S3-26
10733

P-10

N91-28340

APPENDIX C

EFFECT OF Li LEVEL, ARTIFICIAL AGING, AND TiB_2
REINFORCEMENT ON THE MODULUS OF WELDALITE™ 049

The dynamic Young's Modulus (E) was determined for alloys 049(1.3)[heat 072], 049(1.9), and 049(1.3)-TiB_2 in the T3 temper and after aging at 160°C (320°F) for 0.08, 0.25, 1.5, 6, 24, and 100 h. Measurements for each alloy were made on a single 0.953-cm (0.375-in) cube to reduce scatter from microstructural inhomogeneities. Both shear and transverse wave velocities were measured for the L, LT, and ST directions by a pulse-echo technique, detailed in ASTM Standard Recommended Practice (ASTM E494-75). These velocities were then used to calculate modulus according to equations in the Appendices of the ASTM standard.

Figures C1-C3 show the change in E with aging time at 160°C (320°F) for the three alloys. It is clear from these plots that aging has a minor, but measurable, influence on the E of alloys 049(1.3) and 049(1.9): E decreases by ~2.5% for 049(1.3) and 049(1.9) during the initial stages of artificial aging (Figs. C1 and C2). This decrease in E generally follows the strength reversion (Fig. C4). On further aging beyond the reversion well, E increases, peaks between 24 and 100 h, and then decreases again as the alloys over-age. The slightly higher, although not statistically significant, modulus in the T8 than in the T3 temper is consistent with the presence of the high-modulus T_1 phase in the T8 temper. A similar, but more subtle, change in E was observed on aging for the TiB_2-reinforced variant (Fig. C3) that also follows the aging curve (Fig. C5).

