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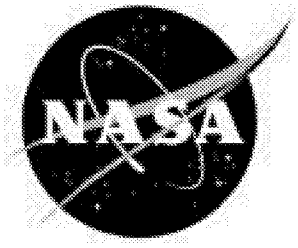

Influence of Crack-Tip Configurations on the Fracture Response of 0.04-Inch Thick 2024-T3 Aluminum Alloy Sheet

William M. Johnston
Analytical Services and Materials Inc., Hampton, Virginia

February 2002

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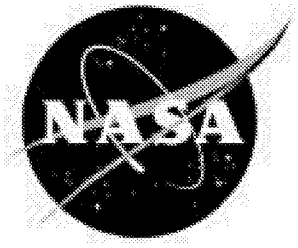

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Abstract

A series of fracture tests were conducted on Middle-crack tension M(T) and compact tension C(T) specimens to determine the effects of specimen type, specimen width, notch tip sharpness and buckling on the fracture behavior of cracked thin sheet (0.04 inch thick) 2024-T3 aluminum alloy material. A series of M(T) specimens were tested with three notch tip configurations: (1) a fatigue pre-cracked notch, (2) a 0.010-inch-diameter wire electrical discharge machined (EDM) notch. and (3) a EDM notch sharpened with a razor blade. The test procedures are discussed and the experimental results for failure stress, load vs. crack extension and the material stress-strain response are reported.

Introduction

Thin sheet 2024-T3 aluminum alloy has been used in commercial aircraft fuselages for the past 50 years. As these commercial aircraft age, it is important to have fracture mechanics models developed to assess failure of the structure subjected to cracking scenarios such as multi-site-damage (MSD) and multi-element-damage (MED). When developing these methodologies it is important to first verify crack growth models using flat aluminum alloy sheets prior to addressing crack growth in the actual structure. The objective of this paper is to report the experimental results from fracture tests on 0.04-inch-thick 2024-T3 aluminum alloy specimens. The flat thin sheet tests were designed to demonstrate the effects of notch tip sharpness, specimen width, and buckling on the fracture behavior of 0.04-inch-thick 2024-T3 aluminum alloy material. The test procedures are discussed and the experimental results for failure stress, load versus crack extension and the material stress-strain are reported.

Experimental Procedure

The fracture behavior was characterized through a series fracture tests conducted on compact tension, C(T), and middle crack tension, M(T), specimens. The M(T) specimens were tested with and without anti-buckling guides for a variety of widths to generate experimental data to study the effects of crack buckling on fracture. A series of 12-inch-wide M(T) specimens were tested with three notch tip configurations to determine the effect of notch sharpness.

The M(T) and C(T) specimens were configured in the L-T orientation. The L-T orientation represents orientating the crack perpendicular to the rolling direction and applying load parallel to the rolling direction. A schematic of a C(T) specimen is shown in Figure 1. One size C(T) specimen was tested (W = 6 inches) with an initial crack length-to-width ratio (a/W) of approximately 0.4. All C(T) specimens were tested with guide plates and did not experience buckling. A schematic of a M(T) specimen is shown in Figure 2. M(T) specimens with four different widths (W = 3, 12, 24, and 40 inches) were tested with an initial crack length-to-width ratio, 2a/W = 1/3. The 12-inch-wide M(T) specimens were tested with three crack configurations: (1) a fatigue pre-cracked notch, (2) a 0.010-inch-diameter wire EDM notch, and (3) a sharpened EDM notch. The sharpened EDM notch was

0.010-inches-wide with the ends sharpened with a razor blade. The fatigue precracked M(T) and C(T) specimens were precracked at a stress-intensity factor of approximately $\Delta K = 8 \text{ ksi}\sqrt{\text{inch}}$. The specimens were fractured under displacement control, at a ramp rate in the range of 0.01-0.04 inch/minute. Experimental measurements of load and crack extension were made during the fracture tests.

Tensile tests were conducted on standard 0.5-inch-wide rectangular tension specimens as shown in Figure 3. Three specimens were tested in the L direction (rolling direction). The tensile tests were conducted according to the ASTM E8 standard. Young's modulus, yield stress and ultimate tensile stress were calculated from the test data. A linear piecewise function was used to fit to the data.

Experimental Results

The measured failure loads from the C(T) tests are listed in Table 1. The failure stresses calculated from the M(T) tests with and without buckling constraint are listed in Table 2 and plotted in Figure 4. Results from the 12-inch-wide M(T) specimens show that notch tip sharpness did not affect the ultimate failure load of the fracture specimens. The following sections describe the crack length measurements made for each of the specimen types.

Crack Extension Data

Optical measurements of crack extension at the surface and the corresponding applied load were recorded for each of the C(T) specimen tests. The crack extension measurements were made on one surface of the specimens. The measurement data for specimens are listed in Table 3 and plotted in Figure 5.

