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Corrosion behavior of cast aluminum alloys for electric vehicle applications: Influence of Cu, Fe and Mg alloying elements

ABSTRACT

The rapid expansion of electric vehicle (EV) production has driven demand for cast aluminum alloys with improved corrosion performance. Unlike internal combustion engine components, EV parts such as battery housings, e-motor housings, and stator covers operate at lower temperatures, are encapsulated, and experience increased exposure to condensation, all of which significantly intensify corrosion. The present paper reviews the corrosion behavior of cast Al-Si alloys applied in EV applications, with particular focus on the role of the three major alloying elements: copper (Cu), iron (Fe), and magnesium (Mg). The electrochemical effects of each element are discussed in relation to the microstructural features they generate: Al_2Cu precipitates, Fe-rich intermetallics (β-Al5FeSi), and Mg2Si phases, and how these interact with the aluminum matrix. In addition to corrosion, a brief overview of the other key properties required for EV parts' mechanical performance, dimensional stability, electromagnetic compatibility, and crashworthiness is provided to highlight the multi-property design challenge facing foundry engineers and alloy developers.

***Keywords**: aluminum casting; electric vehicles; corrosion resistance; Al–Si alloys; copper; iron; magnesium; battery housing.*

1. INTRODUCTION

The global automotive industry is undergoing a fundamental transformation driven by electrification. The shift towards battery electric vehicles (BEVs) is primarily driven by increasingly stringent environmental regulations aimed at reducing CO_2 emissions and urban air pollution [1]. Cast aluminum alloys have become the material of choice for EV structural and functional components, owing to their low density, high specific strength, excellent thermal conductivity, good castability and outstanding recyclability [2,3]. A recent study commissioned by European Aluminum has confirmed that the average aluminum content per European car increased by 18% from 174 kg in 2019 to 205 kg in 2022, with projections reaching 256 kg by 2030 [4]. Much of this growth is attributable to EV-specific components such as battery pack housings, e-drive housings, cooling plates, and ballistic battery protection structures.

EV components impose requirements that are fundamentally different from those of traditional internal combustion engine (ICE) parts. The operating temperatures are lower, the designs are more tightly encapsulated, and condensation is more pronounced. These conditions significantly increase the severity of corrosion attacks [5]. For example, sealing surfaces and electrical connectors on battery housings are particularly vulnerable to corrosive degradation, which can compromise both structural integrity and electrical safety [6].

The aim of this paper is to demonstrate how the main alloying elements of aluminum alloys copper (Cu), iron (Fe), and magnesium (Mg) influence the corrosion behavior of cast Al-Si alloys used in EV applications. Understanding the electrochemical and microstructural mechanisms by which these elements operate is essential for selecting and developing corrosion-resistant alloys for next-generation electric vehicles. In addition, a brief overview of the other required properties mechanical strength, dimensional stability, electromagnetic compatibility (EMC), and crash worthiness is provided, since any viable alloy for EV use must satisfy all these requirements simultaneously.

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2. ALUMINUM ALLOYS FOR EV APPLICATIONS

Aluminum-silicon (Al–Si) cast alloys are the dominant material class for EV structural components due to their excellent casting characteristics, good mechanical performance, and balanced corrosion resistance. Among the alloys most frequently applied, AlSi7Mg (EN AC 42100), AlSi10MgMn (EN AC 43500), AlSi12(Fe) (EN AC 44300) and AlSi9Cu3(Fe) (EN AC 46200) are well established, and all, being available as standardized alloys according to DIN EN 1706, are listed in Table 1 [7]. Selection depends strongly on the component function, casting process, and required property profile.

Table 1. Overview of main Al–Si cast alloys used in EV applications (DIN EN 1706) [7]

Alloy (EN AC)	Cu content (wt. %)	Primary application	Key characteristics
AlSi7Mg (42100)	< 0.05	Battery housings, e-motor covers	Low Cu, excellent corrosion resistance, heat-treatable
AlSi10MgMn (43500)	< 0.03	Structural battery enclosures	Very low Cu, high strength, good EMC shielding
AlSi12(Fe) (44300)	< 0.10	Heat sinks, thin-walled covers	High Si, good fluidity, moderate corrosion resistance
AlSi9Cu3(Fe) (46200)	2.0–4.0	Housings, brackets (lower corrosion demand)	Higher strength, but reduced corrosion performance

Three casting processes dominate the production of EV aluminum parts: High-Pressure Die Casting (HPDC), Low-Pressure Die Casting (LPDC), and Core Package System (CPS). HPDC offers the highest production rates and dimensional precision for thin-walled complex parts; LPDC ensures high casting quality and is preferred for structural battery housings; CPS provides exceptional integrity and minimal inclusion content, making it suitable for demanding structural applications [8, 9].

3. OVERVIEW OF REQUIRED PROPERTIES FOR EV CAST PARTS

3.1. Mechanical Properties

EV structural components, while generally less geometrically complex than engine blocks or cylinder heads, must satisfy well-defined minimum mechanical properties. According to Original Equipment Manufacturer (OEM) specifications, typical requirements in the as-cast condition include yield strength (*YS*) ≥ 140 MPa, ultimate tensile strength (*UTS*) ≥ 180 MPa, and elongation at fracture (A) between 1 and 2% [5]. With the introduction of high-torque electric motors (> 1000 Nm), future requirements are expected to increase to YS > 240 MPa and A = 2–3%, creating the well-known strength-ductility trade-off challenge [10].