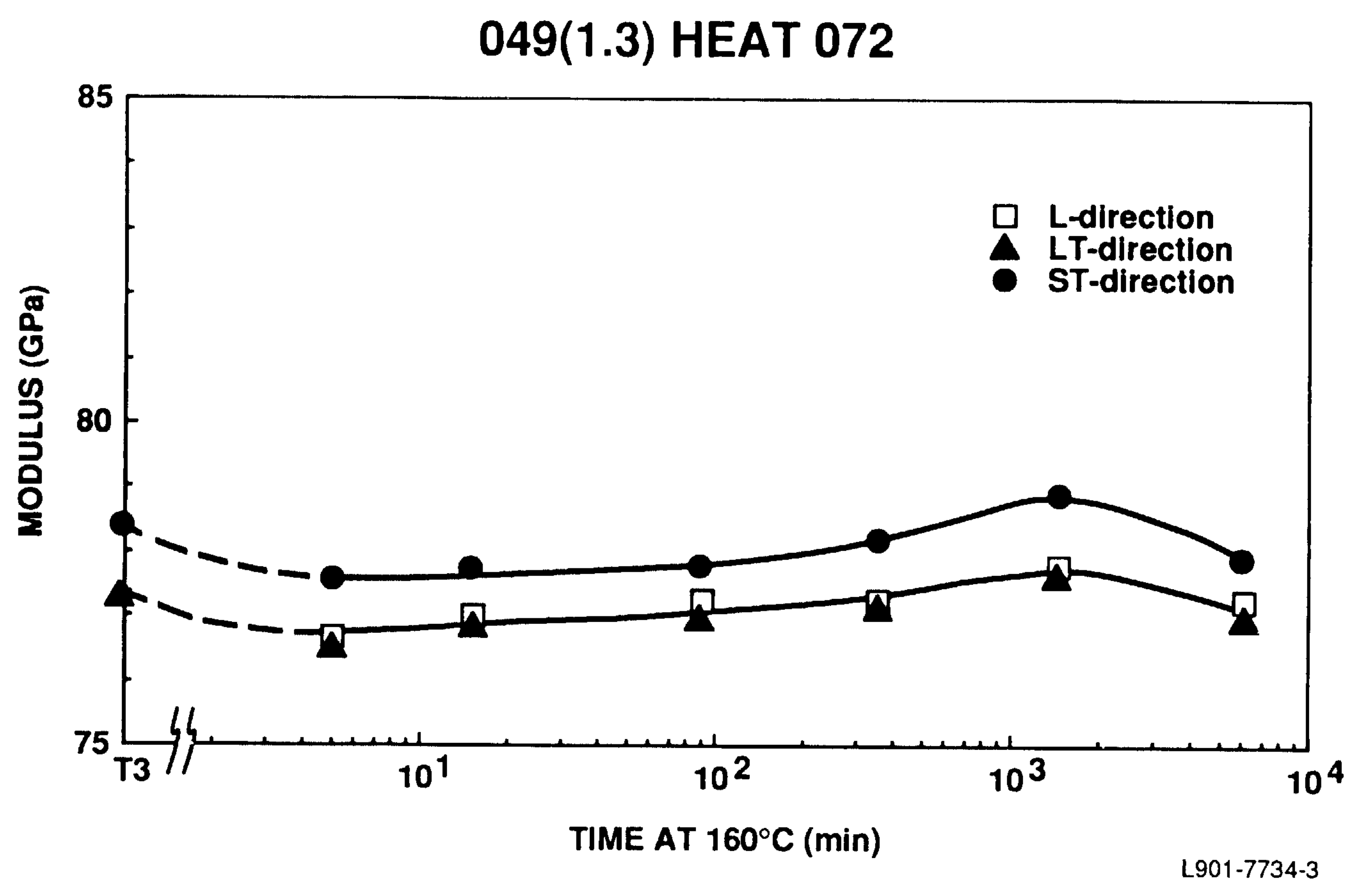

Fig. C-1 Young's Modulus (E) vs. aging time at 160°C for 049(1.3)[heat 072] for three directions relative to the extrusion direction of the bar.

