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Improving crack resistivity in Al alloy pressure vessels by FSW

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ABSTRACT

Purpose: Fuel or oil transmission pipelines are made with light metal alloys to prevent corrosion and to provide a better safety record. This is achieved by the combination of perfect design, selection of materials and functioning practices. However, like any engineering structure, these lines also fail occasionally. Major cases of such failure it induces due to external interference or corrosion or due to manufacturing defects; so such of defects if they were detected before failure and that can be treated to avoid failure or the life time can be improved.

Design/methodology/approach: In this study an aluminum alloy sample with micro crack was treated with FSW process with ZN powder. And studies were carried out against both treated and untreated samples with cracks.

Findings: From the studies it is clear that FSW treatment over surfaces will reduces the crack initiation in light metal alloy structures. The process can be done before or after installation.

Research limitations/implications: The results were recorded and suggested FSW as a best process for crack treatment in Al alloys. Especially in pressure lines or pressure vessels.

Originality/value: Friction stir welding (FSW) is a solid-state metal joining process. This is energy efficient, ecofriendly, and versatile light metal joining technique. In particular, high-strength aerospace aluminum alloys can be welded by using this technique. This will produces high harden joints in light metals as just like conventional arc welding techniques. It is considered as the most significant research development in light metal joining.

Keywords: FSW; Micro structural analysis; Pipeline maintenance; Scanning Electron Microscope

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PROPERTIES

1. Introduction

Frictions stir welding (FSW) is a solid-state metal joining process. This is energy efficient, ecofriendly, and versatile light metal joining technique. In particular, high-strength aerospace aluminum alloys can be welded by using this technique. This will produces high harden joints in light metals as just like conventional arc welding techniques. It is considered as the most significant research development in light metal joining [2-9].

In this process the tool provides two basic functions namely: (a) heating of the workpiece, and (b) Stirring of metal of material to produce the weldment [1]. The process is shown in Fig. 1. This localized heating makes the metal softens and there after due to stir action as well as the translation of tool leads the metal to move towards front and back of the pin. This will produces the joint after solidification.

In this study the principle is used as a tool for defect rectification (Removing micro cracks) in high pressure transmission lines made with aluminum alloys.

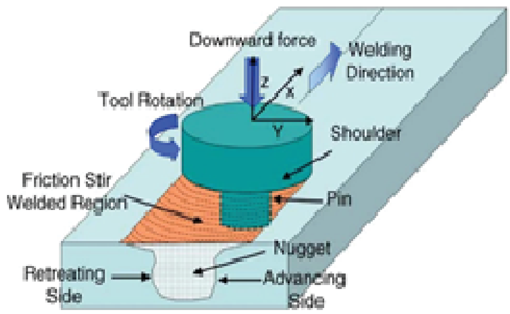

Fig. 1. Friction Stir welding [1]

Fig. 2. Crack propagation in pipeline

In the long pipe lines the defects were starts from external surfaces in most of the cases. This might occur due to the corrosion or external inferences. Some of the defects in such of the cases are shown in Figure 2. Even though during the initial stage itself it is got identified; it become tough to protect. Because these kind of pipes are made by light metal alloys. So welding also not possible. So it becomes necessary to think of FSW as a solution for all these issues.

Corrosion is usually occur due to the reaction of a metal caused with its environment. Most metals occur its oxide form by naturally and are also chemically stable too. When exposed to atmospheric oxygen or other chemical agents which may induces oxidization will bring the parent metals oxide state. In the case of Fe, the oxides will be of ferrous oxide or ferric oxide, known as rust.

2. Experimental procedure

2.1. Materials and methods

Al 7020 samples were collected with initial cracks. And were already in service. These plated were made cleaned to see the whole area where the crack is propagated. The sample with crack is shown in Figure 3 and the material properties are given in Table 1.

Fig. 3. Sample with crack

Table 1.
Chemical Composition of aluminium alloy 7020

Weight, %	Al	Si	Fe	Cu	Mn	Cr
7020	Bal	0.35	0.40	0.20	0.05-0.50	0.10-0.35
	Mg	Zn	Zr	Zr + Ti	Other Each	Others Total
	1.0-1.4	4.0-5.0	0.08-0.20	0.80-0.25	0.05 max	0.15 max

Because of the internal pressure these kind of cracks may reaches yield point very soon. To avoid such of failures it is planned to till the crack by Zn powder and that can be melted and allowed to fill and bond the gap with the help of FSW tool setup.

