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# An Overview High Performance of Stress Corrosion Cracking Behavior for Aeronautic Applications

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**Abstract.** Tensile stress combined with exposure to a corrosive environment result in a cracking process known as stress corrosion cracking (SCC). It falls in the threshold of the material's fatigue limit and dry cracking. Tensile stress can be applied directly or exist as residual stress within the material. SCC results from specific combinations of composition, environment, and stress. Processes like cold forming, welding, heat treating, machining, and grinding introduce residual stresses. Stress erosion cracking (SCC) occurs when cracks form under static tensile stress and the environment around us . It develops by the result of the interaction between mechanical stress and corrosion/oxidation reactions. The occurrence and progression of SCC depend on the materials, applied loads, and environmental conditions. Some Contributing Factors to SCC In summary, two main features of SCC are emphasized: localization and acceleration of oxidative reactions.

## 1. INTRODUCTION

As a result of the combined effects Stress corrosion cracking (SCC), also known as tensile stress corrosion cracking, is a progressive fracture phenomenon that affects metals. Failure could happen hours later in a structural failure caused by SCC. To produce an even solid solution, components are mixed with molten aluminium to generate alloys. These substances include copper, iron, magnesium, silicon, and zinc, and they can make up as much as 15% of the mass of the alloy. In comparison to pure aluminum, the addition of these elements improves the alloy's strength, functionality, resistance to corrosion, electrical conductivity, and density. Aluminium alloys are widely prized for being corrosion-resistant and lightweight, which makes them perfect for uses that call for lightweight materials, including Aeroplan components. The coldest melting point amongst alkaline earth metals is that of the mineral magnesium, one of the components used to make these alloys (923 K or 1,202 °F). Due to its hexagonal close-packed crystals and low elastic modulus of 45, pure magnesium is relatively soft.

## 2. STRESS CORROSION CRACKING

This study aims to investigate the effects of different ageing techniques on the toughness and susceptibility to emphasise corrosion crack (SCC) of 7075 aluminium alloy plates. The T7X standard is achieved through ageing according with the standard, beginning with the solution healed and refrigerated (W) stage and finishing with the T6 stage. [4]. Due to its exceptional strength, superb weldability, and laudable corrosion resistance, AA6061 aluminium alloys are widely used in automobiles marine, and aerospace applications. However, due to changes in the phase makeup and structure during the process of welding, these alloys are especially prone to stress-induced corrosion crack [5]. The composite still demonstrated some sensitivity to stress corrosive cracking at a nominal tension rate of 10(-6) s(-1), despite the coating's improved resistance to SCC in the test environment [6]. The primary factor causing cracking due to stress corrosion in the PEO-coated specimens was found to be the coating's fracturing under filtering conditions. The findings indicated that tempering at T6 and T7 temperatures for 250 minutes produced the highest resistant to stress corrosion cracking (SCC). However, samples that had been annealed for 8 minutes at 200°C showed decreased resistance to stress corrosion cracking

[7]. The results of the electrochemical tests showed the fact that the PEO covering increased corrosion resistance, but that it had no effect on SCC protection within the ASTM D1384 solution used for the sample. The underlying reason for SCC behaviour in the PEO-coated specimens was determined to be the presence of tiny fractures within the covering, which led to substrate failure after slow strain testing [8]. A lot of research are put into creating aluminium alloys with high ratios of strength to weight since there is a growing need for them in aerospace and aviation applications. But it's important to recognise that stress corrosive cracking (SCC) can occur with these high-strength aluminium alloys [9].

**FIGURE 1**. Stress Corrosion Cracking

## 3. MICROSTRUCTURE

A study looking at how the Zn/Mg ratio affects the quenching sensitivities of the Al-Zn-Mg-Cu AA7175 alloy (as well as 1.2-2.0 wt%) has shown that a higher Zn/Mg ratio can significantly lessen its vulnerability to quenching sensitivities.An comprehensive analysis has been conducted to investigate stress-induced corrosion cracking (SCC), In order to maintain a total Zn+Mg content of 7 wt%, the research examined the corrosion behaviour, precipitated micro structure, and electrochemical properties of Al-Zn-Mg alloys with various Zn/Mg ratios [30]. The 6013-T6 alloy was also aged in sheet form for 100 hours at 191 °C before being exposed to heat for 3000 hours at temperatures between 85 and 150 °C. The material's microstructure, tensile characteristics, and corrosion behaviour were investigated using a variety of techniques, such as scanning calorimetry, electron microscopy with transmission, tensile analysis, and corrosive tests. Metastable ″ or Q' phases were found in the microstructure of the peak-aged material as precipitates that were hardening.