For the M(T) fracture tests the experimental setup generally allowed crack extension to be measured at both crack tips. The crack extension (Δa) results reported for the panels represent extensions at two crack tips listed as two columns of data in Tables 6-11. When the 3-inch-wide M(T) specimens were tested the total front crack length (2a) was recorded. The stresses reported are nominal stress values in the M(T) specimens defined by:

$$\sigma = \frac{F}{W \cdot B} \tag{1}$$

where F is the applied load, W is the specimen width and B is the specimen thickness. The load vs. crack extension response for specimens with and without buckling constraint is compared for the 3-inch and 12-inch-wide M(T) specimens in Figures 6 and 7, respectively. The crack initiation and early growth behavior of the constrained and buckling specimens are compared for the 12-inch-wide M(T) specimens in Figures 8 and 9, respectively. In these two figures the fatigue precracked data are shown with solid symbols and the dat for specimens with EDM notches are show by the open symbols. The data indicates that the specimens that were not fatigue precracked required higher load to initiate crack growth and followed different load vs. crack extension paths. The load vs. crack extension results from the 24-inch and 40-inch-wide M(T) specimens are shown in Figures 10 and 11, respectively.

Tension Tests

Results from the tensile tests are presented in Figure 12. This figure shows the stress-strain results from the three tensile tests in each orientation along with a piecewise linear curve fit to the data. Tabulated values for the linear fit are shown in Figure 12.

Summary

Fracture and tensile tests were conducted on thin sheet specimens of 2024-T3 aluminum alloy material. Both middle crack tension M(T) and compact tension C(T) specimens were tested in the L-T orientation. Specimens with four widths (W= 3, 12, 24, and 40-inch) were tested for the middle crack tension specimens, and 6-inch-wide compact tension specimens were tested. The M(T) specimens were tested in constrained (no out of plane displacement) and a unconstrained conditions where the specimen was free to buckle in the out-of-plane direction. Results in the form of load vs. crack extension and stress-strain behavior were reported. Buckling was shown to reduce the failure load of M(T) specimens by up to 31% (40-inch-wide M(T) specimens). The notch tip sharpness did not affect the ultimate failure load for the M(T) specimens but the fatigue precracked specimens did have lower crack initiation loads, and different load-crack extension behavior than the specimens with EDM notches.

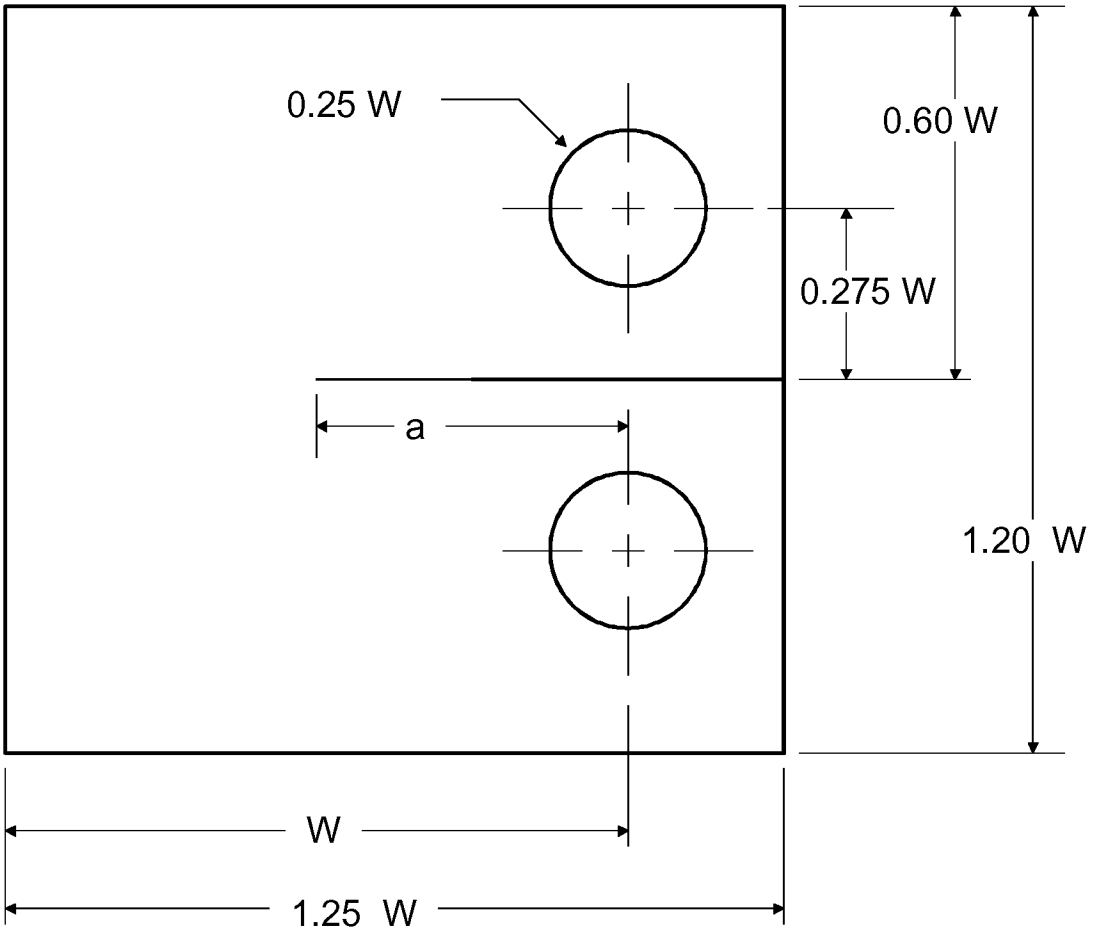
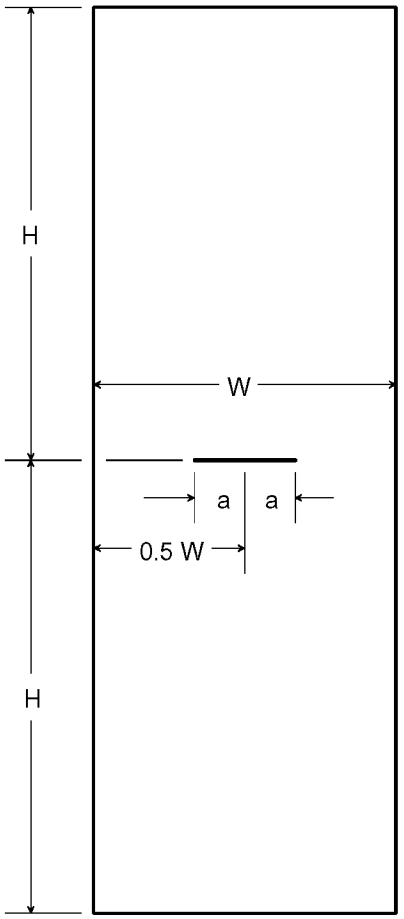


