Mechanical properties of AA5083 in different tempers at low temperatures

Chuanjun Huang[1], Zhixiong Wu[1], Rongjin Huang[1,2], Wei Wang[1], Laifeng Li[1,2,]*

1. State Key Laboratory of Technologies in Space Cryogenic Propellants, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, China
2. University of Chinese Academy of Sciences, Beijing 100049, China

Background

The Al-Mg alloy 5083 (AA5083) takes advantage of exceptional combination of economy of fabrication, weldability, and corrosion resistance, which is suitable for utilization at room temperature. Moreover, the AA5083 in annealed treatment (temper O) demonstrates extremely high fracture toughness both at room and cryogenic temperatures. Research results have shown that the tensile strength, elastic moduli, and fatigue properties of the AA5083-O at cryogenic temperature were as high as, or even higher than those at room temperature. This makes it be suitable for arctic and cryogenic applications, for instance, storage and transport for liquid natural gas (LNG).

The strain hardening treatment is also widely used for AA5083, mainly including the strain hardened only (temper H1), and strain hardened and following stabilized (temper H3). In the present work, the tensile, bend, Charpy impact, and fatigue crack propagation behavior of the AA5083 in different temper, i.e., O, H112, and H32 were investigated at room and cryogenic temperatures.

Methods

Sample preparation

The AA5083 plates with a thickness of 30 mm in temper O, H112, and H32 conditions were used as-received.

The dumb-bell shape tensile specimen has a gauge length, width and thickness of 30 mm, 15 mm and 2 mm respectively, which complies with requirements by standard ISO 6892-3.

The specimen geometry for three-point bend test complies with requirements by standard ISO 7438.

The V-notch specimen for Charpy impact testing complies with requirements by standard ISO 148-1.

The compact tension specimen for test of fatigue crack growth rate complies for standard ISO and ASTM E647 and ISO 12108 and the specimen has an initial crack length/width ratio of 0.35.

Experimental Procedures

The tensile and bend tests were conducted with a model MTS SANS CMT5105S test machine with a load capacity of 100 kN at 77 K under a displacement-controlled mode. The local deformation was monitored with an Epsilon extensometer with a GL of 25 mm. The 77 K environment was obtained through immersing the test jigs and the whole specimens into liquid nitrogen in the cryostat.

The Charpy impact test was conducted with an model MTS SANS XJ-300A Charpy impact test machine with an alternative hammer of 150 J energy. The test at 77 K was conducted with specimens immersed in liquid nitrogen for more than 15 min and then transferred to the tested machine within 5 s to keep the temperature.

The fatigue crack propagation behaviour was investigated with an Instron 8850 axial/torsion fatigue machine (axial load capacity: ± 120 kN). The CMOD was recorded with a Epsilon clip-on extensometer. The test was conducted with a constant-load controlled mode and with a load ratio (R) of 0.1, i.e., a stress intensity factor *K*-increasing method.