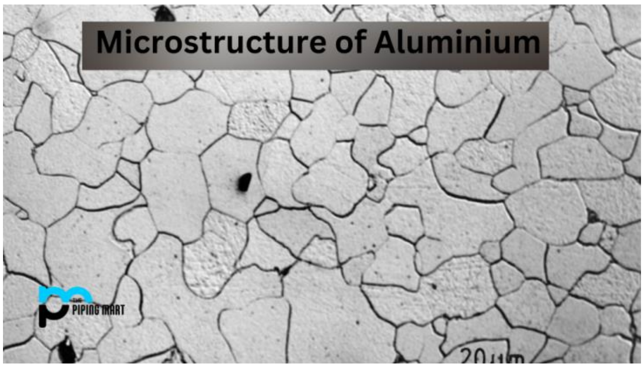



**FIGURE 2**. Microstructure of Aluminium

The 6013-T6 alloy showed vulnerability to pitting or intergranular corrosion when submerged in chloride solutions. Precipitate growth was coarsened and precipitate sequencing was improved at elevated ageing temperatures of 191°C. Long-term ageing, however, had little impact on the tensile characteristics and did not significantly alter corrosion behaviour. Peak-aged 6013 sheet's microstructure, tensile characteristics, and corrosion resistance were unaffected by prolonged contact with temps of 85°C and 120°C. These results emphasise the alloy's thermal stability in fuse applications, proving its applicability for such applications [34]. Scandium addition to aluminium alloys has been shown in the literature to successfully inhibit recrystallization and increase strength through polishing the grain structure. When scandium and zirconium are both added to aluminium alloys at the same time, they generate Al3ScxZ1-x dispersoids that are evenly distributed inside the aluminium matrix. Because of their thermal stability, these dispersoids have a high number density and maintain their dispersion even at high temperatures[23]. To learn how Zn/Mg ratios affect electrochemical corrosion characteristics, cracking due to stress corrosion (SCC), and the deposition of an Al-Zn-Mg alloy with roughly 7 wt% Zn and Mg, a thorough analysis was conducted. The investigation included mechanical testing, cracking from stress corrosion (SCC) analyses, cyclic polarisation tests utilising electrochemical techniques, and TEM inspection of microstructures. There are two key reasons for the increased electrochemical corrosion characteristics and higher resistance against stress corrosion cracking (SCC). These elements help to increase the performance of the alloys overall [54]. The intermetallic particles that were seen ranged in length from 1 to 8 m. Through investigation using semi-low energy dispersive X-rays (EDX) analysis, it was determined that these particles primarily consisted of Al, Cu, and Fe. The relative proportions of these three elements within the intermetallics suggest that they are more abundant compared to the A17Cu2Fe type [55].

## 4. ALUMINIUM ALLOYS

More than 95% of the structural parts in aeroplanes are made of polymer matrix composites (PMCs), titanium (Ti) alloys, and aluminium (Al) alloys. Due to their well-established mechanical qualities, superior damage resistance, well-established production processes, and trustworthy inspection systems, aluminium alloys have become the lightweight material of choice in the aerospace sector. The Airbus A380 is a well-known example, with nearly sixty percent of the aircraft made of aluminium alloys. In a similar vein, over seventy percent of the components in Boeing models including the 747, 757, 767, & 777 series are made of aluminium alloys. Due to its remarkable mix of unique strength, rigidity, and fatigue qualities, composites made of polymer matrix (PMCs) are also becoming more and more popular as a substitute for thin aluminium alloys. Additionally, developments in composite processing technologies have improved their market position [33].