Mechanical properties can be improved through three main routes: selection of an appropriate casting process (which controls cooling rate and microstructure refinement), application of heat treatment (T5, T6 or T7 temper conditions), and optimized alloying with both major elements (Mg, Mn, Cu, Zn) and minor additions (Zr, Sc, Mo, La) [11, 12]. For example, T6 heat treatment of AlSi7Mg alloys has been shown to approximately double the yield strength compared to the as-cast condition, at the cost of some elongation [12]. The balance between strength and elongation is particularly critical for crash-relevant EV components where energy absorption is also required.

3.2. Dimensional Stability

Dimensional stability, defined as the resistance of cast parts to irreversible dimensional change (casting growth) during service, is a critical requirement for EV housings and covers, where tight sealing tolerances must be maintained over the vehicle's lifetime [13]. In aluminum alloys, irreversible growth is caused by the precipitation of metastable phases (*e.g.*, θ' and θ phases related to Al_2Cu and Mg_2Si) during natural or artificial aging, which is accompanied by a net volume increase of the matrix. Alloys with higher Cu and Mg content are therefore more susceptible to irreversible growth [13].

Temperature and exposure time are the dominant variables controlling casting growth. Studies have shown that at operating temperatures above 120°C, irreversible growth becomes significant even for low-Cu alloys [13]. Since most EV components, particularly battery housings, operate below this threshold, dimensional instability is primarily a concern for localized hot spots. Applying a stabilizing heat treatment (T5, T6, or T7) prior to assembly ensures that metastable phases have fully transformed and prevents further growth

during service [5, 13].

3.3. Electromagnetic Compatibility (EMC)

The EMC is the ability of a device or system to function correctly within its electromagnetic environment without causing or being affected by unacceptable interference [5]. In EVs, where high-current electronics, power inverters, and battery management systems operate in proximity, EMC is particularly critical. Failures in EMC compliance can range from minor interference (e.g., with communication systems) to safety-critical events such as unintended airbag deployment.

Aluminum is inherently well-suited for EMC shielding due to its very low magnetic permeability ($\mu_r \approx 1.000022$), which places it firmly in the paramagnetic category, in contrast to ferromagnetic iron (μ_r = 300–10,000) [5, 14]. The primary shielding mechanism in aluminum is the induction of Eddy currents at the surface, which oppose and reduce external electromagnetic fields. Copper additions to aluminum alloys enhance this shielding effect: Al_2Cu precipitates absorb electromagnetic waves, and the higher electrical conductivity of Cu increases Eddy current intensity [5, 14]. Therefore, Al–Si alloys containing copper are advantageous from an EMC perspective, creating a trade-off with corrosion requirements (see Section 4.1).

3.4. Crashworthiness

Crashworthiness is the ability of a structure to protect its occupants during an impact by plastically deforming in a controlled manner to absorb collision energy [15]. For EV battery housings and body structural castings, this requirement is particularly rigorous, as these components must deform plastically within milliseconds during a crash event without fracturing, thereby preventing battery damage and thermal runaway.

The crashworthiness of cast aluminum alloys is primarily governed by elongation at fracture (ductility) and energy absorption capacity. Silicon modification by strontium (Sr) or sodium (Na) additions transforms coarse, plate-like eutectic silicon particles with sharp edges into fine, rounded particles, significantly reducing crack initiation sites and improving fracture toughness [5, 16]. Solution heat treatment (T4 or T7 temper) is also highly effective, as it dissolves brittle intermetallic phases and promotes spheroidization of silicon particles, both of which enhance elongation. Studies on AlSi7Mg alloys have confirmed that Sr-modified, T6-treated castings achieve the best combination of strength and crash energy absorption required for EV structural components [16].

4. CORROSION BEHAVIOR OF CAST Al–Si ALLOYS IN EV CONDITIONS

4.1. General Corrosion Mechanisms

Aluminum is thermodynamically very active but exhibits outstanding corrosion resistance in most environments due to the spontaneous formation of a stable, self-healing amorphous oxide layer (Al_2O_3) 2–4 nm thick on the surface [17]. This passive film remains unbroken in the pH range of 4–9 and reforms immediately after mechanical damage in oxidizing environments [17, 18]. Outside this pH range, or in the presence of aggressive ions (particularly Cl^-), localized breakdown of the oxide film occurs, leading to pitting, intergranular, or galvanic corrosion [19]. The effects of major alloying elements on the electrochemical potential (ECP)of Al alloys are shown in Figure1 [18].

