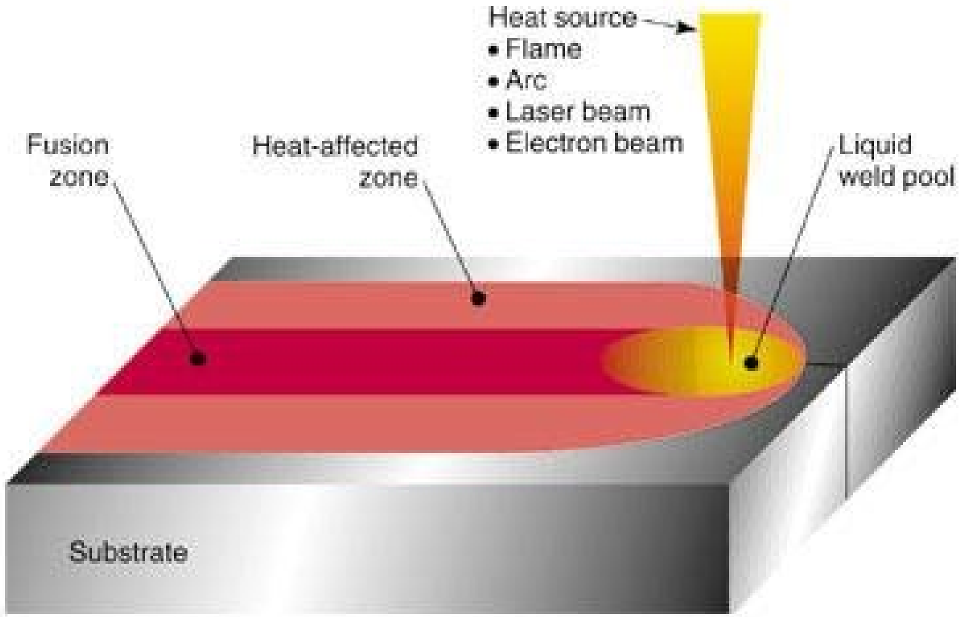
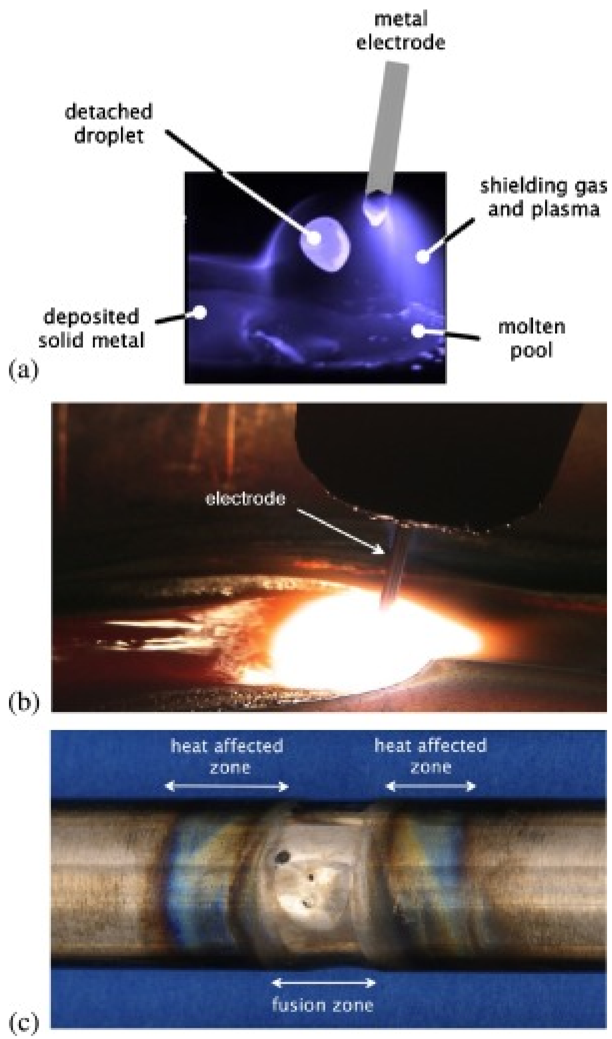
Module 6

