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Study of the use of FSE solid state recycled wires for fusion welding and WAAM process

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Abstract

This study explores the use of wires recycled by FSE using aluminium machining chips as filler metals for gas tungsten arc welding (GTAW). It evaluates the impact of cleaning the machining chips before the FSE process. The results show that cleaning the chips improves wire uniformity and decreases the porosity. This study confirms the potential of using FSE-recycled aluminium wires while emphasizing the importance of chip cleaning and the need to further optimize the process to reduce the porosity of the weld.

Keywords: Welding, GTAW; Friction Stir Extrusion; chip recycling; Circular economy

1. Introduction

The growing need to reduce the environmental impact in engineering extends beyond fuel and energy use to include material waste and sustainable manufacturing. This creates both a challenge and an opportunity for the manufacturing sector to address waste and minimize the environmental impact of production.
To reduce the environmental impact innovative process like Friction Stir Extrusion (FSE) of light alloys, such as aluminium, could be introduced. This process uses recycled material as input and could dramatically reduce both waste and energy consumption [1], [2]. The energy consumption is reduced since it allows the production of new wire without melting that input material, that could also be machining chips, thus reducing material waste and saving up to 74% of energy [1]. Basically, FSE uses heat from friction to soften the aluminium chips, which are then extruded into rods, wires, and profiles. Recycling aluminium through FSE can create continuous wires that can be used as filler material in welding, offering an innovative way to reuse machining waste.
However, using FSE aluminium wires for welding produced from chips is challenging due to the susceptibility to porosity of aluminium. Porosity is a common defect in welding and additive manufacturing that impacts on mechanical properties like ductility, corrosion resistance, and conductivity. Aluminium alloys are particularly prone to porosity because hydrogen is highly soluble in molten aluminium but not in its solid form [3]. Thus, hydrogen often remains trapped in the weld after solidification. Thus, it is essential to investigate ways to reduce the porosity when using these wires for deposition, as reported in the literature [4].
Therefore, the present work addresses the use of FSE-recycled wires in welding, analysing the effect of a cleaning treatment for the machined chips before the FSE process. Then, a comparison between the results obtained using wires manufactured with cleaned and non-cleaned chips were compared.

2. Methods, Results and Conclusions

The welding process used is the GTAW process with AC. The FSE wires filler metals were produced by the University of Palermo, following the manufacturing process described by Buffa et al. [5] with 500 RPM and 18 kN force, using AA6082 chips, starting from the chips created by a milling process. Two types of wires were produced by FSE: one using chips directly from the machining without any treatment, and the second applying a cleaning consisting of dipping the chips in acetone to remove grease and other contaminants. The internal porosity of the walls was analysed by high-resolution 3D microtomography, collecting µm-CT data using a Skyscan 1172 high-resolution micro–CT.
Figure 1 shows the two depositions using the wires produced with non-cleaned and cleaned machining chips. Using non-cleaned chips for the FSE wire production resulted in a very irregular and porous bead. Using the wires with cleaned chips, there is a significant improvement in uniformity, external porosity, and overall quality.

Figure 2 shows 3D microtomography of the depositions, where the white portion represents the metal (the aluminum alloy) and the red portion represents the voids within the bead. Both depositions presented significant porosity, but the beads using wires manufactured with non-cleaned chips presented larger pores and in much more quantity. Furthermore, many of them reached the surface. The results show that cleaning the machining chips before manufacturing the wires using FSE is essential for obtaining a better wire.

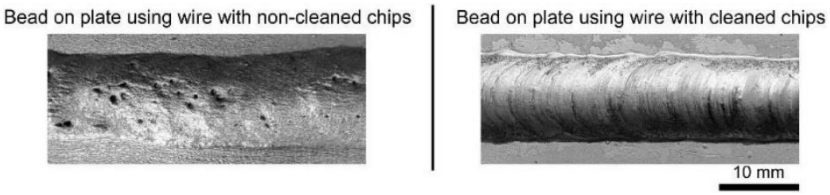

Figure 1 – Comparison between bead welded with wire produced without chip cleaning and wire produced with chip cleaning before the FSE process.

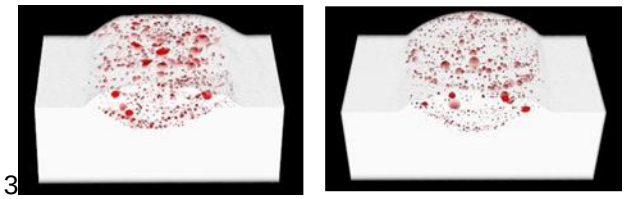

Figure 2 – Comparison between bead welded with wire produced without chip cleaning and wire produced with chip cleaning before the FSE process.

This study tested using FSE recycled wires as a filler metal for welding. The following conclusions were drawn:

- The wires produced by FSE can be used for welding deposition.
- It is essential to clean the chips before the FSE of the wires to decrease impurities and hydrogen sources.
- Porosity was significant using both wires, but wires with cleaned chips presented much better results.

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