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Review of Aluminium Lithium Alloy Manufacturing Procedures, Mechanical Characteristics and Precipitations for Usage in Aerospace Applications

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Abstract

Military applications and the aeronautic industry are increasingly interested in aluminum lithium alloys (Al–Li) because of the properties required due to the presence of Lithium, which provides a very considerable gain concerning the mechanical properties compared to conventional aluminum alloys. The research and development departments are interested in improving these alloys especially in additive manufacturing process, which leads today to focus on the 3rd generation of Al–Li in terms of part quality - low density compared to the 1st and the 2nd generation. The objectives of this paper is to present a review of Al–Li alloys applications, its carachetrization, the precipitations and their impact on mechanical properties and grain refinement. The various manufacturing processes, methods and tests used are then deeply investigated and presented. The last investigations that have been gotten by scientists over the previous few years on Al–Li for different processes are also reviewed in this research.

Keywords: Formability • Mechanical properties • Manufacturing processes

Introduction

Aluminum lithium alloys (Al–Li) are gaining popularity for use in military applications and the aerospace industry due to the properties required by the presence of lithium, which provides a significant improvement in mechanical properties over conventional aluminum alloys. The departments of research and development are interested in making these alloys better, especially for the additive manufacturing process. As a result, the current focus is on the third generation of Al–Li because of its lower part quality than the first and second generations. This paper aims to provide an overview of the applications of Al–Li alloys, their carachetrization, precipitations, and the effects they have on mechanical properties and grain refinement. The various manufacturing procedures, approaches, and tests are then presented after thorough examination. This study also reviews the most recent Al–Li research conducted by scientists over the past few years on a variety of processes [1].

Literature Review

After the first utilization of the first generation of Al–Li alloys (2020 in 1958's developed by alcoa) with so many advantages like: high creep resistance between 150°C and 200°C, and high strength, however, this alloy had a poor ductility, which aimed to develop the 1420 with low density, good weldability and stiffness. The 1421 alloy was also made with higher values of yield stress and ultimate strength, but the main defect of these alloys is the poor toughness caused by shearing of Al3Li which considered as the most strengthening phase. The 2nd generation Al–Li alloys is created for aerospace and aircraft applications with the objective of reducing density (for 8%–10%) compared to traditional al alloys, and stiffness improvement. Therefore, a main challenge was to develop materials with enhancements in both mechanical properties and life cycle that can be used in the construction of wings and fuselage [2].

Accordingly, in the 1970's and 1980's. The majority of prior research has focused on the optimization of Silicon and Iron contents that have the primary effect on ductility and toughness, the same for Manganese that was replaced zirconium to produce Al3Zr precipitates for ductility, toughness, and grain refinement. The increase in the percentage of lithium can generate an increase in size and volume fraction of δ' which is responsible on strengthening and was the reason for increasing lithium percentage in the second generation of Al–Li-X alloys, but this higher % addition of lithium cased several advantages that limited their usage like fracture toughness, corrosion, anisotropic and fatigue [3].

The defects faced in the 1st of 2nd generations have been reduced in the 3rd generation of Al–Li alloys. Reducing inspection and maintenance, weight savings, and performance are the main reasons for the development of this generation were tailored to cover the requirements of aeronautic and military industry. The image below shows an example of the application of Al–Li alloys in the aircraft manufacturing. Lower amounts of Lithium (<2%) and an important Cu/Li ratio compared to the 2nd generation alloys. It was noted that decreasing lithium amounts can positively influence the thermal stability and toughness of aluminum lithium alloys [4].

The sheet metal forming is widely used in the aeronautic industry for manufacturing aircraft parts such as leading, trailing edges, access covers, and wing skin etc. Deep drawing process consists of manufacturing, from a thin flat blank, a part of complex shape that is generally non-developable. The blank being pressed, with a certain force against the die, by the punch force using a press, and the flange is clamped the blank holder. In this part, the different studies on the lithium aluminum alloy for the stamping process will be investigated, as well as the various parameters (geometrical and process) which influence the formability from a numerical and experimental perspective [5].