Initially the specimen is fixed in the FSW machine and the cracks were filled with Zn powder as shown in Fig 4. Then the tool is allowed to pass through the crack. Due to the high pressure, heat and stir effect of the tool, the metal powder first melts and occupies the crack. By providing traverse speed to the tool the same defect can be removed

Fig. 4. Stir welding process with Zn powder

2.2. Process parameters

High Speed Steel (HSS) tool is used, the welding tool is holded and allowed to rotate in clockwise direction from retreating side to forward side of the weld. Then to do the welding the tool is feed against the tightly clamped job. Which is shown in Figure 4. The process parameter which was considered are given in Table 2.

Table 2.
Process parameters

Material	Tool speed, rpm	Tool feed rate, mm/min	Axial load, KN
Al 7020	1400	32	32
Zn powder is added as filler material in the crack			

3. Experimental results and discussion

3.1. Impact test

The impact test carried out for both the samples made with FSW treated crack and non-treated crack. It becomes important based on the application. The samples were tested using by Charpy impact test machine, of pendulum type, with maximum range is of 300 joules. The test results were tabulated in Table 3.

Table 3.
Impact strength results of specimens

Zinc interlayer	Strength, J
Without treated	1.8
With FSW treated	2

The impact test result shows that the sample treated with FSW produces more impact strength than the open crack propagated sample.

3.2. Tensile properties

Tensile strength also analyzed to ensure the effectiveness. The study was extended between samples with FSW treated micro crack and plain crack. The results Shows that there is a drastic improvement in the sample after treatment. The range of the test machine is 100 KN load with 1000 mm cross head stroke. With a cross head displacement of 0.1 mm and speed of 0.5 to 250 mm/min. The samples are tested without any surface modification after FSW treatment. The tensile sample was prepared as per ASTM standards shown in Figure 5.

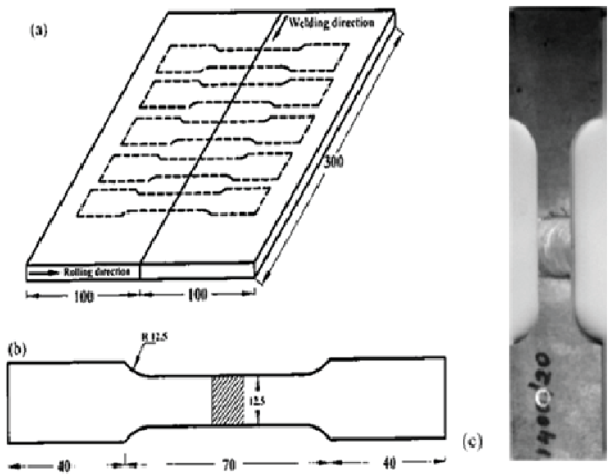

Fig. 5. (a) Scheme of extraction [1] and (b) dimensions of tensile specimen (c) sample specimen

The results of the tensile test is tabulated in Table 4. This shows the sample with FSW treatment is hardly improved than non-treated (Figs. 6,7).

Table 4.
Tensile test results

Parameters	FSW treated sample	Sample with open crack
Peak Load Fmax, kN	3.235	2.265
UTS, MPa	67	38
Yield Stress, MPa	525	39
Disp. at Fmax, mm	1.00	2.88
Max. Disp., mm	1.50	3.22
Elongation, %	3.00	6.44

This shows open cracks produces much elongation than FSW treated. But in the meantime the strength is almost half. So as for pressure lines elongation is not expected hence, it further improves stress accumulation and there by blast accurse. The stress strain plot also shown below for both the samples (Figs. 8,9).

