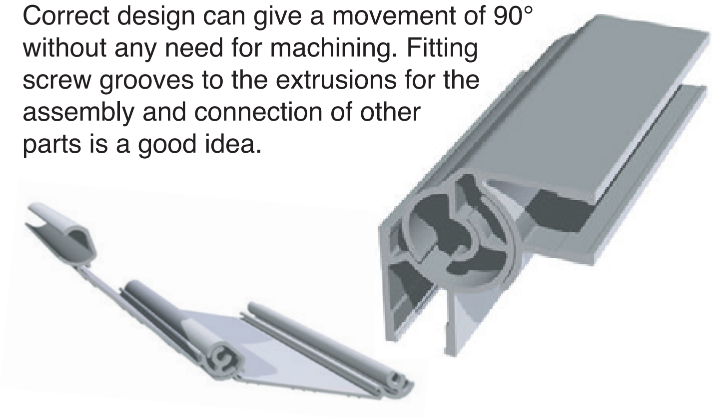






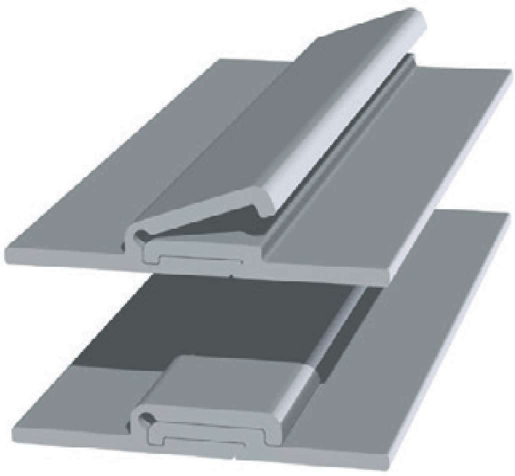
Joint functions – hinges

Aluminium extrusions provide many opportunities for designing integrated joints and hinge functions. Correct design can give a movement of 90° without any need for machining. Fitting screw grooves to the extrusions for the assembly and connection of other parts is a good idea.



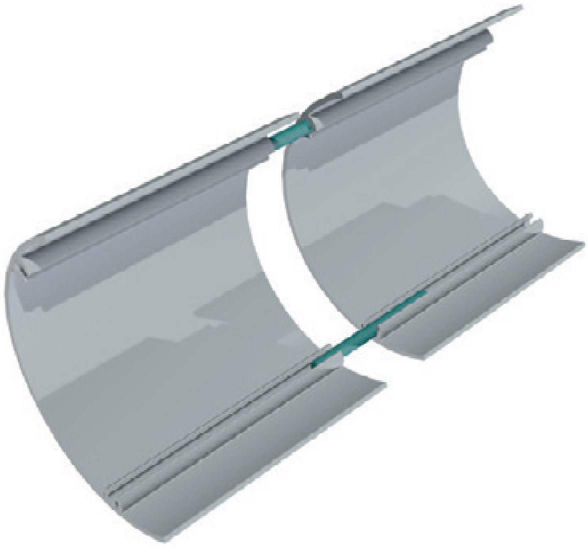
Milling

Milling can be a good solution if a permanent joint between two extrusions or an extrusion and another material is required. Aluminium's excellent characteristics are then used to the full at the same time as giving the opportunity to optimise the design of the aluminium extrusion. Long, narrow gaps in the extrusion that cannot normally be pressed can be produced by opening the gap and then milling it together to the required dimension.



Butt joint

Butt joints can be made by using guide pins or by screwing lengthways.

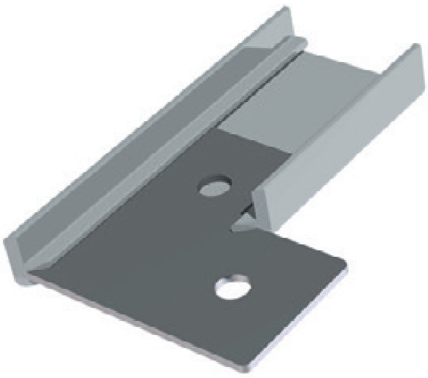


Connected extrusions

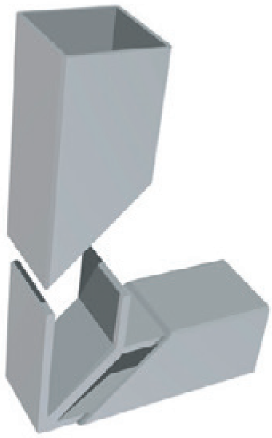
Dividing a large extrusion into several smaller ones can often be economically advantageous. Aluminium extrusions can also be designed so that, together, they create a larger structure with sufficient strength to cope with even larger loads.

Corner joints

Simple joining of two extrusions that are screwed, riveted or bonded.



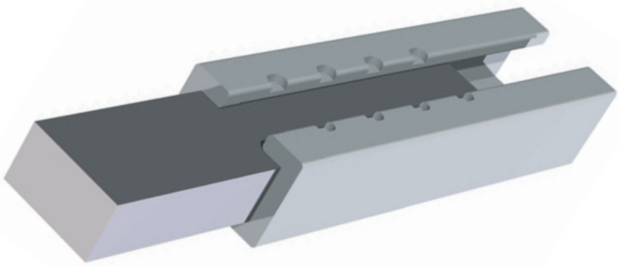
Corner joint using a steel cleat.



Extruded corner cleat.

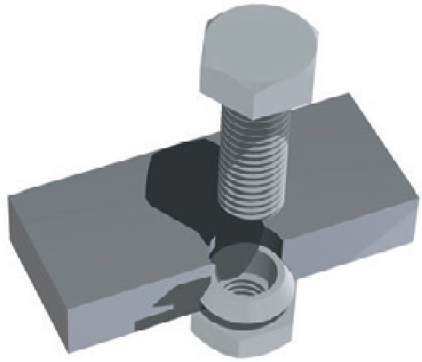
Sleeve joint

A sleeve joint gives a more durable and permanent joint.

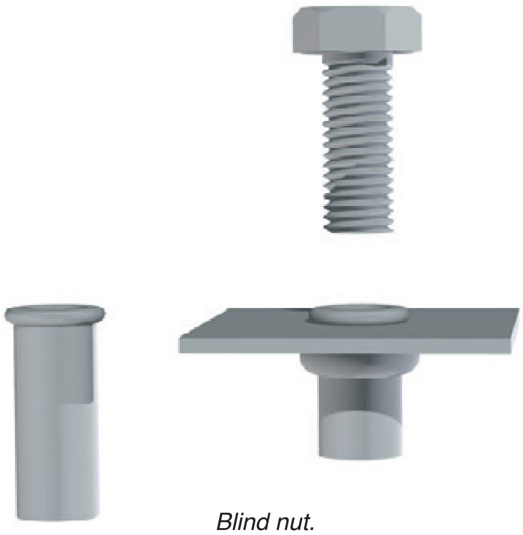


Riveting

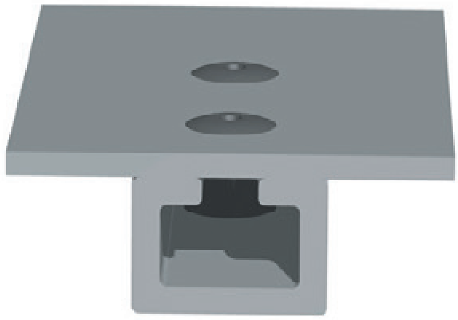
Joints using blind nuts or nutserts are often used when it is impractical to thread thin wall extrusions or for joints that will be continually joined/separated. Riveting is a useful method for permanent joints.



Nutsert.



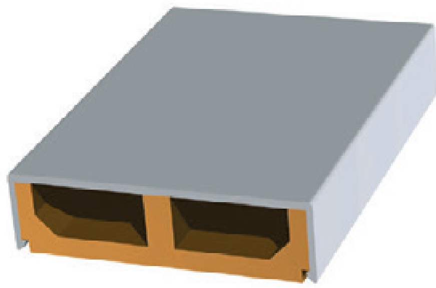
Blind nut.

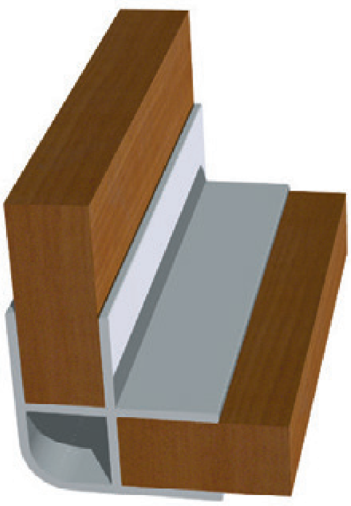


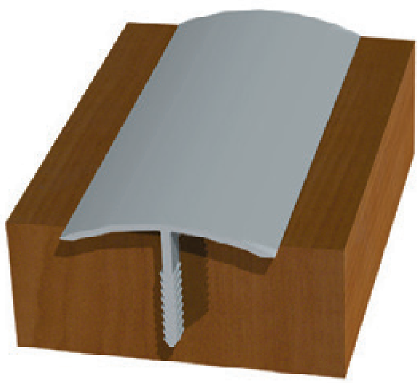
Riveting.

Joining to other materials

When joining to other materials, extrusions should be designed taking into account the other material's properties such as elasticity, strength, avoiding corrosion, etc. By devising innovative extrusion solutions, strength and function joints can be achieved with the majority of materials.







Adhesive bonding

Adhesive bonding is an important complement to the conventional joining techniques. Aluminium is by far and away the most adhesive bonded metal. Adhesive bonded joints in aircraft have been used since the 1940s. There are many other examples of bonding aluminium, and within the automotive industry bonding is one of the most commonly used joining methods.

There are a number of adhesives together with surface pre-treatment and bonding methods to choose from. It is not always easy to select the right combination, neither is bonding without the required know-how free from risk. The distance between the molecules in the material to be bonded and those in the adhesive should be 0.5 nm (a half a millionth of a mm) at the most to be able to apply a load. To achieve this closeness means that the adhesive has to have a lower surface tension than the material to be bonded otherwise the adhesive will form a drop rather than flow over the surface. Different surfaces have different properties. The presence of impurities and oxides means that the expected interaction between the adhesive and the aluminium does not happen. The surfaces to be joined should be clean and reproducible in order to achieve an even bonding result.