Figure 1. Schematic of a compact tension specimen (W = specimen width).



Specimen Width, W (in.)	Specimen Height, H (in.)
3.0	6.0
12.0	26.5
24.0	50.5
40.0	70.5

Figure 2. Schematic of a middle tension specimen (W = specimen width).

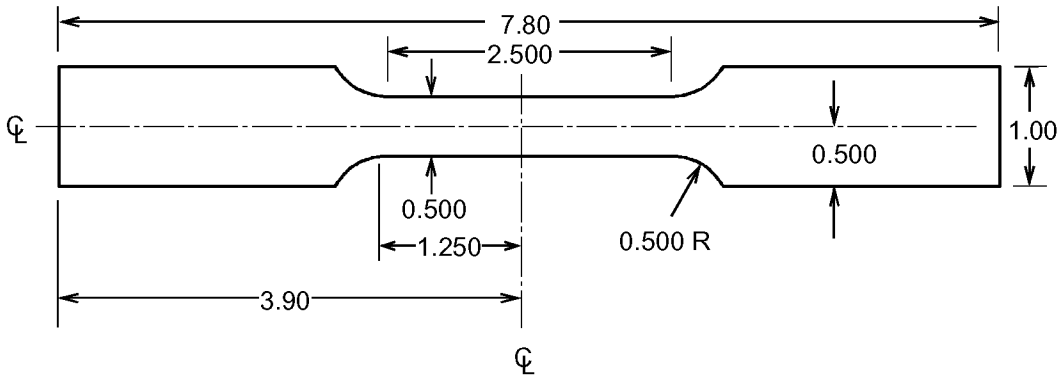


Figure 3. Dimensions of tensile specimen used for static tests.

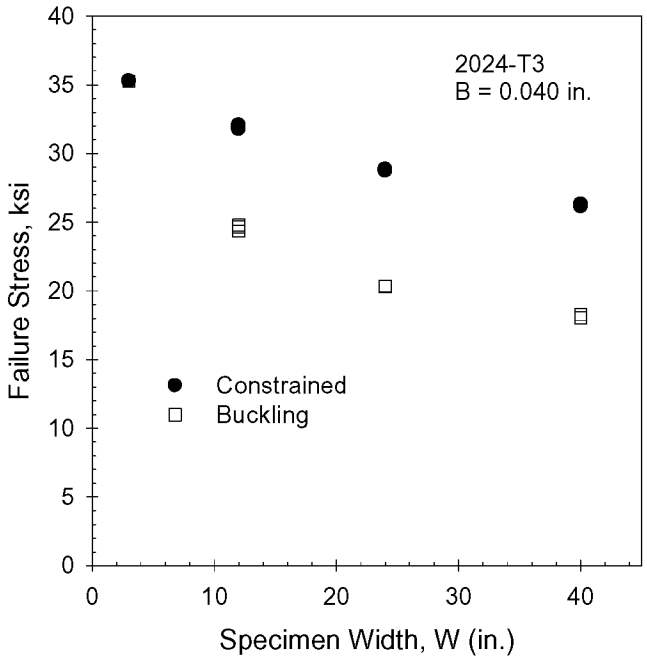


Figure 4. Failure stress results for M(T) specimens of different widths.