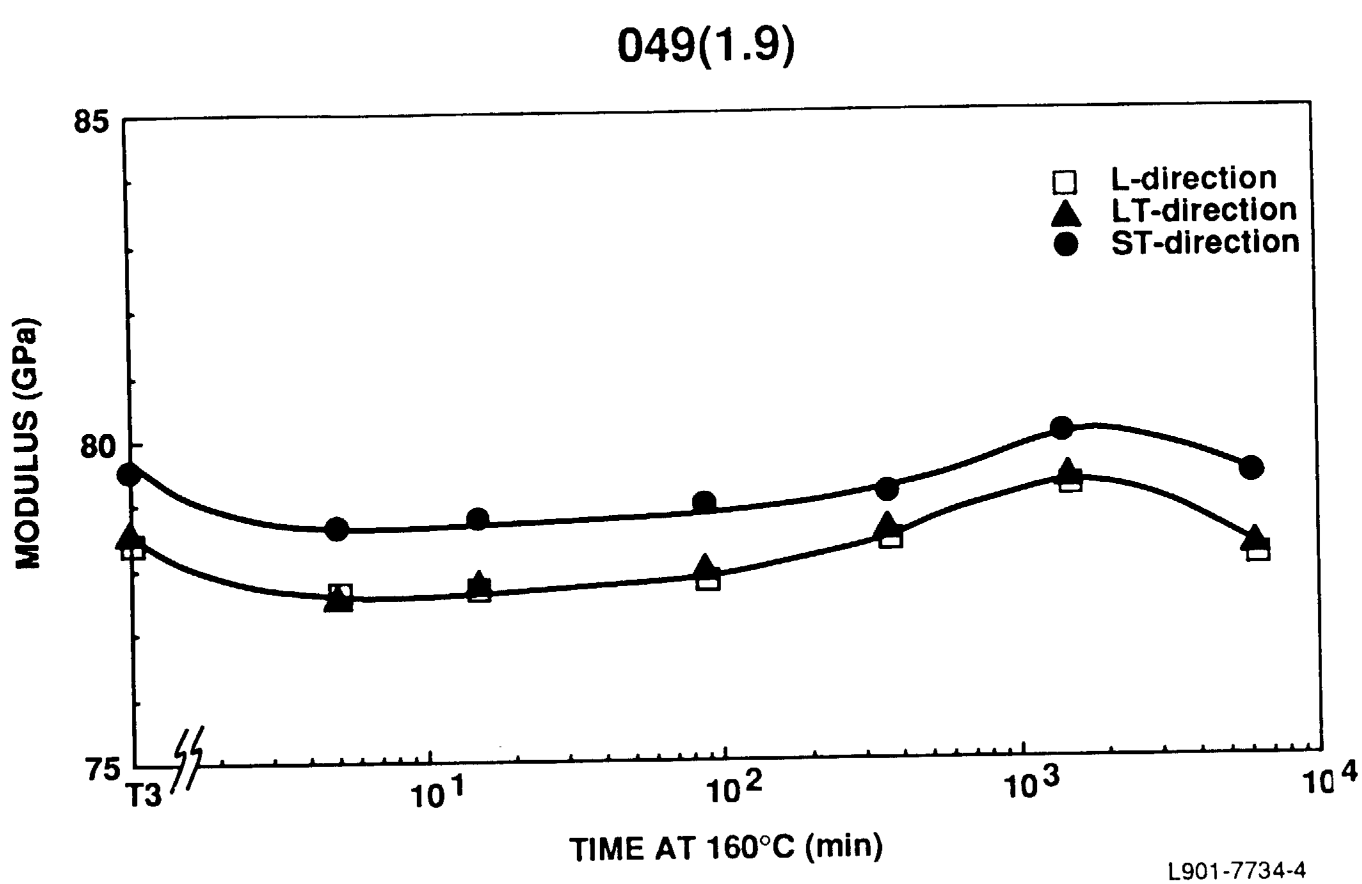

Fig. C-2 Young's Modulus (E) vs. aging time at 160°C for 049(1.9) for three directions relative to the extrusion direction of the bar.