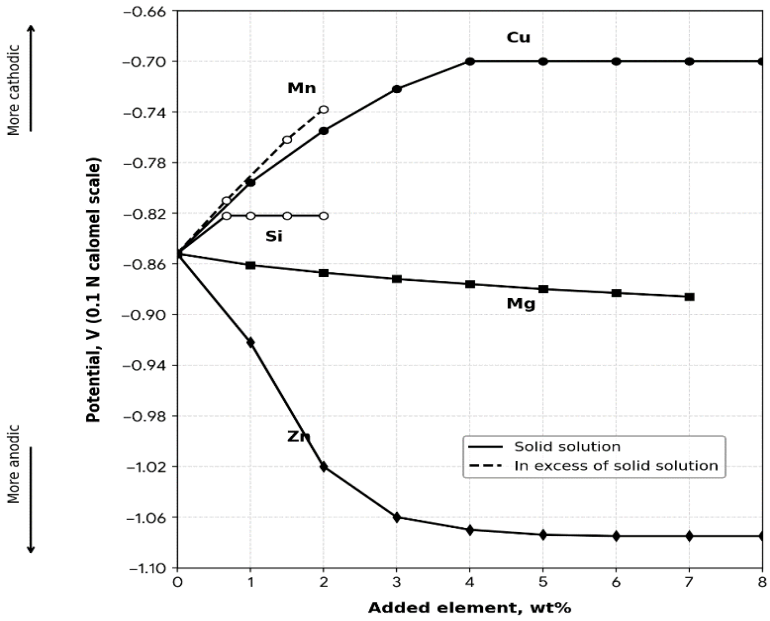

Figure 1. Effects of major alloying elements on the ECPI of Al alloys, Adapted from [18]

Figure 1 illustrates the effect of various alloying elements (Cu, Mn, Si, Mg, and Zn) and their concentrations (in weight percent, wt.%) on the ECP of aluminum, measured against a 0.1 N calomel electrode scale. The chart differentiates between elements that remain in solid solution (solid lines) and those present in excess of solid solution (dashed lines). The baseline potential of pure aluminum is located at approximately -0.85 V. The addition of alloying elements drastically shifts this potential in two opposite directions, defining the micro-galvanic relationships within the alloy's microstructure.

EV operating conditions are particularly conducive to corrosion. Lower operating temperatures increase time-of-wetness (condensation within battery housings), and encapsulated designs trap moisture and contaminants. Sealing surfaces and electrical connections are identified as the most vulnerable locations [5, 6]. Localized corrosion mechanisms dominate, driven by ECP differences between the aluminum matrix and second-phase intermetallic particles [19, 20].

4.2. Influence of Copper (Cu)

Copper is the alloying element with the most detrimental effect on the corrosion resistance of cast aluminum alloys. Even small Cu additions (> 0.1 wt.%) significantly shift the ECP of intermetallic precipitates relative to the Al matrix, creating strong galvanic couples [18, 21]. The primary mechanism is the precipitation of Al_2Cu (*θ*-phase) at grain boundaries. Since Al_2Cu is electrochemically nobler than the surrounding aluminum matrix (more cathodic), two distinct corrosion processes are activated: (i) galvanic dissolution of the Cu-depleted matrix zone adjacent to the precipitates, and (ii) intergranular corrosion propagating along the grain boundary network [6, 21].

A study by Wang et al. [21] on Al–Si–Mg–Cr alloys systematically demonstrated that increasing Cu addition from 0 to 2 wt.% progressively increased pitting susceptibility, raised the passive current density, and shifted the pitting potential to more negative values, all indicative of deteriorating corrosion resistance. In the context of EV applications, OEM specifications for battery housings and sealing critical components now explicitly require Cu < 0.05 wt.% (as in AlSi7Mg) or Cu < 0.03 wt.% (as in AlSi10MgMn) to prevent intergranular corrosion at sealing flanges and electrical connectors [5, 6].

As illustrated in Figure 2, the corrosion of this alloy is driven by microgalvanic cells formed between the grain boundary precipitates, the matrix, and the precipitation-free zone (PFZ). The PFZ, having the most negative potential, acts as a preferential anode and undergoes selective dissolution. While early aging stages initiate corrosion through anodic grain boundaries, the cooling stage of the non-isothermal aging treatment significantly improves resistance by narrowing the PFZ and ensuring a discontinuous distribution of precipitates. This microstructural refinement effectively interrupts the corrosion path, resulting in superior durability. This mechanism is especially critical for EV components where sealing integrity is paramount.

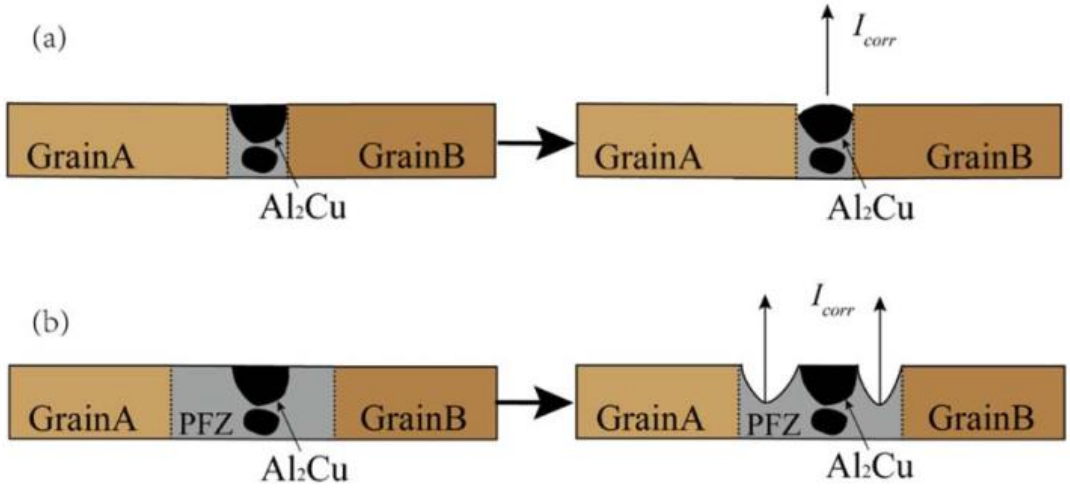

Figure 2. Schematic representation of intergranular corrosion driven by Al_2Cu grain-boundary precipitates in the PFZ of the AlSiCu alloy, Adapted from [21]

