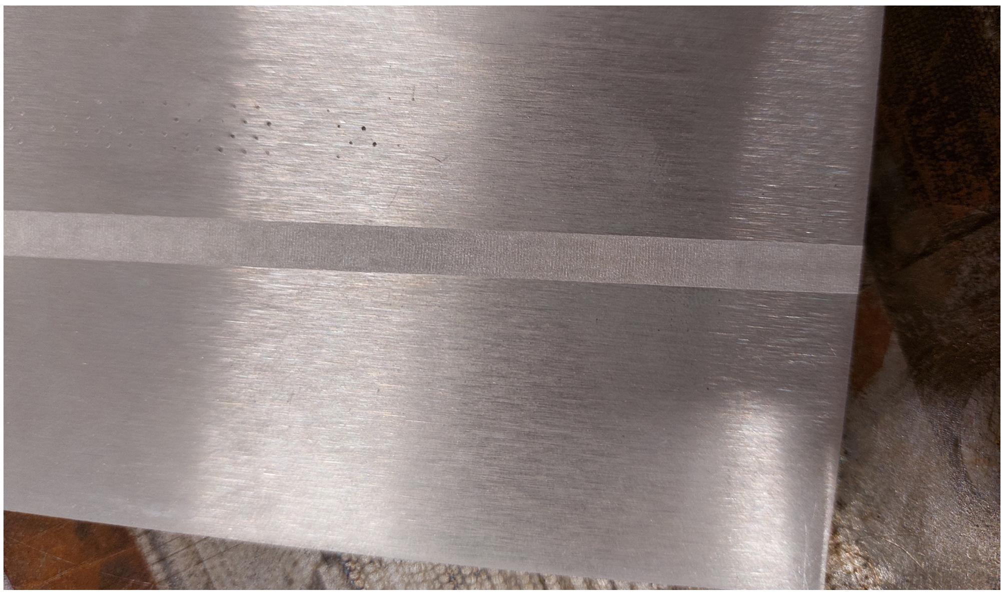
Laser cleaning of Aluminium surfaces prior to welding and post laser cleaning process.

In today's industry, aluminum (Al) is one of the most widely used non-ferrous materials after steel and stainless steel.



About aluminum welding: Metal inert gas welding (MIG), tungsten inert gas welding (TIG) and laser welding (LW) are the most commonly used methods for welding aluminum materials.

The success of aluminum welding is determined by the resistance of the weld metal to the cracks, especially solidification cracks, and the porosity in the weld. If these are not observed in a certain group of aluminum welds, we can consider the weldability acceptable. On the other hand, the weldability is influenced by the welding process, the effect on the aluminum base material and the surface conditions, chemical composition and mechanical properties before welding, welding parameters, shielding gas, and filler wire.

If the aluminum oxide on the surface is not cleaned, it will act as cores for gas pores during welding. The oxides on the surface also contain dust, lubricant, and hydrogen (H_2) from surface oxide film, lubricant on the aluminum welding wire, and the purity level of the shielding gas. Argon or Helium is never 100% pure and may contain other unwanted gases and contaminants. Low temperature (eutectic) melting elements in the aluminum such as Mg, Zn, Mn, Si, etc. during welding can form gas porosities. These low-temperature fusing elements (Mg, Zn, Mn, Si, ...) cause hot cracks in the welds, which are typical disadvantages of aluminum welds.

About aluminum:
The main properties of aluminum are summarized as follows: low melting point 660°C, high oxide layer (Al_2O_3) melting temperature 2300°C. High coefficient of thermal expansion (2x higher than steel), high thermal conductivity, high oxidation potential, high cold workability, large freezing range.

Studies have shown that the common oxide on the aluminum surface is amorphous Al_2O_3. The thickness of the oxide layer is 1-2 microns on top of the Al substrate. This layer protects the aluminum surface from further corrosion and is very essential.

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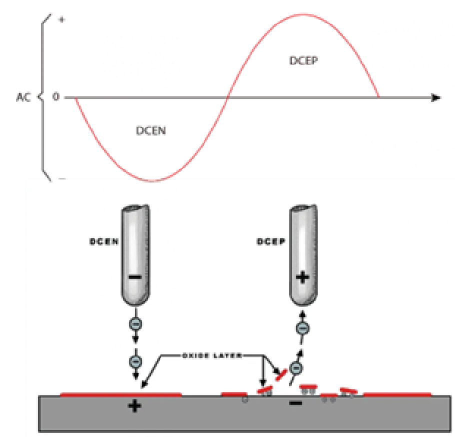
Why is surface cleaning of Aluminium essential? Aluminium oxide density is higher than steel oxide therefore if it is not cleaned during and/or prior to welding, the aluminium oxide will sink into the molten metal and will form oxide inclusions with weld porosities and cracks as a result.