Fundamentals of welding

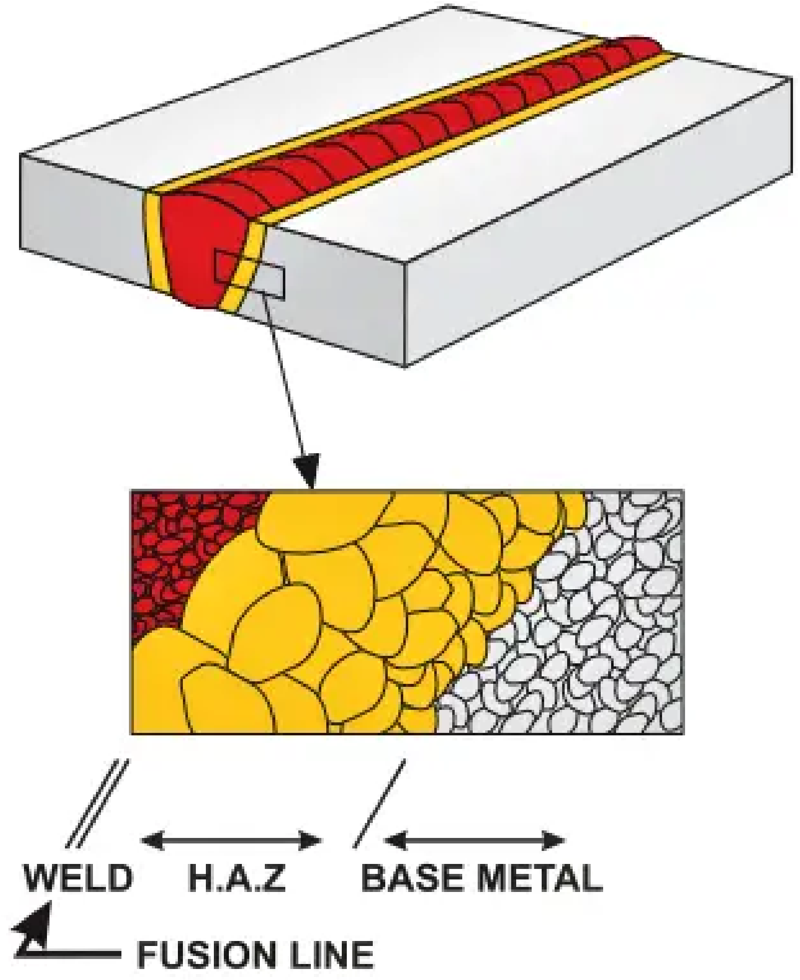
Weld metal



Heat source
• Flame
• Arc
• Laser beam
• Electron beam
Fusion zone
Heat-affected zone
Liquid weld pool
Substrate