Type of adhesives	Properties	Strength:	Temperature range:	Chemical resistance:
Anaerobic adhesives	Cure in contact with metal in the absence of oxygen. Longer curing times on aluminium than on steel. Maximum slit opening 0.6 mm. Used as sealing compound and locking compound for screws.	17-30 MPa	-50 to 177°C	
Cyanoacrylates	Super adhesives, rapid curing in damp conditions require at least 40% relative humidity to cure. Maximum slit opening 0.25 mm.	12-16 MPa	-50 to 80°C	Little known. Variable.
Modified acrylates (High performance)	1- or 2-component adhesives that also cure rapidly at room temperature. Good impact resistance and peel strength.	25-35 MPa	-70 to 120°C	Good after sufficient surface pretreatment.
Epoxy resins	The most common adhesives used in structural bonding. 1- or 2-component adhesives. Normally require heat curing for high strength. Additives make the adhesives stronger, more flexible and give a better peeling strength but poorer high temperature properties.	25-45 MPa	-55 to 200°C	Good after sufficient surface pretreatment.
Polyurethanes	1- or 2-component adhesives, rapid curing with good flexibility. Strength lies in the thickness of the bonded joints. The adhesives are very water resistant but do not bond all surfaces equally well, something that can give poor long-term bonding properties for the joints. This problem can be solved by using a primer. The adhesives are used in the automotive industry for bonding metal to fiberglass.	17-25 MPa	-160 to 80°C	Good after sufficient surface pretreatment (primer).
Phenolics	The first type of adhesives to be used for metals. Require pressure (0.3-0.7 MPa) and heat (<150°C) to cure.	30 MPa	-50 to 176°C	
Polyimides	Expensive, high-temperature adhesives that are relatively complicated to use. Cope with over 300°C for hundreds of hours. Properties are maintained during continuous use to temperatures of 232°C and for short excursions, as high as 482°C. Molded polyimide parts and laminates have very good heat resistance. Normal operating temperatures for such parts and laminates range from cryogenic to those exceeding 260°C.	20 MPa		
Hot-melt adhesives	Offer possibilities for high productivity and are therefore used in industrial mass production of structures with small loads.			
Rubber adhesives	Cure through evaporation of a solvent. Many types and qualities. Mainly used for bonding other materials (wood, rubber, plastics, glass) to aluminium. Not normally used structurally.			
Silicon adhesives	Adhesives with relatively low strength but good high temperature properties and flexibility.	3-6 MPa	+60 to 250°C	Good after correct surface pretreatment and with high quality adhesives.
Pressure-sensitive adhesives	Often used in tape form. Do not cure and therefore has relatively low strength. Used among other things for fastening décor strips etc. to aluminium on cars and anodised or painted outer plating of aluminium on trucks, caravans and cars.			

Adhesive types

To make the right choice of adhesive, detailed information should be available on:

- *Which materials are to be bonded as well as any surface treatment*
- *The environment to which the bonded joint is to be exposed (indoors, outdoors, industrial, marine)*
- *Normal, maximum and minimum temperatures*
- *Loads, load frequency and load type*
- *The size and shape of the bonded area, preferably with a drawing*
- *Production conditions (batch size, productivity requirements, possibility of heat curing)*
- *Any other requirements for the joint (aesthetic, easy to separate)*

Advantages and limitations

An adhesive bonded joint has many good properties.
To make the most of these properties it is important to think about adhesive bonding starting at the design stage.

Advantages with bonding

- Various materials can be joined
  – Galvanic corrosion can be avoided
- The joint is permanent
- Stronger and more rigid structures
- A more even distribution of load and stress in the joints. Stress concentrations are avoided
- The adhesive seals and bonds at the same time, crevice corrosion can be avoided
- Low costs for finishing
- Good fatigue characteristics
- Dampens vibration
- Reduced weight and number of components

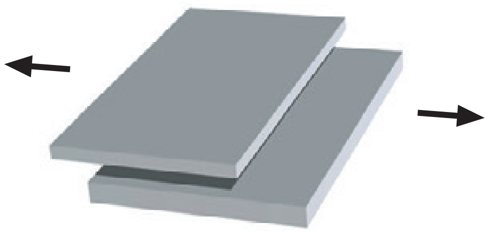
Limitations with bonding

- Handling directly after bonding is poor
- High temperatures result in reduced strength
- A bonded construction is difficult to disassemble for repair and service
- The need for pretreatment of the surface before bonding
  – Essential for structural bonding and to obtain satisfactory quality in corrosive environments
  – It is necessary to ensure that the adhesive wets the surface
- Health, environmental and safety aspects

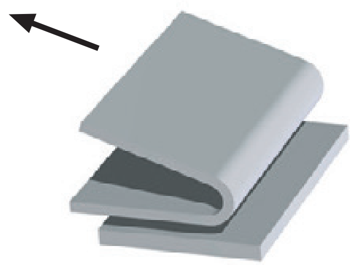
Construction of the joints

It is important to know the types of loads to which the joint will be exposed. When bonding a joint it is essential to:

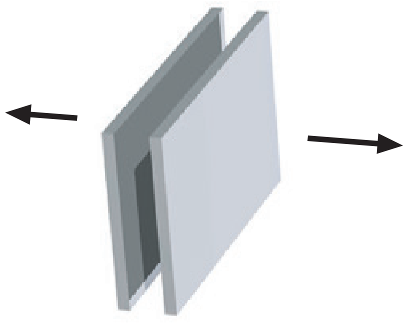
- Maximise tension, shearing and compression
- Minimise peeling and cleavage
- Maximise the area over which the load is spread



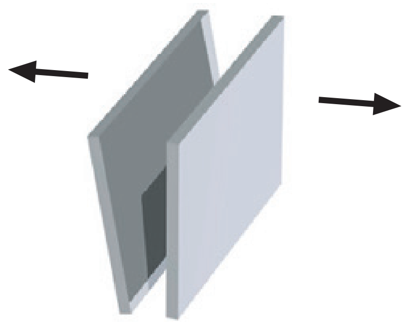
Shearing



Peeling



Tension/Compression

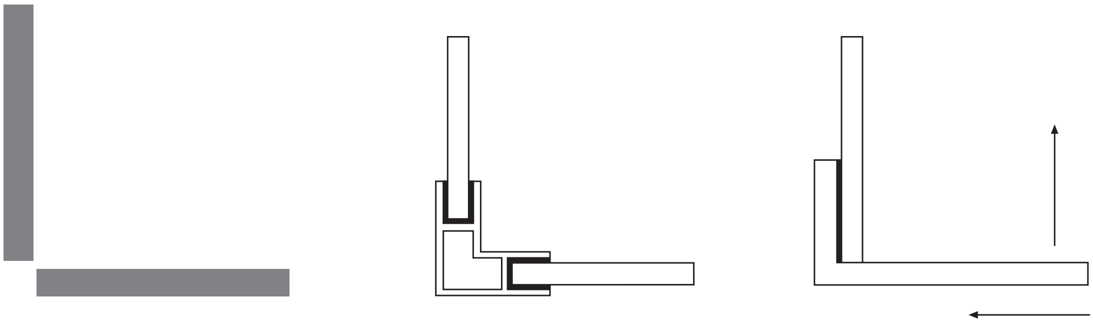


Cleavage

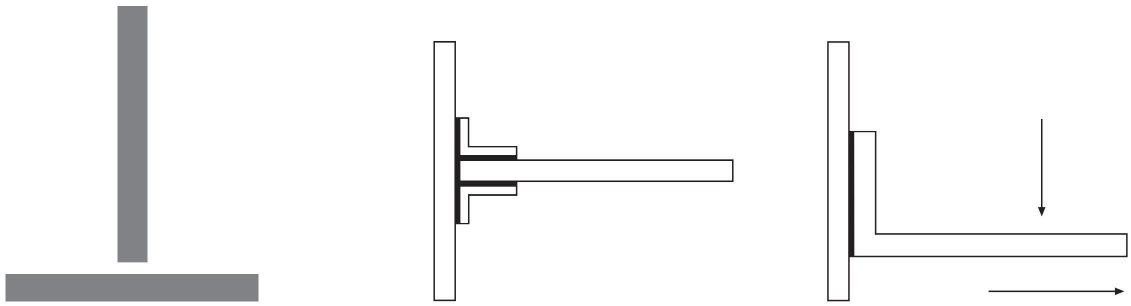
Basic adhesive bonded joints

It is possible to group the majority of joints into four basic types.
Examples of solutions (The arrows show in which direction the bond best absorbs loads):

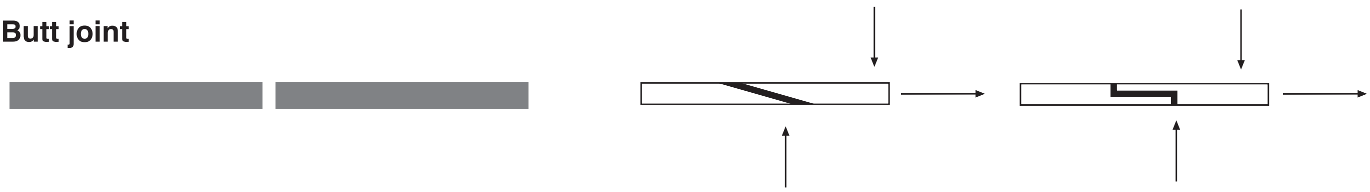
1. Angle or corner joint



2. T-joint



3. Butt joint



4. Lap joint

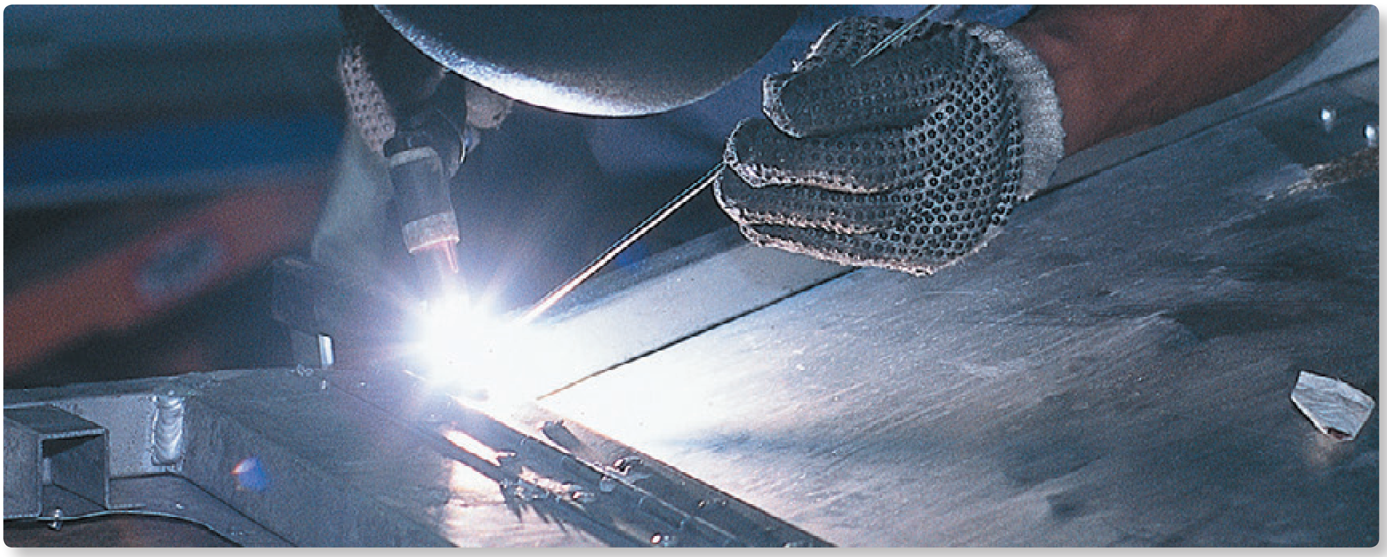
Surface treatment prior to adhesive bonding

A bonded joint is a chain with a number of links where the weakest one determines the strength and service life of the joint.