Figures 2a and 2b schematically illustrate the two primary models of IGC degradation, which correspond, respectively, to the peak-aged (T6) and overaged (T7) temperature states.In the peak-

aged T6 condition, artificial aging triggers the rapid precipitation of highly cathodic Al_2Cu phases directly along the grain boundaries. Because these intermetallic particles have a significantly higher ECP than the adjacent aluminum solid-solution matrix, they form severe micro-galvanic cells. This scenario is depicted in Figure 2a, where localized galvanic coupling generates a highly concentrated corrosion current density, I_{corr}, at the immediate boundary. Consequently, the surrounding aluminum matrix dissolves rapidly, producing narrow, deep, fissure-like intergranular cracks that significantly compromise the alloy's structural integrity and crashworthiness.Conversely, extending the heat treatment into the overaged T7 condition results in a more complex electrochemical landscape, characterized by the formation of a PFZ adjacent to the grain boundaries (Figure 2b). During overaging, solute copper atoms rapidly diffuse from the areas surrounding the grain boundaries to feed the coarsening Al_2Cu boundary particles. This diffusion leaves behind a localized, copper-depleted band (the PFZ). Since copper in solid solution significantly elevates the corrosion potential of aluminum, this Cu-depleted PFZ exhibits a much lower, more anodic potential than both the bulk grain interior and the highly noble Al_2Cu boundary phases.As a result, when exposed to a corrosive environment, the PFZ zone acts as a sacrificial anode and undergoes selective dissolution, as highlighted by the dual I_{corr} pathways in Figure 2b. Although this localized thinning creates wider corrosion trenches around the grain boundaries, it effectively distributes the galvanic attack over a broader area. This spatial distribution reduces the stress intensity factors at the crack tips, making T7-treated components considerably more resistant to continuous intergranular cracking and stress corrosion cracking (SCC) than their T6 counterparts.

4.3 Influence of Iron (Fe)

Iron is typically present as an unavoidable impurity in secondary (recycled) aluminum alloys and is one of the most common sources of localized corrosion in Al–Si foundry alloys. The primary Fe-containing phase in Al–Si alloys is *β*-Al_5FeSi, which precipitates as coarse, brittle plate-like needles (Chinese script morphology) with a strongly cathodic ECP relative to the Al matrix [22, 23]. These intermetallic particles act as preferential cathodic sites, concentrating oxygen reduction reactions and driving anodic dissolution of the adjacent aluminum matrix, thereby initiating pitting corrosion [23].

The morphology of Fe-rich intermetallics strongly governs their corrosion impact. Plate-like *β*-Al_5FeSi phases are particularly detrimental, as they provide an extended cathodic surface area and create mechanical stress concentrations that facilitate crack propagation. Mn additions (Mn/Fe ratio ≥ 0.5) are commonly used to transform the harmful needle-like *β*-phase into the less detrimental *α*-$Al_{15}(Fe,Mn)_3Si_2$ phase (Chinese script or polyhedral morphology), which is less cathodic and less geometrically aggressive [22]. For EV alloys, Fe content is typically limited to Fe < 0.15 wt% in corrosion-critical alloys such as AlSi10MgMn. Electrochemical studies have shown that the corrosion potential of *β*-Al_5FeSi (approximately −0.52 V vs. SCE) is significantly more noble than the Al matrix (approximately −0.75 V vs. SCE), establishing a potential difference of over 200 mV that drives sustained anodic dissolution under humid EV operating conditions [23, 24].

The relevance of Fe-driven corrosion is particularly pronounced in EV service conditions. The microstructure obtained by SEM/Optical microscopy, containing *α*-Fe, *β*-Fe, and *π*-Fe phases that act as cathodic corrosion initiation sites in Al–Si alloy, is presented in Figure 3 [25].

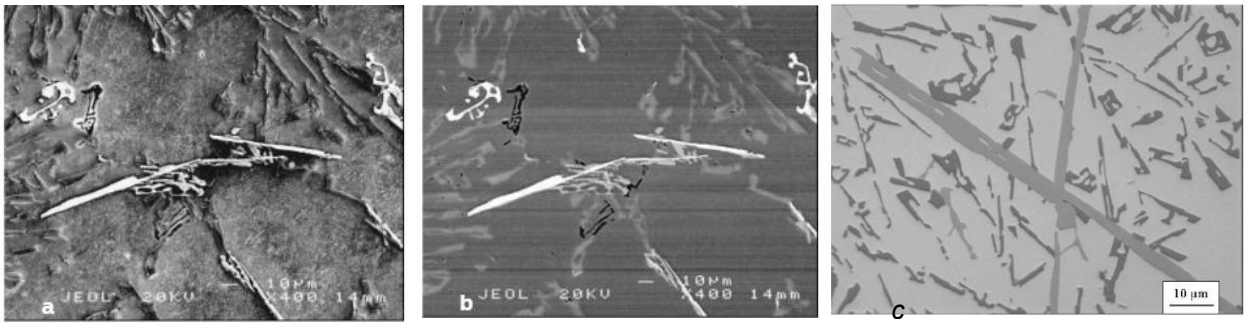

Figure 3. SEM/Optical microstructure showing α-Fe, β-Fe and π-Fe phasesacting as cathodic corrosion initiation sites in Al–Si alloy [25]