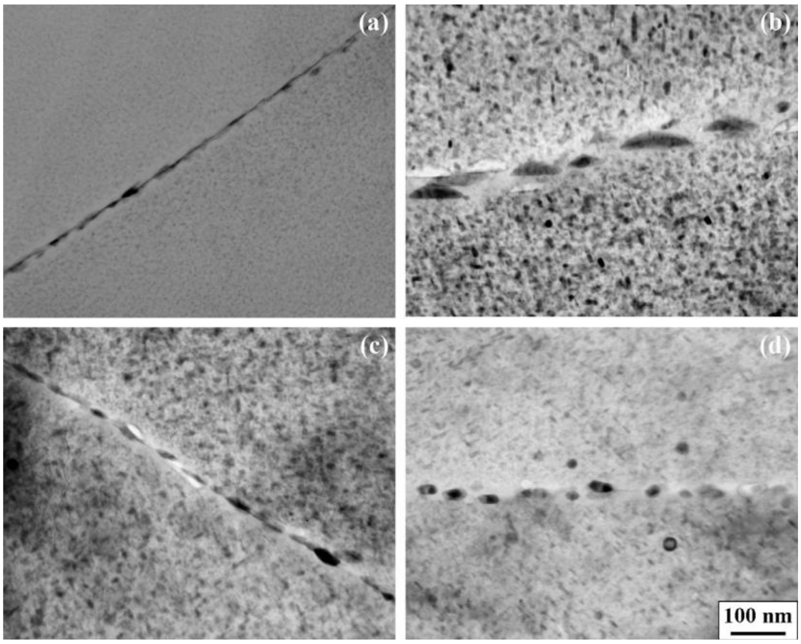



**FIGURE 3**. depicts the presence of grain-border precipitates (GBPs) in 7050 specimens subjected to various temperature treatments. The GBPs emerged as tiny and equally dispersed precipitates in the T6 test (Figure 3a). In contrast, the T76 specimen (Figure 3b) had bigger and irregularly distributed particles at the grain boundaries, which was consistent with earlier findings. The CR 4 modelling (Figure 3c) revealed GBPs with greater spacing than the T6 sample.

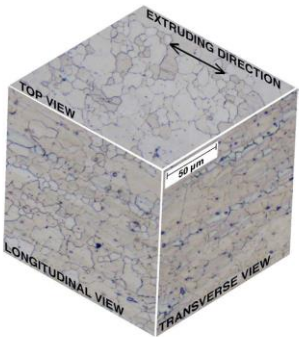
Furthermore, an increase of cold rolling decrease resulted in a modest increase in both the amount of GBPs and particle spacing (Figure 3d) [38]. Aluminium alloys with high strength-to-weight ratios are in high demand, particularly in aircraft & aerospace applications. However, it is critical to recognise that particular alloys are vulnerable they are more susceptible to stressed corrosion cracking (SCC), especially at their optimum strength. Scandium and zirconium are added to aluminium alloys to help offset this, allowing the creation of evenly distributed Al3ScxZ1-x dispersoids having a high number density. The distribution of these dispersoids is maintained even at high temperatures thanks to their extraordinary thermal stability [12]. In recent years, 7075 aluminum alloys have gained popularity in applications requiring high mechanical performance. The T6 state of the alloy is renowned for its impressive ultimate and yield strength but has limitations in terms of stress corrosion cracking (SCC) resistance. This study investigated the tensile properties and SCC behaviour of thick

7075 alloy plates subjected to single-step ageing, with varying ageing times. The tests were carried out using standard procedures, and the SCC data obtained from the tests were used to address this concern in aeronautical applications. However, conventional fusion welding methods face challenges with these alloys. A well-liked method for attaching them is friction stir welding (FSW). FSW has made great strides as a trustworthy solid-state welding method, finding use in a variety of industries. Therefore, important load-bearing structures and demanding applications use FSW-welded joints [16]. With AA7075 on the advancing side, friction stir welding (FSW) was utilised for combining AA6056 and AA7075 aluminium alloys. A lump of the recrystallized microweld with two separate grains coming from the various base materials was discovered by microstructural examination. FSW, created by The Welding Institute (TWI), proved to be very successful for connecting aluminium alloys [22]. This study's major goal is to look at how interfacial interaction affects the corrosion behaviour of an aluminium alloy with alumina borate whiskers added to it (Al18B4O33w). The analysis was done in a 3.5% NaCl solution at ambient temperature. The application of whisker as reinforcing in aluminium matrix composites has generated interest in the aviation and defence industries due to its improved mechanical properties and lightweight design. Despite extensive research being done on the development of such composite and their chemical and mechanical characteristics, little is known about how these composites react to corrosion. Aluminium alloy 6061Al is often used as a basis metal in multiple strengthened metal-matrix composites (MMCs) because of its large strength and relatively strong corrosive resistivity. These composites can be made with non-metallic fibres. [42].To address this cost constraint, zirconium (Zr) is introduced alongside Sc to achieve comparable mechanical properties without the need for high Sc content. Recent studies have demonstrated that the ternary complex of Al3ScxZr1-x precipitates, resulting from the combined addition of Sc and Zr, exhibit excellent stability, and their ability to prevent recrystallization is highly significant [47].