One or more of the following processes can be used for pretreatment before bonding:

- Cleaning – degreasing (acidic, alcaline or solvent based)
- Grinding or blasting with subsequent cleaning
- Chemical etching, conversion coating, anodising
- Primer

It is no problem in this context to find a pretreatment that gives sufficiently high quality. The problem is to specify how high the quality should be and find a treatment that satisfies this at the same time as it being economically and environmentally justifiable even in mass production.



Welding

The design opportunities offered by aluminium extrusions can facilitate assembly and possibly eliminate the need for welding and other demanding fabrication. It is advisable to seek assistance at an early stage of inquiry and if possible send drawings showing details of the proposed joints and a description of its function.

The majority of general engineering aluminium alloys can be welded using conventional welding processes. Welding can have the following advantages:

- Welding is one of the safest and easiest methods of creating airtight and watertight joints.
- It is possible to weld materials in thicknesses below 1 mm and up to several centimetres thick. Using special equipment it is possible to weld foil.
- Welding is established in Hydal in fully automatic, robotized processes to ensure a maximum of repeatability and process capability as well as hand welding with regards to higher flexibility and lower investments
- In general welding can be a cost efficient method of creating a joint.

Material properties

Oxide formation

Aluminium and its alloys naturally form an oxide layer which contributes to their general corrosion resistance. The disadvantage of this oxide layer is that its melting point is approximately 2060°C.

This means that the oxide layer does not melt when welded and the combination of heat and oxygen around the welded joint aids the formation of more oxide. Removal of the oxide layer can be carried out in several ways - during the welding process using fluxes that dissolve and remove the oxide, or before welding using a clean stainless steel wire brush. The TIG and MIG welding processes use an inert gas shield that prevents the creation of more oxide on the newly formed weld. The welding arc also helps to break down any residual oxide layer.

The thermal conductivity of aluminium is four times higher than steel, however as a result of other characteristics described below it does not require four times the energy to create a similar joint.

Specific Heat Capacity

This is the heat required to raise the temperature of 1 kg of material by 1 degree C.

The specific heat capacity of aluminium and its alloys does not vary significantly and is approximately double that of steel. However the density of aluminium is one third that of steel.

Melting point

The melting point of pure aluminium is about 660°C and between 570°C and 660° for the majority of alloys. The melting point of steel is about 1500°.

The combination of lower melting point, density, thermal conductivity and specific heat can mean that overall an equal amount of heat is required for a similar size joint in steel.

Creation of pores

Gas pores can be created in the weld by the absorption of hydrogen. If the dissolved hydrogen is too great the excess separates as gas during cooling and results in porosity.

Hydrogen absorption can be caused by moisture or other contaminants on joint materials, filler wires or in the gases used for flames or shielding.

Alloy additions to aluminium can also affect the molten metal’s tendency to absorb hydrogen.

Formation of cracks

The tendency to form cracks is associated with the materials strength and elasticity.

The strength of the material reduces as it gets closer to its melting point.

Restraining welded joints for the control of deformation can set up stresses in the welds that can result in cracks. Shrinkage of the molten weld pool can also create cracks. Multiple weld assemblies should have balanced welding sequences to minimise the restraint required and therefore eliminate the possibility of cracks.

Cracks can occur in the weld joint or the interface between the weld and parent material.

Good control of filler wire selection, weld sequence and process parameters reduces the risk of crack formation.

Fusion welding

The most common fusion welding methods are tungsten inert gas welding (TIG) and metal inert gas welding (MIG).

In general both these methods give good results. Gas welding is used on a limited scale and metal arc welding is used even less.

Fillers

The thickness of parts to be welded determines the amount of filler required. Fillers are standardised and are available in coiled wire or rods. Coiled wire is generally available in 1.2 and 1.6 mm diameters and is specific to MIG welding. Rods are generally available in diameters ranging from 1.6 to 6.4 mm. Filler rod diameters cover a range of metal thicknesses from 0.7 to 10 mm.

It is important that the filler is clean and dry. If the surface is contaminated it should be cleaned prior to use. See the table for choice of filler.

Choice of filler for various alloys and combinations of alloys

PARENT METAL	7108	6060/6101 6063/6005A 6082	1050
1050		AlSi5	Al99.5
6060/6101 6063/6005A 6082	AlMg 5 AlSi 5 AlMg 4.5 Mn	AlSi 5 AlMg 5 AlMg 3	
7108	AlMg 5 AlSi 5 AlMg 4.5 Mn		

Al Si 5 has advantages for welding but has slightly lower strength than Al Mg 5 and higher Ozone emissions

Al Mg 5 and Al Mg 3 give better colour match when anodised

Al Mg 5 wire is more controllable at high speeds in newer welding equipment

Fusion welding	Flux	Type of Arc	Min Material thickness mm	Relative variables				
				Heat Affected Zone Width	Welding Speed		Cost	
					Manual	Automatic	Investment	Variable
TIG welding	No	 Spray	0.7 3	1.2-1.3	0.5	5	10-20	1.2
MIG welding	No	Short Pulse	1.6 0.7	1	1	6-10	20-30	1
Gas welding	Yes		1	3.5-4	0.2	–	1	1.6
Arc welding	Yes		3.5	1.5-1.6	0.4	–	10	1.4

Pre heat should only be considered on thicker materials. Where pre heat is used it should be kept below 120°C where possible. Temperatures above this will begin to affect the parent material properties, particularly alloys that obtain their properties by heat treatment or cold work.

MIG Welding

MIG welding has been developed from TIG welding in order to speed up the welding process. The difference between the two methods is that MIG uses the filler welding wire as the electrode to create the arc instead of a tungsten tip. This method can be used for all types of joints and all welding positions and gives good results. MIG is used for material thicknesses from 3 mm and up. With more specialised equipment thickness can be reduced down to 0.7 mm. The main advantage of MIG welding is the high welding speed and good penetration. The width of the Heat Affected Zone (HAZ) is less than with any other welding method because of the speed of the process.

Welding deformation will therefore be less with MIG than with TIG welding. However MIG welding is at a disadvantage when making short weld runs and on poorly accessible joints.

MIG welding equipment requires thorough maintenance and cleaning and costs more to buy than other welding equipment. The welding speed is around 35 to 70 cm/min for 4 to 20 mm thick material. The inert gases used for optimum performance should be ”super clean” and consist of Argon (Ar 99.9) or mixtures of Argon and Helium.

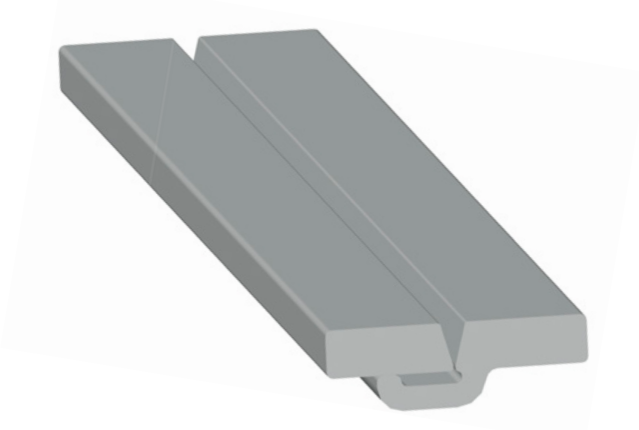
TIG Welding

The TIG method does not require flux as it also uses an inert gas shield to protect the weld pool from oxidisation. This makes it highly suitable for aluminium. TIG is used to advantage with materials from 0.7 mm to 10 mm thick and for shorter joints. TIG welding can be carried out on all weldable aluminium alloys and when controlled to the correct standards gives the most fault free welding of all conventional welding methods.

The speed of manual welding can be significantly increased by automation.

Extrusion design for simplified welding

Welding work can be simplified and the joint’s strength increased at the design stage. Consequently extrusions can be optimised by taking into account joint preparation, material compensation, backing bars and reduced number of welds.

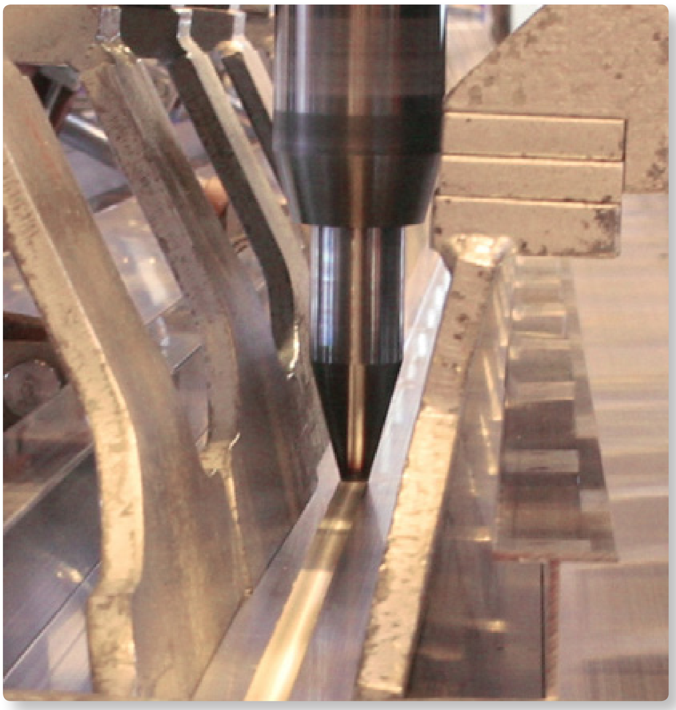


Other welding methods

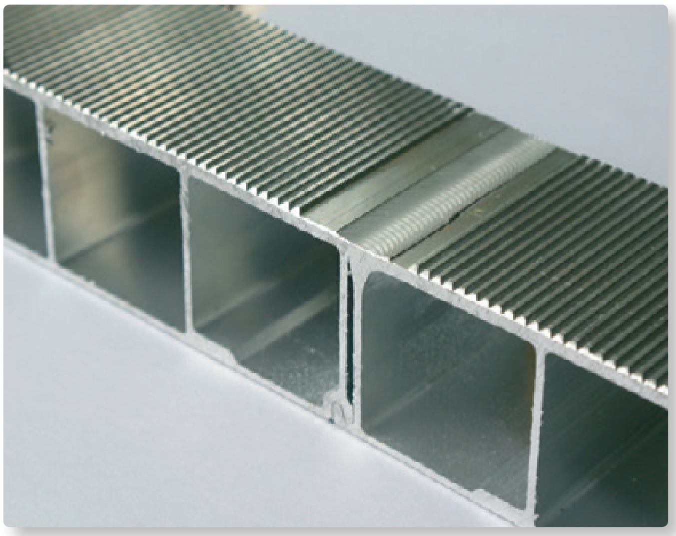
Other welding methods include spot and seam welding, flash welding as well as cold and hot pressure welding. Methods such as explosion, high frequency laser, ultrasound and electron beam welding are all used under special circumstances.

