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K. E. Lulay
University of Portland, lulay@up.edu

Khalid Khan
University of Portland, khan@up.edu

D. Cyaaya

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The science of altering the room temperature properties of metals by first exposing them to extreme temperatures has been extensively studied and is very well understood. Although much of this work has involved studying the effects of high temperature thermal treatments, significant work has also been performed investigating the effects on properties by treating metals at cryogenic temperatures (near −196 °C). Cryogenic treatments were first shown in the 1930s and 1940s to improve the performance of steel cutting tools.[1] Over the decades, significant work has been conducted to measure and explain the effects of cryogenic treatment on steel.[2,3] Some research has also been conducted on nonferrous alloys. The effects of cryogenic treatment on the wear performance of copper alloy contact tubes for gas metal arc welding was investigated,[4] but no changes were observed.

In this investigation, the effect of cryogenic thermal treatment on the room temperature strength, hardness, and toughness of aluminum 7075-T651 was studied. This is a precipitation-hardened material that is used in applications requiring high strength and good corrosion resistance.

Test specimens were received and then deep treated cryogenically. The treatment consisted of placing the test specimens in a commercial cryogenic freezer (−196 °C) for two different lengths of time: 2 h and 48 h. The 2-h treatment was conducted to determine whether there were any time-independent effects. The 48-h treatment was conducted to evaluate soaking effects. No processing was performed after the cryogenic treatment. A set of specimens was also tested in the as-received condition to establish a baseline.

All testing was performed at room temperature. Tensile tests were conducted per ASTM E8. From this testing, the proportional limit, yield strength (0.2% offset), ultimate tensile strength, and elongation were determined. Hardness testing and Charpy impact testing were also conducted.

As shown in Table 1, the effect of 48-h cryogenic treatment on the basic mechanical properties was very small, generally about a 1% difference.[5] The largest percent change was observed in the Charpy impact testing, which was nearly a 12% difference. There was almost no difference between the as-received and the 2-h treatment for any of the properties.

To determine whether the difference was a result of actual changes in the material or whether the observed differences were due to normal data variation (not a real difference), statistical *t*-tests were performed. The *t*-test is a method of analyzing two sets of data to determine whether the difference in measured averages is real or a byproduct of chance variation. The larger the difference in averages between the two sets of data, and the smaller the deviation from the average within each set of data, the more likely the difference is real.

There were nine specimens for each condition of all tests. This results in 16 degrees of freedom ($9 + 9 - 2 = 16$). A value of the *t*-estimator of 1.75 means there is a 90% confidence level that the two sets of data are truly different. For a *t*-estimator of 2.12, there is a 95% confidence that the difference is real.

The results of the *t*-test are shown in Table 2. The first column compares data from the as-received specimens and the 2-h cryogenic specimens. All of the data resulted in very small *t*-values. This shows that treating the specimens for 2 h at cryogenic temperatures had no measurable statistical effect on the basic mechanical properties. The second column contains the *t*-values for the as-received specimens and the 48-h treatment. The *t*-test from these sets of data shows there is a high probability that the 48-h cryogenic treatment has a real effect on some properties, albeit small.

Table 2 shows that there is about a 90-95% confidence level ($t > 1.75$); that there was a difference in strength, toughness, and hardness as a result of 48-h cryogenic treatment. There was no measured effect on percent elongation. There was about a 1% increase in the proportional limit and yield strength, and a half a percent increase in the ultimate tensile strength (Table 1). There was about a half a point decrease in Rockwell B hardness. The Charpy impact toughness showed the largest change (11% increase) resulting from the 48-h cryogenic treatment.

If there indeed was an effect of 48 h of cryogenic treatment, as the statistical analysis indicates, the mechanism of this effect is unknown. The simultaneous increase of strength and decrease of hardness is difficult to reconcile.

The purpose of this investigation was to determine the effects of cryogenic treatment on 7075-T651 aluminum. The data show that there was no statistically significant effect on basic properties as a result of a 2-h cryogenic treatment. There was a slight increase in strength and toughness and a slight decrease in hardness as a result of 48 h of cryogenic treatment. No explanation as to how cryogenic treatments could affect the properties of the alloy can be provided at this time.

To confirm that cryogenic treatment does have an effect, further testing should be conducted. More extended soak times should be used (such as 96 h or more) to determine if the soak time does indeed make a difference. Advanced microscopy, such as transmission electron microscopy (TEM), should also be performed to evaluate changes in microstructure.

K.E. Lulay, K. Khan, and **D. Chaaya,** Mechanical Engineering Department, University of Portland, 5000 North Willamette Boulevard, Portland, OR 97203. Contact e-mail: lulay@egr.up.edu.

Table 1 Results From Mechanical Testing

	Published Values[5]	As Received	2 h	48 h	Percent Diff: As Rec'd vs 48 h
Proportional limit, MPa		484	485	491	+1.5
Yield strength, 0.2%, MPa	505	530	530	534	+0.8
Ultimate tensile, MPa	570	583	583	585	+0.3
Percent EL, 51 mm gauge	11	16.8	17.1	17	+1.2
Charpy, J		8.5	8.8	9.5	+11.8
Hardness	150 BHN (approx. 80 R_B)	91.3 R_B	91.1 R_B	90.8 R_B	–0.5

Table 2 *t*-Estimators for the Mechanical Property Results

	As Received and at 2 h	As Received and at 48 h
Proportional limit	0.26	2.0
Yield strength	0.00	2.0
Ultimate tensile strength	0.02	1.78
Percent EL, 51 mm gauge	0.60	0.37
Charpy impact	0.62	1.72
Hardness	0.74	2.14

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