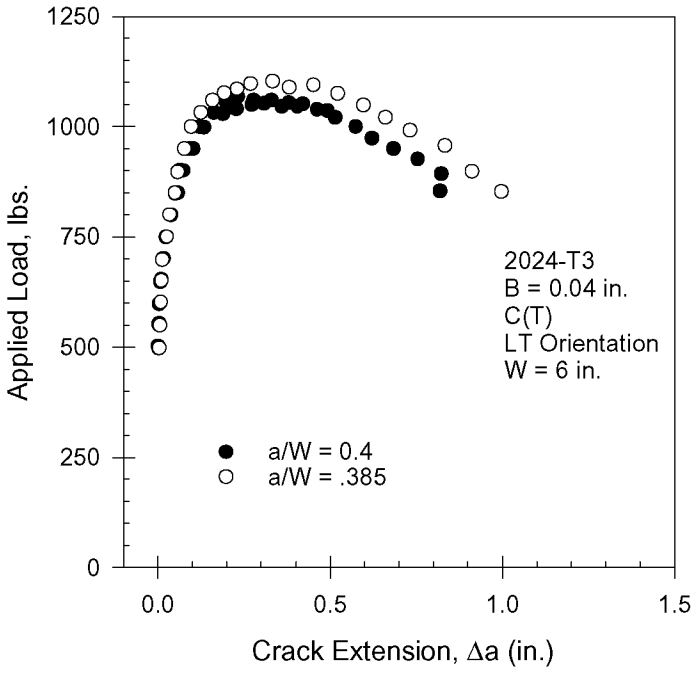


Figure 5. Applied load vs. crack extension results for the 6-inch-wide C(T) specimen.

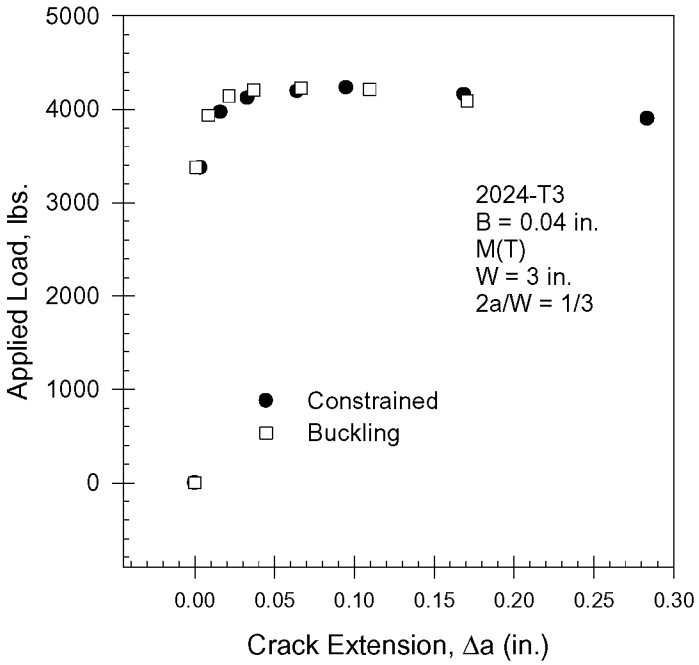


Figure 6. Applied load vs. crack extension results for the 3-inch-wide M(T) specimen.

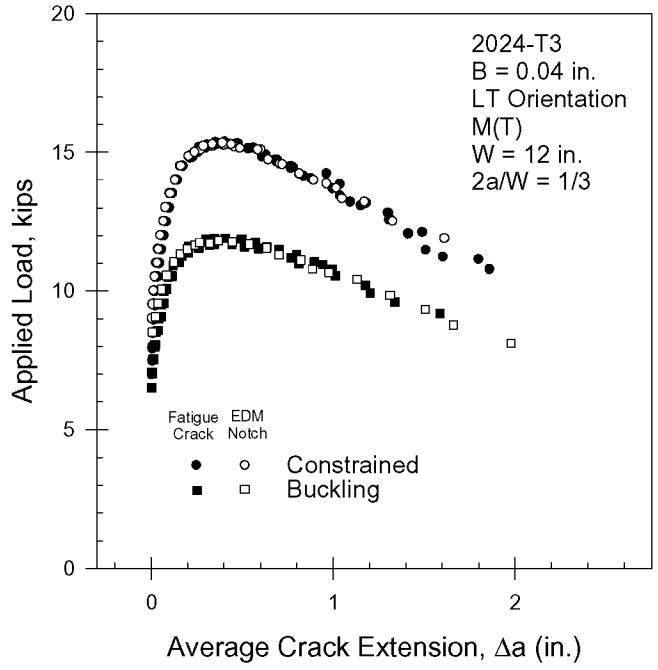


Figure 7. Applied load vs. crack extension results for LT orientation 12-inch-wide M(T) specimens with and without buckling constraint.

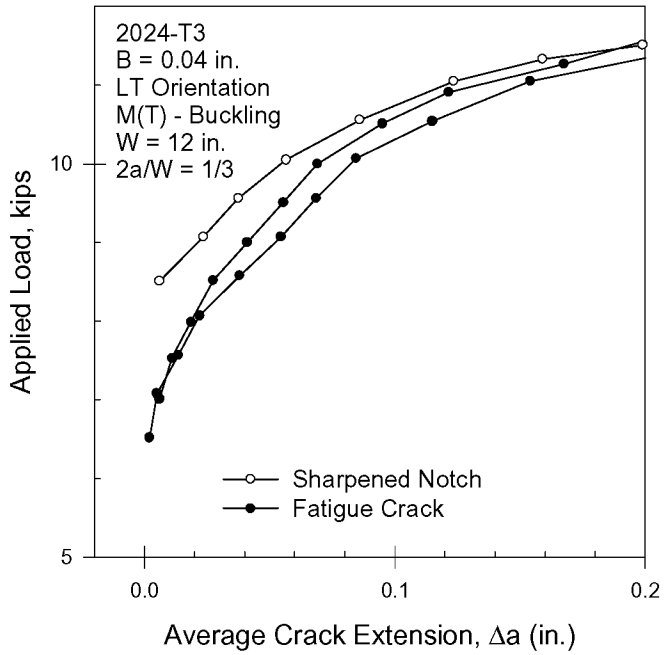


Figure 8. Initial applied load vs. crack extension results for buckling 12-inch-wide M(T) specimens.