Friction Stir Welding

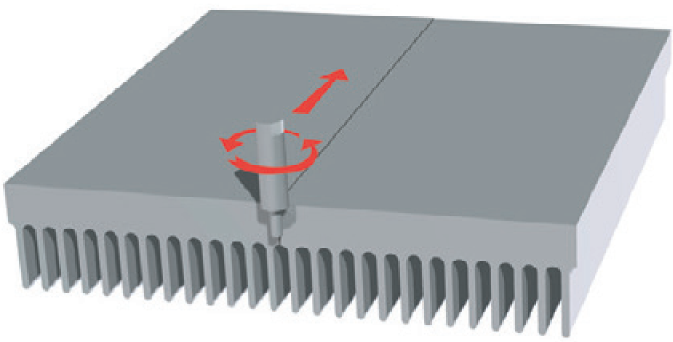
Friction Stir Welding (FSW) is a method for joining. It involves the surfaces of the aluminium to be joined being pressed together and a rotating tool being pressed down into the metal and run along the joint. The rotating tool generates a temperature in the metal of between 100 and 150°C below aluminium's melting point and mixes the material together in a plastic state without melting. The method requires neither filler nor a protective atmosphere and generates a weld virtually free from heat deformations. The method is suitable for joining aluminium extrusions of between 2 and 8 mm thick and the welding speed is about 1 m/min.



Friction Stir Welding is suitable for joining aluminium extrusions between 2 and 8 mm thick, up to 15 metres length and with a welding speed of approx. 1 m/min.



FSW requires neither filler nor a protective atmosphere and creates a weld that is virtually free from heat deformations.



A rotating tool is pressed down in the metal and run along the joint.

Fabrication

Some form of fabrication is required even if the extrusion's properties and functions have been optimised. Generally extrusions made of aluminium can be fabricated using all the methods available for other metals.

In the same way all the usual engineering machines can normally be used for fabricating aluminium.

At Hydal Aluminium Profiler we use cutting-edge technology and methods for quality fabrication with high precision and tight tolerances. We have special machines (including CNC controlled multioperation and long-length machines) for fabricating aluminium. These give faster, more rational and more cost effective processing.

Fabrication is usually divided into machining and plastic forming.

Machining

Higher machining speeds can be achieved with aluminium than with steel. The majority of aluminium alloys allow far greater machining speeds and in most cases the method is an economic and very advantageous solution.

The good machining properties of aluminium do not just depend on the alloy and its condition but also the interaction of fixtures, clamps, tools, cooling, lubrication and the alloy.

Generally it can be said that machining work is best achieved economically and rationally if tools are used with a large cutting edge angle and chips are effectively removed. Although all usual engineering machines can be used for fabrication of aluminium, Hydal is often using equipment especially developed for aluminium and aluminium extrusions in terms of speed and accuracy.

Sawing

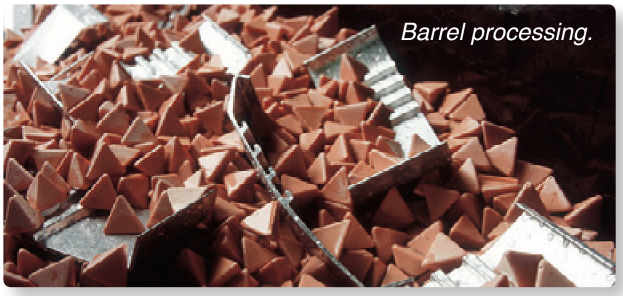
Aluminium extrusions can be sawn accurately with limited formation of burrs. The appearance of the cut, the alloy used and the extrusion's strength determine the size of the teeth, the number of revolutions per minute, the number of teeth, the diameter of the blade and the feed. The number of teeth should be sufficiently large to give a clean cut effectively.

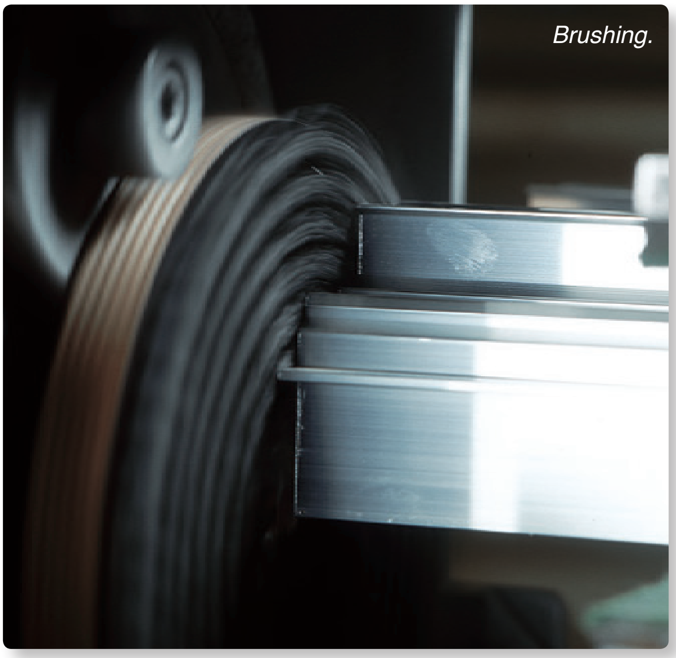
When sawing thin extrusions, several teeth should always cut in the material and cutting lubricant should always be used.

Also important for the quality is the fixation equipment. The stronger the profile is fixed and the closer the fixations are to the saw blade, the lower the material vibration will be.

Deburring

Deburring is a process for removing small chips and any remaining burrs on the extrusion cut. The most common method is mechanical using a brush or a grinding machine. Abrasive tumbling, where fragments are removed by friction using circulating stones, is a suitable method for deburring smaller and medium large parts. The level of abrasiveness can be influenced by the right choice of material and shape of the circulating stones.


Barrel processing.


Brushing.

Milling

Milling machines for fabrication of aluminium have larger teeth pitches than equivalent tools for steel and therefore a more spacious groove for chips.

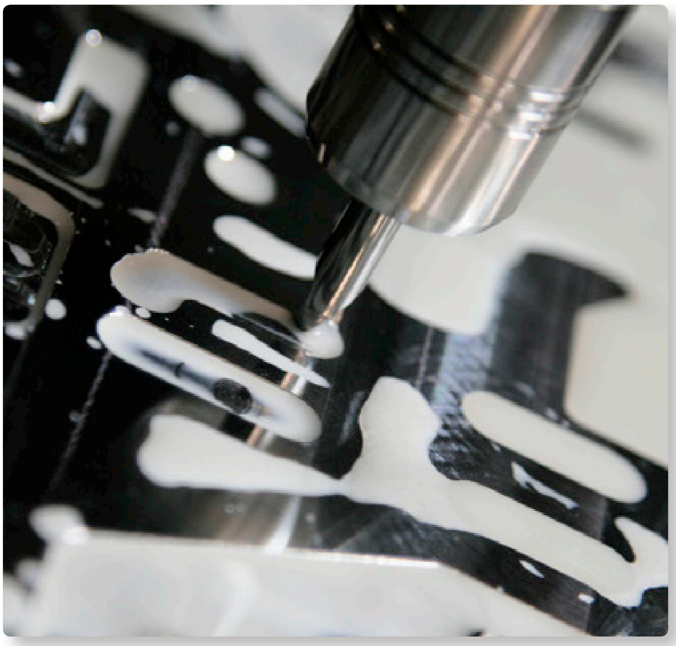
As with other sawing, a high cutting speed is required for a good result. A high quality surface demands high power and stability in the tool and feed mechanism.

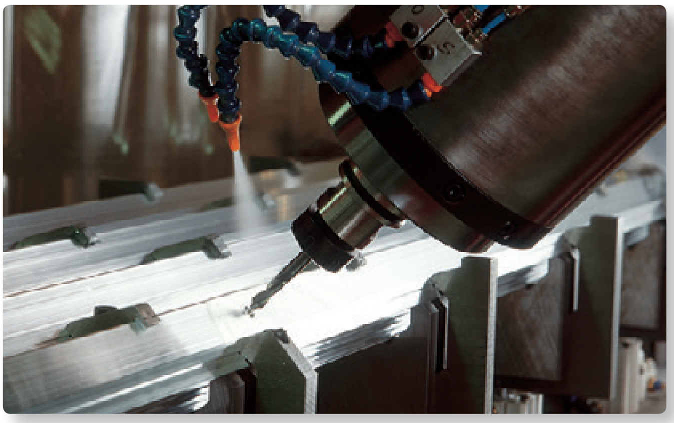
There is a difference between end and peripheral milling machines depending on where the surface to be milled is situated in relation to the milling spindle's central line.

The milling diameter should be at least 20% larger than the width of the surface being treated when surface milling with an end mill. 2/3 of the surface should be moved against and 1/3 with the cutting direction during milling.

The milling teeth should move in the line of feed (down-feed milling) when milling peripherally (i.e. slab milling cutter, shank-end mill, side-milling cutter or spindle moulding cutter).

As aluminium is able to conduct heat much better than other metals, lubrication during the milling process is more important than cooling.



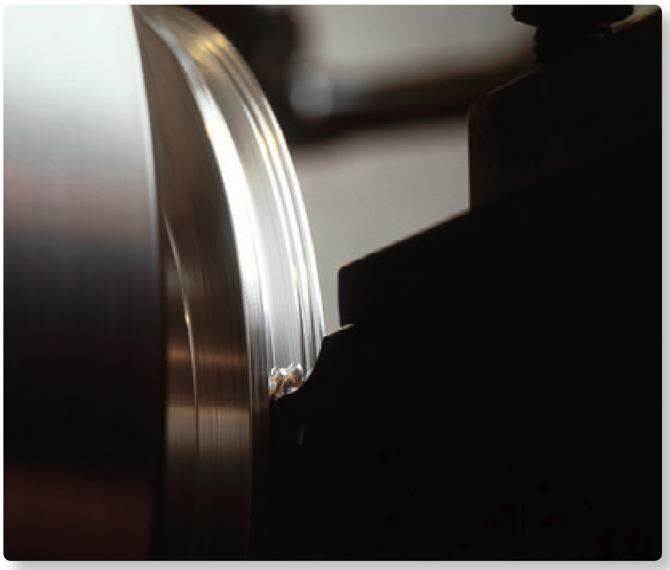


Drilling

As with most machining, drilling should be carried out at a high speed. When using standard bits, they should be sharp-ended so as to reduce the pressure required and obtain a better result. Special bits for aluminium are only required for deep holes or soft alloys. It is important to note that the hole will be considerably larger than the bit diameter when drilling in aluminium, especially when drilling in soft alloys with high pressure. A considerable amount of heat is generated when drilling deep holes, especially if the diameter is large. Cooling (in those cases) is therefore essential to avoid the hole contracting.

Turning

Aluminium can be turned in standard, special and automatic lathes and should be carried out at high speeds of rotation. Parts to be turned should therefore be fitted securely to avoid vibration. Spacers between the part and the mounting prevent marks on the metal and deformation.



Tapping

Internal and external threads can be made using all available machining methods as well as through plastic deformation. Heat treatable alloys give especially high quality results. Taps for steel can be used for threads under 6 mm but special taps should be used for larger diameters.

Internal threads can either be made with taps in series or with a single tap. The groove for chips should be large and wide, well rounded and polished as well as have a large cutting edge angle.

The back surface should run radially or be undercut so that the chips do not fasten between the tool and the thread when the tap is drawn out.

Special threading taps are normally divided into three types.