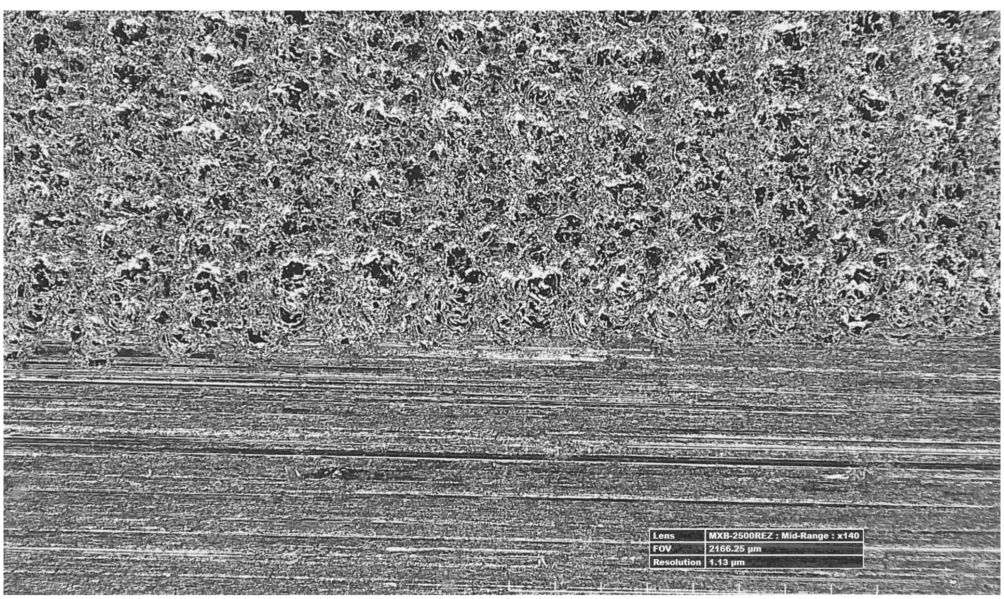
Why is surface cleaning of aluminium welds needed? After MIG welding, aluminium mostly gets a dark colouring on the welds. This arises mainly from MIG welding fume originating from welding wire (95%) and base materials (5%). For some applications such as the cleaning of aluminium battery trays, fuel tanks or air tank welds, the visual and esthetic aspects of the welds are very important and they should look clean and free of weld smokes and tints. With aluminium, the most popular cleaning methods are chemical cleaning, brushing, and grinding/milling. Laser cleaning is not well-known yet and the investment in a new method is still seen as unaffordable compared to conventional cleaning methods for most industries.

Laser cleaning is a state-of-the-art cleaning process, and can be fully automated. It is not yet widely accepted by many industries. Laser cleaning has emerged as a potential non-contact, nonchemical solution for the surface preparation of aluminium alloys. It is an ecological and dry process without chemicals. The thermal oxidation principle of aluminium alloys after laser cleaning is demonstrated in a recent study by Wei Wang at all (source: laser Optics & Laser Technology Volume 148, April 2022, 107742).



Conventional cleaning methods

Method 1: Using AC TIG or MIG welding convertors: The best way to avoid the cleaning of the oxide layer is to use an AC TIG welding power source for aluminium welding, as illustrated below.
Method 2: Brushing: The oxide layer can be removed by grinding or using stainless steel wire brushes before welding.
Method 3: Chemical cleaning, namely alkaline or acid picking, is used to remove oxide layers prior to welding and used after welding to pickle Al welds to stimulate corrosion resistance.
Method 4: Fabric cleaning before and or after welding. The surface can be gently cleaned with a special fabric that can remove (to some extent) surface contaminants.



