WAAM of Duplex Stainless Steels

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WAAM (Wire and Arc Additive Manufacturing) is becoming an increasingly popular method to produce components from metals which are usually not so suitable for conventional production methods. One of the good examples is duplex stainless steels (DSS), which are quite complex for welding and machining. Excessive ferrite amount is a common problem for them and controlling an interlayer temperature could offer a solution. However, using too low interlayer temperature will slow down the whole process and compromise one of the WAAM's main advantages - the high productivity. Aim of this study is to find the relationship between interlayer temperature and process duration and to determine the influence of the interlayer temperature on product structure and other properties. Three samples (walls) were made using different interlayer temperatures (50 °C, 100 °C and 150 °C) and they were tested to analyze their surface texture, chemical composition, ferrite amount, the appearance of porosity and the hardness. Ferrite amount was higher and there was more porosity on lower interlayer temperatures, while there is no significant difference between surface texture and chemical composition for the samples. Considering the fact that higher interlayer temperatures provide a faster process, they should be preferred to produce duplex stainless steel products.

wire and arc additive manufacturing (WAAM) | duplex stainless steel (DSS) | interlayer temperature | ferrite amount | porosity | hardness

1. Introduction

Growth and evolution of the modern industries always bring the need for developing and researching the new technologies and the novel production methods. In the latest years, AM (additive manufacturing) technologies caught the eye of researchers, thanks to their possibility to produce the complex geometries with more design freedom, high productivity and less waste. However, the majority of these technologies are still limited to produce only the prototypes and they often use only polymer materials. The appearance of the WAAM technology and its development could be a potential solution for some problems and challenges which are the main drawbacks for conventional AM technologies, like excessive porosity, limited choice of the materials, low mechanical properties, etc.

2. Materials and methods

An experiment was carried out in Welding Laboratory at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. WAAM system was constructed particularly for this study, by combining welding robotic hand OTC Almega AX-V6 (six axes of freedom) with MIG welding machine DP-400 (conventional power source) and wire feeder CM-7401 (all three devices were supplied by Daihen Varstroj). Welding wire used as a feedstock was 1.2 mm diameter duplex stainless steel solid wire Avesta 2205 (Voestalpine Böhler Welding, designed for welding DSS grade 2205 or 1.4462). Shielding gas mixture was prepared by Messer Croatia Plin, containing 98% Ar and 2% N_2. The substrate was austenitic (grade 304 or 1.4301) stainless steel plate, with dimensions 300x150x8 mm.

4. Conclusions

As a result of this study, conclusions are as following.

1. These parameters are appropriate to build the wall with satisfying geometrical characteristics and without major distortions, but porosity could not be avoided. Even if it is true that the majority of the external sides are additionally post-processed and machined, some of the porosity still could be inside. Further researches are necessary in order to improve the process. Additionally, since the distortions were minor, the focus for the further researches should be on the measuring of the residual stresses.
2. Interlayer temperature does not affect surface roughness at all. Minor differences amongst samples could not be attributed to temperature since there is no regular pattern. All the walls have shown similar behaviour during machining, which adds to that.
3. Chemical composition of the walls was similar amongst all of them, but also similar to the composition of the wire. However, there was a limitation of the impossibility of N_2 detection, and further researches should aim to improve that.
4. Ferrite amount analysis has shown there is more ferrite in the walls produced with the lower interlayer temperature. It is important finding directly related with our first objective since now it is proved that it is possible to produce the parts with lower ferrite amount by using higher interlayer temperatures, which consequently means shorter idle time and faster process.
5. Radiography testing has shown there is some porosity inside the walls. Since there are still no standards which would be suitable for WAAM products, standards used for assessment were the ones that are the closest by nature of the process – standards for weldments. According to them, all the walls are acceptable even using the acceptance levels for strictest class (B) and it is important finding related to our second objective. However, solutions which may be found to reduce the external porosity could also be helpful to reduce the internal porosity.
6. Hardness values amongst the walls are close and do not have significant differences. An important finding is a fact that these products fulfil the hardness values requirements defined by appropriate standards for duplex stainless steel products. It means we reached our goal and prove it is possible to produce the WAAM parts which are comparable (in terms of hardness properties) with the products made using conventional methods.
7. Considering production time, ferrite amount and porosity, it is strongly suggested to use higher interlayer temperatures to produce parts using this duplex stainless steel grade. Wall produced using the interlayer

temperature of 150 °C was made for more than twice less time than the one with 50 °C while having about 5% lower ferrite amount and significantly less porosity.