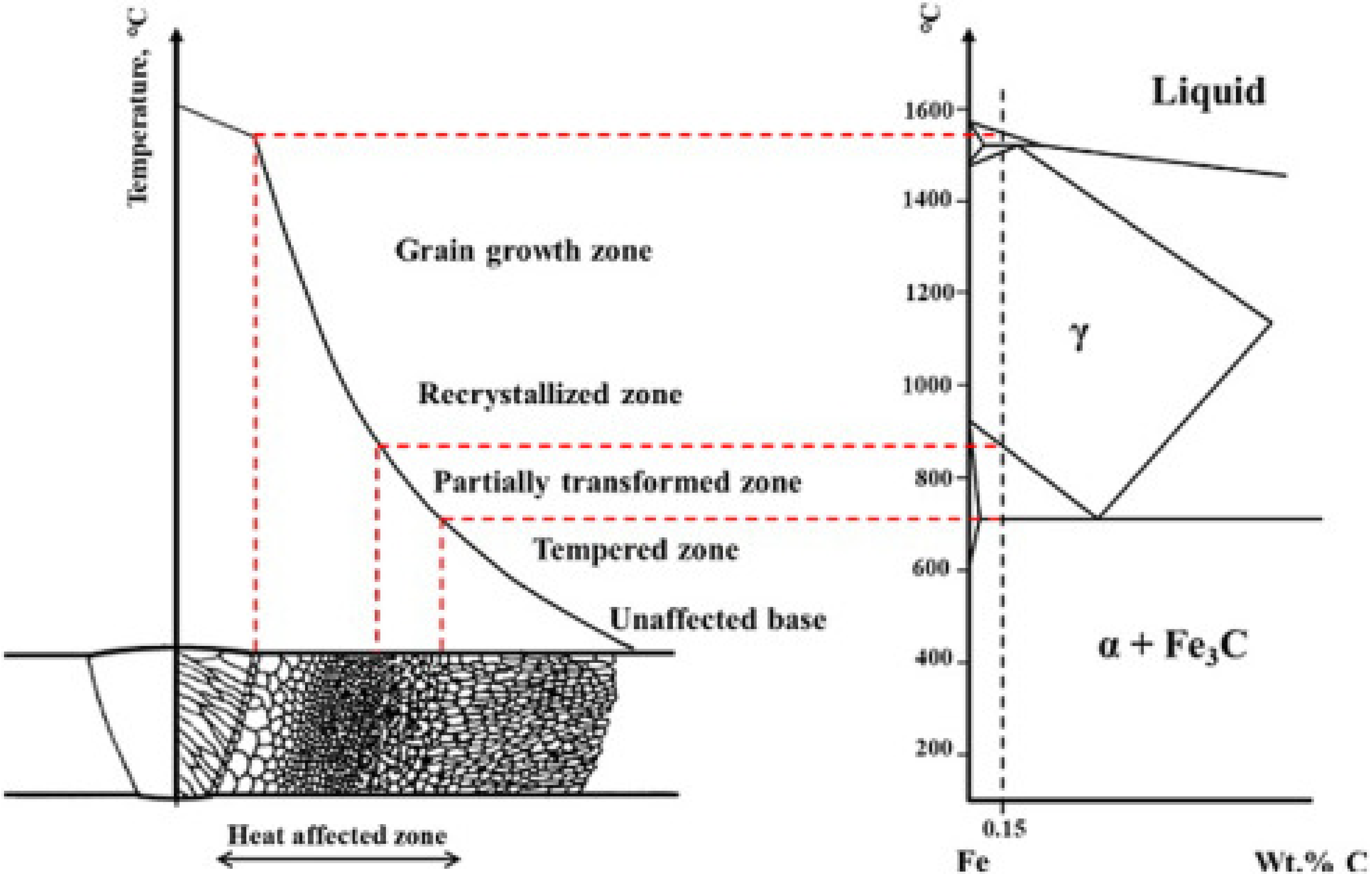


metal electrode
detached droplet
shielding gas and plasma
deposited solid metal
molten pool
(a)
electrode
(b)
heat affected zone
heat affected zone
fusion zone
(c)

