

Aluminum-Lithium Light Weight Frangible Collar Development

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ABSTRACT

Light weight aerospace fastening collars were manufactured from 2099 alloy which is a new generation Al-Li alloy developed by Alcoa. The collars studied in this work are threaded self-locking collars with controlled torque-off feature and are to be used in a fastener assembly with a treated pin. The mechanical properties of 2099 collars were measured and compared to the ones made of incumbent alloys such as 7075 and 2024. It was found that the 2099 collars were 16% lighter but provided the equivalent mechanical properties.

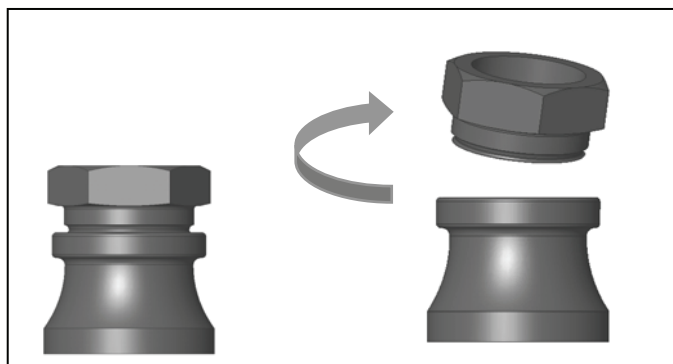
In addition, the corrosion characteristics of the 2099 collars were studied using the salt spray and alternate immersion test methods. It was observed that 2099 collars exhibited an improved corrosion performance as compared to the base line 7075 collars. This paper presents the results obtained from the mechanical and corrosion testing of the Al-Li collars along with the weight saving potentials of the new product.

INTRODUCTION

Aluminum-lithium alloys were developed primarily to reduce the weight of aircraft and aerospace structures. Additions of lithium to aluminum are made not only to lower the density but also to increase the strength of the alloys. Each 1% of lithium added to aluminum reduces alloy density by about 3% and increases modulus by about 5%. Although lithium has a solubility limit of 4.2% in aluminum, the amount of lithium ranges between 1 and 3% in commercial alloys [1]. Aluminum-lithium alloys are most often selected for aerospace components because of their low density, high strength, and high specific modulus. However, other applications now exploit their excellent fatigue crack growth resistance and high fracture toughness [2-4]. AA 2099 is the third generation Al-Li alloy developed by Alcoa. It is based on Al-Li-Cu-Mg-Zn-Zr systems and heat treatable alloy with improved strength and superior corrosion resistance [5-8]. It has been approved by Aerospace Material Standards, AMS 4287, [9]. This alloy has a low density

(0.095 lbs/in³ or 2.64 g/cm³), higher mechanical strength, improved resistance to corrosion and Stress corrosion cracking (SCC), higher fracture toughness and longer fatigue life [10] than the conventional aluminum alloys and could replace 6061, 2024 and 7075 alloys in statically and dynamically loaded aerospace structures [5].

The main objective of the research was to assess the suitability of 2099 alloy for aerospace fastener applications. In present study, frangible collars were fabricated using 2099-T83 alloy and their performances were evaluated. Frangible collars were selected for initial screening since they are the most common female threaded fasteners used in fuselage construction. They are self-locking type collars with controlled torque-off feature such as a wrenchable hex section designed to separate at predetermined torque as shown in Figure 1. This design feature prevents over-torquing and eliminates the need for torque inspection during installation.



Aluminum frangible collars are currently made of 2024-T6 and 7075-T73 material. In this work, the light weight 2099 collars were developed with an attempt to replace the current collar alloys. The mechanical properties of 2099 collars were measured and compared to the ones made of incumbent alloys. In addition, the corrosion characteristics of the 2099 collars were investigated using the salt spray and alternate immersion test methods.

II. Experimental Procedure

2.1 Material

Table I: Chemical composition of the as received 2099

Elements (Wt. %)	Si	Fe	Cu	Mn	Mg	Zn	Ti	Zr	Li
2099 as-received	0.02	0.03	2.75	0.31	0.29	0.72	0.023	0.10	1.80
AMS 4287	0.05 max	0.07 max	2.4-3.0	0.1-0.5	0.1-0.5	0.4-1.0	0.10 max	0.05-0.12	1.6-2.0

Commercial 2099 extrude bars were supplied by Alcoa. The chemical composition of the received alloy is given in Table I. Composition of the bars were found to be within the designated AMS 4287 range [9].

