



EXOACM – Aluminum & Corrosion Resistance

Strength

Aluminium alloys commonly have tensile strengths of between 70 and 700 MPa. The range for alloys used in extrusion is 150 – 300 MPa. Unlike most steel grades, **aluminum does not become brittle at low temperatures. Instead, its strength increases.** At high temperatures, aluminum's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account.

Conductivity

Aluminium is an excellent conductor of heat and electricity. An aluminium conductor weighs approximately half as much as a copper conductor having the same conductivity.

Screening EMC

Tight aluminium boxes can effectively exclude or screen off electromagnetic radiation. The better the conductivity of a material, the better the shielding qualities.

Zero toxicity

After oxygen and silicon, aluminium is the most common element in the Earth's crust. Aluminium compounds also occur naturally in our food.

Non-magnetic material

Aluminium is a non-magnetic (actually paramagnetic) material. To avoid interference of magnetic fields aluminium is often used in magnet X-ray devices.

Corrosion resistance

Aluminium reacts with the oxygen in the air to form an extremely thin layer of oxide. Though it is only some hundredths of a (my)m thick (1 (my)m is one thousandth of a millimeter), this layer is dense and provides excellent corrosion protection. The layer is self-repairing if damaged.

Anodizing increases the thickness of the oxide layer and thus improves the strength of the natural corrosion protection. Where aluminium is used outdoors, thicknesses of between 15 and 25 µm (depending on wear and risk of corrosion) are common.

Aluminium is extremely durable in neutral and slightly acid environments. In environments characterized by high acidity or high basicity, corrosion is rapid.

Reflectivity

Another of the properties of aluminium is that it is a good reflector of both visible light and radiated heat.

Aluminum corrosion resistance is very good in untreated aluminium. Untreated aluminum has very good corrosion resistance in most environments. This is primarily because aluminium spontaneously forms a thin but effective oxide layer that prevents further oxidation.

Aluminum oxide is impermeable and, unlike the oxide layers on many other metals, it adheres strongly to the parent metal. If damaged mechanically, aluminum's oxide layer repairs itself immediately.

This oxide layer is one of the main reasons for aluminum's good corrosion properties. The layer is stable in the general pH range 4 – 9.

Galvanic corrosion

Galvanic corrosion may occur where there is both metallic contact and an electrolytic bridge between different metals. The least noble metal in the combination becomes the anode and corrodes. The most noble of the metals becomes the cathode and is protected against corrosion. In most combinations with other metals, aluminium is the least noble metal. Thus, aluminium presents a greater risk of galvanic corrosion than most other structural materials. However, the risk is less than is generally supposed.



Close-up of galvanic corrosion in an aluminium rail post (25 year's use). The rectangular hollow profile was held in place by a carbon steel bolt. The contact surfaces between the steel and the aluminium were often wet and attack was aggravated by wintertime salting.

Galvanic corrosion of aluminium occurs:

- Only where there is contact with a more noble metal (or other electron conductor with a higher chemical potential than aluminium, e.g. graphite).
- While, at the same time, there is an electrolyte (with good conductivity) between the metals.

Galvanic corrosion does not occur in dry, indoor atmospheres. Nor is the risk great in rural atmospheres. However, the risk of galvanic corrosion must always be taken into account in environments with high

chloride levels, e.g. areas bordering the sea. Copper, carbon steel and even stainless steel can here initiate galvanic corrosion.

Problems can also occur where the metallic combination is galvanized steel and aluminium. The zinc coating of the galvanized steel will, at first, prevent the aluminium being attacked. However, this protection disappears when the steel surface is exposed after the consumption of the zinc.

As it has a thicker zinc coating than electroplated material, hot dip galvanized material gives longer protection. Thus, in combination with aluminium in aggressive environments, hot dip galvanized material should be used.

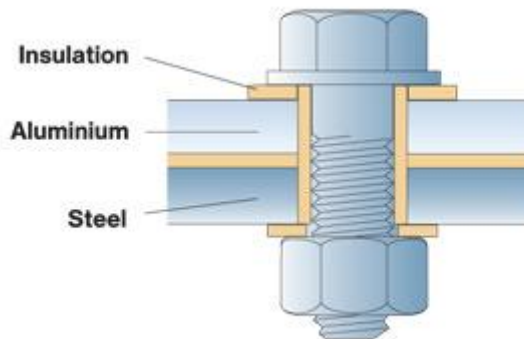
Preventing galvanic corrosion

The risk of galvanic corrosion should not be exaggerated – corrosion does not occur in dry, indoor atmospheres and the risk is not great in rural atmospheres.

Electrical insulation

Where different metals are used in combination, galvanic corrosion can be prevented by electrically insulating them from each other. The insulation has to break all contact between the metals.

The illustration shows a solution for bolt joints.