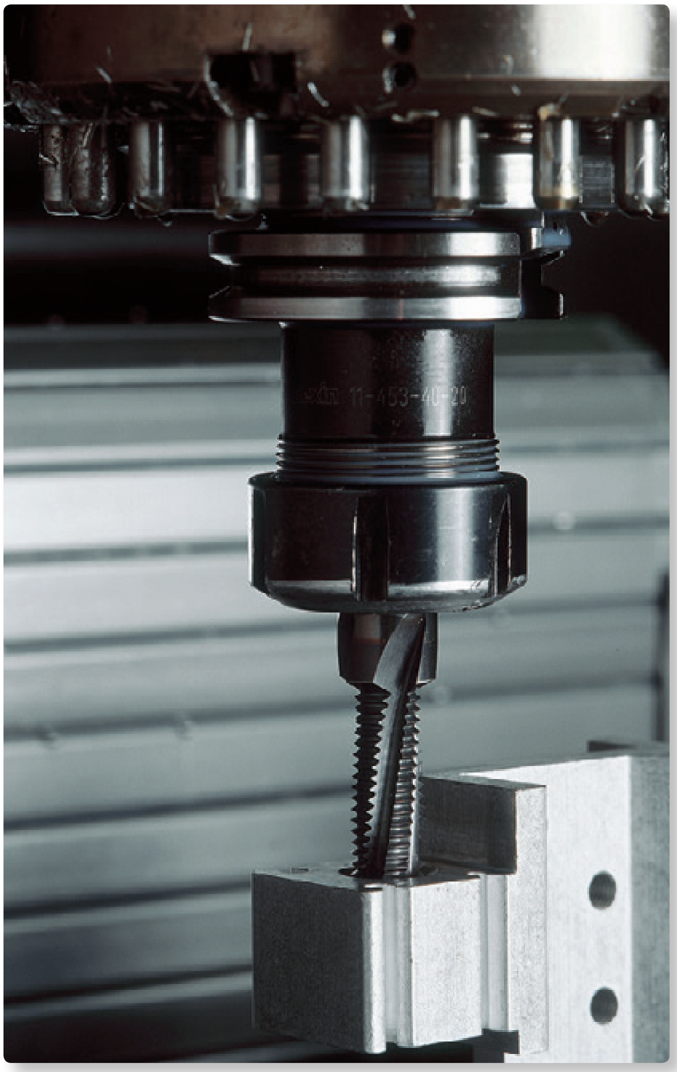
The first is hole polished with the pitch against the cutting line so that the chips are pushed forward in front of the tap during threading. Another type is designed so that the thread is interrupted from groove to groove. Finally there is one that has a spiral chips groove for lighter cutting with better pressure during threading. External threads are made using ordinary threading tools or screw cutting dies.

The threads can also be formed plastically by rolling without any chips being formed. This creates a very strong thread.

The external diameter of the part to be threaded should be 0.2 to 0.3 times the size of the screw pitch compared to the nominal thread diameter.

It is very important that the centre lines of the metal part and the tool are aligned.

Very good results are also obtained with threading down to M5.

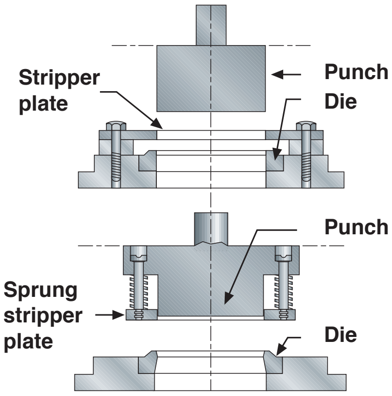


Die cutting

Press work is normally carried out in eccentric presses with a cutting (shearing) tool. The press tools for aluminium are slightly different from those designed for other metals. Punch and die of hardened tool steel are recommended. Burrs are avoided by regularly sharpening the punch and die. Furthermore, the cutting force required can be reduced considerably if the punch's surface is ground at an angle (shear). The angle ground part should at the most be equivalent to the thickness of the part of the material that is to be cut out. In certain cases, especially when punching holes, it can be an advantage to grind the punch at an angle while keeping the die flat.

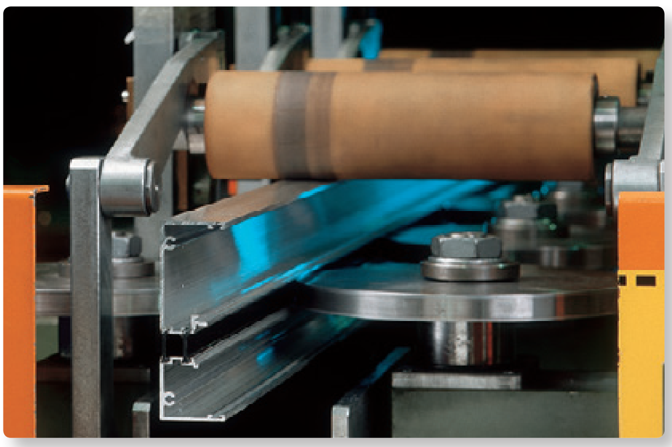
The punch should be left flat irrespective of the shape of the die if the part cut out is to be used. It is important to maintain the correct clearance between the punch and the die during the actual cutting process. The clearance is determined by the material's composition and the thickness of the cut material.

Press tools with stripper plate



Insulation

Aluminium's high coefficient of thermal conductivity is not so desirable in applications where low heat transfer is wanted such as in windows. There are many ways of insulating. Two techniques that greatly reduce the ability to conduct are commonly used. In the first the extrusion is pressed in one piece and a closed space in the extrusion is filled with polyurethane. When the polyurethane has set, the extrusion is divided into two parts held together by the polyurethane. In this way the thermal bridge is interrupted (fill and mill).

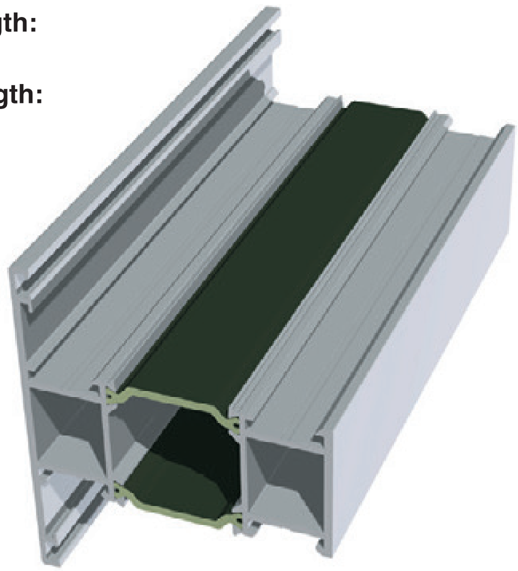


In the other method two extrusions are joined using polypropylene or polyamide strips. These are rolled into position. This way of insulating makes it possible to use different colours on the inside and outside of the window.

Limitations:
feed cross section 322x300 mm

Minimum length:
3,400 mm

Maximum length:
8,000 mm



Plastic forming

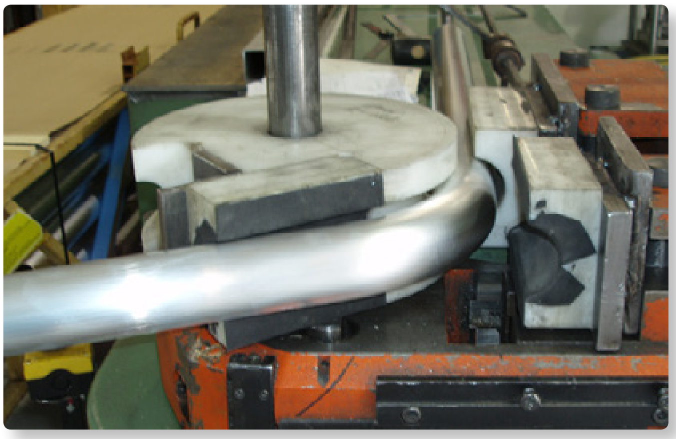
Aluminium extrusions can be bent using the same equipment as for other metals. Bending can take place with the hardened metal for larger radii but smaller ones usually require soft-annealed or T4 (half-hardened) metal. It is possible to harden to full strength after bending.

Bending should be carried out before anodising if a complete anodised layer without cracks is required.

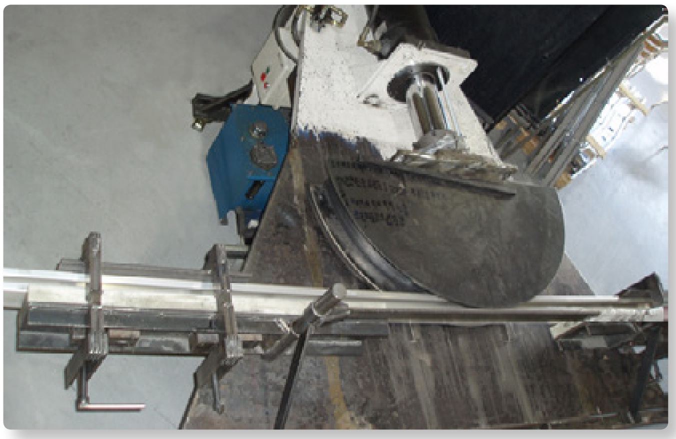
The need for bending should be taken into consideration at the design stage.

Large batches should not be produced in the T4 condition as there is a risk that the material will be left standing and will self-harden.

The four main methods used for bending:

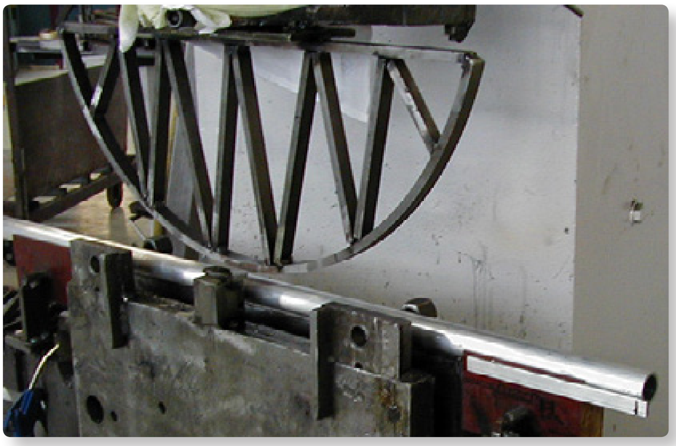


Bending
High shaping accuracy. The extrusion is held tightly at both ends and the shaping takes place by the tool moving.



Stretch forming
With or without internal and external supports. The extrusion is held tightly and rotates with the tool. This method is suitable for small radii and can be repeatedly carried out.

Roller bending
Used to bend extrusions with large radii. The extrusion is rolled between three wheels of which one is adjustable. It is possible to vary the radius on the same component using CNC-controlled machines.



Press bending
Suitable for simpler operations in large batches. The parts are shaped in a two-part tool in, for example, an eccentric or hydraulic press or other simple equipment.

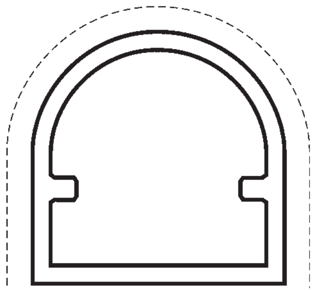
Surface treatment

There are two main reasons for surface treating aluminium extrusions, for aesthetic purposes or to give the surface special properties.