## 5. MAGNESIUM ALLOYS

Magnesium alloys are highly desirable lightweight structural materials known for their excellent technical properties. Their remarkable strength-to-weight ratio makes them particularly appealing for industries like transportation and aerospace, where reducing weight is crucial for fuel efficiency and pollution reduction. However, the limited corrosion resistance of magnesium alloys hampers their widespread adoption and usage [20]. In recent times, magnesium compounds have gained popularity in various industries such as electronics, automotive, and aerospace due to their desirable properties. However, these alloys often suffer from poor corrosion resistance, making them susceptible to environment-assisted cracking [10]. The behavior of SCC in the PEO-coated samples indicated that a slower strain rate resulted in the formation of cracks in the substrate, which could be attributed to the emergence of microcracks within the coating. A robot friction stir welders and optimised welding parameters were used in an experiment on friction swirl weldments of the magnesium alloy AZ61. The study's main objective was to examine the weldments' microstructure, mechanical characteristics, corrosion resistance, and cracking due to stress corrosion (SCC) behaviour. Further investigation was done into how surface modification affected the plasma electrolytic oxidised (PEO) coating pattern. When the weldments' corrosion performance was assessed, a joint effectiveness of 94% was found. A 3D optical image in Figure 4 depicts the magnesium alloy AZ61 in visual form [17].




. **FIGURE 4.** 3D Optical Micrograph

The first degradation of metal biomaterials is likely caused by a complex interaction between physiological stressors and corrosive body fluids. This study's objective was to assess how susceptible to stress corrosion cracking three brittle magnesium alloys—ZX50, WZ21, and WE43—were. Tensile testing were carried out in a synthetic environment that approximated body fluids using a progressive strain rate [36].

## 6. SCANNING ELECTRON MICROSCOPE (SEM)

The usage of magnesium alloys in the transport, aviation, and car industries is regulated because of their excellent resistance to corrosion and stress corrosion cracking. It is mainly noted that die-cast components plus a few semi-solid formed parts are growing. Every sample is categorised as discharged. Using an electron microscope (SEM) outfitted with energy-dispersed X-ray spectroscopy (EDXS) & X-ray diffraction (XRD), phases in Mg-6% Zn-0.5% Mn (ZSM) alloys were identified. By evaluating failure (F) and maximum tensile strength (UTS) characteristics in both corrosive and inert atmospheres (air), the vulnerability to stress corrosive cracking (SCC) was assessed.The fracture surfaces were studied utilising scanning electron microscopy after the slow strain rate (SSR) tests. Figure 5 shows SEM micrographs of the intermetallic elements detected in the extruded ZSM6X0 mg alloy, notably MgZn2, Mn5Si3, and Mg2Si, and their unique shape. The MgZn2 phase is detected as an accumulation of small particles oriented in the discharged direction, which could be the result of intermetallic compound breakdown throughout the extrusion process. Mn5Si3 intermetallics are commonly polygonal in form. The Si content influences the microscopic makeup of Si-containing alloys. Alloys with a low Si concentration (less than 0.5 wt%) exhibit a Chinese script-like Mg2Si shape. Mg2Si, on the other hand, turns into a polygonal form when the Si level exceeds 0.5 wt%.