Unlike combustion engine components that operate at elevated temperatures where the

electrolyte evaporates rapidly, EV battery housings and e-motor covers are exposed to persistent moisture due to lower operating temperatures and encapsulated designs that promote condensation [5, 6]. Under these conditions, the time-of-wetness, a critical parameter governing the corrosion rate, is significantly extended, allowing the micro-galvanic cells formed between *β*-Al_5FeSi particles and the surrounding matrix to remain active for longer. Furthermore, the increasing use of secondary (recycled) aluminum in EV production, driven by sustainability targets, introduces higher, less controlled Fe levels than in primary alloys, making Fe management a growing practical concern for EV foundries [22, 26].

4.4. Influence of Magnesium (Mg)

Magnesium,compared to Cu and Fe,plays a dual, more complex role in the corrosion behavior of cast Al–Si alloys. On one hand, Mg is essential for precipitation hardening: dissolved Mg combines with Si to form Mg_2Si precipitates (*β*'' and *β*' phases) upon aging, which are the primary strengthening mechanism in AlSi7Mg and AlSi10MgMn alloys [11, 27]. On the other hand, the ECP of Mg_2Si (approximately −1.54 V vs. SCE) is more negative (anodic) than the aluminum matrix, meaning these precipitates dissolve preferentially, acting as anodic corrosion sites [18, 28].

The net corrosion effect of Mg depends strongly on its concentration and heat treatment state. At low Mg concentrations (0.2–0.45 wt%, as in AlSi7Mg), Mg primarily remains dissolved in the matrix and in fine β'' precipitates that are too small to establish significant galvanic coupling. At higher concentrations or after prolonged aging, coarser *β*-Mg_2Si particles form at grain boundaries, increasing susceptibility to intergranular corrosion [27, 28]. Jegdić et al. [28] demonstrated that the temper condition (e.g., T4, T6, T7) has a profound effect on pit initiation and growth kinetics in Al–Mg alloy systems, confirming that proper heat treatment is a key lever for optimizing the corrosion strength balance. Over-aging (T7) reduces the Mg_2Si at grain boundaries and improves corrosion resistance at some cost to strength [12, 28]. While Cu presents the most critical corrosion risk in EV alloys, Fe and Mg require careful compositional and process control to ensure adequate performance under EV-specific service conditions.

A summary of the influence of the main alloying elements, *i.e.,* Cu, Fe, and Mg, on corrosion mechanisms in cast Al-Si alloys for EV applications is presented in Table 2.

Table 2. Summary of the influence of Cu, Fe and Mg on corrosion mechanisms in cast Al-Si alloys for EV applications

Element	Phase formed	Electrochemical role	Corrosion mechanism	Effect on EV alloy
Cu	Al_2Cu (*θ*-phase)	Cathodic (nobler)	Intergranular, pitting, galvanic	Strongly detrimental; restrict Cu < 0.05%
Fe	*β*-Al_5FeSi	Cathodic	Pitting (initiation at needles)	Detrimental; Mn additions neutralize effect
Mg	Mg_2Si (*β*'', *β*')	Anodic (less noble)	Anodic dissolution, intergranular	Dual role; control via heat treatment (T6/T7)

4.4. Influence of Heat Treatment and Temper Conditions (T4, T5, T6, and T7)

To satisfy the demanding multi-property requirements of the EV components, cast Al–Si alloys are rarely used in the as-cast (F) condition. Instead, they are subjected to specific heat treatments—most notably T4, T5, T6, or T7 tempers—which fundamentally alter the morphology of the eutectic silicon, dissolve harmful intermetallics, and trigger the precipitation of strengthening phases like Mg_2Si or *θ*'/*θ*'' (Al_2Cu). However, these microstructural changes simultaneously modify the electrochemical landscape of the matrix, creating a complex trade-off between mechanical performance and corrosion susceptibility.

*T4 Temper (Solution Heat-Treated and Naturally Aged).*The T4 treatment involves high-temperature solution heat treatment followed by quenching and natural aging. This process spheroidizes the eutectic Si particles, thereby reducing local stress concentrations and improving ductility and crashworthiness. From a corrosion standpoint, solutionization homogenizes the matrix by dissolving Mg_2Si and Al2Cu phases back into the solid solution. This reduces the number of localized galvanic couples, generally enhancing the alloy's resistance to pitting and intergranular corrosion (IGC). However, the mechanical strength remains lower than that of artificially aged tempers.

*T6 Temper (Solution Heat Treated and Artificially Aged).*The T6 temper is the most widely applied treatment when maximum mechanical strength is required for structural EV parts. Following solutionization and quenching, artificial aging is performed at elevated temperatures (typically 150–180 °C) to promote the uniform, dense precipitation of coherent β'' (Mg_2Si) or θ'' (Al_2Cu) transition phases. While T6 maximizes yield strength, it often compromises corrosion resistance. The nanoscale precipitates can act as micro-cathodes or micro-anodes relative to the adjacent aluminum matrix. Specifically, in Cu-containing alloys (AlSi9Cu3), the precipitation of Al_2Cu depletes the surrounding matrix of copper, forming a Cu-depleted zone along grain boundaries that is highly susceptible to severe intergranular attack.