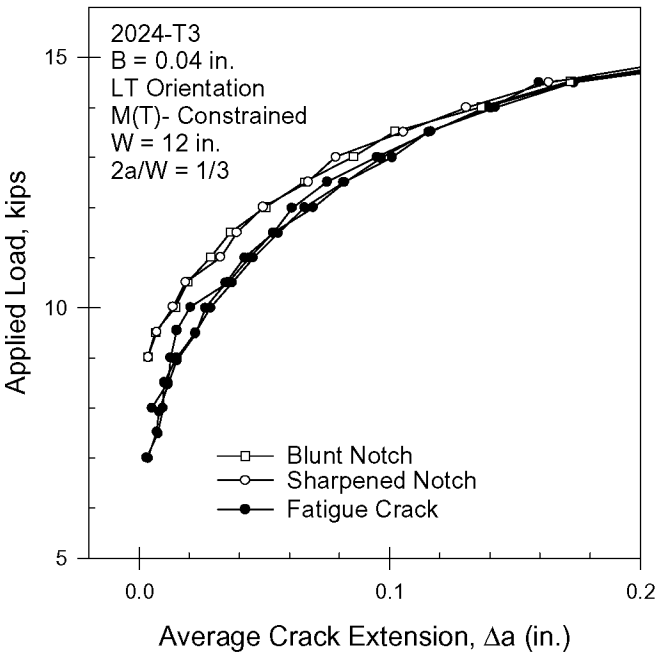


Figure 9. Initial applied load vs. crack extension results for constrained 12-inch-wide M(T) specimens.

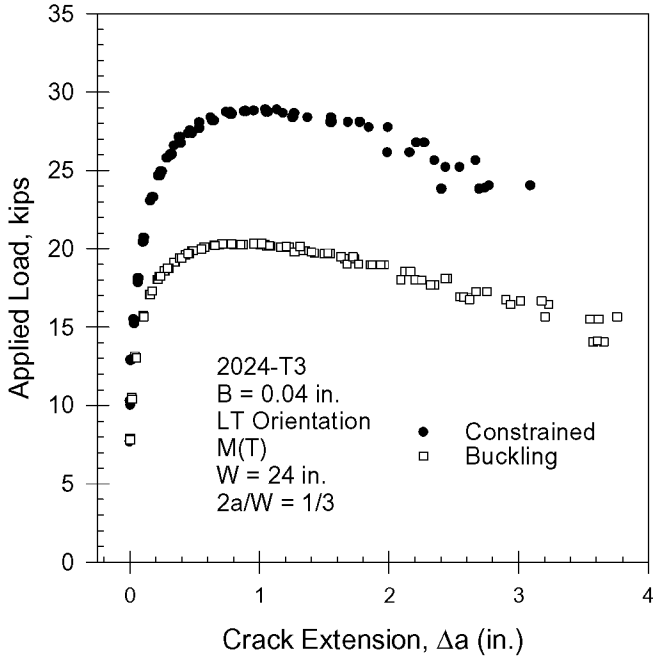


Figure 10. Applied load against crack extension results for 24-inch-wide M(T) specimens with and without buckling constraint.

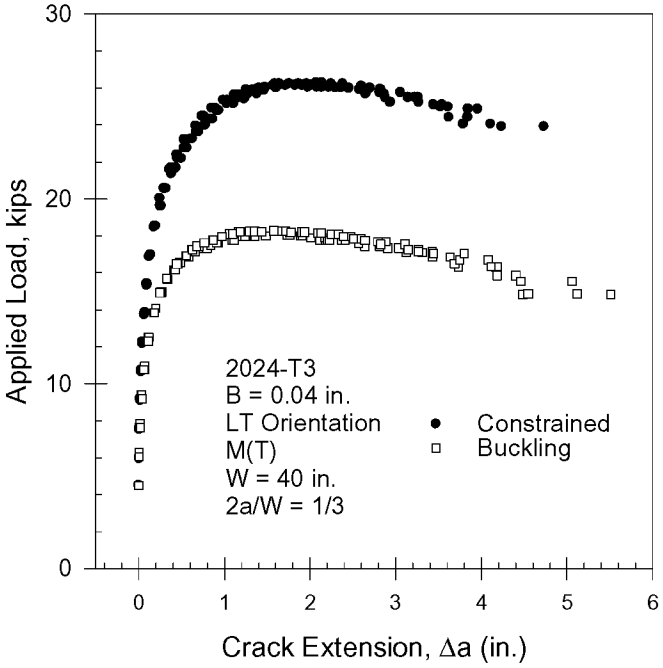


Figure 11. Applied load against crack extension results for 40-inch-wide M(T) specimens with and without buckling constraint.

