

Time-Temperature-Precipitation Behavior in An Al-Cu-Li Alloy 2195

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Abstract

Al-Cu-Li alloy 2195, with its combination of good cryogenic properties, low density, and high modulus, has been selected by NASA to be the main structural alloy of the Super Light Weight Tank (SLWT) for the Space Shuttle. Alloy 2195 is strengthened by an aging treatment that precipitates a particular precipitate, labeled as T_1 (Al_2CuLi). Other phases, such as GP zone, θ' , θ'' , θ , δ' , S' are also present in this alloy when artificially aged. Cryogenic strength and fracture toughness are critical to the SLWT application, since the SLWT will house liquid oxygen and hydrogen. Motivation for the Time-Temperature-Precipitation (TTP) study at lower temperature (lower than 350 °F) comes in part from a recent study by Chen [1]. The study found that the cryogenic fracture toughness of alloy 2195 is greatly influenced by the phases present in the matrix and subgrain boundaries. Therefore, the understanding of TTP behavior can help develop a guideline to select appropriate heat treatment conditions for the desirable applications.

The study of TTP behavior at higher temperature (400 to 1000 °F) was prompted by the fact that the SLWT requires a welded construction. Heat conduction from the weld pool affects the microstructure in the heat-affected zone (HAZ), which leads to changes in the mechanical properties. Furthermore, the SLWT may need repair welding for more than one time and any additional thermal cycles will increase precipitate instability and promote phase transformation. As a result, considerable changes in HAZ microstructure and mechanical properties are expected during the construction of the SLWT. Therefore, the TTP diagrams can serve to understand the thermal history of the alloy by analyzing the welded microstructure. In the case welding, the effects of thermal cycles on the microstructure and mechanical properties can be predicted with the aid of the TTP diagrams.

The 2195 alloy (nominally Al + 4 pct Cu + 1 pct Li + 0.3 pct Ag + 0.3 pct Mg + 0.1 pct Zr) used in this study was received in the form of 1.7 inch thick rolled plates. The alloy was initially

solutionalized at 950 °F for 1 hour and then stretched for 3 pct, before being thermally exposed. A variety of heat treatment conditions (shown in Figure 1) were employed to explore the precipitation sequence and the development of microstructure. Transmission electron microscopy was performed to establish the nucleation and growth behavior of the strengthening precipitates in Al-Cu-Li alloy 2195. Phase fields of GP zone, θ'' , θ' , θ , δ' , S' , T_1 , T_B , and T_2 are identified and schematic time-temperature-transformation (TTP) curves are proposed for both matrix and subgrain boundaries (shown in Figure 2 and 3). Hardness variation as a function of heat treatment conditions is also measured (see Figure 4).

In brief, the goal of this study is to develop TTP diagrams for the solution treated and stretched alloy 2195 from which the precipitation sequence at any service or aging conditions can be predicted. A subgrain boundary TTP diagram is also presented since precipitation at subgrain boundary can control and/or modify a wide variety of material properties, such as cryogenic fracture toughness. This paper will present the TTP diagrams and detail the nucleation and growth behavior of various precipitates in Al-Cu-Li alloy 2195.

Reference

1. P.S. Chen, A.K. Kuruvilla, T.W. Malone, and W.P. Stanton, "The Effects Of Artificial Aging On The Microstructure And Fracture Toughness of Al-Cu-Li Alloy 2195," Accepted for Publication in Journal of Materials Engineering & Performance, 1998.