The specialized term for remote correspondence advancements to send information among airplane and ground is "computerized aeronautical information connecting?" One regularly separates among earthbound and spacebased frameworks, which are intended for various flight spaces. Earthbound frameworks are utilized for short-or long-range mainland correspondence in the Airport (APT), Terminal Maneuvering Area (TMA), or En-Route (ENR) area, while space-based frameworks cover the Oceanic Remote Polar (ORP) area give an outline [6].

Final grain size control is the main influencing factor to enhance mechanical properties for aluminum alloys in general. Grain refinement of the third generation Al–Li alloys has been investigated by so many researchers. Xinxiang et al. have worked on the effect of Cerium and Zirconium microalloying addition in Al–Cu–Li alloys, they proved that the intermetallic dispersoids can be refined by Ce

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addition after homogenization, grain refinement can be obtained also by four methods: Severe Plastic Deformation (SPD), the addition of Grain Refiner (GR), Rapid Solidification (RS), Vibration and Stirring (VS) during solidification. The presence of Zr on Al–Li alloys can control grain structure during high temperature by promoting Al3Zr_Al3Li dispersoids, which minimize the planar slip and improve ductility [7].

For the 2099 alloys, the dendritic structures can disappear after two-step of homogenization treatment with a degreasing of segregation at the grain boundaries with residual AlCuFeMn/AlCuMn particles around it. Concluded that for the 2195 Al–Li alloy, the grain size increases with annealing at a lower temperature (300–350°C), and increase when the annealing temperature rose (350–400°C) as well as the deformation texture. Suresh et al. in the investigation on effect of Sc addition on the evolution on the texture of AA2195 alloys during thermo-mechanical processing, they concluded that the Sc addition reduce the grain size and enhanced precipitation kinetics with hardness and strength improvement as well as the presence of fine Al3(Sc,Zr) dispersoids [8].

Discussion

Several parameters can influence the anisotropy of Al–Li alloys such as crystallographic texture, shearing of the Al_3Li phases and the subsequent flow localization orientation relative to the current stress states, recrystallization degree, type and history of the deformation process before artificial ageing, the distribution and morphology of the main strengthening phases, which are governed by alloying additions . Al–Li alloys presents high anisotropy than traditional Al alloys, and its due to the coherent ordered δ′ phase (up to 20%). For the 1445 Al–Li alloy sheet; the non-recrystallization is caused by Al_3(Sc,Zr) nano-sized that can be coarsened when being solutionized of 575°C and pin the grain boundaries, dislocations and subgrain boundaries while the main recrystallization model is subgrain coalescence and increase. Controlling sheet metal's anisotropy can improve its formability and plastic anisotropy. For 2195 Al–Li alloy cold-rolling sheet, the investigation for the anisotropy during aging treatment shows that the anisotropy decrease during aging time as long as over-aging is not reached [9].

During the sheet metal forming of Al–Li alloys anisotropy affect the final formed shape. Bouchaâla et al. investigated the effect of anisotropic and isotropic yield functions of AA2090 Al–Li alloy on the thickness distribution during sheet metal forming process. Many phenomenological yield functions have been proposed to predict the anisotropic plastic behavior of the sheet metal forming. Bouchaâla et al. studied the influence of contact surface between the blank and the tools (Punch force, die shoulder radius, Blank holder force, Friction), two aluminum lithium alloys were used AA 2090 and AA2198, for this studies; a combination between FEM and Tagushi optimization was carried out [10].

Conclusion

This paper aimed to review and summarize studies for Al–Li alloys, especially on the different types of precipitations, the influence of the addition elements and their impact on the microstructure and mechanical properties. The mechanical properties of Al–Li alloys are dramatically affected by the precipitates in their microstructures. The phase structures (T1 phase) control is the key influencing factor to enhance mechanical properties for the third generation of aluminum lithium alloys. Final grain size control and the control of the different types of precipitations are the main influencing factor to enhance mechanical properties for aluminum alloys in general. Research and development priorities have been discussed in the literature.

Acknowledgement

None.

Conflict of Interest

None.

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