Breaking the electrolytic bridge

In large constructions, where insulation is difficult, an alternative solution is to prevent an electrolytic bridge forming between the metals. Painting is one way of doing this. Here, it is often best to coat the cathode surface (i.e. the most noble metal).

A further solution is to use an insulating layer between the metals.

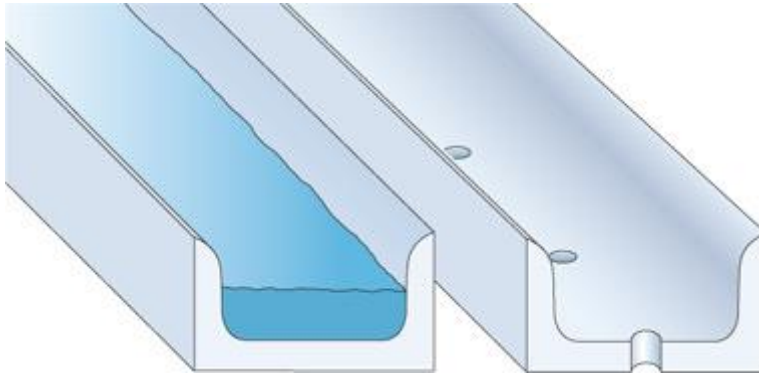
Pitting

For aluminium, pitting is by far the most common type of corrosion. It occurs only in the presence of an electrolyte (either water or moisture) containing dissolved salts, usually chlorides.

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The corrosion generally shows itself as extremely small pits that, in the open air, reach a maximum penetration of a minor fraction of the metal's thickness. Penetration may be greater in water and soil.

As the products of corrosion often cover the points of attack, visible pits are rarely evident on aluminium surfaces.

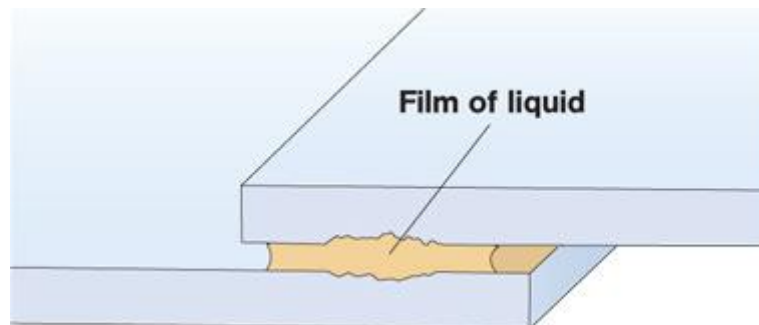


Stagnant water is avoided by suitably inclining the profile and/or providing drain holes. The ventilation of "closed" constructions reduces the risk of condensation.

EXOACM extrusions incorporate both drainage and inclined profiles

Crevice corrosion

Crevice corrosion can occur in narrow, liquid-filled crevices. The likelihood of this type of corrosion occurring in extruded profiles is small. However, significant crevice corrosion can occur in marine atmospheres, or on the exteriors of vehicles. During transport and storage, water sometimes collects in the crevices between superjacent aluminium surfaces and leads to superficial corrosion ("water staining").



The source of this water is rain or condensation that, through capillary action, is sucked in between the metal surfaces. Condensation can form when cold material is taken into warm

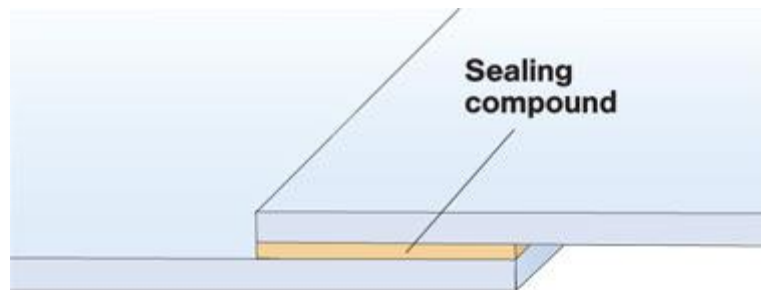
premises. The difference between night and day temperatures can also create condensation where aluminium is stored outdoors under tarpaulins that provide a tight seal.

EXOACM assembly practices include adhesive sealant providing a film barrier

Preventing crevice corrosion and aluminium corrosion resistance

Using sealing compounds or double-sided tapes before joining two components prevents water from penetrating into the gaps.

In some cases, rivets or screws can be replaced by, or combined with, adhesive bonding. This counteracts the formation of crevices.



EXOACM assembly practices include adhesive sealant providing a film barrier

Aluminium in the open air

The corrosion of metals in the open air depends on the so-called time of wetness and the composition of the surface electrolytes. The time of wetness refers to the period during which a metal's surface is sufficiently wet for corrosion to occur. The time of wetness is normally considered to be when relative humidity exceeds 80% and, at the same time, the temperature is above 0°C (e.g. when condensation forms).