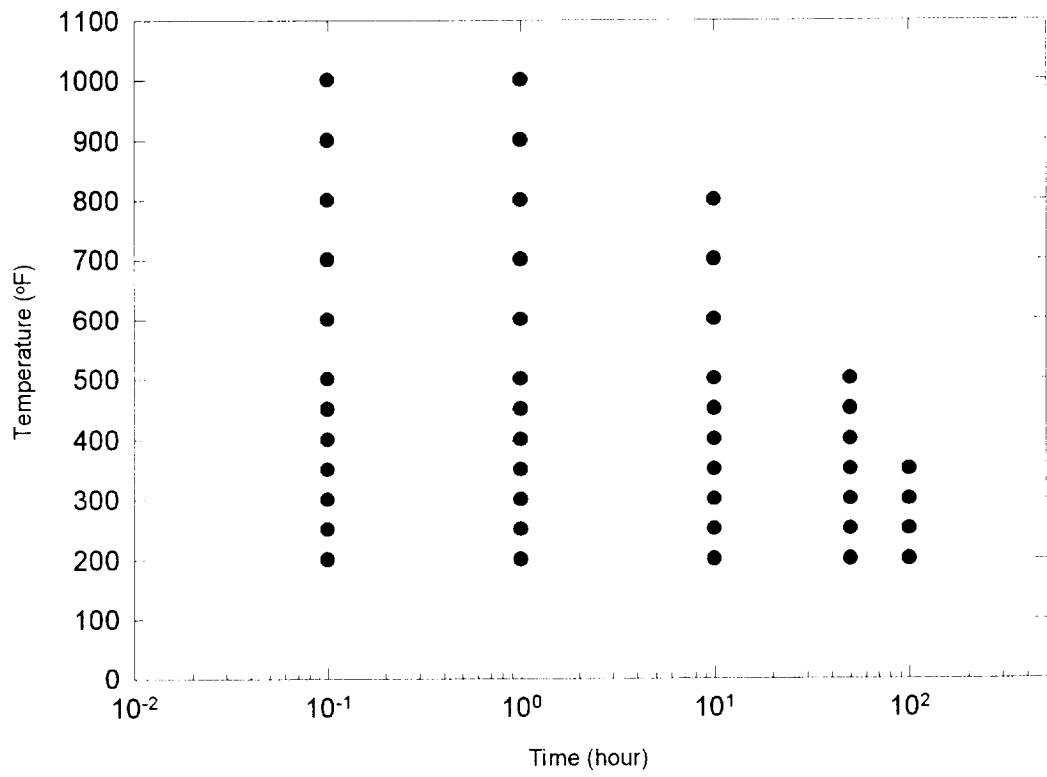


Figure 1. TTP Heat Treatment Matrix for Alloy 2195

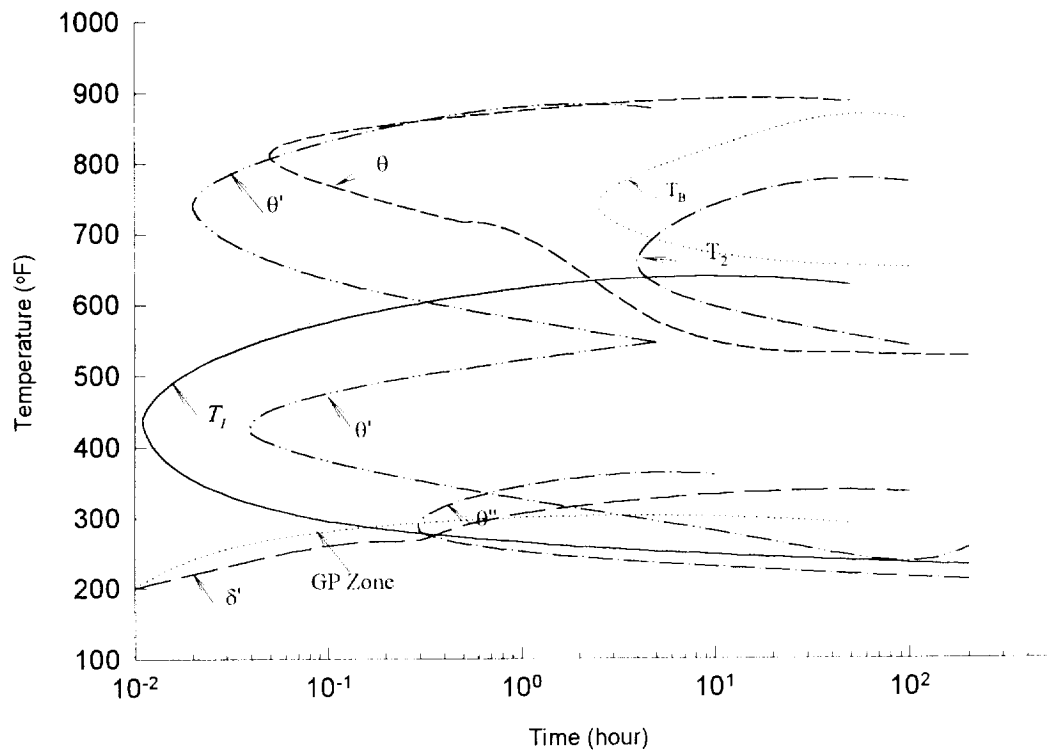


Figure 2. TTP Diagram for Alloy 2195 Matrix