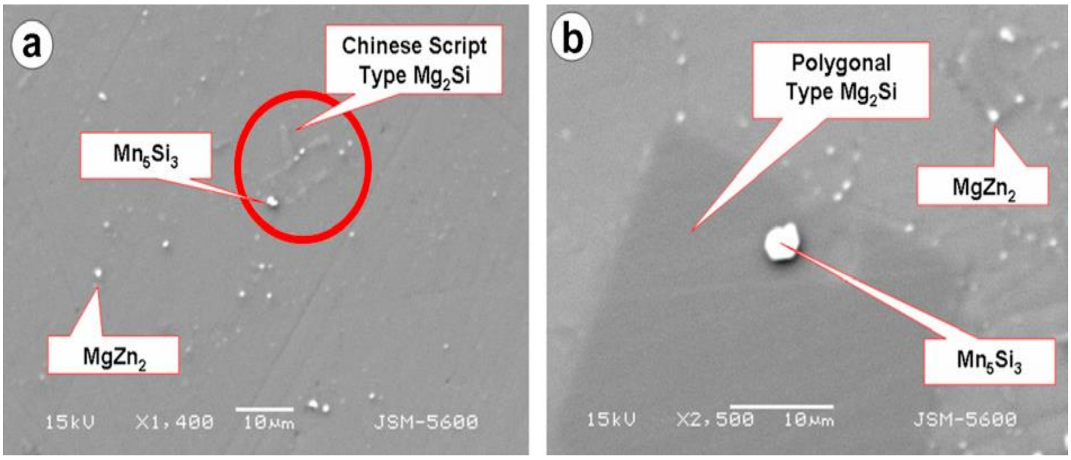
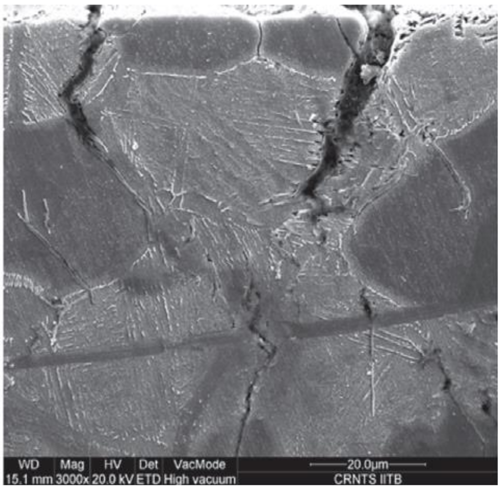
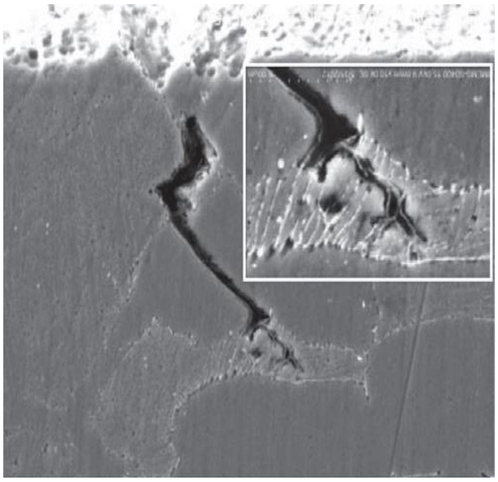



**FIGURE 5**. shows SEM images of the microstructures of alloys ZSM600 (a) and ZSM620 (b) [26].

Crack inspection of the gauge surfaces of the rejected samples was performed using a stereomicroscope. Scanning electron microscopy (SEM) was used to examine representative fracture surfaces to identify crack initiation sites and crack propagation paths. Failed samples were separated for further analysis. Magnesium alloys are highly desirable lightweight structural materials known for their excellent technical properties. Their remarkable strength-to-weight ratio makes them particularly appealing for industries like transportation and aerospace, where reducing weight is crucial for fuel efficiency and pollution reduction . However, the limited corrosion resistance of magnesium alloys hampers their widespread adoption and usage [20]. In recent times, magnesium compounds have gained popularity in various industries such as electronics, automotive, and aerospace due to their desirable properties. However, these alloys often suffer from poor corrosion resistance, making them susceptible to environment-assisted cracking[10]. The micrographs in Figure 6 show that cracks have initiated at the a/b interface (Figures 6a, c, and d). In Fig. 6b, crack propagation through the b transition phase is observed, with branching occurring where the b grain hits, possibly blunting before cracking. The a/b boundary seems to be the most vulnerable phase. The presence of hydrogen at the a/b interface is essential for compound decomposition. Hydrogen is highly soluble and readily diffuses into the larger body-centered cubic P phase. On the other hand, the close-packed hexagonal α-phase has a smaller structure, which allows more precipitation and is more susceptible to hydrogen embrittlement. Hydrogen can migrate through the lamellae to the substituted b regions, thereby contributing to disruption of the a/b interface. Evidence from altered b colonies supports the idea that hydrogen plays an important role in compound degradation. The observed high temperature stress corrosion cracking (HSSCC) was severe.