In normal rural atmospheres, and in moderately sulphurous atmospheres, aluminum's durability is excellent. In highly sulphurous atmospheres, minor pitting may occur. However, generally speaking, the durability of aluminium is superior to that of carbon steel or galvanized steel.

The presence of salts (particularly chlorides) in the air reduces aluminum's durability, but less than is the case for most other construction materials. Maximum pit depth is generally only a fraction of the thickness of the material. Thus, in marked contrast to carbon steel, strength properties remain practically unchanged.

The picture below shows an untreated sample after 20 years off the south-west coast of Sweden. UV radiation, sulphuric acid and nitric acid in combination with chlorides have not left any deep marks. After 22 years in a marine atmosphere, examination of an untreated aluminium sample (alloy AA 6063) showed that corrosion attack was so limited (max. depth approx. 0.15 mm) that strength was not affected.



Aluminium in soil

Soil is not a uniform material. Mineral composition, moisture content, pH, presence of organic materials and electrical conductivity can all vary widely from site to site. These differences make it difficult to predict a metal's durability in soil. Furthermore, other factors (e.g. stray currents from DC voltage sources) can also affect durability.

Aluminium's corrosion properties in soil very much depend on the soil's moisture, resistivity and pH value. Unfortunately, present knowledge about the corrosiveness of different types of soils is not comprehensive.

When using aluminium in soil, some form of protective treatment, e.g. a bitumen coating, is recommended. Corrosion can also be prevented by cathodic protection.



Bitumen coating prevents corrosion

Aluminium in water



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A metal's corrosion in water is largely dependent on the composition of the water. For aluminium, it is the presence of chlorides and heavy metals that has the greatest effect on durability.

In natural fresh water and drinking water, aluminium may be subject to pitting. However, with regular drying and cleaning, the risk of harmful attack is small. Pots, pans and other household equipment can be used for decades without there being any pitting.

The likelihood of harmful attack increases where water is stagnant and the material is wet for long periods.

In sea water, AlMg alloys with over 2.5% Mg (and AlMgSi alloys) show particularly good durability.

Copper containing alloys should be avoided. Where they are used, they must be given effective corrosion protection.

Aluminium and alkaline building materials

Splashes of damp alkaline building materials, e.g. mortar and concrete, leave superficial but visible stains on aluminium surfaces. As these stains are difficult to remove, visible aluminium surfaces should be protected on, for example, building sites. Other materials also require the same sort of protection.

Aluminium cast into concrete is similarly attacked. This increases the adhesion between the materials. Once the concrete has set (dried), there is normally no corrosion. However, where moisture persists, corrosion may develop. The volume of the products generated by corrosion can give rise to cracks in the concrete.

This type of corrosion can be effectively prevented by coating the aluminium with bitumen or a paint that tolerates alkaline environments. As the oxide layer is not stable in strongly alkaline environments, anodizing does not improve durability here.

Provided that the concrete has set, aluminium does not need to be protected in dry, indoor atmospheres.

Aluminium and chemicals

Thanks to the protective properties of the natural oxide layer, aluminium shows good resistance to many chemicals. However, low or high pH values (less than 4 and more than 9) lead to the oxide layer dissolving and, consequently, rapid corrosion of the aluminium. Inorganic acids and strong alkaline solutions are thus very corrosive for aluminium.

Exceptions to the above are concentrated nitric acid and solutions of ammonia. These do not attack aluminium.

In moderately alkaline water solutions, corrosion can be hindered by using silicates as inhibitors. Such kinds of inhibitors are normally included in dishwasher detergents.

Most inorganic salts are not markedly corrosive for aluminium. Heavy metal salts form an exception here. These can give rise to serious galvanic corrosion due to the reduction of heavy metals (e.g. copper and mercury) on aluminium surfaces.

Aluminium has very good resistance to many organic compounds. Aluminium equipment is used in the production and storage of many chemicals.

Aluminium and dirt

Coatings or build-ups of dirt on the metal's surface can reduce durability to a certain extent. Very often, this is attributable to the surface now being exposed to moisture for considerable periods. Thus, depending on the degree of contamination, dirty surfaces should be cleaned once or twice a year.

Aluminium and fasteners

When choosing fasteners for use with aluminium, special attention should be paid to avoiding galvanic corrosion and crevice corrosion (above). Galvanic corrosion of aluminium occurs where there is metallic contact with a more noble metal. It should be pointed out that, indoors and in other dry atmospheres, aluminium can be in permanent contact with brass and carbon steel with no risk of galvanic corrosion.

The pictures below show the results of an accelerated corrosion test, the Volvo indoor Corrosion Test (VICT). The test cycle is 12 weeks and corresponds to five year's use of a car in a moderately large town.