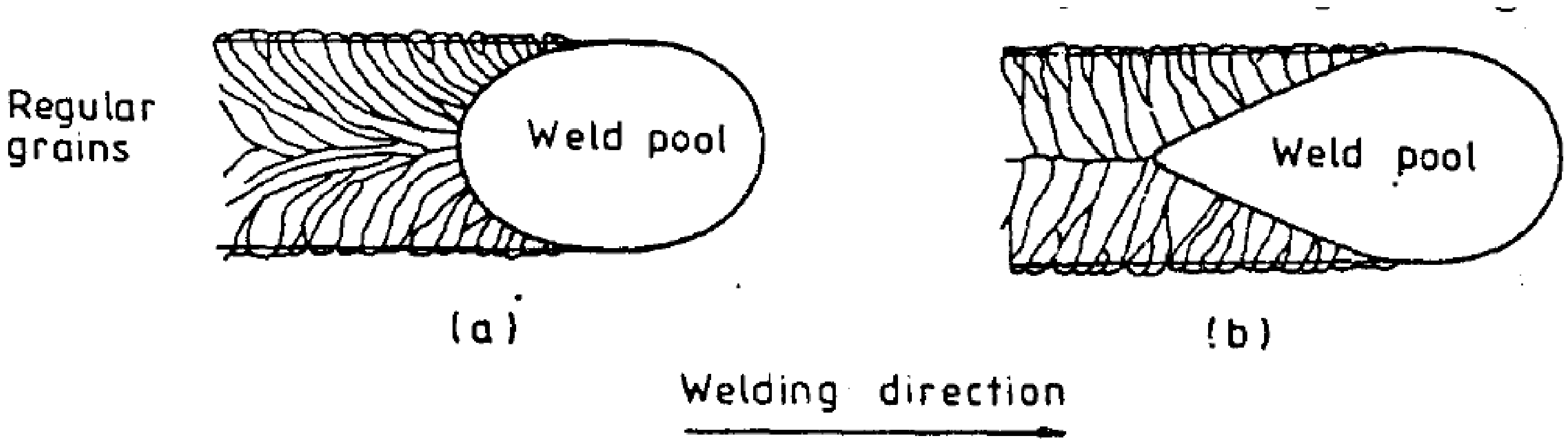


WELD
H.A.Z
BASE METAL
FUSION LINE

Epitaxial growth



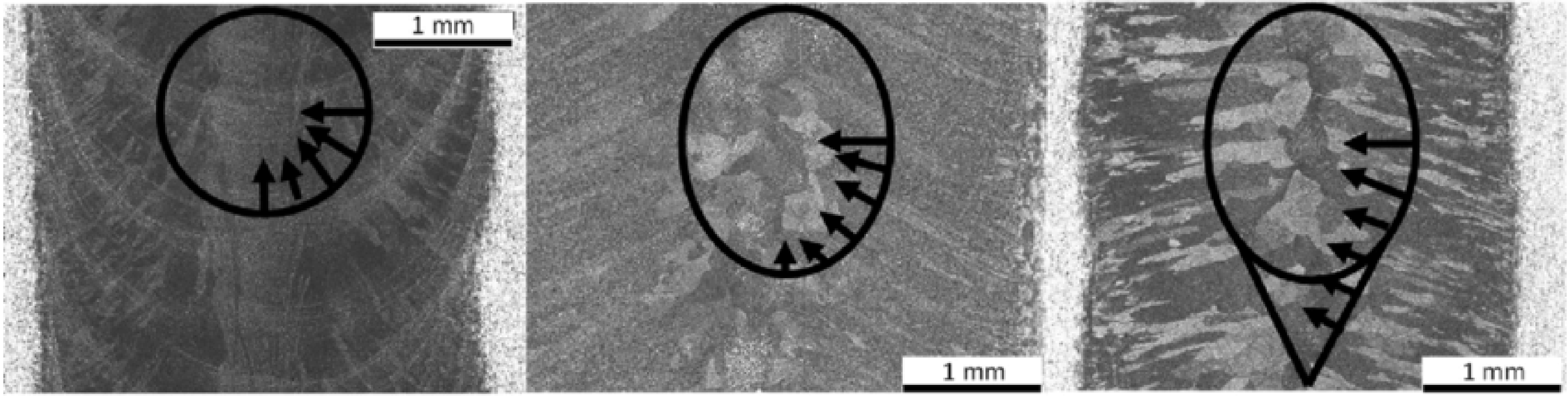
Temperature, °C
Grain growth zone
Recrystallized zone
Partially transformed zone
Tempered zone
Unaffected base
Heat affected zone
°C
1600
1400
1200
1000
800
600
400
200
Liquid
γ
α + Fe3C
0.15
Fe
Wt.% C



Low speed

High speed

Effect of Welding speed on microstructure of steel



(a) (b) (c)

Weldability of Steel

Steel is one of the most common materials in the world. It is widely used for its high tensile strength and unparalleled versatility. Used in everything from structural construction to detailed aesthetic designs, steel comes in a vast range of grades. Each grade has specific strengths and is optimized to a certain type of project.

The weldability of steel grades depends mostly on how hard it is. In turn, this depends on the material's chemical composition, specifically its carbon content. Other alloying elements that have a lesser effect on the hardness of steel include manganese, molybdenum, chromium, vanadium, nickel, and silicon. Therefore, to successfully weld this versatile material, it is important to first familiarize yourself with the distinct types of steels and their properties.

Carbon Steel

The ease of welding carbon steel largely depends on the amount of carbon present. As the carbon content increases, the weldability tends to decrease. This is because the increase in hardness makes the steel more prone to cracking. However, most carbon steels are still weldable.