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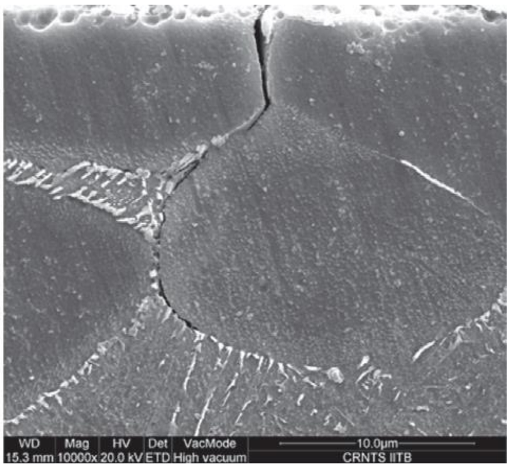


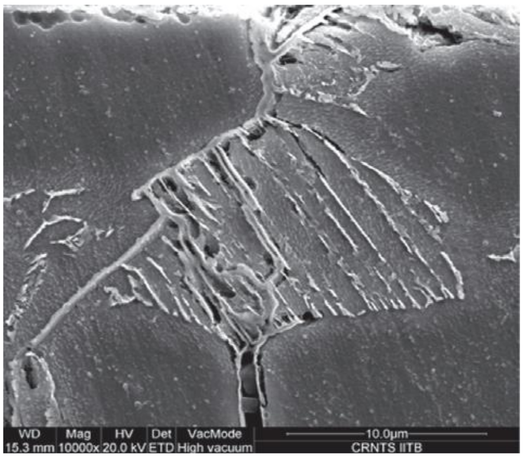


**C** **D**

**FIGURE 6.** shows an SEM micrograph of an axial cross-section sample of IMI 834 alloy after SSR testing under salt coating conditions at 400 °C. These images show different aspects of crack initiation and propagation. B. Crack initiation at the a/b interface (marked by a bright arrow) (Fig. 6a), vertical crack front propagation through the b lamella (Fig. 6b), and crack initiation at the a/b interface. Propagation (marked by bright arrows) (Fig. 6c and d) [35].

Welds were chop and standard metallurgical capability for microstructural analysis were applied. Samples were etched with 3.5 g picric acid solution and examined by visual inspection and scanning electron microscopy (SEM). In addition, energy dispersive X-ray analysis (EDX) was also performed. To identify secondary particles, Vickers hardness measurements were taken on the polished parts along the weld line with a force of 0.1 HV practiced for 10 seconds.

 