Left – Zinc/iron-coated steel nut and bolt. The fastener is completely rusted. In the aluminium, 0.43 mm deep pits have formed.

Right – Dacrolit-coated steel nut and bolt. The fastener has not been attacked. No pits have formed in the aluminium.

At-a-glance guide for choosing fasteners

The table below lists some of the most common materials and coatings for fasteners used with aluminium. It also gives an evaluation of corrosion resistance in different environments.

Evaluations: +++ = very good; ++ = good; + = acceptable with moderate demands as regards lifetime (up to 10 years) and surface finish.



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Substrate material	Surface treatment	Atmospheres			Comments
		Marine	Industrial	Rural	
Carbon steel	Electroplated (Zn/Ni) approx. 7 – 10 µm+ yellow chromating.	++	+++	+++	Used in the automotive industry. Good protection against galvanic corrosion.
Carbon steel	Electroplated (Zn/Fe) approx. 7 – 10 µm+ yellow chromatin.	-	+	+++	Negative results on vehicles. The Zn layer disappears relatively quickly and galvanic corrosion then sets in.
Stainless steel, 18/8	Electroplated, approx. 7 – 10 µmZn + yellow or bright chromating.	++	+++	+++	Used primarily in the building industry. The Zn coating is principally to reduce friction (bolt threads).
Stainless steel, 18/8	Dacrolit Zn and Al flakes in an organic binder containing, amongst other things, chromate.	+++	+++	+++	Used primarily in the building industry. The Dacrolit coating is used to reduce friction (bolt threads) and the risk of galvanic corrosion.
Stainless steel, 2302	Electroplated (Zn/Fe) 7 – 10 µm + yellow or bright chromating.	+	+++	+++	Used primarily in the building industry.
Carbon steel	Dacrolit – Zn and Al flakes in an organic binder containing, amongst other things, chromate.	++	+++	+++	Used primarily on vehicles and, in some cases, buildings. Withstands 12 weeks VICT (Volvo Indoor Corrosion Test)
Carbon steel	Geomet – Zn and Al flakes in a matrix of Si, Zn and AL oxides. Chrome-free.	++	+++	+++	Very good corrosion resistance shown in tests in the automotive industry. Suppliers state that it withstands 1,000 hours in a neutral salt spray (ISO 9227).
Carbon steel	Polyseal – Zn phosphating approx. 3 µm + organic protection layer (seal)+ organic top coat.	-	++	+++	Used in the automotive industry, Good results in acetic acid and neutral salt spray (ISO 9227).
Aluminum rivet with electroplated steel mandrel.	No coating.	++	+++	+++	Used in the building industry.
Stainless steel(18/8) rivet with stainless steel mandrel.	No coating.	+	++	+++	Galvanic corrosion in marine atmospheres.



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Corrosion checklist

The summary below is intended to give a picture, from the perspective of durability, of aluminium as a construction material. Used correctly, aluminium has a very long life.

Environments	
Rural atmosphere	Aluminium has excellent durability.
Moderately sulphurous atmosphere	Aluminium has excellent durability.
Highly sulphurous and marine atmosphere	Superficial pitting can occur. Nonetheless, durability is generally superior to that of carbon steel and galvanized steel.
Corrosion problems can be overcome	
Profile design	The design should promote drying, e.g. good drainage. Avoid having unprotected aluminium in protracted contact with stagnant water. Avoid pockets where dirt can collect and keep the material wet for protracted periods.
pH values	Low (under 4) and high (over 9) values should, in principle, be avoided.
Galvanic corrosion	In severe environments, especially those with a high chloride content, attention must be paid to the risk of galvanic corrosion. Some form of insulation between aluminium and more noble metals (e.g. carbon steel, stainless steel, copper) is recommended.
Closed system (liquid)	In closed, liquid containing systems, inhibitors can often be used to provide corrosion protection.
Severe, wet environments	In difficult, wet environments, the use of cathodic protection should be considered.

EXOACM – Structural Material

The 6000 series, which has silicon and magnesium as the alloying elements, is by far the most widely used in extrusion.

Pure aluminium is relatively soft. To overcome this, the metal can be alloyed and/or cold worked. Most of the aluminium reaching the marketplace has been alloyed with at least one other element.

There is a long-established international system for identifying aluminium alloys (see the table below). The first digit in the four-digit alloy code identifies the major alloying element.

The European standard uses the same codes.

The table below gives the broad outline of the systems.

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EXOACM uses 6061-T6

Alloying element	Alloy code	Alloy type
None (pure aluminium)	1000 series	Not hardenable
Copper	2000 series	Hardenable
Manganese	3000 series	Not hardenable
Silicon	4000 series	Not hardenable
Magnesium	5000 series	Not hardenable
Magnesium + silicon	6000 series	Hardenable
Zinc	7000 series	Hardenable
Other	8000 series	