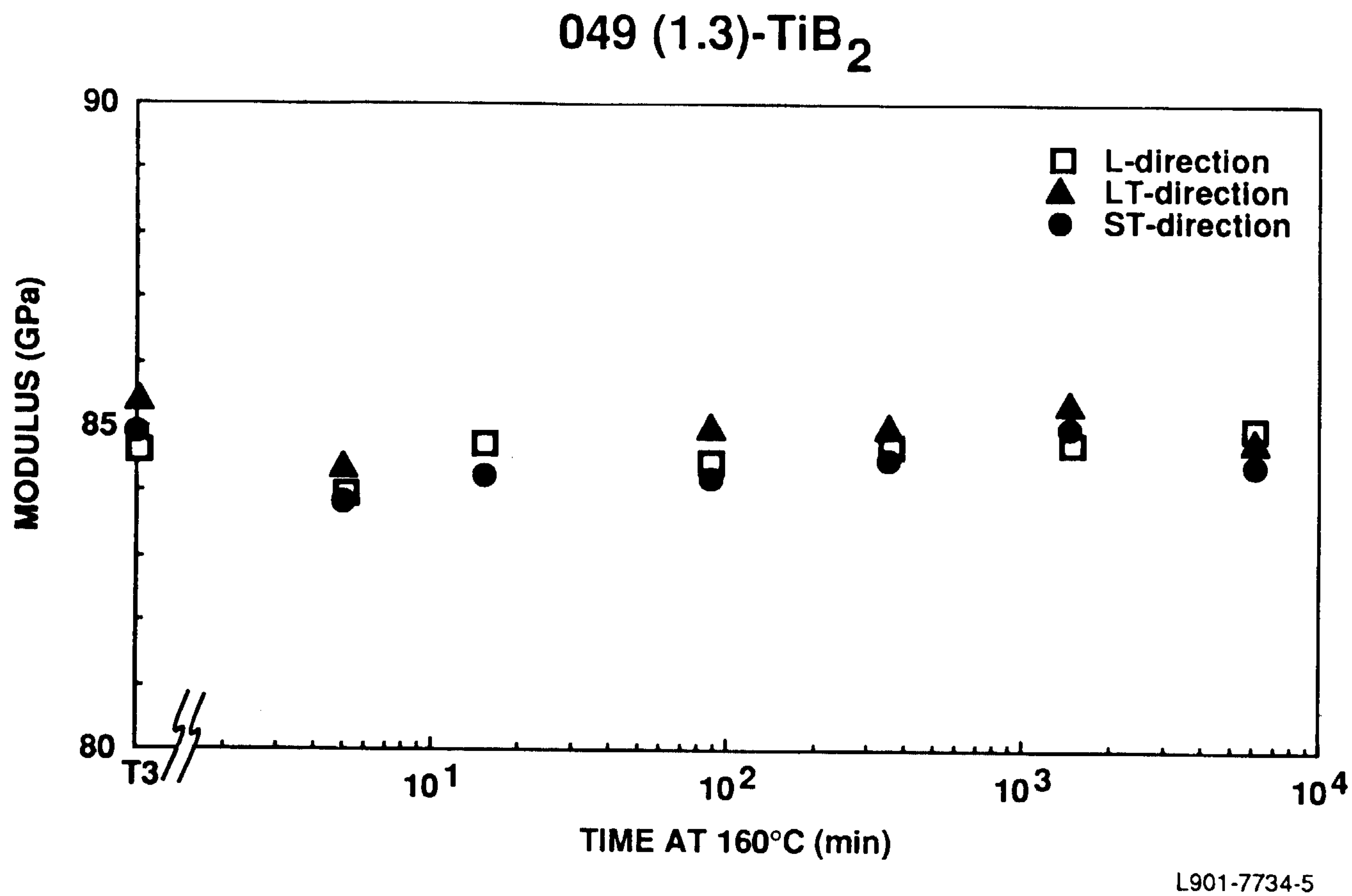

Fig. C-3 Young's Modulus (E) vs. aging time at 160°C for 049-TiB_2 for three directions relative to the extrusion direction.