The microstructures of the extruded bars were characterized using an optical microscope. The metallographic specimens were section parallel to the extrusion direction. These samples were etched with standard Keller's reagent to reveal the grains and other microstructure details. The as-received material was artificially aged to increase the strength of the material and to achieve T83 final temper condition. Tensile specimens were then cut parallel to the longitudinal axis of the extruded bars with a gage length of 2 inches and the room temperature tensile properties of these specimens were determined in accordance with ASTM E8 using a universal servo-hydraulic test systems operating at a constant cross head speed.

The -8D size (0.25 inch) frangible collars with 0.2500-28 UNJF-3A internal threads were fabricated using a standard CNC machining. After cleaning operation the machined collars were anodized per Mil-A-8655 Type II (Sulfuric anodize) and class II (colored) specification. Finally the collars were lubricated using cetyl alcohol. In order to prevent the collars to loosen after installation a locking feature was created by a crimping process which slightly deformed the upper threaded portion of the collar in two or more locations causing the collar to be locally non-circular.

Finished collars were subjected to various tests listed in Table II in accordance with NASM 1312 fastener test specifications [11]. 7075 and 2024 collars were also tested simultaneously to establish the base line for comparison.

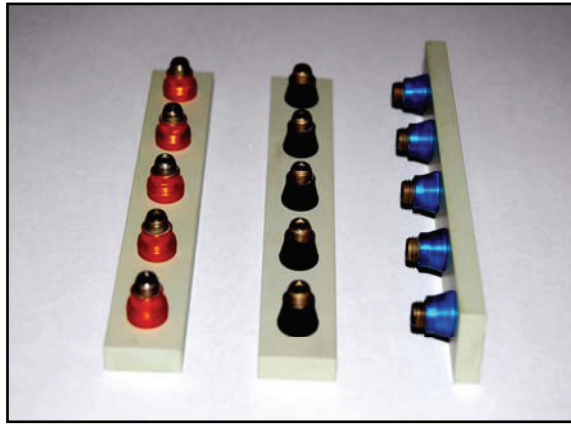
Table II: Collar testing matrix

Test method	Engineering requirement
Torque-Tension	Fastener does not yield or fracture, threads do not strip
Break-away Torque	3.5 inch-lbs minimum
Locking Torque	17 inch-lbs maximum
Torque off	60-80 inch-lbs
Pre-load	1500 lbs minimum
Ultimate Tension	3000 lbs minimum
Salt Spray	1000 hours
Stress Corrosion Cracking	60 days

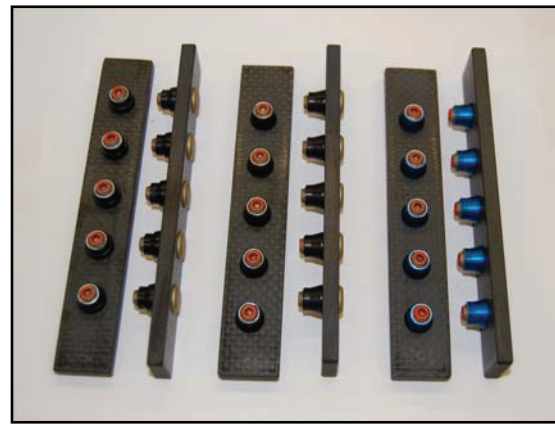
8 pieces of each alloy type collars were tested for break-away, locking torque and torque-off using a hand-held torque wrench and the torque values were recorded using a torque transducer. Pre-load and ultimate tensions testing of the collars were performed using a universal tension test unit per NASM 1312-16 and NASM 1312-8 [11], respectively. All the collar test installations were done without sealant on TB12-8 alloy steel bolts which were lower 1/3 pitch, cadmium plated and cetyl alcohol lubricated.