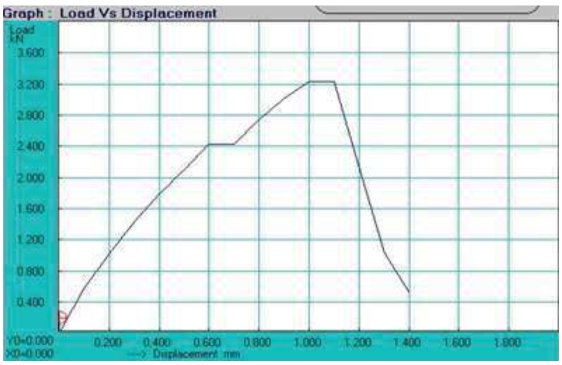

Fig. 6. Load vs. displacement of sample with FSW treatment

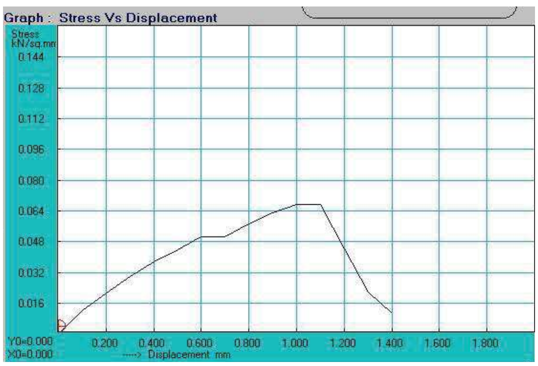

Fig. 7. Stress vs. displacement of sample with FSW treatment

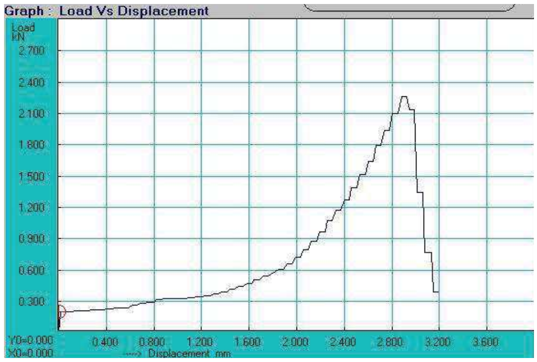

Fig. 8. load vs. displacement of sample without FSW treatment

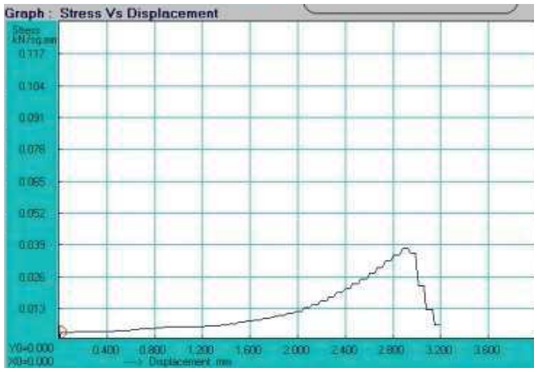

Fig. 9. Stress vs. displacement of sample without FSW treatment

3.3. Micro structural analysis

Micro structure of the sample which treated with FSW is obtained by High resolution SEM equipment with 3,000x magnification. The micro analysis was done at the fusion line present in the micro crack which is treated. And is shown in Figure 10.

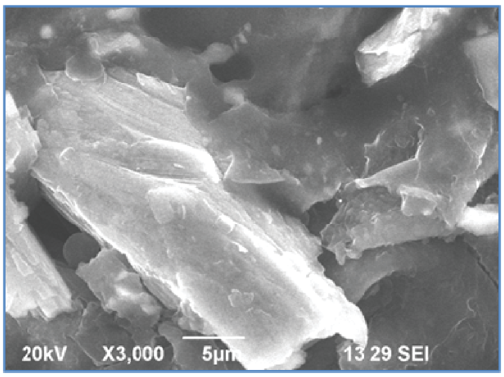

Fig. 10. Micro structure of fusion line in treated crack

In the micro structure the Zn particles glow more than aluminum particles. For ant crack propagation the initiation will me from the accumulation of voids in grain boundaries. From this figure it is clear that that the Zn particles enter into the voids present in the parent metal and thereby fills the voids. This will prevent the void accumulation and there by crack initiation. So it is clear that FSW treating will prevent crack propagation in light metal alloy structures.

4. Conclusions

From the studies it is clear that FSW treatment over surfaces will reduces the crack initiation in light metal alloy structures. The process can be done before or after installation. The identified tips for implementing this process are concluded below:

- If any micro cracks were identified before installation by NDT techniques, then that can be treated with FSW process with filler material.
- After installation and during service if any cracks identified before failure; then that can also treated and removed by this process.
- Choose the filler material with lower melting point than parent metal. Since it will melt fist and occupy the voids. Zn can be suggested for Al alloys.

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