The treatment methods are divided into four main types – *mechanical, chemical, electrochemical and organic* – which cover a series of different techniques. Some of the properties that can be changed and improved by surface treatment are corrosion resistance, surface structure, hardness, wear, reflectivity and electrical insulation capacity.

Shaping the extrusion

The extrusion process provides opportunities for improving the surface as early as the design stage. Wide extrusions can be divided and the structural variations of extrusions with uneven material distribution can be hidden by, for example, decorative grooves in the surface.



Many problems can be avoided if the visible surfaces in the final product are shown with dashed lines on the drawings.

Methods of surface treatment

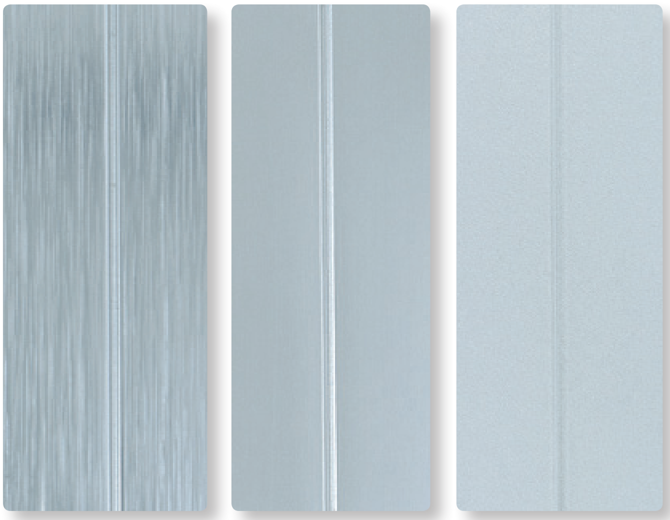
Type	Technique	Characteristics
Mechanical	Grinding / Brushing Polishing Vibration polishing Highly polished	Fine lines in the direction of grinding. Gives a faint silky matt appearance Polish the surface and the grinding lines partly disappear Matt to shiny surface, suitable for small areas Gives a mirror finish
Electrochemical	Anodising Electrolytic polishing	Gives a hard, clear or coloured oxide layer. For decoration or increased surface protection Gives a smooth surface with high reflectivity
Organic surface coating	Powder coating Screen printing Coating with protective foils	Gives various degrees of protective and decorative surfaces Printing of text, décor patterns etc. For decoration, protection or other properties

Mechanical surface treatment

Special surface finishes can be achieved by mechanical treatment such as polishing and brushing. These methods remove all small faults on the surface, give a uniform surface and make further treatment possible to give a reflective or decorative surface.

Polishing

Polishing is a process that consists of grinding, oiling and polishing with chamois leather in several stages, automated or manually. A smooth, brightly reflective and scratch-free surface with good lustre can be achieved with negligible loss of material.



Grinding

Grinding gives a decorative, non-reflective surface that can vary from sandblasted to a velvety appearance. Ground surfaces should be anodised or painted to inhibit corrosion.

Barrel processing

A very good method for smaller aluminium parts to remove burrs, smooth sharp edges and polish to a certain extent.

Electrochemical surface treatment

Anodising

Anodising is an electrochemical process that creates a significantly thicker layer of oxide than occurs naturally. This provides protection against mechanical wear and corrosion at the same time as electrically insulating the surface.

The process involves placing the extrusion in an electrolyte bath with a DC current where the extrusion acts as the anode (hence the name). When the current is applied a thick oxide layer is formed, which becomes an integrated part of the material. The thickness of the layer is determined by a combination of the temperature and composition of the bath, applied current and anodising time.

The oxide layer created consists of a number of a high number of open pores that make the material sensitive to corrosion. The process is therefore completed by either closing the pores by sealing with boiling water or in a dual step sealing process, based on nickel fluoride

(cold-sealing). This process consumes much less energy which is another contribution to our environment.

The anodic oxide layer can also be coloured in a wide range of shades. Colouring takes place prior to sealing.

Properties

The anodic oxide layer formed by anodising provides very good resistance to corrosion. The surface is not normally affected by contact with solutions and substances with pH 4 to 8.5. The surface can be stained and damaged by strongly alkaline substances. This is something to remember for aluminium building components, which should be protected during work against concrete, cement, etc.

Aluminium's natural oxide layer has a thickness of about
0.02 μm. By anodising, the thickness of the oxide layer can be increased to 25 μm.

The hardness of the anodised layer exceeds that of steel, nickel and chromium and is the same as corundum. At the same time the melting point of the surface increases to around 2000°C. The oxide layer formed by anodising has good insulation properties and a breakdown voltage of 500 – 600 V at a thickness of 12 – 15 μm. The wear and corrosion resistance of the surface can be improved by increasing the thickness of the anodised layer. The table below gives recommended thicknesses for various applications.

Anodised extrusions are suitable for a range of architectural and decorative applications that require a beautiful and durable surface. Anodised aluminium extrusions minimise the need for maintenance. They should however, for aesthetic reasons, be cleaned regularly with, for example, water and neutral detergent. Strong acids and alkalis should not be used.

Recommended layer thickness after anodising

Layer thickness μm	Application
25	Surfaces strongly affected by corrosion or wear, especially outdoors in corrosive environments
20	Strong or normal exposure outdoors, (e.g. building materials, vehicles and boats)
20	Strong exposure indoors to chemicals, in damp air, (e.g. the food industry)
15	Relatively hard wear indoors, (e.g. handrails or decorative features outdoors)
10	Normal exposure indoors or outdoors in dry, clean air. For reflectors, fittings, decorative strips on vehicles, sports equipment
5	Normal indoor exposure

Colour anodising

Before the final sealing of the pores, the anodic oxide coating can be coloured. Two methods are used:

Dying is carried out directly after anodising in a separate step. Both organic or inorganic colouring agents are used. The process is completed by sealing. Many colours are available. However, the organic dye stuffs are not resistant to UV light and this method is most suitable for products that are to be used indoors.

Electrolytic colouring is carried out in a separate step after anodising using an AC current. The pigments, which consist of metallic salts, penetrate into the pores. This process is followed by sealing. The result is very resistant to the effects of UV light and is highly suitable for products to be used outdoors. The colours range from golden bronze to black.

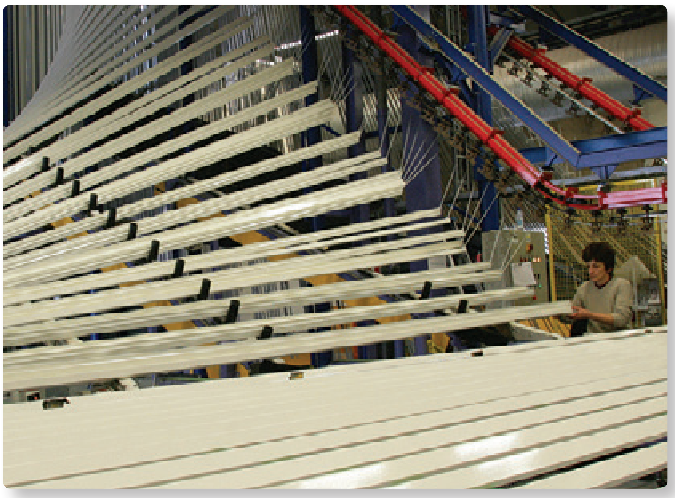
Organic surface treatment

Powder coating

The powder coating of aluminium extrusions is a solvent-free and environmentally friendly painting method that gives access to a wide colour spectrum. The method has the following advantages:

- wide range of colours
- variety of surface finishes
- good corrosion resistance
- good wear and low surface friction

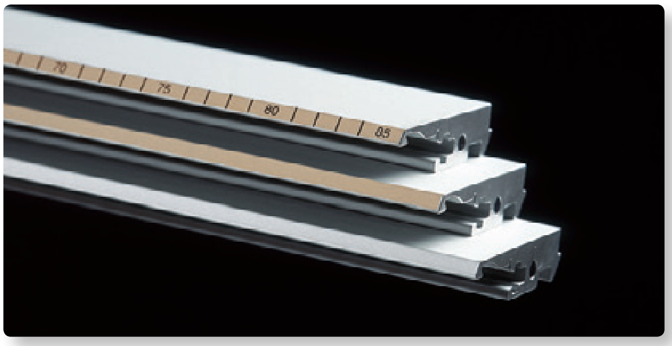
Powder coatings are resistant to UV light and therefore suitable for products to be used outdoors.



Correct pretreatment is important to achieve a satisfactory and durable result. Normal pretreatment consists of degreasing and etching as well as chromating. Powder coating gives access to the whole scale of RAL and NCS colours.

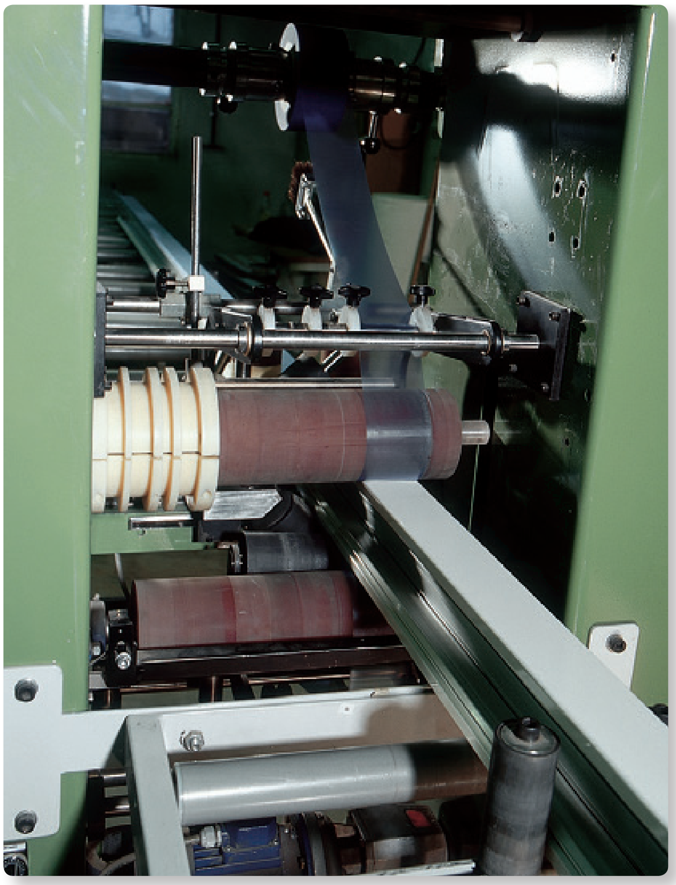
Screen printing

A durable and decorative result can be achieved on aluminium extrusions using screen printing. This can be carried out on both untreated and anodised surfaces. Especially durable results can be achieved if the screen printing is carried out between the anodising and sealing processes. The pores in the oxide layer absorb the ink and the final sealing closes the pores and therefore provides extra protection against wear.