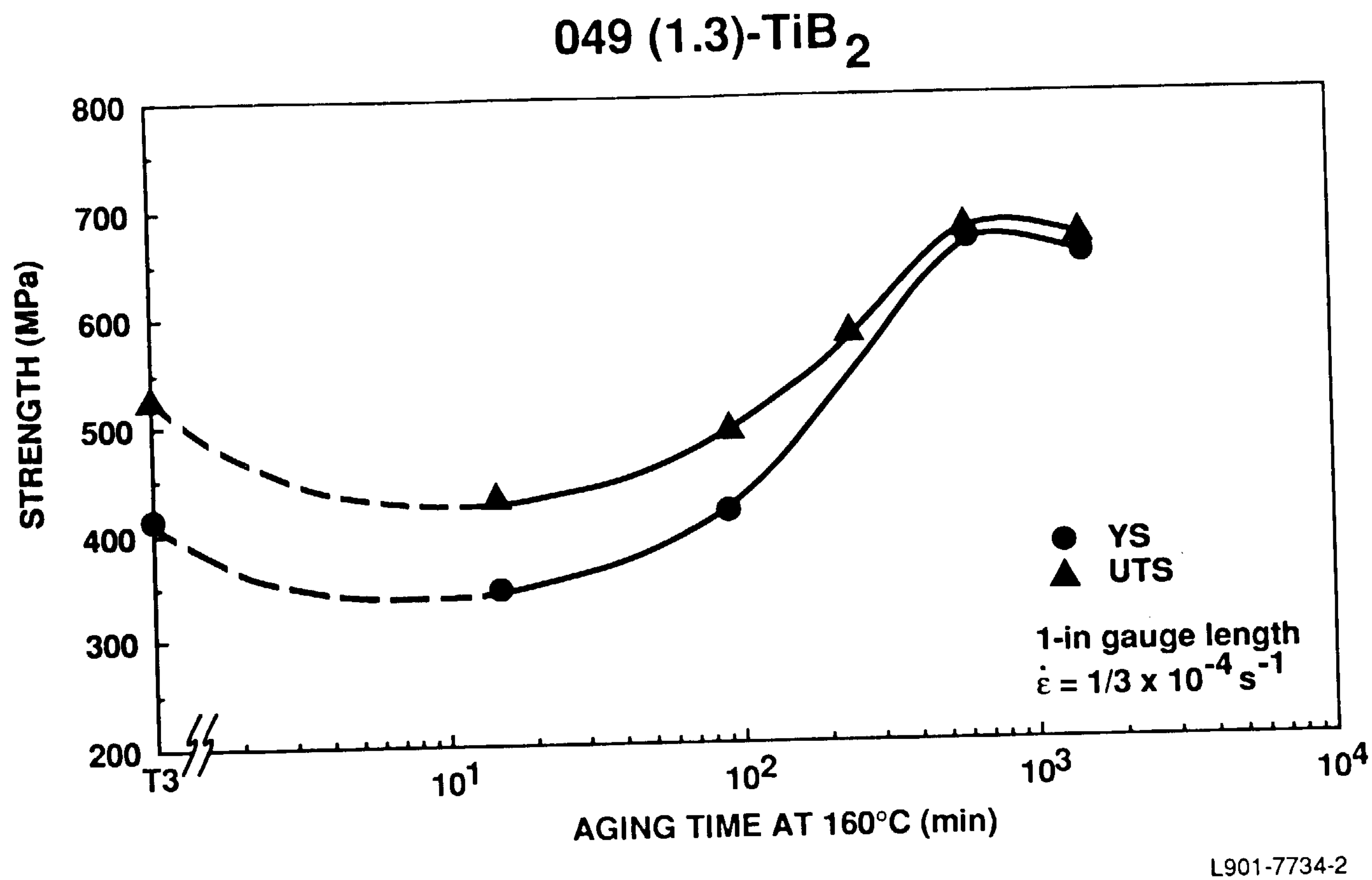

Fig. C-4 Tensile yield strength (YS) and ultimate tensile strength (UTS) vs. aging time for 049(1.3)[heat 072].