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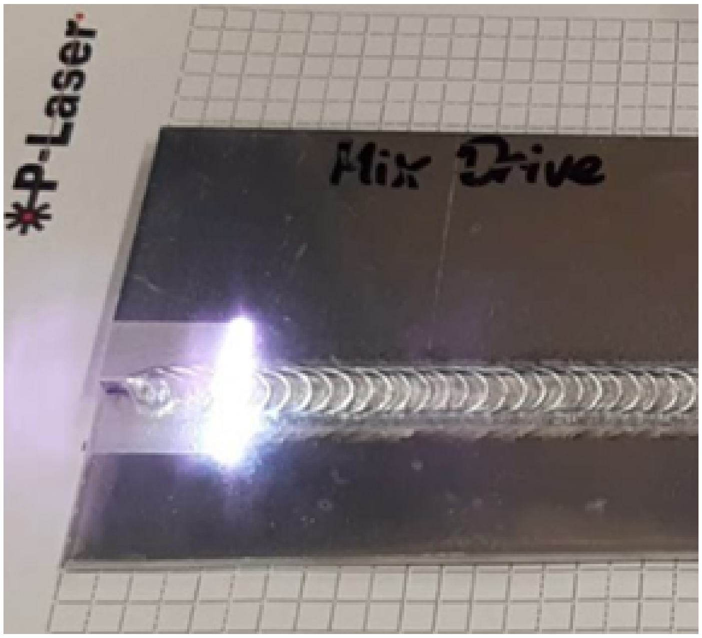
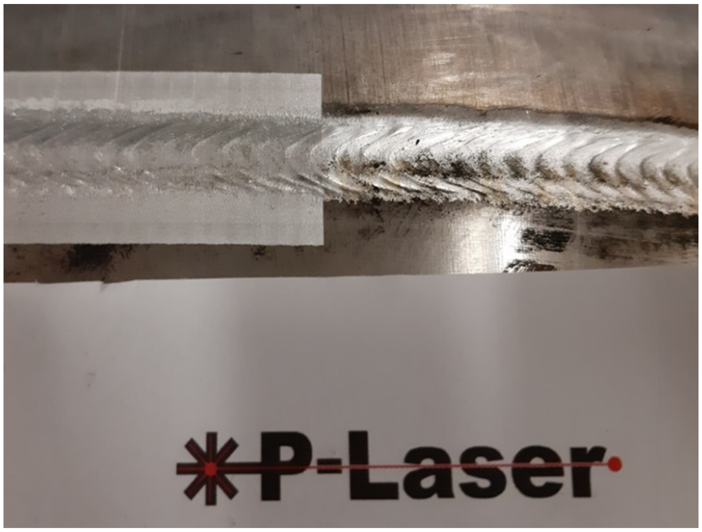
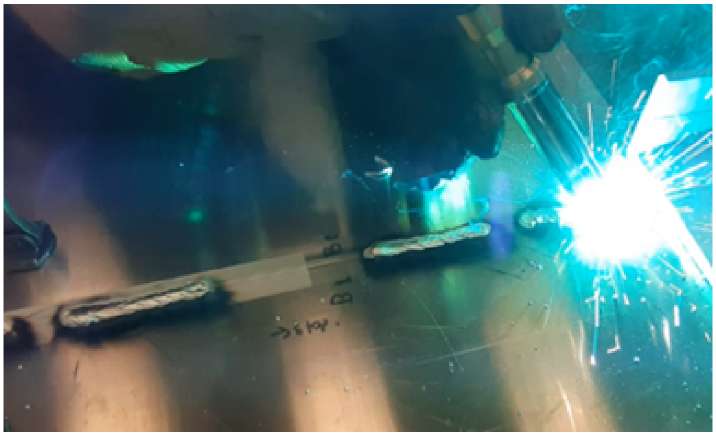
Case studies by P-Laser

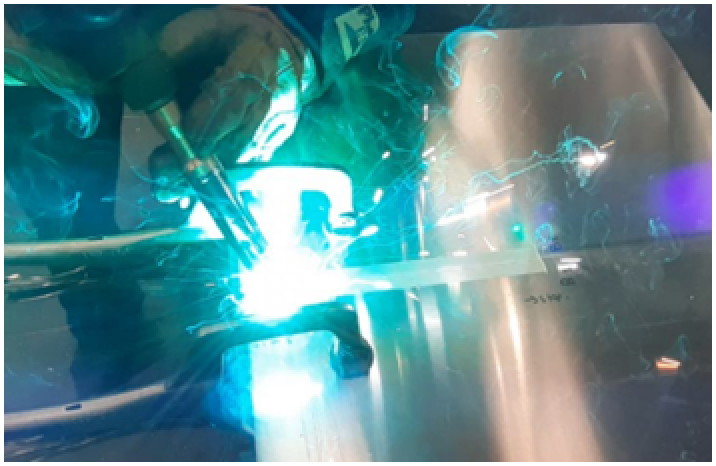
The 2 pictures below show laser cleaning results after MIG welding. We used a QF-100W: Cleaning travel speed of 2 m/min. with a focal distance of 300 mm, mounted on an ABB robot.







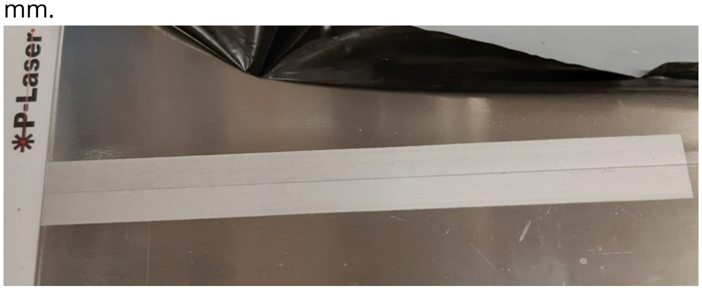
The photos above and below show MIG welding on the laser-prepared aluminum at 5083°C. Different welding setups are used using ESAB MIG welding converters. Argon gas is used as shielding. Excessive welding spatter and welding fumes are observed on the surface if the surface has not been previously cleaned with the laser. Less smoke and spatter are observed on the laser-prepared Al surface during MIG welding.