Low Carbon Steel (Mild Steel)

These steels typically contain less than 0.3% carbon content and up to 0.4% manganese. Low carbon steels with 0.15-0.3% carbon and up to 0.9% manganese possess good weldability. Those with less than 0.2% carbon are ideal.

If the impurities are kept low, these metals rarely present problems during the welding process. Steels with carbon over 0.25% are prone to cracking in certain applications. Conversely, steels with less than 0.12% carbon can be susceptible to porosity. All low carbon steel can be welded using any of the common welding processes. But the steels with more carbon content are best welded with a low-hydrogen process or with low-hydrogen fillers.

Medium Carbon Steel

Medium carbon steels contain 0.30-0.60% carbon and 0.60-1.65% manganese. They are stronger than low carbon steel but are more difficult to weld. This is because they are more prone to cracking. Medium carbon steels should always be welded using a low-hydrogen welding process or controlled hydrogen fillers.

High Carbon Steel (Carbon Tool Steel)

High carbon steels contain 0.60-1.0% carbon and 0.30-0.90% manganese. They are extremely hard and strong, but also have poor weldability and are difficult to weld without cracking. Once heat treated, these are extremely hard and brittle. If welded, high carbon steels require preheating, careful interpass temperature control, and post weld stress relief.

Weldability of Stainless Steel

Stainless Steels are high alloy steels containing a minimum of 10.5% chromium. Also, they are usually alloyed with other elements to improve heat resistance, mechanical properties, and fabricating characteristics. These alloying elements also modify and influence the weldability of stainless steel.

To successfully weld stainless, it is important to know the diverse types of stainless and their properties. They are divided into ferritic, martensitic, and austenitic.

Austenitic

This class of stainless steel is highly corrosion-resistant, strong, and highly formable. But it is also prone to stress cracking. These are considered the most easily weldable stainless steel. There is no need for pre- or post-weld heat treatment.

Ferritic

All ferritic alloys have lower ductility, are more brittle, prone to hot cracking, and possess lower corrosion resistance than the austenitic grades. But they offer higher resistance to stress corrosion cracking. This type is generally considered to have poor weldability because at high temperatures it undergoes rapid grain growth. This leads to brittle, heat affected zones.

Martensitic

These alloys have higher strength, wear resistance and fatigue resistance than the austenitic and ferritic grades. But they are less corrosion resistant. This grade becomes hard and brittle upon cooling, making it a great material for wear resistance but more difficult to weld as it tends to weld crack on cooling.

Weldability of Aluminium and its alloys

Aluminum and its alloys are extremely popular for a wide range of applications. Nevertheless, there is a common misconception that aluminum cannot be effectively joined through normal welding processes the way steel alloys can. Many people think they have no choice but to join aluminum pieces with mechanical fasteners, like rivets — but the truth is more complex. There are some nuances when it comes to welding aluminum.

Its weldability varies between different alloy series. It can range from “very good” to “unweldable by common arc welding methods.” That said, most aluminum alloys can be welded under the right conditions and by taking proper precautions.

Due to its physical and chemical properties, the techniques for welding aluminum are different from other metals. As such, only professionals who are specifically trained for aluminum welding should perform this practice.

Two properties, in particular, make welding aluminum tricky.

1. The oxide layer on its surface
2. Aluminum’s thermal conductivity

Oxide Layer
One of the precautions welders need to take with aluminum is to prepare, or clean, the surface they are going to weld. Aluminum naturally forms a layer of oxide on its surface, which causes issues.
This oxide layer is corrosion-resistant — a desirable feature most of the time — but the material is hard. It has a melting point **nearly three times that of aluminum**. So if the aluminum oxide is not thoroughly removed, it can create impurities in the joint, leading to porosity and fractures.

Thermal Conductivity
Another thing to keep in mind is that aluminum has a much higher thermal conductivity than steel. And although its melting point is lower than steel’s, you need to apply more heat energy to the weld.
One way to help combat this high thermal conductivity in some joints is to preheat the aluminum. Experienced welders do this to prevent burn-through on thinner aluminum portions and, for thicker materials, to ensure sufficient weld penetration.

The two most common welding methods for aluminum are Metal Inert Gas (MIG) welding and Tungsten Inert Gas (TIG) welding.