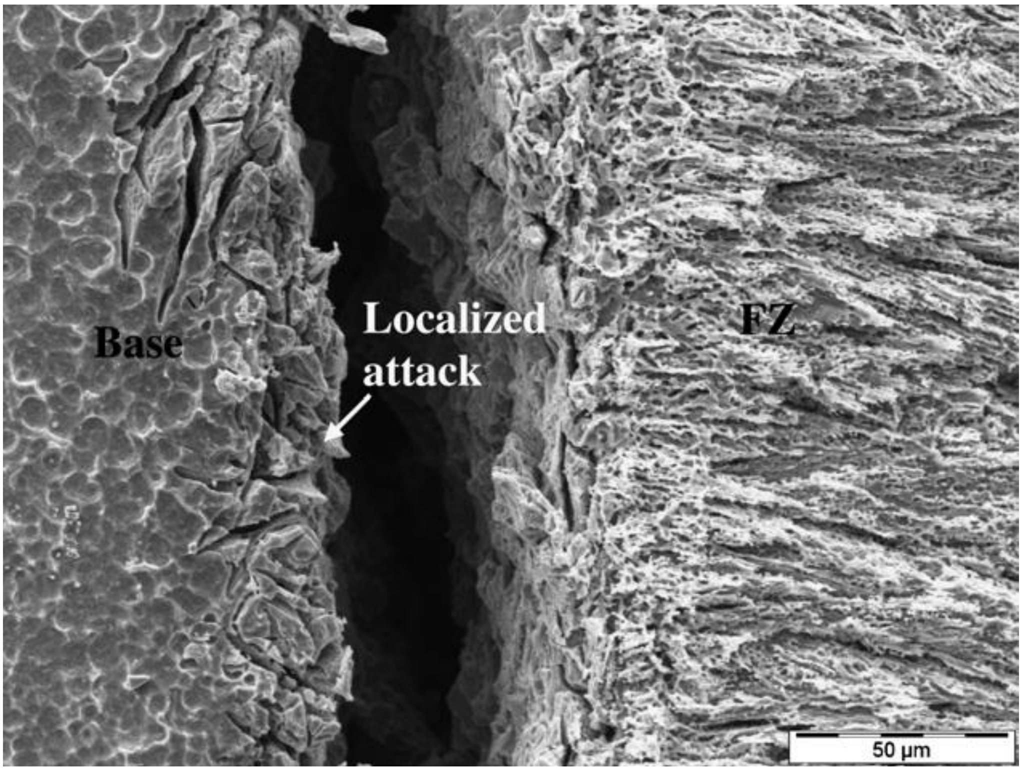


**FIGURE 7**. display the surface of an AZ31-Mg specimen that underwent SSRT-LB welding and failed when exposed to the ASTM D1384 solution. The image clearly shows cracks at the melt boundary and localized corrosion in the base region. [53].