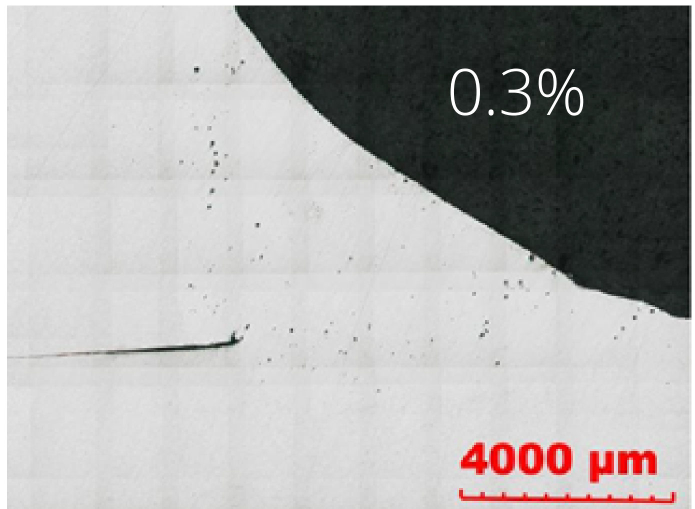
Laser cleaning of Aluminium surfaces prior to welding and post laser cleaning process.

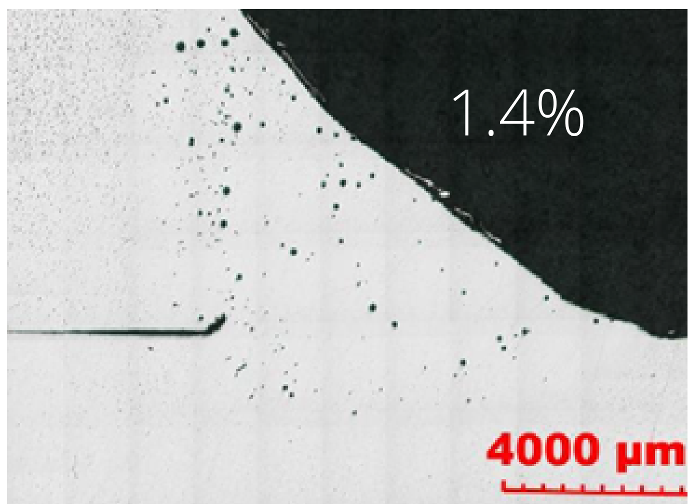
Case studies by P-Laser

In the pictures above and below you can see the results of laser cleaning prior to welding. We used a QF-100 mounted on an ABB robot. Successful cleaning of Al oxide is shown at a cleaning travel speed of 2 m/min. with a focal distance of 300 mm.



These aluminum weld micrographs below illustrate cross-sections of the MIG welds of laser-cleaned and non-cleaned aluminum prior to welding.
A_ Weld cross section laser cleaning applied before MIG welding. 0.3% welding porosity in the welds.
B_ Weld cross section without laser cleaning for MIG welding: 1.4 % welding porosity in the welds.





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Conclusions

Recently, laser cleaning has emerged as a non-contact, non-chemical solution for the surface preparation of aluminum alloys. Laser cleaning of aluminum is a sustainable and dry process without intermediates. The success of laser cleaning before and after aluminum welding is demonstrated at P-Laser using the QC-100 mounted on an ABB robot with a driving speed of 2 meters/min.

We recommend that laser cleaning of the aluminum surfaces requires the use of a soft lens setting and a focal length of 500mm. The processing speed can be adjusted depending on the energy output and can vary from 4 to 12 cm 2 /sec. Due to the reflection from the Al surface, the optical head must be tilted against the reflection at the back.

Laser cleaning shows a promising effect on oxide removal for MIG welding. After laser cleaning, a drastic reduction of the weld porosity in the weld was observed.

Although the investment in the laser cleaning machine (from €45,000) is high, the operating costs are very low, with only 3KW power for a 100-watt laser. In terms of ecology, laser cleaning also beats other techniques. No chemicals are needed, no waste is created, the vapor that is released during cleaning is extracted directly and the CO_2 production is considerably lower than with other cleaning techniques such as dry ice blasting.

Contact us at P-Laser for more information.