REPAIR OF ALUMINUM ALLOYS BY OVERLAY WELDING

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https://doi.org/10.47833/2026.1.ENG.002

Keywords:
aluminium alloy, TIG welding, overlay welding

Article history:
Received 10 November 2025
Revised 2 February 2026
Accepted 4 February 2026

Abstract

Nowadays, aluminum alloys play a dominant role in the automotive industry due to their many favorable properties. A disadvantage of these components is that high-strength metal screw connections cause corrosive chemical processes, which can lead to damage and destruction of the aluminum casting during assembly. If it is not possible to replace the component, for example in the case of high-value vintage vehicles, then it is necessary to manufacture a new component or develop some kind of repair technology. In the case of manufacturing a new component, it is necessary to model the old damaged component and then manufacture it in a machine shop using some kind of cutting process, which is a very expensive method. This article presents the repair of an A360 aluminum alloy generator bracket using argon tungsten arc welding followed by fabrication technology post-processing, which is a cost-effective way to repair such components.

1 Introduction

Tungsten Inert Gas (TIG) welding, similar to MIG/MAG, was developed in the 1940s at the beginning of the Second World War. It was created to facilitate the welding of materials that are difficult to work with, such as aluminum and magnesium. Today, the use of TIG welding has expanded to a wide range of metals, including stainless steel, structural steel, and high-tensile steel. TIG welding, known in Hungary as AWI welding, is a widely used arc welding process that employs a non-consumable tungsten electrode and an inert shielding gas, typically argon, to produce high-quality and precise welds. TIG welding has become essential in industries requiring strong, clean, and aesthetically refined joints, such as aerospace, chemical processing, nuclear energy, and high-end fabrication. [1] Aluminium alloys are alloys in which aluminium is the predominant metal. The typical alloying elements copper, magnesium, silicon, tin and zinc. Aluminium and aluminium alloys plays an important role in engineering and metallurgy field because of fabrication and formability. [2] In TIG welding process the heat is generated by an electric arc formed between the tungsten electrode and the workpiece. A shielding gas, usually argon or helium, is used to protect the weld area from atmospheric contamination, preventing oxidation and ensuring a clean, high-quality weld. For TIG welding of aluminum, AC (Alternating Current) is typically used. During welding, the electrode-positive portion of the AC cycle helps remove the oxide layer (“cleaning action”), while the electrode-negative portion provides deeper penetration. Pure argon shielding gas is commonly used to protect the molten weld pool from contamination. A pure tungsten or zirconiated tungsten electrode is often recommended for AC welding, as

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these electrodes maintain stability and resist degradation. Filler rods such as ER4043 or ER5356 are selected based on material composition and desired weld characteristics. [3-4] The TIG welding process is shown in Figure 1.

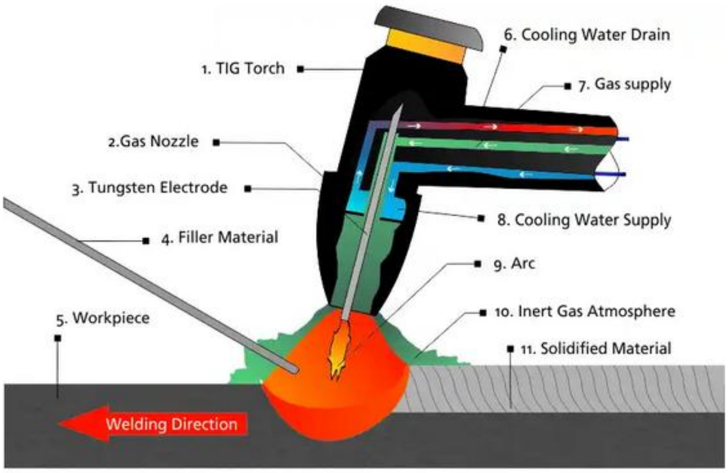

Figure 1. TIG welding process

A360 aluminum is a popular die-casting alloy owing to its high corrosion resistance and excellent strength at elevated temperatures. The composition of the alloying elements is given in Table 1.

Table 1. Alloying elements of A360 aluminum

Element	
Copper (Cu)	$\leq 0.6\%$
Iron (Fe)	$\leq 1.3\%$
Magnesium (Mg)	$0.4 - 0.6\%$
Manganese (Mn)	≤ 0.35
Nickel (Ni)	$\leq 0.5\%$
Silicon (Si)	$9.0 - 10.0\%$
Tin (Sn)	$\leq 0.15\%$
Zinc (Zn)	$\leq 0.5\%$

The main alloying element is silicon (9.0-10.0%), which enhances the alloy's fluidity, allowing it to flow easily into complex molds during the die-casting process. A360's higher silicon content also contributes to its corrosion resistance. Copper is restricted in A360, which further enhances corrosion resistance. It also reduces hardness and tensile strength, so magnesium is used as a controlled addition to make up for this. [5-7] The mechanical and physical properties of A360 aluminium alloy are listed in Table 2.

