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Temperature Variation of the Elastic Constants of Aluminum Alloy 2090-T81

J. Glazer* and J. W. Morris Jr.†
Lawrence Berkeley Laboratory
University of California Berkeley, California

and

S. A. Kim,‡ M. W. Austin,‡ and H. M. Ledbetter§
National Bureau of Standards, Boulder, Colorado

ALUMINUM is often the material of choice for weight-critical structures used at cryogenic temperatures. Current aerospace applications include the external tank of the space shuttle, currently manufactured from aluminum alloy 2219. Future applications might include tanks for proposed hypersonic vehicles. Aluminum-lithium alloys have been proposed for these applications because they provide mechanical properties comparable or superior to those of existing aerospace aluminum alloys at 7-10% lower density and higher stiffness. Since stiffness is an important design criterion for structures like tanks, the elastic constants for these materials at low temperature are important design properties. This Note focuses on a particular aluminum-lithium alloy that may see cryogenic service, namely alloy 2090-T81.

Aluminum-lithium alloys of commercial compositions have elastic moduli at room temperature approximately 7-12% higher than those of conventional aluminum alloys. The increase in elastic modulus is related primarily to the amount of lithium in the alloy, so it can vary significantly even within the specified composition ranges of commercial alloys.[1,2] The temperature variation of the elastic constants of various commerical aluminum alloys has been studied previously.[3,4] All aluminum alloys behave similarly, displaying an increase in elastic modulus of about 12% between room temperature and 4 K. This Note confirms this trend for the aluminum-lithium alloy 2090-T81. Titanium alloys, which are also used for cryogenic tanks, show a smaller increase in stiffness at low temperatures.[4]

The alloy studied in this investigation, 2090-T81, has a nominal chemical composition of Al-2.7Cu-2.2Li-0.12Zr in weight percent. The chemical composition limits and the actual chemical composition, as determined by atomic absorption spectroscopy, are given in Table 1. In longitudinal and transverse orientations, this alloy shows improved strength, elongation, and fracture toughness at low temperatures. The mechanical properties at 298 K, 77 K, and 4 K are given in Ref. 5. The elastic-constant measurements were performed using ultrasonic (10 MHz) pulse techniques. The experimental procedure is described in detail elsewhere.[4,6] Except for high-strain cases, dynamic elastic constants equal static-elastic constants within the usual uncertainty of the latter. For the dynamic values, we estimate the uncertainty as 0.1%. Static and dynamic values should show essentially identical temperature behavior.

Figure 1 shows the Young's modulus and Poisson's ratio of 2090-T81 alloy as a function of temperature between 295 K and 4 K. The values at selected temperatures are listed in Table 2. The room-temperature value of the Young's modulus lies close to the reported average values from static tensile tests.[2] The temperature variation is similar to that observed for other aluminum alloys.[4]

Table 1 Chemical composition limits for 2090 alloy and actual composition of the material used in this study

Element	Al	Cu	Li	Zr	Fe
Composition limits	Balance	2.4–3.0	1.9–2.6	0.08–0.15	0.10
Actual composition	Balance	2.86	2.05	0.12	0.02

Element	Si	Mg	Mn	Ti
Composition limits	0.12	0.25	0.05	0.15
Actual composition	<0.01	<0.01	<0.005	0.02

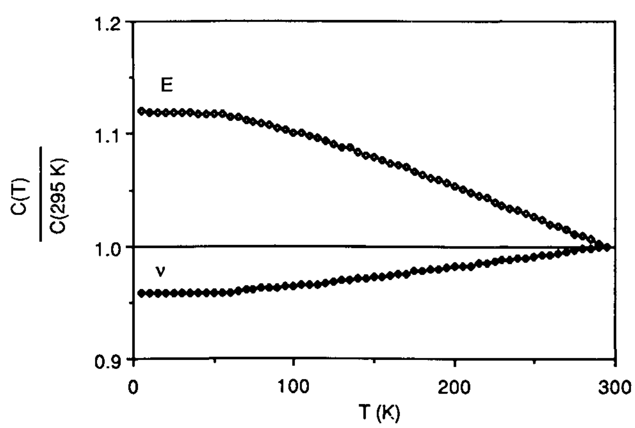

Fig. 1 Young's modulus (*E*) and Poisson's ratio (*v*) of 2090-T81 alloy as functions of temperature. The plotted values are ratios between the actual values and the room-temperature values given in Table 2.

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*Graduate Student.
†Structural Materials Group Leader, Center for Advanced Materials, and Professor of Metallurgy, Department of Materials Science and Mineral Engineering.
‡Reseach Engineer, Fracture and Deformation Division, Institute for Materials Science and Engineering.
§Metallurgist, Fracture and Deformation Division, Institute for Materials Science and Engineering.

Table 2 Elastic constants of 2090-T81 alloy

Elastic constant	Temperature 295 K	77 K	20 K	4 K
E (GPa)	78.3	86.9	87.6	87.6
(10^6 psi)	11.36	12.60	12.70	12.70
v	0.320	0.308	0.307	0.307

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