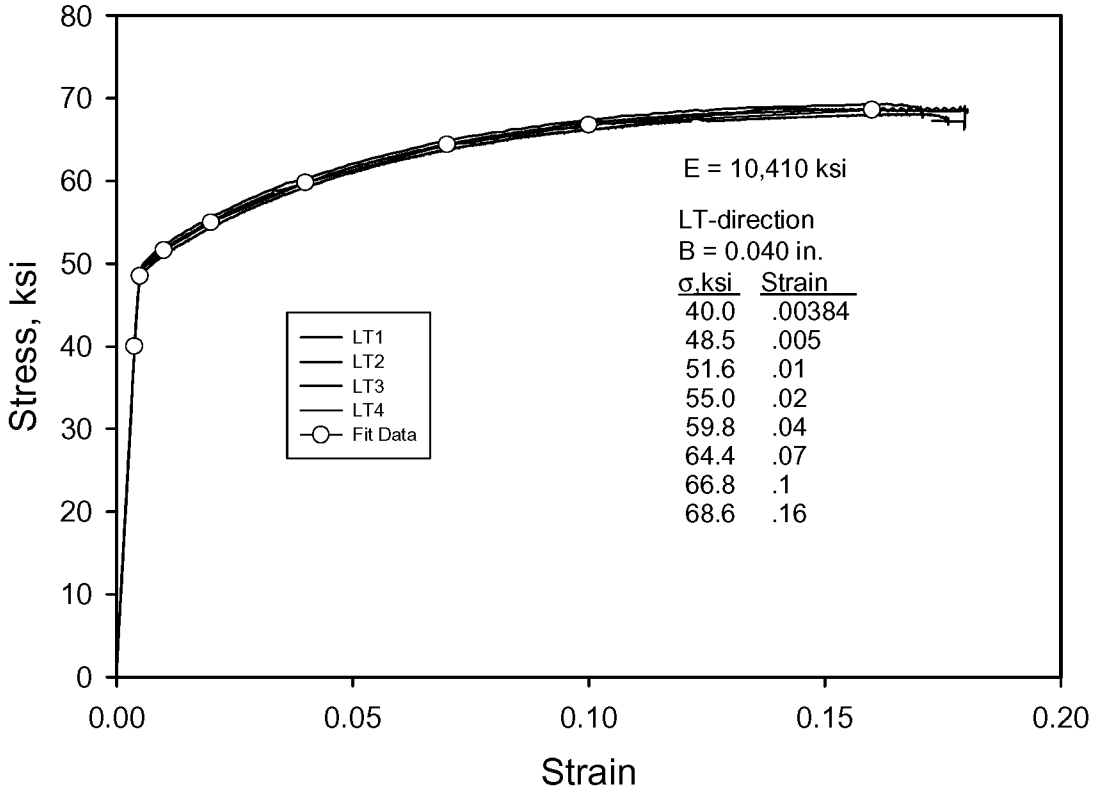


Figure 12. Tensile stress vs. stain results for 0.04-inch-thick 2024-T3 aluminum alloy sheet.

Table 1. Failure Loads for the C(T) LT Fracture Test Specimens (B = 0.04 in.)

Width (inch)	Crack Length, a (inch)	Failure Load (lbs)
6.0	2.400	1067
6.0	2.308*	1102
6.0	2.406	1079

* Angled Pre-crack

Table 2. Failure Stresses for the M(T) LT Fracture Test Specimens (B = 0.04 in.)

	M(T) LT constrained		M(T) LT unconstrained	
Width (inch)	Failure Stress (ksi)	Crack Length, 2a (inch)	Failure Stress (ksi)	Crack Length, 2a (inch)
3	35.28	1.000	35.24	1.001
12(sharp notch)	31.94	4.000*	24.625	4.000*
12(blunt notch)	31.79	4.000*	-	-
12	31.90	3.998	24.35	4.000
12	32.06	4.001	24.79	4.000
12	31.85	4.000	-	-
24	28.86	8.000	20.31	8.000
24	28.75	8.000	20.33	8.000
40	26.16	13.333	18.03	13.333
40	26.29	13.333	18.28	13.333

*EDM Notch

Table 3. Load and Crack Extension Measurements for 6-inch-Wide C(T) LT Test Specimens.

W=6 in., a = 2.400 in.		W=6 in., a = 2.406 in.		W=6 in., a = 2.308 in.	
Load (lbs)	Δa (inch)	Load (lbs)	Δa (inch)	Load (lbs)	Δa (inch)
502	0.001	498	0.002	498	0.004
553	0.004	551	0.003	549	0.007
599	0.007	598	0.005	602	0.009
654	0.011	648	0.008	650	0.011
700	0.017	699	0.015	698	0.014
750	0.027	749	0.024	750	0.027
799	0.039	800	0.039	800	0.035
848	0.051	849	0.058	849	0.05
901	0.065	900	0.075	897	0.058
949	0.093	950	0.103	950	0.078
999	0.123	998	0.134	999	0.097
1031	0.163	1029	0.189	1032	0.126
1052	0.201	1040	0.228	1059	0.16
1067	0.233	1049	0.273	1076	0.193
1060	0.278	1052	0.309	1085	0.23
1059	0.331	1045	0.361	1097	0.27
1054	0.381	1045	0.406	1102	0.334
1051	0.421	1038	0.463	1089	0.382
1036	0.493	1020	0.516	1094	0.452
		999	0.575	1075	0.522
		973	0.623	1048	0.597
		950	0.684	1020	0.661
		926	0.755	991	0.733
		893	0.823	957	0.834
		854	0.820	898	0.913
				852	0.998

Table 4. Load and Crack Extension Measurements for 3-inch-Wide M(T) LT Test Specimens.