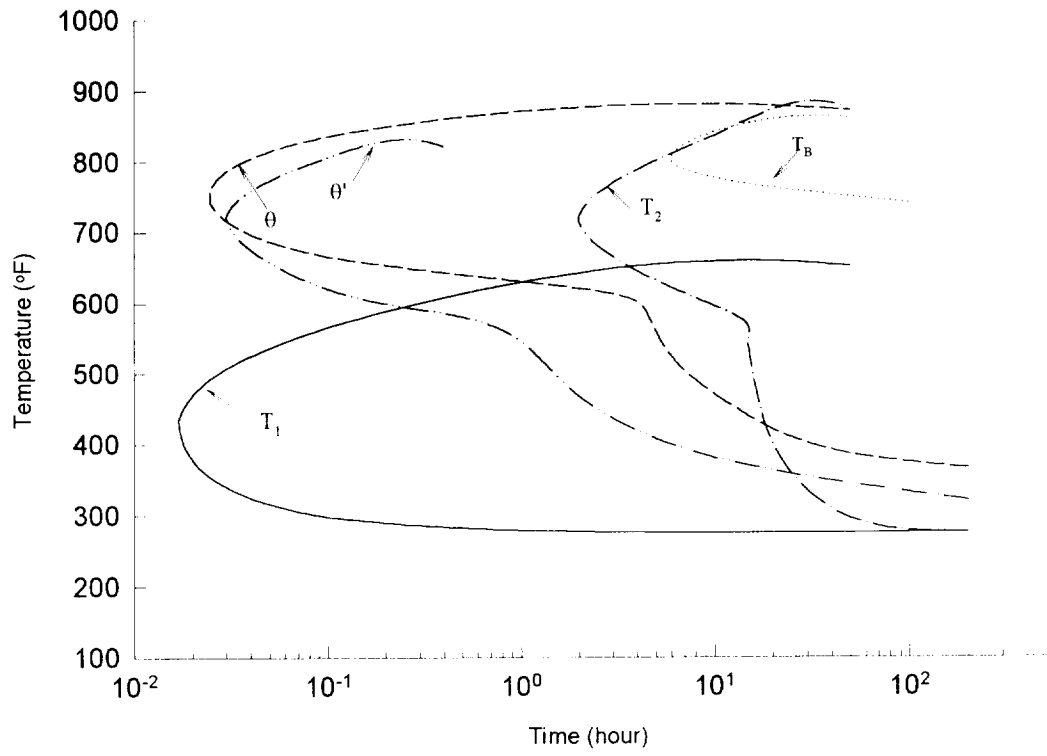


Figure 3. TTP Diagram for The Subgrain Boundaries of Alloy 2195

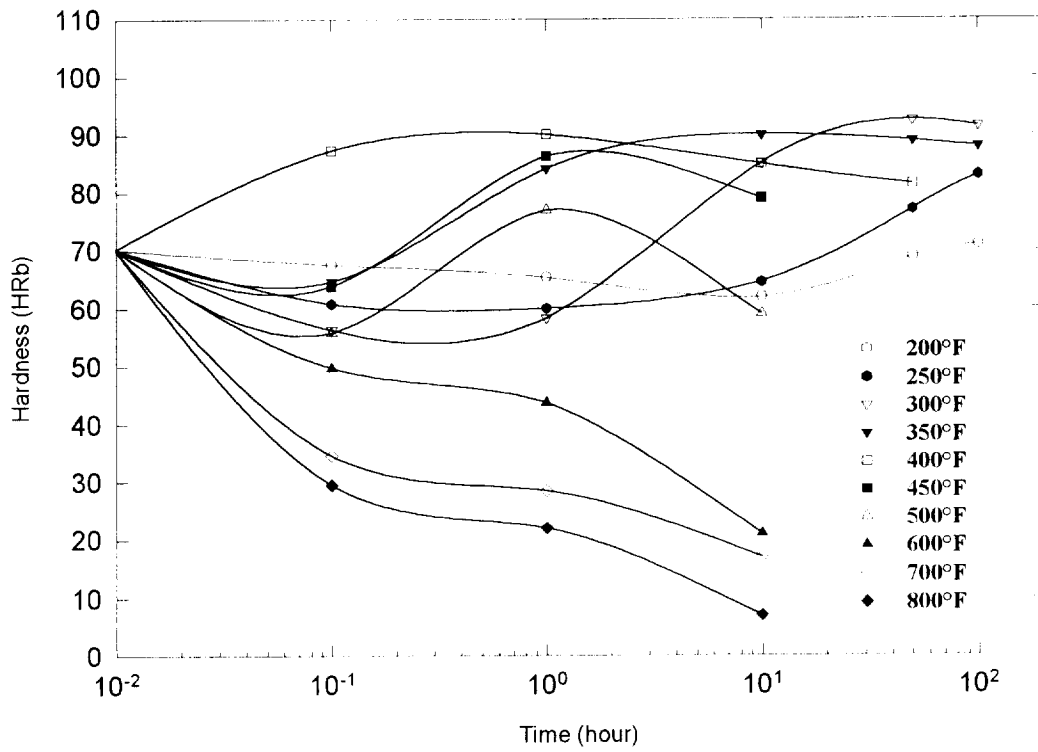


Figure 4. Hardness Variation As A Function of Heat Treatment Conditions