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Corrosion behavior in AA5754 friction Stir Selded Alloys

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Abstract. Friction Stir Welding (FSW) has been applied to AA5754-H111 alloy. Taguchi method has been applied to optimize the process parameter s for these alloys and it was observed that the optimal parameters made welded samples with 98% efficiency of the base material. The Taguchi method also allowed to an understanding of the parameters influence on the weld properties. The corrosion testing has been very positive showing that this process does not create any preferential site for corrosion or shows any increase in corrosion when compared to the base materials. The “kissing bond” defect is a preferential site for corrosion having an increased corrosion in that site. Cautions must be taken to avoid having these defects in corrosion prone areas.

Keywords: Aluminium alloys, Friction Stir Welding, Corrosion testing, Taguchi Method

1 Introduction

Nowadays one of the main goals in the in several industries is the reduction of the carbon emissions. In the automotive industry this can be obtained through the reduction of the fuel consumption during a car drive or by the development of more efficient engines where the losses from are decreased [1]. Our work is focused in the reduction of fuel reduction by introducing lighter solutions using materials that have a lower density than the usual materials used in automotive applications.

Several authors [2-4] have studied the effects of FSW parameters in different aluminium alloys to understand the best parameters to have the best joining efficiency of a weld. It was observed that the joining of different aluminiums is possible and that the properties are usually between the properties of the base materials [5-6]. A need for a structured approach that can help in understanding the interaction between the welded samples properties and process parameters is needed. Taguchi method is a method to do that and it has been applied to other friction stir processed aluminium

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alloys [7, 8] however no definite relationship has been established in these studied alloys. This study aims to learn the relationships between the process parameters and material properties. The second goal focuses on the behavior of the welded samples to corrosion environments.

2 Experimental Procedure

Sheets of AA5754-H111 with 2mm thickness were friction stir welded using a tool with a scrolled shoulder and a threaded conic pin (Figure 1). The shoulder had a diameter of 15mm and has a variable pin depth. The pin has a 4mm diameter in the base that decreases to 3mm in the tip. Different process variables (mainly advancing speed (V), applied force (F) and Pin Length (L)) were investigated in order to identify the best variables for these alloys. Table 1 resumes the variable parameters that were tested in this work. On the other hand, other parameters were kept constant in our studies the tool rotation speed of 800rpm, the plunge speed of 0.1mm/s , a the dwell time of 6s and a pitch angle of 0^0. The tested parameters have been selected for being the parameters that most influence the properties of the welded samples.

Table 1. – Test parameters with Taguchi N9 matrix

Trial	V (mm/min)	F (Kg)	Pin Length (mm)
1	100	500	1,92
2	100	550	2
3	100	600	2,09
4	200	500	2
5	200	550	2,09
6	200	600	1,92
7	400	500	2,09
8	400	550	1,92
9	400	600	2

3 Results

The base material has an average hardness of 72.21±1.6. It was observed that the welded samples with the same advancing had similar profiles between themselves. In fig. 3, it is presented the profiles between the samples which show that the welded samples have small differences between themselves. There is an increase in the hardness in the nugget of each sample with the increase of the welding speed but besides the nugget region there are not many differences between them. One can also observe that outside the nugget region the average hardness is most of the times close to the average hardness taking into account their standard deviation. The average hardness in the heat affected zone (HAZ) and BM is similar between the three samples.

The Taguchi method is an improvement method that has been used from these tested samples which parameters are the ones most suitable to increase the efficiency of the weld to the different tested parameters. This method uses a combinatory analysis and gives the best parameters based on the efficiency results observed before.

