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MICROSTRUCTURAL ANALYSIS OF THE 2195 ALUMINUM-LITHIUM ALLOY WELDS

Prepared by: George E. Talia, Ph.D.

Academic Rank: Associate Professor

Institution and Department: The Wichita State University, Department of Mechanical Engr.

MSFC Colleague: Arthur C. Nunes, Jr., Ph.D.

NASA/MSFC:

Office: Materials & Processes Laboratory
Division: Metallic Materials & Processes
Branch; Metallurgical Research

Introduction

The principal objective of this research was to explain a tendency of 2195 Al-Li alloy to crack at elevated temperature during welding. Therefore, a study was made on the effect of welding and thermal treatment on the microstructure of Al-Li Alloy 2195. The critical roles of precipitates, boundaries, phases, and other features of the microstructure were inferred from the crack propagation paths and the morphology of fracture surfaces of the alloy with different microstructures. Particular emphasis was placed on the microstructures generated by the welding process and the mechanisms of crack propagation in such structures. Variation of the welding parameters and thermal treatments were used to alter the micro/macro structures, and they were characterized by optical and scanning electron microscopy. A theoretical model is proposed to explain changes in the microstructure of welded material. This model proposes a chemical reaction in which gases from the air (i.e., nitrogen) release hydrogen inside the alloy. Such a reaction could generate large internal stresses capable to induce porosity and crack-like delamination in the material.

Experimental Procedures

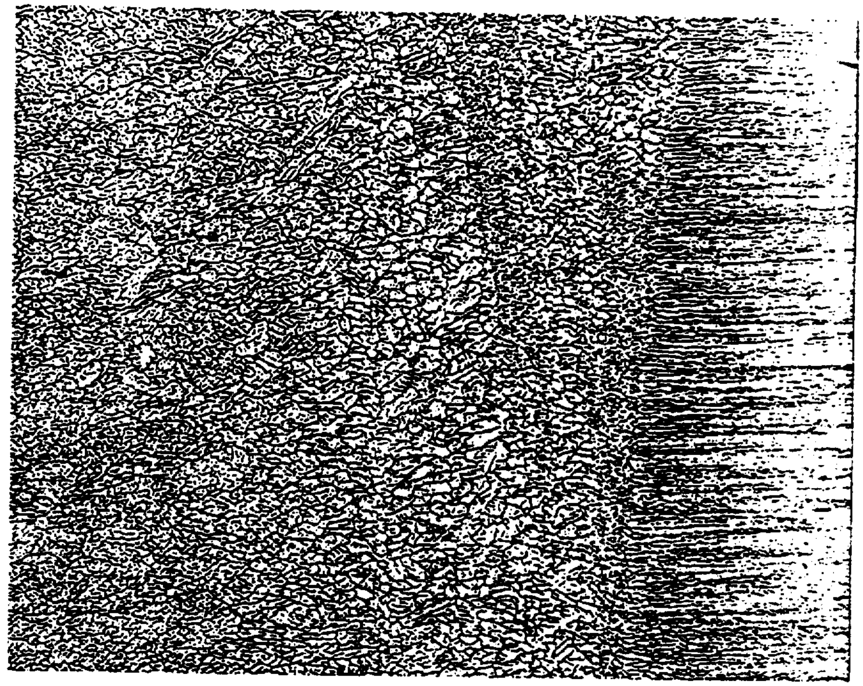
2195 Al-Li alloy plates were produced by the Reynolds Metals Company, one pass (root pass) and two passes (root pass and cover pass) welds were performed at the Marshall Space Flight Center. Transverse and longitudinal sections of the welds were analyzed by optical micrographic techniques. Each metallographic sample was prepared for examination using standard polishing preparation techniques and etched with Keller's reagent. Optical microscopy observations were performed using a Nixon inverted microscope. One pass autogenous welds were selected for further thermal processing, i.e., heat treatment at different temperatures in vacuum, air, or Helium atmosphere.

Results

Optical micrographs of the fusion zone of a single pass and two-pass welds in 2195 Al-Li alloy are shown in Figure 1. The initial metallographic analysis of the single pass weld revealed a well formed grain structure with a small amount of porosity. This porosity compares with the initial porosity of the parent metal. See Figure 1-a. For two pass welds a large amount of porosity is observed in the first pass fusion zone (but not in the second or cover pass) and some of the pores take a crack-like shape as shown in Figure 1-b.