W=3 in., constrained 2a = 1.000 in.		W=3 in., unconstrained 2a = 1.001 in.	
Load (lbs)	2a (inch)	Load (lbs)	2a (inch)
0	1.000	0	1.001
3375	1.007	3378	1.003
3971	1.032	3935	1.018
4121	1.066	4140	1.044
4193	1.128	4207	1.075
4234	1.190	4229	1.134
4160	1.337	4213	1.220
3900	1.567	4088	1.342

Table 5. Load and Crack Extension Measurements for 12-inch-Wide M(T) LT Test Specimens.

W=12 in., sharpened notch unconstrained 2a = 4.000 in.*			W=12 in., sharpened notch constrained 2a = 4.000 in.*		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
8.51	0.007	0.005	9.01	0.004	0.003
9.07	0.026	0.021	9.52	0.008	0.006
9.56	0.042	0.033	10.02	0.015	0.012
10.05	0.060	0.053	10.51	0.022	0.015
10.56	0.097	0.075	11.01	0.036	0.029
11.05	0.129	0.118	11.50	0.041	0.037
11.33	0.173	0.145	12.01	0.053	0.046
11.51	0.205	0.193	12.51	0.073	0.062
11.66	0.253	0.224	13.01	0.084	0.073
11.74	0.279	0.254	13.51	0.107	0.104
11.72	0.340	0.300	14.00	0.129	0.132
11.82	0.382	0.358	14.50	0.161	0.166
11.78	0.477	0.416	14.86	0.207	0.208
11.69	0.569	0.508	15.00	0.238	0.237
11.56	0.660	0.605	15.22	0.283	0.291
11.31	0.719	0.686	15.29	0.337	0.335
11.11	0.862	0.784	15.33	0.384	0.399
10.79	0.915	0.859	15.28	0.434	0.449
10.66	1.026	0.928	15.15	0.477	0.501
10.42	1.211	1.054	15.09	0.570	0.601
9.84	1.405	1.221	14.74	0.624	0.662
9.34	1.645	1.369	14.56	0.709	0.731
8.77	1.907	1.417	14.23	0.806	0.823
8.12	2.370	1.588	13.99	0.882	0.901
2.07	2.443	1.683	13.71	0.979	1.057
			13.21	1.124	1.221
			12.51	1.262	1.392
			11.90	1.449	1.776

*EDM notch length

Table 6. Load and Crack Extension Measurements for 12-inch-Wide M(T) LT Test Specimens.

W=12 in., blunt notch constrained 2a = 4.000 in.*			W=12 in., fatigue crack constrained 2a = 3.988 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
9.02	0.005	0.002	7.01	0.003	0.003
9.51	0.010	0.003	7.49	0.010	0.005
10.01	0.021	0.008	8.00	0.012	0.007
10.52	0.025	0.014	8.51	0.012	0.008
11.01	0.033	0.024	9.00	0.017	0.013
11.51	0.049	0.024	9.51	0.024	0.021
12.01	0.058	0.043	10.00	0.026	0.031
12.51	0.075	0.057	10.49	0.038	0.036
13.02	0.089	0.082	11.00	0.045	0.046
13.52	0.105	0.099	11.49	0.056	0.055
14.01	0.133	0.140	12.00	0.062	0.070
14.52	0.165	0.179	12.50	0.082	0.081
14.86	0.213	0.216	13.00	0.101	0.101
15.08	0.271	0.275	13.51	0.112	0.119
15.22	0.336	0.340	13.99	0.138	0.143
15.26	0.400	0.396	14.50	0.190	0.129
15.20	0.460	0.456	14.82	0.225	0.229
15.10	0.584	0.620	15.09	0.273	0.271
14.58	0.690	0.728	15.22	0.319	0.323
14.23	0.789	0.836	15.31	0.369	0.372
13.87	0.925	1.000	15.30	0.409	0.426
13.33	1.019	1.080	15.31	0.478	0.474
			15.16	0.550	0.573
			14.91	0.618	0.638
			14.72	0.682	0.703
			14.50	0.761	0.776
			14.23	0.982	0.945
			13.43	1.040	1.035
			13.17	1.161	1.202
			12.56	1.315	1.300
			12.12	1.605	1.378

*EDM notch length

Table 7. Load and Crack Extension Measurements for 12-inch-Wide M(T) LT Test Specimens.