Results

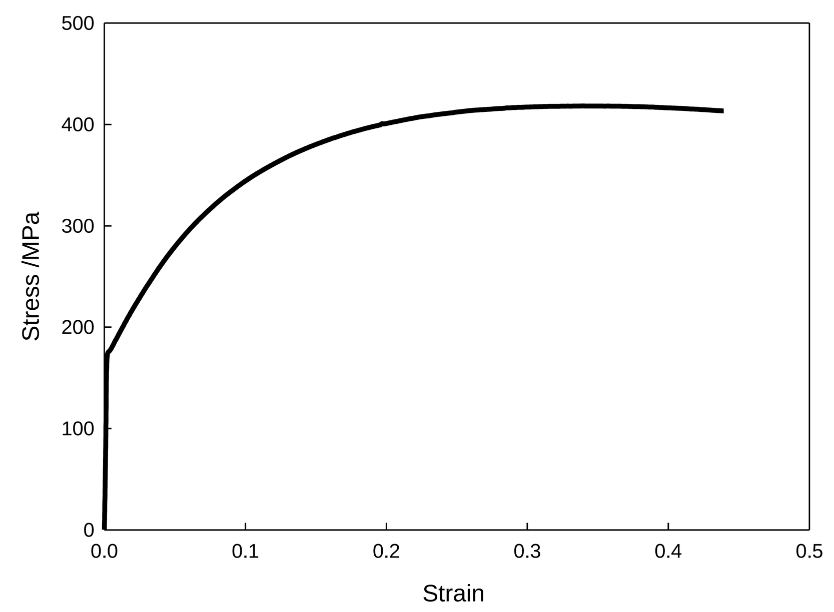

Figure 1. The stress-strain curve of the AA5083-O at 77 K

Table 1. The tensile properties the AA5083-O, AA5083-H112, and AA5083-H32 at 77K

No.	$R_{p0.2}$ /MPa	R_m /MPa	E /GPa	A /%
AA5083-O	177.4±1.82	421.0±2.24	82.4±4.04	46.4±1.52
AA5083-H112	175.4±1.95	417.0±2.74	82.6±8.38	46.0±2.00
A5083-H32	176.0±2.0	419.8±0.45	81.6±4.39	44.8±4.09

Test results of tensile properties including the 0.2% proof stress, ultimate tensile strength, and elongation at failure indicates that the effect of temper in terms of O, H112, and H32 on cryogenic tensile strength and ductility is slight.

Results

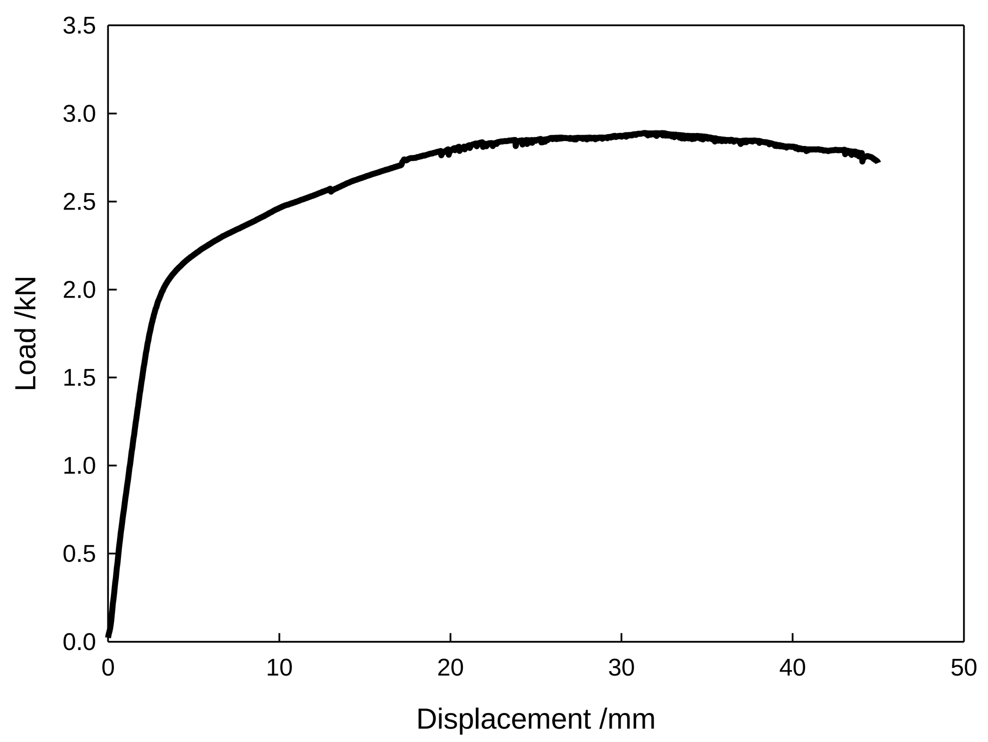

Figure 2. Typical load-displacement curve of bend test of AA5083-O at 77 K

Table 2. Bend properties of the AA5083-O, AA5083-H112, and AA5083-H32 at 77 K

No.	Bend strength /MPa	Bend Moduli /GPa
AA5083-O	670±21.8	76.0±4.36
AA5083-H112	649±7.42	71.8±1.92
A5083-H32	705±6.12	71.8±1.10

As shown in Table 2, the average bend strength of the AA5038-H32 is larger than those of AA5038-O and AA5038-H112, whereas the AA5083-O exhibits a slightly larger value than that of AA5038-H112.

Typical load-displacement curve of AA5083 at 77 K is shown in Fig. 2, which indicates a typical ductile behavior. Moreover, serrated stress-strain behavior was observed, as shown in Fig. 2.