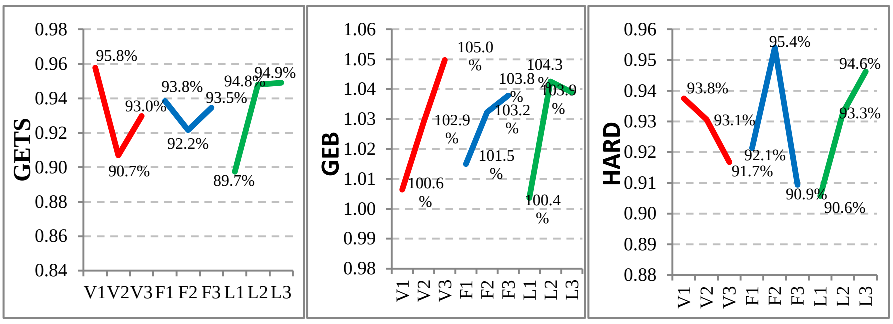

Fig. 1. – Effect of the process parameters on the GETS, GEB and HARD

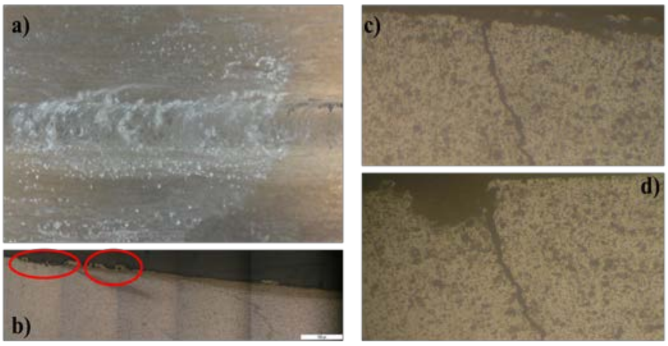

Fig. 2. – Samples submitted to corrosion testing: a) corroded plate, b) Top of the sample, c) sample with defect before corrosion testing and d) sample with defect after corrosion testing

In the corrosion test it was observed the behavior of these aluminium samples with the optimal parameters and it was also observed how a welded sample with a “kissing bond” defect would behave after being in a saline environment for 350h. It can be observed (Figure 6) that the corrosion of these aluminium samples is controlled and there is a preferential area of corrosion. In fact, it can be observed that there some spots that corroding but it is due to the roughness of the surface after being processed. In the samples with defect it can be clearly observed that the defect is a preferred area of corrosion in which a big corrosion hole is created due to the existence of this defect in its vicinity.

4 Discussion of results and conclusions

The Taguchi method has been confirmed to be a valuable method to identify the parameters that can optimize the properties of the welded materials. The effect of each parameter on the properties highlights which way one should proceed to improve the properties of the material. To improve GETS efficiency one should use small advancing speeds and forces. Because these alloys are not heat sensitive the higher speeds will induce residual strains in the joint material and the material will fracture much earlier than the joints with slower speeds. On the other hand, the best conditions for the GEB is better with the combination of faster advancing speeds and applied forces which will increase the hardness of the nugget and this improves a bit the resistance of the material to bending forces. The pin length is important in both these properties however it seems that the pin length over 2mm is effective enough and eliminates the defects in this area.

The influence of the process parameters on the hardness have been found to be quite the opposite of what usually happens in this process. This process has shown a tendency of the hardness to decrease with the increasing advancing speed. The hardness also is said to grow with the increasing length of the pin. These results are far from what really happens in the nugget. The increase in speed should be related with an increase in the hardness of the material because with the faster speed there is less heat released during the weld and therefore there would be a smaller effect in the hardness. The applied force and pin length should not have a big impact in the hardness. These results do not make much sense because the aluminium is not heat-treatable and the released heat is not enough to produce an effective coalescence of the grain boundaries. Therefore, these hardness results were disregarded in the following steps in the selection of the optimal parameters.

It can be observed that these alloys and have a very good corrosion resistance. It can also be viewed that the use of FSW does not affect the corrosion properties of the material and do not induce any preferential corrosion area. There is some corrosion in the rougher surface of the processed area and this is related to the rougher surface where the saline solution will concentrate and promote a more severe corrosion. The same fact happens in the “kissing bond” defect located on the root of the weld where the solution will concentrate there and the Cl^- ions will react with the environment around it and promote a very severe corrosion. Has it can be seen the corrosion has promoted a very large hole in this area. Unlike the surface where the surface is a little bit rougher the kissing bond defect goes deep inside the weld and actions must be taken when using this process.

This study has enabled us to conclude the applicability of the Taguchi method on the aluminium alloys and it can be observed that it allows us to deduce the properties of the material when applying this process to these alloys. The Taguchi method is very efficient in the identification of the best process parameters for a certain application.It was observed that the welded aluminium alloys are resistant to corrosion because the process does not decrease the resistance to corrosion of the alloys neither creates a preferred corrosion effect. The “kissing bond” defect has been identified as a defect that must be clearly avoided. Despite, the initial size the concentration of Cl^- will induce a severe corrosion that will increase the defect and therefore decrease the mechanical properties of the welded sample.

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