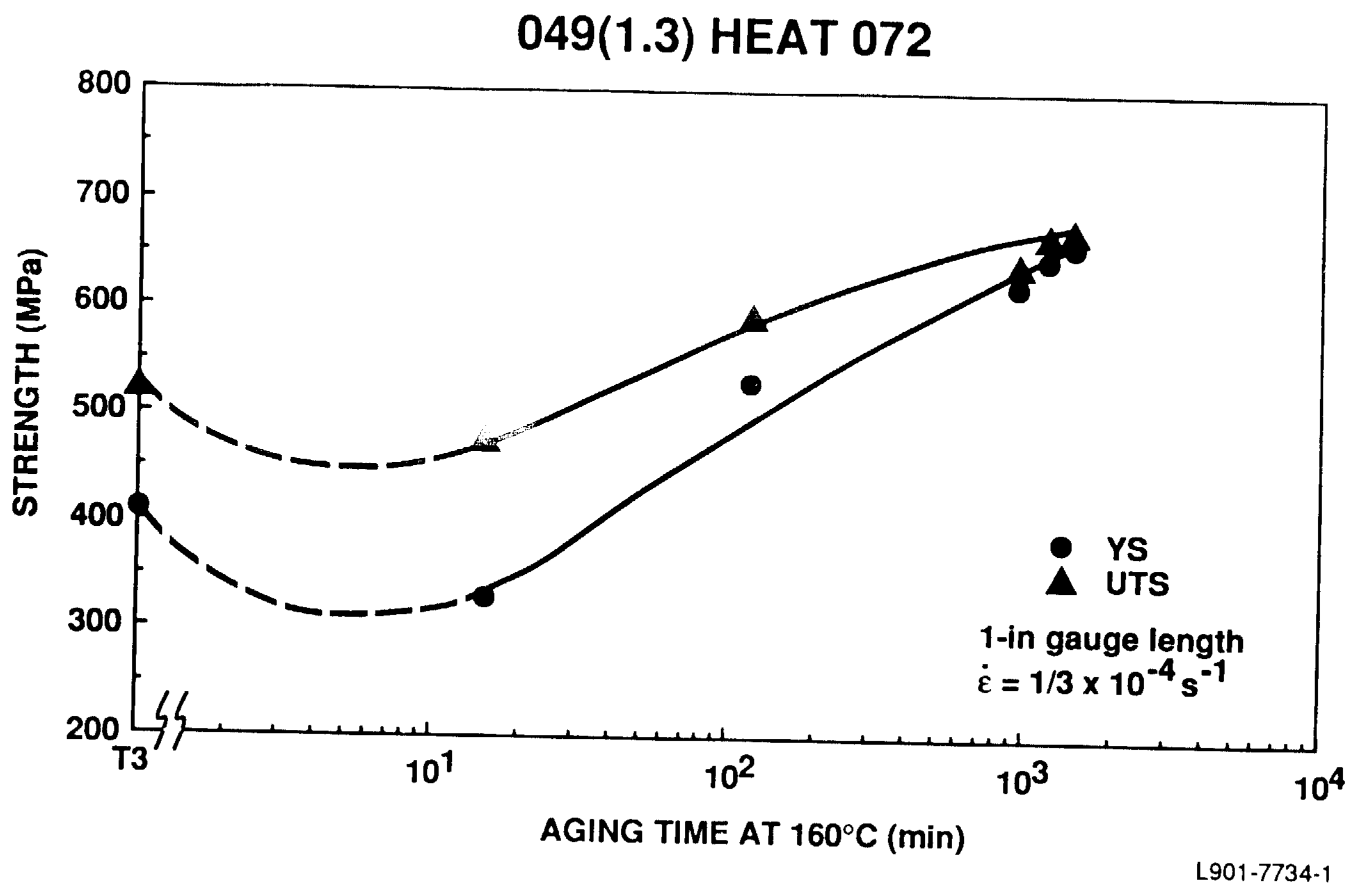

Fig. C-5 Tensile yield strength (YS) and ultimate tensile strength (UTS) vs. aging time for 049-TiB_2.

O'Dowd et al. [1] showed that E is dependent on artificial aging time for 2090-type Al-Li-Cu alloys, and attributed variations in E to precipitation of the T_1 (Al_2CuLi) and δ' (Al_3Li) phases. The modulus of δ' was estimated to be 106 GPa[2], and that for T_1 170 GPa.[2] O'Dowd et al.[1] concluded that the T_1-phase contributes more to E than δ'. Weldalite™ 049 (i.e., alloy 049(1.3)) has approximately the same modulus in the T3 and T8 tempers. In the T3 temper, 049(1.3) is strengthened by the δ'-phase and GP zones, with Li and Cu atoms in supersaturated solid solution; in the T8 temper, the alloy is strengthened primarily by T_1-type precipitates. Thus, for 049(1.3), the contribution to E from δ' and GP zones, plus Li and Cu atoms in solid solution is about the same as that from the uniform T_1-type distribution in the T8 temper.

A small amount of anisotropy was observed for E in the ST vs the L and LT directions for 049(1.3) and 049(1.9). A variation with orientation was also observed by O'Dowd et al. [1] for 2090-type alloys, but they dismissed it as being within the experimental error of their technique. The relative difference in E between orientations for Weldalite™ 049 alloys was approximately 1 GPa (0.15 Msi). However, the trend followed between directions is consistent for all measurements and is the same as that observed by O'Dowd et al.[1]. Thus, it appears that E is slightly dependent on

---

(1) M.E. O'Dowd, W. Ruch, and E.A. Starke, Jr., J. Physique (Paris), 48, C3, pp. C-565-576 (1987).

(2) W. Muller, E. Bubeck, and V. Gerold, in Al-Li Alloys III, Inst. of Metals, London, p. 435 (1986).

direction, with E in the ST direction being a higher (78.9 GPa) than in the L (77.8 GPa) or LT (77.6 GPa).