Table 3. Charpy impact energy of the AA5083-O, AA5083-H112, and AA5083-H32 at 150 and 77 K

	Temperature /K	Impact Energy /J
AA5083-O		
	150	24.7±0.58
	77	22.0±0
AA5083-H112		
	150	24.7±0.58
	77	20.8±0.84
AA5083-H32		
	150	26.7±0.58
	77	21.2±0.45

The Charpy impact energy of the AA5083-O, AA5083-H112, and AA5083-H32 test at 150 K and 77 K is listed in Table 3. At 150 K, the AA5083-O has Charpy impact energy of 24.7 J, which is the same to that of the AA5083-H112, whereas the AA5083-H32 demonstrates a slightly larger value, i.e., 26.7 J. When temperature decreased to 77 K, the average Charpy impact energy of the AA5083-O, AA5083-H112, and AA5083-H32 is 22.0 J, 20.8 J, and 21.2 J, respectively.

As shown in Figure 3, the fatigue crack growth of AA5083 in all interest temper occurs more slowly at low temperature than that at room temperature if small to moderate ΔK-values (8-23 MPa.m$^{1/2}$) are applicable, whereas faster crack growth was observed for larger ΔK-values with K_{max} close to plane stress fracture toughness K_c or K_{Ic}.

The fatigue crack growth rates of the AA5083-H32 are higher than those of AA5083-O, whereas the AA5083-H112 seems to demonstrate the lowest value at 77 K.

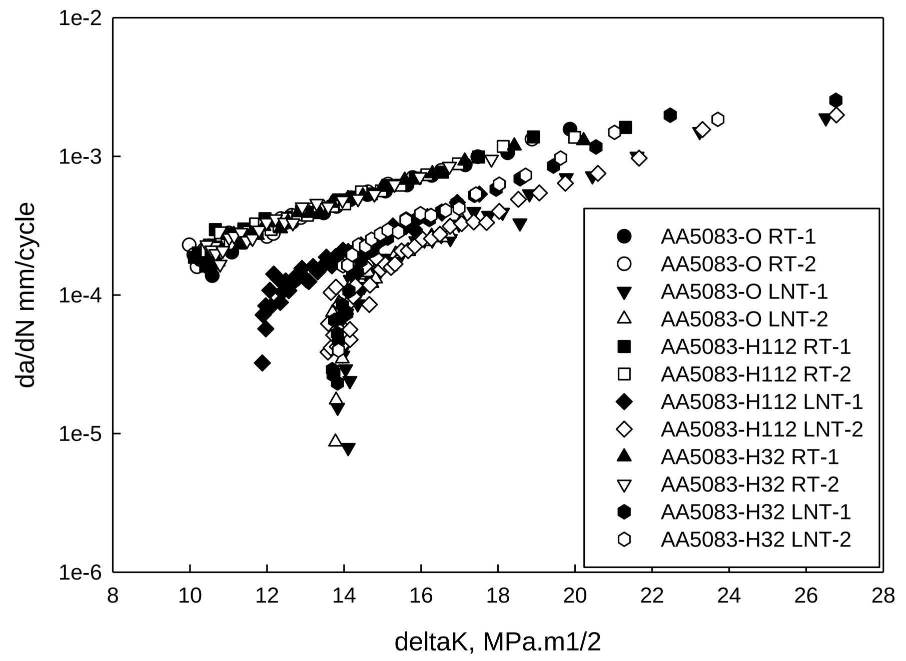

Figure 3. Fatigue crack growth rate for the AA5083-O, AA5083-H112, and AA5083-H32 at room temperature and 77 K.

Conclusion

- The tensile properties including 0.2% proof stress, ultimate tensile stress and elongation at failure depended slightly on the temper at 77 K;
- The temper H32 resulted in a highest bend strength whereas the temper H112 resulted in the lowest bend strength at 77 K;
- The AA5083-O exhibited same Charpy impact energy value as the AA5083-H112 and both are slightly lower than that of the AA5038-H32 at 150 K. The Charpy impact energy of the AA5083-O, AA5083-H112, and AA5083-H32 were close at 77 K and all were lower than those at 150 K;
- At 77 K, the fatigue crack growth rates of the AA5083-H32 were higher than those of the AA5083-O, whereas the AA5083-H112 demonstrated the lowest value.

*Corresponding author: laifengli@mail.ipc.ac.cn