T7 Temper (Solution Heat Treated and Overaged). To mitigate the corrosion risks associated with the peak-aged T6 condition, a T7overaging treatment is frequently employed, particularly for safety-critical structural EV housings. Artificial aging in T7 is conducted at higher temperatures or for longer durations than T6. This induces the growth and coarsening of the strengthening precipitates, transforming them into incoherent, stable phases (β-Mg_2Si or θ-Al_2Cu). Although overaging leads to a slight reduction in mechanical strength (a 10–15 % drop compared to T6), it significantly stabilizes the microstructure. The coarsened, widely spaced precipitates disrupt the continuous networks along grain boundaries, thereby dramatically improving the alloy's dimensional stability and resistance to SCC and IGC.

*T5 Temper (Artificially Aged Only).*Unlike the previous tempers, the T5 treatment bypasses the high-temperature solution heat treatment. The cast components are cooled rapidly directly from the mold and then artificially aged. This temper is highly cost-effective and energy-efficient, making it attractive for large-scale EV foundry operations. It provides a moderate increase in hardness and excellent dimensional stability by relieving residual casting stresses. However, because the coarse, as-cast Fe-rich intermetallics (β-Al_5FeSi) and eutectic Si networks remain unaltered, T5-treated alloys typically exhibit lower crashworthiness and exhibit localized galvanic corrosion profiles very similar to those observed in the as-cast condition.

This structural evolution is consistent with the microstructural features presented in Figure 2.

5. DISCUSSION

The properties reviewed in the preceding sections collectively define the design space for cast aluminum alloys in EV applications. As schematically summarized in Fig. 4, many of these properties impose conflicting requirements on alloy composition, particularly regarding copper and magnesium content.

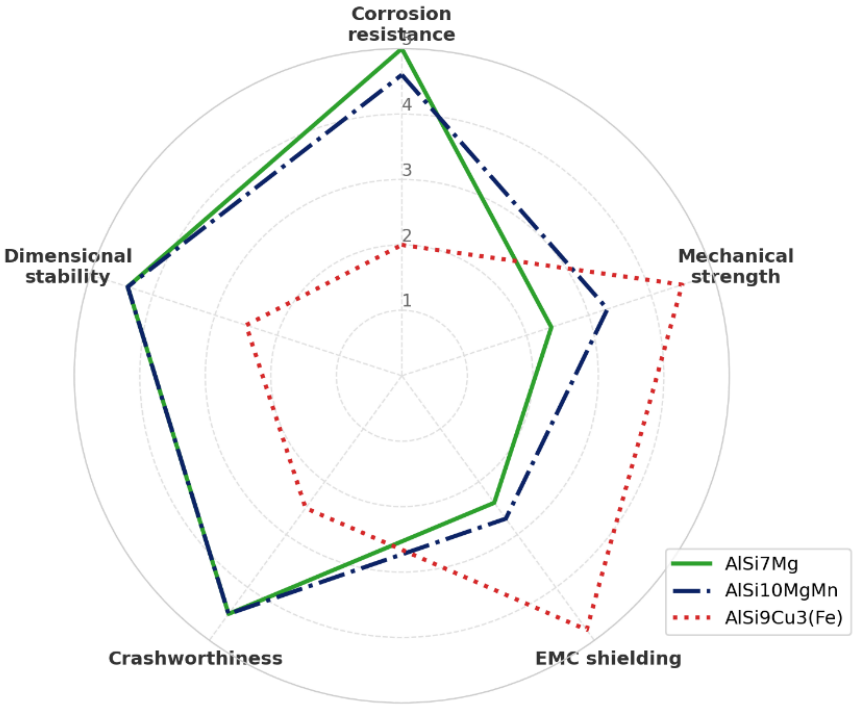

Figure 4. Schematic multi-property comparison of principal cast Al-Si alloys for EV applications. Scale: 1 (poor) – 5 (excellent); relative scores based on literature data, T6/T7 temper conditions assumed

Copper exemplifies this conflict most sharply. From an EMC perspective, Cu additions enhance electromagnetic shielding by increasing eddy current intensity and Al_2Cu-mediated wave absorption [5, 14]. From a mechanical properties standpoint, Cu contributes to precipitation hardening and solid-solution strengthening. However, from a corrosion standpoint, Cu is highly detrimental, promoting intergranular attack on sealing surfaces and electrical connections [6, 21]. The EV industry has largely resolved this conflict by spatial alloy differentiation: high-Cu alloys (e.g., AlSi9Cu3) are accepted for structural brackets and components with lower corrosion exposure, while Cu-free or low-Cu alloys (AlSi7Mg, AlSi10MgMn) are mandated for battery housings and moisture-exposed sealing surfaces [5, 6].

Magnesium presents a more manageable trade-off. The strength benefit of Mg (via Mg_2Si precipitation hardening) can be retained while minimizing corrosion susceptibility by keeping the Mg content within the range of 0.25–0.45 wt.% and applying T6 or T7 heat treatment to control grain-boundary precipitate coarsening [11, 27, 28]. Iron mitigation is best addressed through alloy design (limiting Fe to < 0.15 wt.%) and process control (Mn additions and rapid solidification via optimized die-casting parameters) [22].