To separate the temperature effects from stresses effects generated by the second pass weld some of single pass welded material was furnace heat treated at 450 C for a minute in air and in vacuum. A comparison of the different structures is made

(a)



.5 mm

(b)

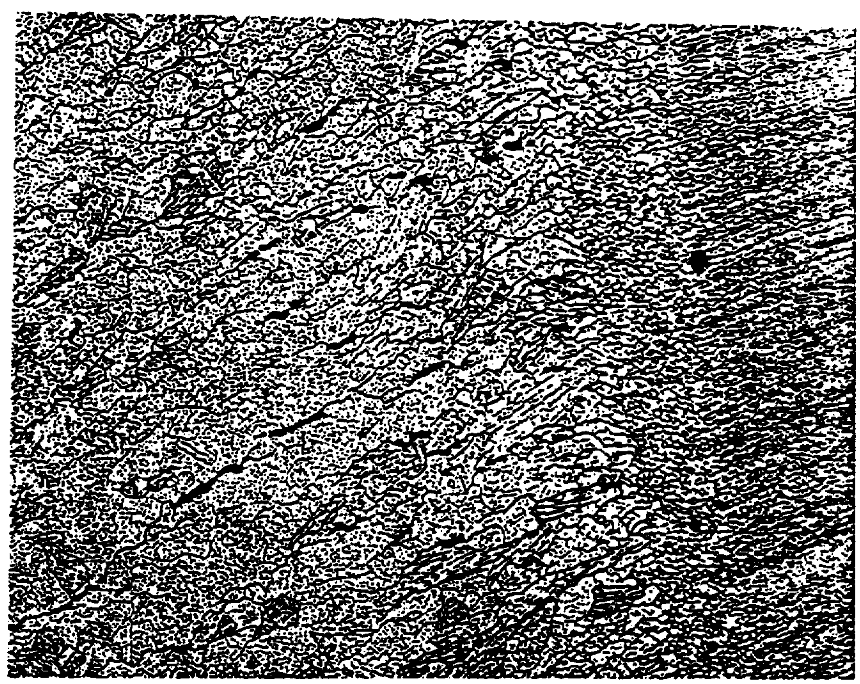


Figure 1.- Optical micrographs of 2195 Al-Li alloy subjected to (a) a fusion pass weld and (b) a fusion pass plus a heating (but not melting) cover pass.

in Figure 2. Figure 2-a presents a microstructure similar to the as-welded materials. In contrast, the air-heated Al-Li alloy shows evidence of a dendritic or grain boundary reaction. See Figure 2-b. In addition to the solid state boundary reaction, an increases in the porosity was observed in the air-heated material.

Furthermore, 1.2 % nitrogen contamination of the helium shield gas of a weld pass was observed to generate a large amount of porosity while, in contrast, electron beam (EB) welds performed in vacuum or welds thermally treated in helium present a porosity similar to that of the parent metal. All these results support nitrogen as a cause of the porosity observed in welds in Al-Li Alloy.

Discussion

Chemical analysis of Al-Li alloy 2195 base and weld metal indicated hydrogen contamination at levels much higher than expected for Alloy 2219, which lacks lithium. It is conjectured that the hydrogen is present in the form of a lithium compound. When the welds are heated in air, nitrogen penetrates rapidly into the material along dendritic boundaries. Then it begins to diffuse into the solid metal. When it encounters a hydrogen-lithium compound, replaces and releases hydrogen as a gas. At elevated temperatures high gas pressure form porosity and promote cracking.

Conclusions and Recommendations

Initial results have led to the following tentative conclusions:

a) Reheating (e.g., by a cover pass) generates both round porosity and crack-like porosity observed in 2195 Al-Li Alloy welds.

b) A tentative model has been developed to predict and understand the porosity formation.

c) Additional work is necessary to verify the proposed model and the mechanical properties of the 2195 Al-Li welds. Microhardness tests at room temperature should be employed to characterize the mechanical properties of the different features observed in the microstructure, especially in the welding zone. Hot tensile tests should also be performed to evaluate the welding zone strength and the effect of the temperature variation on the integrity of the welding.