Table 2. Mechanical and physical properties of A360 aluminum

Hardness, Brinell	75
Tensile strength, Ultimate (MPa)	317
Tensile strength, Yield (MPa)	165
Elongation % in 2in (51 mm)	3.5
Thermal Conductivity (W/m°K)	113
Electrical Conductivity %IACS	21

2 Generator bracket repair technology using filler welding

2.1 Overlay TIG welding process

The part presented in the publication is a generator bracket, which belongs to a high-value veteran Mercedes W116 V8 engine. The repair technology was necessary because during disassembly for renovation, the steel alloy screw broke into the bracket due to the corrosion process that had developed over the years. Drilling out the screw caused damage to the bracket. The damaged console is shown in Figure 2.

Figure 2. Damaged part

. The component must be prepared for the renovation process, which involves first taking the external dimensions, measuring the position of the holes, cleaning them from the surface oxide layer, and finally cutting out the holes in the centerline. The preparation phases are shown in Figure 3.

Figure 3. Phases of preparation (cutting)

After cutting and cleaning the oxide layer, it is necessary to set the welding parameters. When welding aluminum castings, preheating is required, typically to 150-250°C, in this case preheating was done to 200°C, to prevent cracks and improve the quality of the melt. Preheating evens out temperature differences and reduces thermal shock. The welding was done manually with a

Migatronic Pi 200 TIG AC/DC welding inverter. The set parameters were: 180A AC pulse in four steps with WP type electrode with Argon shielding gas. The welding was done in layers with a rest period between each layer. The filling size had to be chosen with an allowance of +3-4 mm for the external dimensions of the part, so that the surface could be reworked later by machining. The welded surface is shown in Figure 4.

Figure 4. Surface elements filled with TIG welding

2.2 Post-processing with machining

After the welding process, excess material is formed on the surface of the part, and geometric distortions may also occur due to heat input. The primary goal of machining is to remove these welding allowances and restore the original geometric and functional characteristics of the generator bracket.

During the operations, the dimensional accuracy of the part, the flatness of the mating surfaces and the positional accuracy of the holes must be ensured so that the bracket fits properly again to the engine block and safely transmits structural loads.

Due to the high silicon content of A360 aluminum, it has an abrasive effect, which causes significant tool wear, especially when using high-speed steel or traditional carbide tools. [8] The most effective solution is to use PCD (polycrystalline diamond) tools, which provide longer tool life and better surface quality. During turning, heat generation is significant, so adequate cooling is of paramount importance, while in milling, tool geometry and rigid fixation play a critical role. In the case of remelted A360, the cutting forces are lower and the surface quality is better than in the case of primary alloys. By applying intensive cooling and precise machining parameters, the alloy can be made excellently suitable for the subsequent repair of automotive components. [9]

A TOS FN20 vertical milling machine was used for machining. The part was fixed directly to the table of the machining machine, thanks to the flat bottom surface of the workpiece and the holes on it. Clamping in a vice was not possible, since the part has a thin wall thickness and can easily crack under the action of the clamping.

An important step before starting the production is to establish the sequence of operations. Several functional surfaces and holes had to be made on the part. The sequence of operations is as follows:

1. Creating base surfaces

2. Center drilling
3. Creating thread holes
4. Expanding holes
5. Tapping

The first step in machining is to create base surfaces on the component. The tool used to machine the base surfaces was a 125X4 HSS disc mill with a tooth count of Z100. The surfaces created in this way were already perpendicular to the spindle axis of rotation, so the next operation could follow, which was drilling.

Before making the thread core hole, center drilling must be performed to guide the tool. HSS tools with a Titanium Nitride (TiN) coating were used for drilling. After making the core hole, the upper hole was expanded. After making the holes, tapping was the next operation. The surfaces of the workpiece after machining are shown in Figure 5.

Figure 5. The machined surfaces

Careful preparation, precise clamping and a step-by-step machining strategy allowed for warp compensation and required tolerances to be maintained. As a result, the repaired part was restored to factory geometric and functional requirements, demonstrating that machining combined with welding is a cost-effective and efficient alternative for the remanufacturing of cast aluminum automotive parts.

During the machining process, surface roughness was not considered a primary quality criterion, as the functional role of the surface was secondary compared to the dimensional accuracy required for proper assembly. The most critical geometric feature after the repair was the distance between the two mounting lugs of the bracket, which is essential for ensuring correct installation and fit. This dimension was produced using a side-milling cutter, and the required dimensional accuracy was maintained with the aid of the digital readout system integrated into the milling machine.

3 Discussion

The study presented the repair of an A360 aluminum generator bracket using TIG welding and finishing by machining. Such parts are no longer available, so it is important that they can be replaced or repaired economically. The cost of remanufacturing the part is almost ten times that of the presented technology, since in this case the entire part would have to be modeled and machined from a block of aluminum on a computer-controlled milling machine. In addition to the costs, the repair time is also a fraction of this technology, making it a good alternative for the automotive repair industry.

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