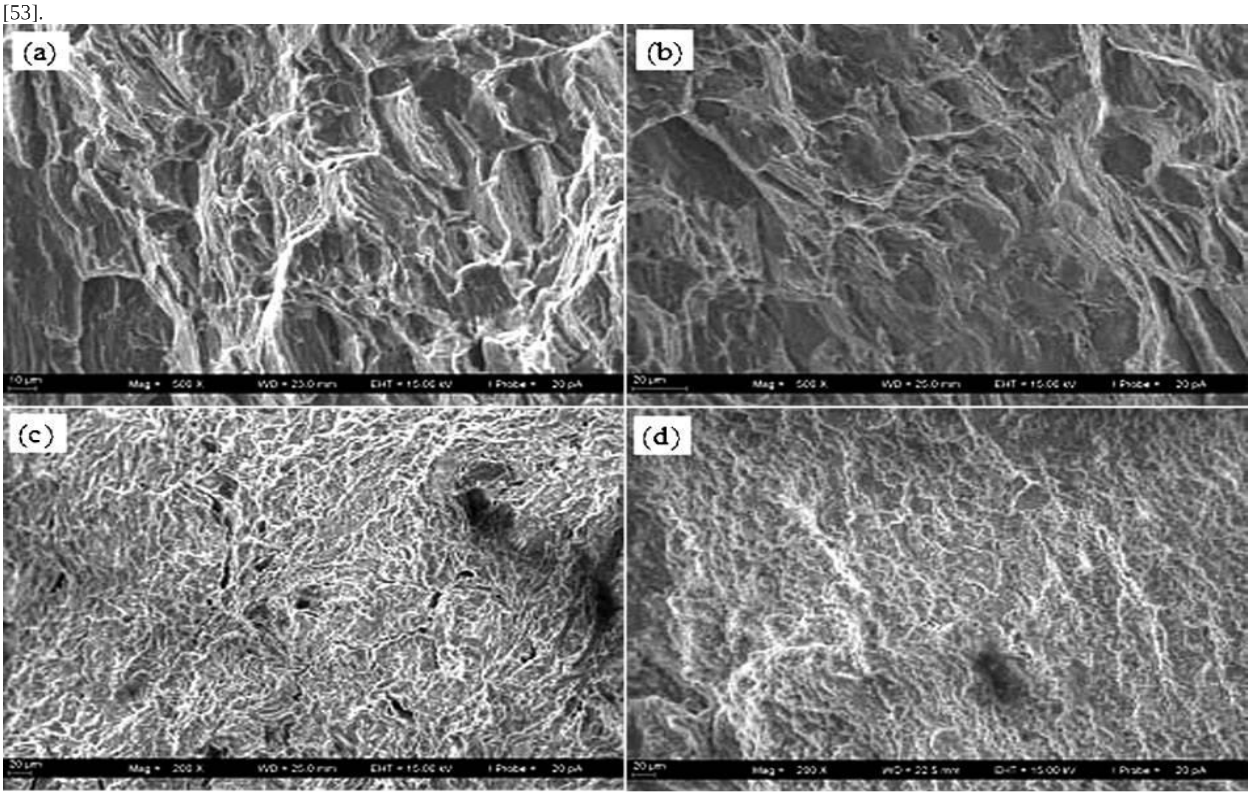


**FIGURE 8**.It displays fractographs (SEM pictures) of specimens made of the magnesium alloy AZ31 under various circumstances. The un-LSP specimen is shown in Subfigure (a), the LSP specimen is shown in Subfigure (b), the un-LSP specimen is shown in Subfigure (c), and the LSP specimen is shown in Subfigure (d).

## 7. CONCLUSION

The findings indicated that tempering at T6 and T7 temperatures for 250 minutes produced the highest resistant to stress corrosion cracking (SCC). However, samples that had been annealed for 8 minutes at 200°C showed decreased resistance to stress corrosion cracking. The results of the electrochemical tests showed the fact that the PEO covering increased corrosion resistance, but that it had no effect on SCC protection within the ASTM D1384 solution used for the sample. The underlying reason for SCC behaviour in the PEO-coated specimens was determined to be the presence of tiny fractures within the covering, which led to substrate failure after slow strain testing. A lot of research is put into creating aluminium alloys with high ratios of strength to weight since there is a growing need for them in aerospace and aviation applications. But it's important to recognise that stress corrosive cracking (SCC) can occur with these high-strength aluminium alloys. Peak-aged 6013 sheet's microstructure, tensile characteristics, and corrosion resistance were unaffected by prolonged contact with temps of 85°C and 120°C. These results emphasise the alloy's thermal stability in fuse applications, proving its applicability for such applications. Scandium addition to aluminium alloys has been shown in the literature to successfully inhibit recrystallization and increase strength through polishing the grain structure. When scandium and zirconium are both added to aluminium alloys at the same time, they generate Al3ScxZ1-x dispersoids that are evenly distributed inside the aluminium matrix. Because of their thermal stability, these dispersoids have a high number density and maintain their dispersion even at high temperatures. More than 95% of the structural parts in aeroplanes are made of polymer matrix composites (PMCs), titanium (Ti) alloys, and aluminium (Al) alloys. Due to their well-established mechanical qualities, superior damage resistance, well-established production processes, and trustworthy inspection systems, aluminium alloys have become the lightweight material of choice in the aerospace sector. The Airbus A380 is a well-known example, with nearly sixty percent of the aircraft made of aluminium alloys. In a similar vein, over seventy percent of the components in Boeing models including the 747, 757, 767, & 777 series are made of aluminium alloys. Due to its remarkable mix of unique strength, rigidity, and fatigue qualities, composites made of polymer matrix (PMCs) are also becoming more and more popular as a substitute for thin aluminium alloys. Additionally, developments in composite processing technologies have improved their market position. Magnesium alloys are highly desirable lightweight structural materials known for their excellent technical properties. Their remarkable strength-to-weight ratio makes them particularly appealing for industries like transportation and aerospace, where reducing weight is crucial for fuel efficiency and pollution reduction. However, the limited corrosion resistance of magnesium alloys hampers their widespread adoption and usage. In recent times, magnesium compounds have gained popularity in various industries such as electronics, automotive, and aerospace due to their desirable properties. However, these alloys often suffer from poor corrosion resistance, making them susceptible to environment-assisted cracking. Magnesium alloys are highly desirable lightweight structural materials known for their excellent technical properties. Their remarkable strength-to-weight ratio makes them particularly appealing for industries like transportation and aerospace, where reducing weight is crucial for fuel efficiency and pollution reduction. However, the limited corrosion resistance of magnesium alloys hampers their widespread adoption and usage. In recent times, magnesium compounds have gained popularity in various industries such as electronics, automotive, and aerospace due to their desirable properties. However, these alloys often suffer from poor corrosion resistance, making them susceptible to environment-assisted cracking.

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