Protective foils

Protective foils can be applied to the majority of extrusions to protect visible surfaces against damage during machining, transport and assembly. The best results are achieved in application machines with press rollers suited to the shape of the extrusion and at temperatures between 15° and 40°C. The thickness of the film should be taken into account when it comes into contact with process equipment where tolerances are decided. The film has a thickness of 50 μm.



Surface criteria

Class	Definition	Production directions Typical applications	Recommended alloy
1	**Extremely high surface requirements** No scratches, marks or noticeable structural lines on the extrusion's visible surfaces. Inspection distance: 0.5 m. Cannot be run on the visible surface. Max. delivery length: By agreement.	**Super quality** Handled individually at all stages. Visible surfaces well protected during packaging. Décor strips, picture frames, radio/TV facias.	6060
2	**Very high surface requirements** No scratches, marks or noticeable structural lines on the extrusion's visible surfaces. Inspection distance: 1.0 m. On non-visible surfaces: Qual. 3. Should not be run on the visible surface.	**Very high paint / anodising quality** Visible surfaces protected during packing. Décor strips, picture frames, radio/TV facias exclusive furniture, kitchen, bathroom.	6060 (6063)
3	**High surface requirements** No noticeable structural lines or other damage on the extrusion's visible surfaces. Inspection distance: 2.0 m. Graphite damage and other minor damage from the run-out table permissible on visible surfaces. On non-visible surfaces: Qual. 4. Free from chips.	**High paint / anodising quality** Visible surfaces protected during packing. Can be produced with the visible surface down towards the table. Can with care be laid in one another during extrusion, stretching and cutting. Damage/marks disappear during anodising can be accepted on visible surfaces. Furniture, lamps, kitchen, bathroom, windows, doors, shop fittings.	6060 6063 (6005)
4	**Normal surface requirements** No noticeable scratches, marks or other damage on the extrusion. Inspection distance: 4.0 m.	**Normal quality** Fine mechanical parts, internal components for radio/TV, building systems apart from windows and doors, balconies, sun-blinds, railings and steps, standard extrusions.	All
5	**Small/no surface requirements** Inspection distance: 6.0 m. Blisters and cracks not permissible.	**Commercial quality** Commercial elements, parts for rough mechanical machining. Standard extrusions.	All

Surface qualities, painted extrusions

Paint Class	Definition, paint surface	Minimum demands for extrusions prior to powder coating. Class:
L1 – Very High	Primary surfaces: Inspection distance: 1.0 m. No faults in the paint accepted. Layer thickness, average 60-100 μ/m Secondary surface: Layer thickness, average 30-60 μ	3
L2 – High	Primary surfaces: Inspection distance: 1.0 m Minor faults in the paint accepted. Layer thickness, average 60-100 μ Secondary surface: Layer thickness, average 30-60 μ	4
L3 – Normal	Primary surfaces: Inspection distance: 3.0 m Minor faults in the paint accepted. Layer thickness, average 60-100 μ Secondary surface: Layer thickness, average 30-60 μ	4

Tolerances

We apply tolerances for shape and dimension according to CEN – the European standardisation organisation, CEN; European Standard EN 755-9. On the following pages we publish an excerpt from this standard.

Specified tolerances are affected by extrusion design, material thickness and alloy. For more detailed information we refer to the complete standard or to our technical support.

Alloy groups

Alloys are divided into two groups corresponding to varying degrees of difficulty when manufacturing the products. The division is specified in Table 1 below.

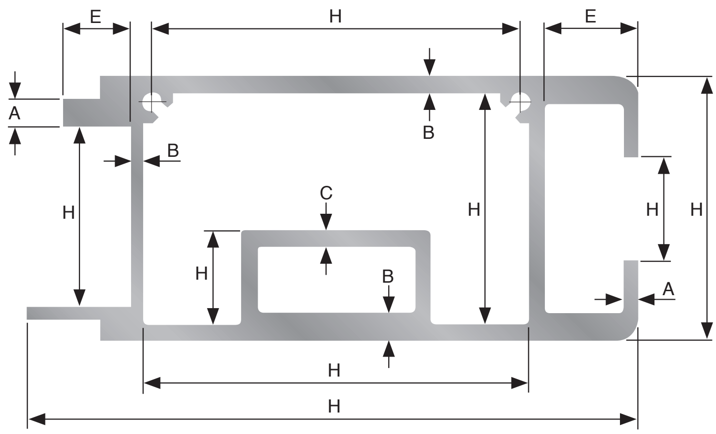
Table 1

Group	Alloy
Group 1	EN AW-1050A, EN AW-6005A, EN AW-6060, EN AW-6063
Group 2	EN AW-6082, EN AW-7003, EN AW-7108

Tolerances

The tolerances on the dimensions listed below are specified in the relevant Tables 2 – 5.

A: Wall thickness except those enclosing the hollow spaces in hollow extrusions.
B: Wall thickness enclosing the hollow spaces in hollow extrusions except those between two hollow spaces.
C: Wall thickness between two hollow spaces in hollow extrusions.
E: The length of the shorter leg of extrusions with open ends.
H: All dimensions between points on the cross section of the extrusion or the centres of open screw holes.



Tolerances on the dimensions other than wall thickness

Table 2 – Tolerances on cross-sectional dimensions of solid and hollow extrusions - Alloy group 1.

Dimensions in mm.

Dimension *H*		Tolerances on *H* for circumscribing circle CD*			
Over	**Up to and including**	**CD ≤ 100**	**100 < CD ≤ 200**	**200 < CD ≤ 300**	**300 < CD ≤ 500**
–	10	± 0,25	± 0,30	± 0,35	± 0,40
10	25	± 0,30	± 0,40	± 0,50	± 0,60
25	50	± 0,50	± 0,60	± 0,80	± 0,90
50	100	± 0,70	± 0,90	± 1,1	± 1,3
100	150	–	± 1,1	± 1,3	± 1,5
150	200	–	± 1,3	± 1,5	± 1,8
200	300	–	–	± 1,7	± 2,1
300	450	–	–	–	± 2,8

** For extrusions with open ends, tolerances shall be increased by the values specified in Table 4, see figure 3 and 4.*

Table 3 – Tolerances on cross-sectional dimensions of solid and hollow extrusions – Alloy group 2.

Dimensions in mm.

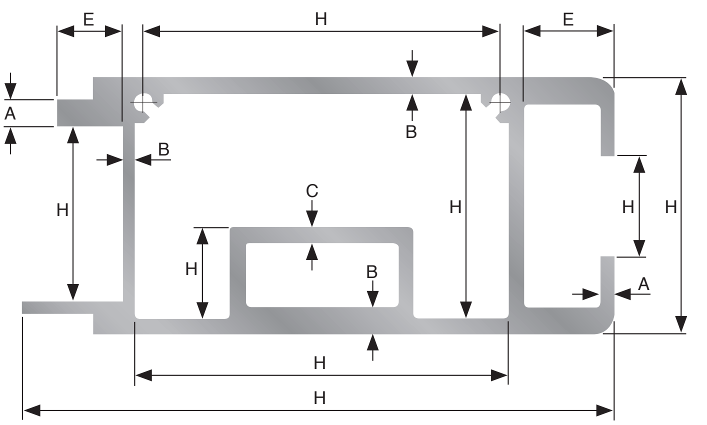
Dimension *H*		Tolerances on *H* for circumscribing circle CD*			
Over	**Up to and including**	**CD ≤ 100**	**100 < CD ≤ 200**	**200 < CD ≤ 300**	**300 < CD ≤ 500**
–	10	± 0,40	± 0,50	± 0,55	± 0,60
10	25	± 0,50	± 0,70	± 0,80	± 0,90
25	50	± 0,80	± 0,90	± 1,0	± 1,2
50	100	± 1,0	± 1,2	± 1,3	± 1,6
100	150	–	± 1,5	± 1,7	± 1,8
150	200	–	± 1,9	± 2,2	± 2,4
200	300	–	–	± 2,5	± 2,8
300	450	–	–	–	± 3,5

For extrusions with open ends, tolerances shall be increased by the values specified in Table 4, see figure 3 and 4.

Table 4 – Additions to the tolerances on cross-sectional dimensions H – Alloy group 1 and 2.

Dimensions in mm.

Dimension *E*		Additions to the tolerances on *H* in Tables 2 and 3 for open ended extrusions
Over	**Up to and including**	
–	20	–
20	30	± 0,15
30	40	± 0,25
40	60	± 0,40
60	80	± 0,50
80	100	± 0,60
100	125	± 0,80
125	150	± 1,0
150	180	± 1,2
180	210	± 1,4
210	250	± 1,6
250	–	± 1,8



A: Wall thickness except those enclosing the hollow spaces in hollow extrusions.

B: Wall thickness enclosing the hollow spaces in hollow extrusions except those between two hollow spaces.

C: Wall thickness between two hollow spaces in hollow extrusions.

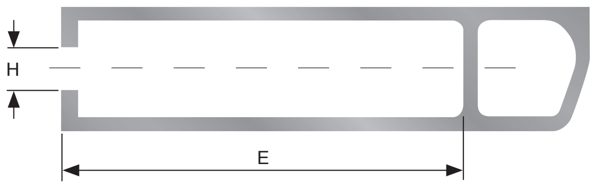
E: The length of the shorter leg of extrusions with open ends.

H: All dimensions between points on the cross section of the extrusion or the centres of open screw holes.

Example 1

Dimension *H*: 30 mm; Dimension *E*: 50 mm; Circumscribing circle, CD up to 100 mm alloy group 1.

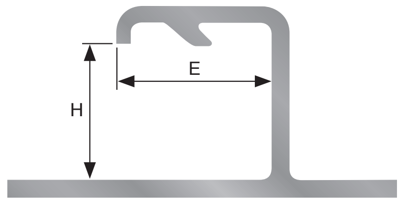
The tolerance on *H* according to Table 2 is ± 0,5, plus the additional tolerance according to Table 4 ± 0,4 mm which gives a total tolerance on *H* = ± 0,9 mm.



Example 2

Dimension *H*: 60 mm; Dimension *E*: 70 mm; Circumscribing circle, CD 100 up to 200 mm alloy group 2.

The tolerance on *H* according to Table 3 is ± 1,0 mm, plus the additional tolerance according to Table 4 ± 0,5 mm which gives a total tolerance on *H* = ± 1,5 mm.



Tolerances on wall thickness

Table 5 – Tolerances on wall thickness for extrusions with a circumscribing circle up to and including 300 mm – Alloy group 1.

Dimensions in mm.

Nominal wall thickness *A, B* or *C*		Tolerances on wall thickness					
		Wall thickness *A* Circumscribing circle CD		Wall thickness *B** Circumscribing circle CD		Wall thickness *C* Circumscribing circle CD	
Over	Up to and including	CD ≤ 100	CD < 100 ≤ 300	CD ≤ 100	CD < 100 ≤ 300	CD ≤ 100	CD < 100 ≤ 300
–	1,5	± 0,15	± 0,20	± 0,20	± 0,30	± 0,25	± 0,35
1,5	3	± 0,15	± 0,25	± 0,25	± 0,40	± 0,30	± 0,50
3	6	± 0,20	± 0,30	± 0,40	± 0,60	± 0,50	± 0,75
6	10	± 0,25	± 0,35	± 0,60	± 0,80	± 0,75	± 1,0
10	15	± 0,30	± 0,40	± 0,80	± 1,0	± 1,0	± 1,2
15	20	± 0,35	± 0,45	± 1,2	± 1,5	± 1,5	± 1,9
20	30	± 0,40	± 0,50	± 1,5	± 1,8	± 1,9	± 2,2
30	40	± 0,45	± 0,60	–	± 2,0	–	± 2,5
40	50	–	± 0,70	–	–	–	–

** For seamless hollow extrusions wall thickness C apply.*

Table 6 – Tolerances on wall thickness for extrusions with a circumscribing circle up to and including 300 mm – Alloy group 2.