In the T3 temper, E for the high-lithium variant, 049(1.9), was 1.5% higher than that for 049(1.3) in each of the three orientations evaluated. In the near-peak-aged temper (24 h at 160°C), the increase in E with increasing lithium content was slightly greater for the L and LT orientations than for the ST orientation: the L and LT orientations showed approximately a 2% increase, while the ST orientation showed an increase of 1.5%. Thus, a 0.6 wt% increase in lithium results in a 1.5 to 2% increase in E, the equivalent of a 3 to 4% increase per wt% lithium, which compares favorably with the results of Peel.[3] He showed that E increases by approximately 3.5% for each wt% increase in lithium for a number of commercial Al-Li-Cu, Al-Li-Cu-Mg and Al-Mg-Li alloys.[3] However, this is lower than the 6% increase in E per 1 wt% Li observed for Al-Li binary alloys by Sankaran and Grant.[4] The reason for the slight difference in the magnitude of increase in E with increasing lithium content for binary vs Al-Cu-Li commercial aluminum-lithium alloys is unclear.

As shown in Section I of this report, increasing the lithium content of Weldalite™ 049 from 1.3 wt% to 1.9 wt% results in a 20% decrease in yield strength. It should also be noted that this increase in lithium results in about a 2% decrease in density. Thus, it appears that for most applications,

(3) Alloying, J.L. Walter, M.R. Jackson and C.T. Sims (eds)., ASM, Metals Park, OH (1988).
(4) K.K. Sankaran and N.J. Grant, Mater. Sci. Eng., 44, p. 213 (1980).

the decrease in strength would outweigh the benefits of increases in modulus associated with increasing the lithium level above 1.3 wt%.

As discussed in Section III of this report, the addition of approximately 4 v% TiB_2 to 049(1.3) results in an 8% increase in modulus. Clearly, further increases in modulus would accompany higher volume fractions of TiB_2, but the tendency for the particles to agglomerate would have to be overcome before the 049-TiB_2 could become a viable engineering alloy.

Report Documentation Page

NASA — National Aeronautics and Space Administration

1. Report No.	NASA CR-4364
2. Government Accession No.	
3. Recipient's Catalog No.	
4. Title and Subtitle	Microstructure-Property Relationships in Al-Cu-Li-Ag-Mg Weldalite™ Alloys
5. Report Date	May 1991
6. Performing Organization Code	
7. Author(s)	T.J. Langan J.R. Pickens
8. Performing Organization Report No.	MML TR 90-27c
9. Performing Organization Name and Address	Martin Marietta Laboratories 1450 S. Rolling Rd. Baltimore, MD 21227
10. Work Unit No.	505-63-50-02
11. Contract or Grant No.	NAS1-18531
12. Sponsoring Agency Name and Address	National Aeronautics and Space Administration Langley Research Center Hampton, VA 23665-5225
13. Type of Report and Period Covered	Contractor Report
14. Sponsoring Agency Code	
15. Supplementary Notes	Langley Technical Monitor: William D. Brewer Final Report - Part II

16. Abstract

The microstructure and mechanical properties of the ultrahigh strength Al-Cu-Li-Ag-Mg alloy Weldalite™ 049 were investigated during this phase of the research. Specifically, the microstructural features along with tensile strength, weldability, Young's modulus and fracture toughness were investigated for Weldalite™ 049-type alloys with Li contents ranging from 1.3 to 1.9 wt.%. The tensile properties of Weldalite™ 049 and Weldalite™ 049 reinforced with TiB_2 particles fabricated using the XD™ process were also evaluated at cryogenic, room, and elevated temperatures. In addition, an experimental alloy, similar in composition to Weldalite™ 049 but without the Ag+Mg, was fabricated. The microstructure of this alloy was compared with that of Weldalite™ 049 in the T6 condition to assess the effect of Ag+Mg on nucleation of strengthening phases in the absence of cold-work.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Al-Li Alloys, Metal Matrix Composites Weldalite™ 049, Elevated Temperature Al Alloy	Unclassified - Unlimited Subject Category 26

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	98	A05

NASA FORM 1626 OCT 86