As illustrated in Fig. 4, the three alloys exhibit markedly different property profiles as a function of their copper content. AlSi7Mg (green, solid line) and AlSi10MgMn (blue, dashed line) show nearly identical and well-balanced profiles, with maximum scores for corrosion resistance (5/5) and good performance in crashworthiness and dimensional stability (4/5). Their mechanical strength and EMC shielding are moderate (3/5), reflecting the absence of copper. AlSi9Cu3(Fe) (red, dotted line), by contrast, achieves the highest scores for mechanical strength and EMC shielding (5/5), driven by the strengthening and Eddy-current effects of Al_2Cu precipitates, but at the cost of significantly reduced corrosion resistance (2/5) and slightly lower scores for crashworthiness and dimensional stability (3/5). This divergence in property profiles confirms that no single alloy is optimal across all criteria, and that component-specific alloy selection low-Cu grades for corrosion-critical battery housings and Cu-containing grades for structural brackets with limited moisture exposure remains the most practical engineering strategy for EV aluminum casting applications.

6. CONCLUSIONS

The following conclusions can be drawn from this paper:

- Copper is the most detrimental alloying element for corrosion resistance in EV cast aluminum components. Al_2Cu precipitates at grain boundaries promote intergranular corrosion, particularly on sealing surfaces and near electrical connections. For corrosion-critical EV parts, Cu content must be restricted to below 0.05 wt.%.
- Iron promotes pitting corrosion through the formation of cathodic *β*-Al_5FeSi intermetallics. Manganese additions (Mn/Fe ≥ 0.5) effectively transform needle-like *β*-phases into less harmful *α*-phases, thereby reducing sensitivity to corrosion initiation.
- Magnesium has a dual role: it provides essential strength through Mg_2Si precipitation hardening but can promote intergranular corrosion at grain boundaries when present in excess or after insufficient heat treatment. Optimized Mg content (0.25–0.45 wt.%) combined with T6/T7 heat treatment provides the best corrosion strength balance.
- Beyond corrosion, EV cast parts must simultaneously satisfy mechanical strength targets (*YS* ≥ 140–240 MPa), dimensional stability (irreversible casting growth < threshold), electromagnetic compatibility (adequate Eddy current shielding), and crashworthiness (sufficient elongation and energy absorption). These requirements interact and impose conflicting constraints on alloy composition.
- Low-Cu Al–Si–Mg alloys (AlSi7Mg, AlSi10MgMn) represent the optimal materialchoice for corrosion-critical EV applications such as battery housings, while copper-containing alloys remain applicable for structural components where corrosion exposure is limited.

Acknowledgements

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7. REFERENCES

[1] A. Grauers, S. Sarasini, M. Karlström(2013) Why Electromobility and What Is It? Systems Perspectives on Electromobility, Chalmers University of Technology.

[2] F. Czerwinski (2021) Current Trends in Automotive Lightweighting Strategies and Materials, Materials 14(21), 6631. https://doi.org/10.3390/ma14216631

[3] R. Michi, A. Plotkowski, A. Shyam, R. Dehoff, S. Babu(2022) Towards high-temperature applications of aluminum alloys enabled by additive manufacturing, International Materials Reviews, 67(3), 298–345. https://doi.org/10.1080/09506608.2021.1951580

[4] European Aluminium / Ducker Carlisle. (2022) European Aluminium Vehicle Benchmark Study https://www.european-aluminium.eu

[5] M.B.Djurdjevic, S. Manasijevic. M. Mihailović, S. Stopic (2023)From bauxite as critical material to required properties of cast aluminum alloys for electro automotive parts, Metals 13(11), 1796. https://doi.org/10.3390/met13111796

[6] M.B.Djurdjevic, F.J. Feikus, R. Fernandez Gutierrez (2019) Properties of cast aluminum alloys suitable for production of E-mobility components. MMSEE, Belgrade,Serbia, Proceedings p.9.

[7] DIN EN 1706:2020 – Aluminum and aluminum alloys – Castings – Chemical composition and mechanical properties.

[8] M.R. Jolly Castings (2003) Comprehensive Structural Integrity, Elsevier Pergamon, Oxford.

[9] J.G. Kaufman,E.L.Rooy (2004) Aluminum Alloy Castings – Properties, Processes and Applications. AFS, Schaumburg.

[10] Dang B. et al. (2016) Breaking through the strength-ductility trade-off dilemma in Al–Si based casting alloy, Scientific Reports, 6, 30874. https://doi.org/10.1038/srep30874

[11] C.H. Caceres, C.J. Davidson, J.R. Griffiths, Q.G. Wang (1999) The Effect of Mg on the Microstructure and Mechanical Behavior of Al-Si-Mg Casting Alloys, Metallurgical and Materials Transactions A, 30A, 2611–2618. https://doi.org/10.1007/s11661-999-0301-8

[12] Rheinfelden Alloys. Primary Aluminum Alloys for Pressure Die Casting. Technical brochure, Rheinfelden Alloys GmbH & Co. KG.

[13] Rohr A. (2012) Dauerfestig keitserhöhung und Reduktion des irreversiblen Gusswachstums bei Aluminium sandgusslegier ungen. PhD Thesis, Technische Universität Berlin.