Acknowledgments

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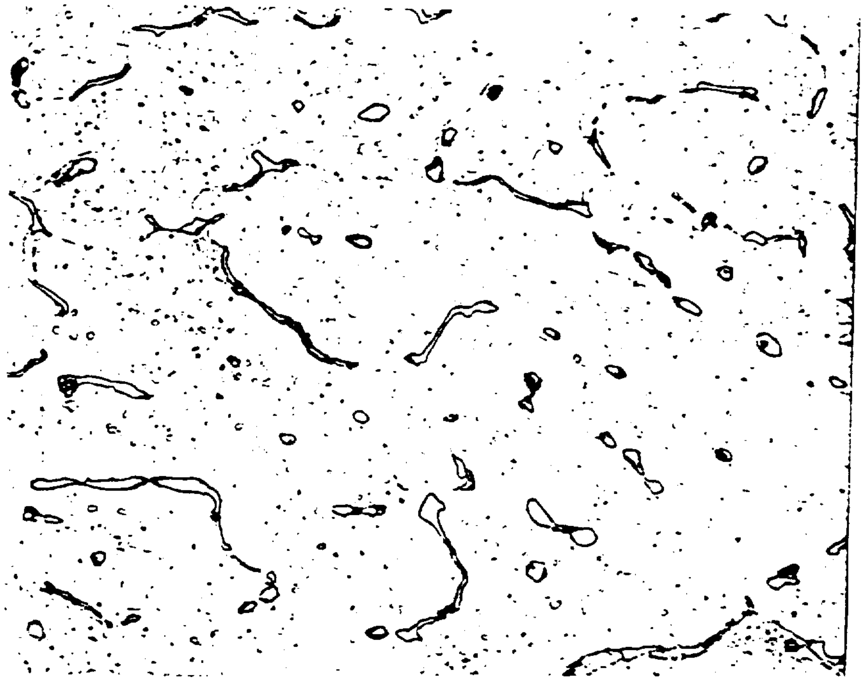
(a)



25 μm

(b)

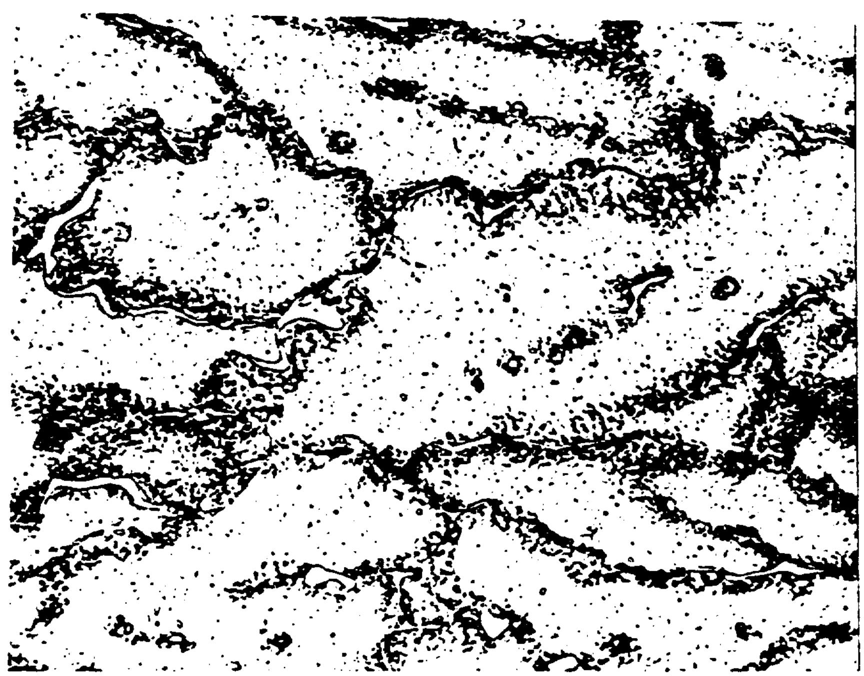


Figure 2.- Micrographs showing the effect of the heating at 450 C for a minute in vacuum (a) and in air (b).