2.2 Salt Spray Corrosion Testing

Five replicate samples of both 2099 and 7075 collars were exposed to a continuous Salt Spray exposure, per NASM 1312-1 [11]. This is a continuous exposure to a spray/fog of 5 weight % NaCl in deionized water, at a temperature of 95°F ± 2°F. The fasteners were installed on titanium (Ti-6Al-4V) pins using two different plate materials – namely an aluminum alloy 2024-T3 and carbon fiber reinforced plastic (CFRP) plates. The exposure period was 1000 hours and 500 hours, respectively. The aluminum plates were anodized and epoxy coated whereas the CFRP plates were sanded with 240 grit sand paper to expose the graphite fibers. No sealant or any insulating material was used between the collars and the base plates. Figure 2 illustrates the salt spray samples.



a) 2024-T3 plates



b) CFRP plates

Figure 2: Corrosion test samples.

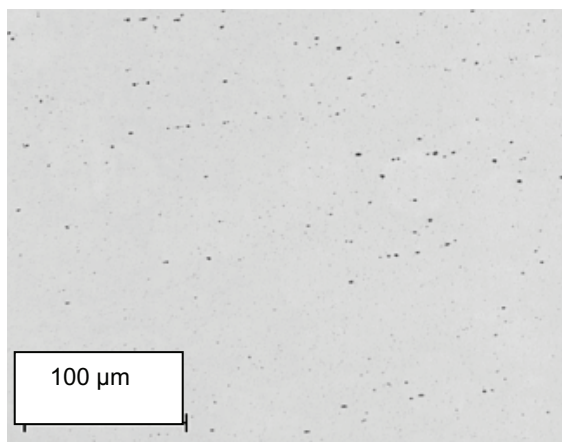
2.3 Stress Corrosion Cracking Testing

SCC testing was performed on 2099-T8 and 7075-T73 collars per the method described in National Aerospace Standard NASM1312-9 [11]. In this test, five replicate collars made from each collar alloys were threaded onto Ti-6Al-4V pins and tightened to a torque of about 70 inch-pounds in order to apply a set level of stress. Similar to the salt spray tests, anodized 2024-T3 and sanded CFRP plates were used for the base plate materials. The stressed specimens were then exposed to an alternate immersion exposure to 3.5 weight % NaCl in deionized water. The alternate immersion cycle was consists of a 10-minute immersion, followed by a 50-minute drying period. This 1-hour cycle is repeated continuously for a total of 60 days which is considered a severe exposure period. The specimens were examined for visual evidence of cracks on a weekly period. At the end of 60 days collars were removed and cleaned using an ultrasonic cleaner. In addition, several metallographic samples were prepared from the worst attacked regions.

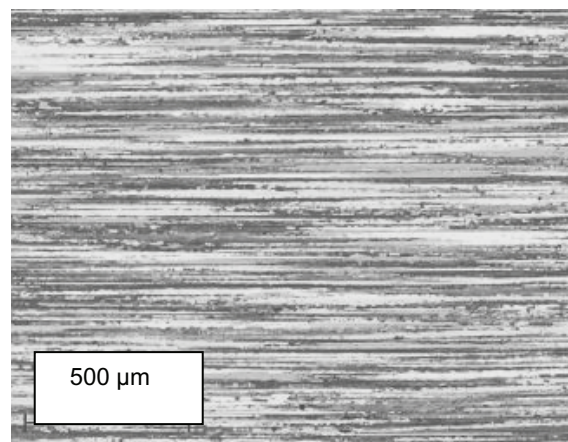
III. Results and Discussion

3.1. Microstructure and Tensile properties

Microstructural and tensile property characterizations were performed on the extruded 2099-T83 alloy. Optical metallography was carried out to document the grain structure and the second phase particle distribution. Samples of the T83 temper material were cross sectioned and viewed in the as-polished and in etched conditions. As a comparison to the incumbent alloy, the samples of 7075-T73 bar material was also prepared and optical micrographs are presented in Figure 3. As can be seen in this figure, although the microstructure of both 2099 and 7075 alloys were similar and consisting of elongated grains and dispersed un-dissolved inter-metallic phases, the 7075-T73 material contains increased amount of the second phase particles, due to the higher Fe and Si concentrations, and more recrystallized grain structure than the 2099-T83.



a) 2099-T83, as polished



b) 2099-T83, etched



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