[14] Ott S., Baumgartner H. (2018) Elektromagnetische Verträglichkeit von Aluminium gehäusenim Fahrzeugbereich. Giesserei, 105(4), 42–49.

[15] N. Jones,T. Wierzbicki (1993) Structural Crashworthiness and Failure, Elsevier Applied Science, London, ISBN 1-85166-969-8

[16] Y. Li, A. Hu, Y. Fu, S. Liu, W. Shen, H. Hu, X. Nie (2022) Al Alloys and Casting Processes for Induction Motor Applications in Battery-Powered Electric Vehicles: A Review. Metals, 12(2), 216. https://doi.org/10.3390/met12020216

[17] M.H. Jacobs (1999) Corrosion and Corrosion Protection, TALAT Lecture 1252, University of Birmingham / European Aluminium Association.

[18] Davis J.R. (2001) Alloying: Understanding the Basics. ASM International, pp. 351–416.

[19] A. Davoodi (2007) Mechanistic studies of localized corrosion of Al alloys by high resolution in situ and ex-situ probing techniques. PhD Thesis, KTH Stockholm, Sweden.

[20] F.C. Campbell (2008) Elements of Metallurgy and Engineering Alloys. ASM International, pp. 502–508.

[21] H. Wang, B. Jiang. Y. Danqing, B. Wang, H. Liu, Ch. Wu, F. Shen (2020) Microstructure, corrosion behavior and mechanical properties of a non-isothermal aging treated cast Al–4.5Cu–3.5Zn–0.5Mg alloy. Mater. Res. Express 7, 016547, https://iopscience.iop.org/article/10.1088/2053-1591/ab638a/pdf.

[22] M. Warmuzek(2004) Aluminum-Silicon Casting Alloys: Atlas of Microfractographs, ASM International.

[23] Revie R.W. (2000) Uhlig's Corrosion Handbook, Chapter 40, 2nd Edition. Wiley. ISBN 0-471-78494-4.

[24] Z. Szklarska-Smialowska(2005) Pitting and Crevice Corrosion.NACE International, Houston, 2005. ISBN 1-57590-185-X.

[25] M. Mahta, M. Emamy, X. Cao and J. Campbell (2007) Overview of beta-Al5FeSi phase in Al-Si alloys, Materials Science Research Trends, Editor: Lawrence V. Olivante, Nova Science Publishers, Inc, pp. 1-16. ISBN: 978-1-60021-654-1

[26] D. Paraskevas, K.Kellens, W. Dewulf, J.R. Duflou(2016) Environmental impact analysis of primary and secondary aluminum production. *Procedia CIRP*, 40, 209–213. https://doi.org/10.1016/j.procir.2016.01.104

[27] T.Pabel,G. F. Geier , H. Rockenschaub, M. Hopfinger(2007) Improved mechanical properties of the HPDC alloy AlSi9Cu3(Fe)(Zn) as a result of the combination of natural and artificial ageing, International Journal of Materials Research, 516–520.https://doi.org/10.3139/146.101504

[28] B. Jegdić, B. Bobić, M. Stevanović, M. Mihailović, D. Daničić, J. Kovačina, B.Radojković (2022) Resistance to pit formation and pit growth for different tempers of AA2024aluminium alloy in presence of benzotriazole, Metals and Materials International, 26(11), 1643–1653. https://doi.org/10.1007/s12540-019-00451-8.

IZVOD

KOROZIJSKO PONAŠANJE LIVENIH ALUMINIJUMSKIH LEGURA ZA PRIMENU U ELEKTRIČNIM VOZILIMA: UTICAJ LEGIRAJUĆIH ELEMENATA Cu, Fe I Mg

Brzi rast proizvodnje električnih vozila (EV) doveo je do povećane potražnje za livenim aluminijumskim legurama sa unapređenom otpornošću na koroziju. Za razliku od komponenti motora sa unutrašnjim sagorevanjem, delovi u EV sistemima, kao što su kućišta baterija, kućišta elektromotora i poklopci statora, rade na nižim temperaturama, u zatvorenim uslovima i uz povećanu izloženost kondenzaciji, što značajno intenzivira korozione procese.U ovom radu dat je pregled korozionog ponašanja livenih Al–Si legura primenjenih u električnim vozilima, sa posebnim osvrtom na ulogu tri glavna legirajuća elementa: bakra (Cu), gvožđa (Fe) i magnezijuma (Mg). Elektrohemijski efekti svakog od ovih elemenata razmatraju se u odnosu na mikrostrukturne karakteristike koje oni generišu - precipitata Al_2Cu, Fe-bogatih intermetalnih faza (β-Al_5FeSi) i Mg_2Si faza - kao i njihov međusobni odnos sa aluminijumskom matricom.Pored korozionih svojstava, dat je i kratak pregled drugih ključnih karakteristika neophodnih za primenu u EV komponentama, uključujući mehanička svojstva, dimenzionu stabilnost, elektromagnetnu kompatibilnost i otpornost na sudar, kako bi se ukazalo na složenost problematike sa kojom se suočavaju inženjeri u livnicama prilikom razvijanja novih legura, uz poštovanje više kriterijuma.

Ključne reči: *Livenje aluminijuma; električna vozila; otpornost na koroziju; legure Al-Si; bakar; gvožđe; magnezijum; kućište baterije.*

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