Dimensions in mm.

Nominal wall thickness *A, B* or *C*		Tolerances on wall thickness					
		Wall thickness *A* Circumscribing circle CD		Wall thickness *B** Circumscribing circle CD		Wall thickness *C* Circumscribing circle CD	
Over	Up to and including	CD ≤ 100	CD < 100 ≤ 300	CD ≤ 100	CD < 100 ≤ 300	CD ≤ 100	CD < 100 ≤ 300
–	1,5	± 0,20	± 0,25	± 0,30	± 0,40	± 0,35	± 0,50
1,5	3	± 0,25	± 0,30	± 0,35	± 0,50	± 0,45	± 0,65
3	6	± 0,30	± 0,35	± 0,55	± 0,70	± 0,60	± 0,90
6	10	± 0,35	± 0,45	± 0,75	± 1,0	± 1,0	± 1,3
10	15	± 0,40	± 0,50	± 1,0	± 1,3	± 1,3	± 1,7
15	20	± 0,45	± 0,55	± 1,5	± 1,8	± 1,9	± 2,2
20	30	± 0,50	± 0,60	± 1,8	± 2,2	± 2,2	± 2,7
30	40	± 0,60	± 0,70	–	± 2,5	–	–
40	50	–	± 0,80	–	–	–	–

** For seamless hollow extrusions wall thickness C apply.*

Tolerances on length

If fixed lengths are to be supplied, this shall be stated in the order document. The tolerances on fixed lengths are specified in the table below.

Table 7 – Tolerances on fixed length

Dimensions in mm.

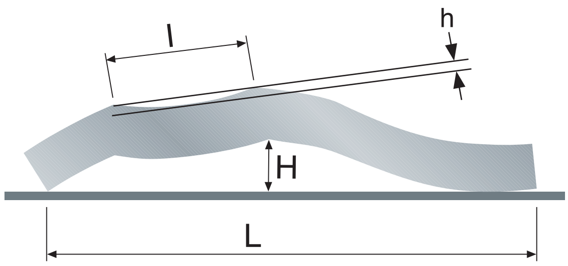
Circumscribing circle CD		Tolerances on fixed length *L*			
Over	Up to and including	*L* ≤ 2000	2000 < *L* ≤ 5000	5000 < *L* ≤ 10000	10000 < *L* ≤ 15000
–	100	+ 5 0	+ 7 0	+ 10 0	+ 16 0
100	200	+ 7 0	+ 9 0	+ 12 0	+ 18 0
200	450	+ 8 0	+ 11 0	+ 14 0	+ 20 0

If no fixed length is specified in the order document, extrusions may be delivered in random lengths. Tolerances shall then be agreed upon between buyer and supplier.

Tolerances on form

Straightness

The straightness tolerance *H* shall not exceed 1,5 mm/m extrusion (e.g. 6 mm maximum deviation for a 4 m length). Local deviations *h* shall not exceed 0,6 mm/300mm length.



Deviations from straightness, *H* and *h*, shall be measured as shown in the figure above with the extrusion placed on a horizontal base plate so that its own mass decreases the deviation.

Convexity – Concavity

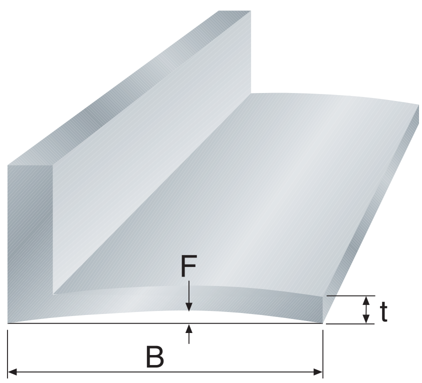
Table 8 – Convexity - concavity tolerances

Dimensions in mm.

Width *B*		Deviation *F*		
		Hollow extrusions*		Solid extrusion
Over	Up to and including	Wall thickness *t* ≤ 5	Wall thickness *t* > 5	
–	**30**	**0,30**	**0,20**	**0,20**
30	**60**	**0,40**	**0,30**	**0,30**
60	**100**	**0,60**	**0,40**	**0,40**
100	**150**	**0,90**	**0,60**	**0,60**
150	**200**	**1,2**	**0,80**	**0,80**
200	**300**	**1,8**	**1,2**	**1,2**
300	**400**	**2,4**	**1,6**	**1,6**
400	**500**	**3,0**	**2,0**	**2,0**

** It the extrusion has varying wall thicknesses, the thinnest wall thickness shall be used.*

In case of width *B* over 150 mm the local deviation shall not exceed 0,7 mm/100 mm.



Convexity - concavity shall be measured as shown in the figure above with the extrusion placed on a horizontal base plate so that its own mass decreases the deviation.

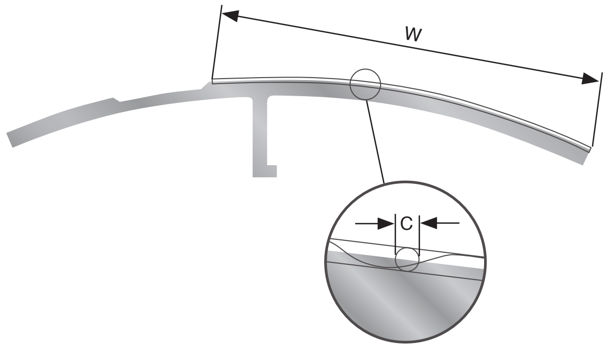
Contour

For extrusions with curved cross sections, the deviation from a theoretically exact line shall not be greater than the appropriate tolerance *C* specified in table 9. Considering all points on the curve, a tolerance shall be defined as the zone between two envelopes running tangentially to all circles of diameter *C* which can be drawn with their centres lying along the theoretically exact line.

Table 9 – Contour tolerances

Dimensions in mm.

Width *W* of the contour		Contour tolerance = diameter *C* of the tolerance circle
Over	Up to and including	
–	30	0,30
30	60	0,50
60	90	0,70
90	120	1,0
120	150	1,2
150	200	1,5
200	250	2,0
250	300	2,5
300	400	3,0
400	500	3,5
500	800	4,0



Contour tolerances can be checked by using gauges or by placing an extrusion on a drawing with the contours indicated.

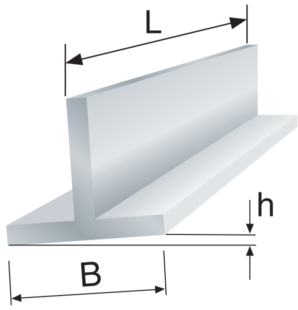
Twist

Twist tolerances are a function of the extrusion width *B* and the length *L* of the extrusion, as defined in the table below.

Table 10 – Twist tolerances

Dimensions in mm.

Width *B*		Twist tolerance *h* for length *L*		
			On total extrusion length *L*	
Over	Up to and including	Per 1000*	Over 1000 including 6000	Over 6000
–	30	1,2	2,5	3,0
30	50	1,5	3,0	4,0
50	100	2,0	3,5	5,0
100	200	2,5	5,0	7,0
200	300	2,5	6,0	8,0
300	450	3,0	8,0	1,5 x L *(L in metres)*



Twist *h* shall be measured by placing the extrusion on a flat baseplate, the extrusion resting under own mass, and measuring the maximum distance at any point along the length between the bottom surface of the extrusion and the baseplate surface.

Twist tolerances for lengths less than 1000 mm shall be subject to agreement between supplier and purchaser.

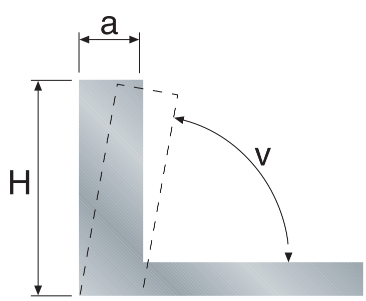
Angularity

The angularity tolerances for right angles shall be as specified in the table below as a function of extrusion width *H*.

Table 11 – Angularity tolerances for right angles

Dimensions in mm.

Width *H*		Maximum allowable deviation *a* from right angle
Over	Up to and including	
–	30	0,4
30	50	0,7
50	80	1,0
80	120	1,4
120	180	2,0
180	240	2,6
240	300	3,1
300	400	3,5



The maximum allowable deviation *v* in an angle other than a right angle shall be ±1°.

* For extrusions with H exceeding 400 mm the tolerance shall be subject to agreement between supplier and purchaser.

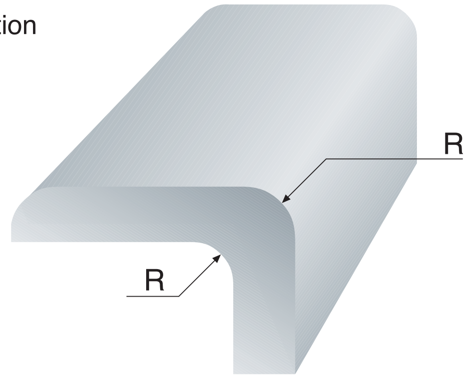
Corner and fillet radii

When a corner or fillet radius is specified, the maximum allowable deviation from this radius shall be as specified in the table below.

Table 12 – Maximum allowable corner and fillet radii

Dimensions in mm.

Specified radius	Maximum allowable deviation
≤ 5	± 0,5 mm
> 5	± 10 %



CEN – European Committee for standardization

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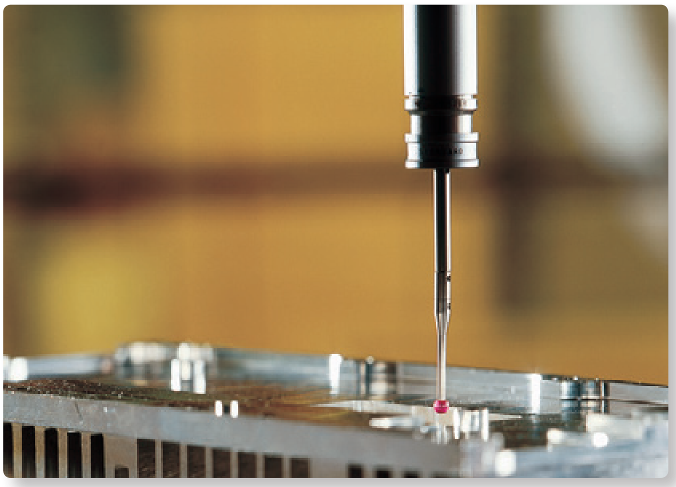
Fabrication tolerances

For fabrication Hydal apply tolerances according to the standards specified in SS-ISO 2768 – 1 Middle.



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