W=12 in., constrained 2a = 4.001 in.			W=12 in., constrained 2a = 4.000 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
7.00	0.003	0.004	8.00	0.007	0.003
7.52	0.006	0.008	8.51	0.012	0.011
7.93	0.007	0.009	9.00	0.014	0.011
8.47	0.010	0.013	9.55	0.016	0.014
8.95	0.015	0.015	10.01	0.021	0.020
9.48	0.023	0.022	10.51	0.034	0.037
10.00	0.028	0.025	11.00	0.041	0.047
10.50	0.036	0.033	11.50	0.046	0.061
11.00	0.042	0.042	12.00	0.066	0.073
11.49	0.055	0.052	12.50	0.080	0.084
11.99	0.063	0.059	12.99	0.096	0.097
12.51	0.079	0.071	13.51	0.113	0.118
13.01	0.096	0.094	14.00	0.139	0.145
13.52	0.118	0.115	14.49	0.172	0.175
14.02	0.142	0.136	14.79	0.212	0.218
14.51	0.177	0.170	15.00	0.254	0.260
14.90	0.227	0.214	15.15	0.303	0.296
15.18	0.268	0.255	15.26	0.351	0.354
15.28	0.317	0.294	15.29	0.460	0.408
15.36	0.360	0.345	15.13	0.531	0.539
15.39	0.421	0.389	14.83	0.612	0.606
15.29	0.474	0.449	14.66	0.670	0.706
15.13	0.532	0.532	14.41	0.765	0.769
14.94	0.612	0.617	14.06	0.859	0.901
14.73	0.694	0.665	13.70	0.955	1.041
14.46	0.777	0.783	13.21	1.080	1.110
14.14	0.844	0.832	12.81	1.251	1.353
13.85	1.084	0.990	12.06	1.308	1.518
13.08	1.175	1.131	11.48	1.467	1.551
12.62	1.334	1.289	11.14	1.679	1.918
11.23	1.630	1.578			
10.78	2.090	1.628			

Table 8. Load and Crack Extension Measurements for 12-inch-Wide M(T) LT Test Specimens.

W=12 in., unconstrained 2a = 4.004 in.			W=12 in., unconstrained 2a = 4.004 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
6.52	0.000	0.004	7.01	0.008	0.004
7.08	0.005	0.005	7.53	0.013	0.009
7.57	0.013	0.014	7.99	0.019	0.018
8.07	0.023	0.021	8.52	0.032	0.023
8.58	0.034	0.042	9.00	0.041	0.041
9.07	0.054	0.055	9.51	0.059	0.052
9.56	0.070	0.067	10.00	0.071	0.067
10.07	0.087	0.082	10.51	0.098	0.092
10.54	0.117	0.113	10.91	0.125	0.118
11.05	0.155	0.153	11.27	0.178	0.157
11.38	0.208	0.204	11.60	0.209	0.2
11.56	0.269	0.251	11.78	0.262	0.336
11.66	0.321	0.320	11.88	0.308	0.292
11.68	0.360	0.334	11.90	0.362	0.332
11.69	0.454	0.436	11.90	0.411	0.404
11.60	0.520	0.506	11.88	0.511	0.482
11.53	0.590	0.590	11.75	0.585	0.562
11.39	0.701	0.701	11.59	0.657	0.613
11.19	0.767	0.767	11.50	0.712	0.693
10.98	0.810	0.810	11.32	0.835	0.761
10.95	0.944	0.944	11.05	0.934	0.859
10.55	1.013	1.013	10.08	1.05	0.938
10.21	1.177	1.177	10.53	Not Visible	1.057
9.93	1.203	1.203	10.11		1.147
9.60	1.340	1.340	9.79		1.333
9.19	1.587	1.587	8.91		1.417
			8.05		1.528
			8.10		1.627

Table 9. Load and Crack Extension Measurements for 24-inch-Wide M(T) LT Test Specimens.

W=24 in., constrained 2a =7.998 in.			W=24 in., constrained 2a = 8.000 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
9.62	0.004	0.004	7.38	0.001	0.000
14.62	0.037	0.032	9.88	0.002	0.002
17.12	0.064	0.066	12.38	0.005	0.011
19.62	0.106	0.100	14.88	0.030	0.027
22.12	0.158	0.159	17.38	0.069	0.064
23.66	0.219	0.235	19.88	0.111	0.104
24.76	0.292	0.286	22.36	0.173	0.183
25.52	0.340	0.342	23.94	0.238	0.249
26.02	0.379	0.393	24.96	0.311	0.325
26.44	0.462	0.462	25.66	0.377	0.398
26.94	0.540	0.537	26.26	0.451	0.482
27.24	0.625	0.624	26.58	0.539	0.536
27.56	0.745	0.775	27.04	0.636	0.651
27.64	0.894	0.957	27.44	0.777	0.790
27.72	1.048	1.135	27.60	0.905	0.878
27.50	1.182	1.270	27.58	1.051	1.068
27.24	1.373	1.554	27.26	1.255	1.264
26.64	1.845	1.992	26.96	1.560	1.547
25.08	1.986	2.160	26.96	1.684	1.776
			25.70	2.273	2.212
			24.20	2.436	2.544
			23.08	3.092	2.773

Table 10. Load and Crack Extension Measurements for 24-inch-Wide M(T) LT Test Specimens.

W=24 in., unconstrained 2a = 8.022 in.			W=24 in., unconstrained 2a = 7.999 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
7.60	0.003	0.003	7.50	0.003	0.002
10.12	0.013	0.016	10.00	0.014	0.017
12.62	0.043	0.040	12.52	0.053	0.053
15.10	0.101	0.106	15.02	0.105	0.108
16.40	0.154	0.158	16.60	0.176	0.173
17.32	0.208	0.218	17.52	0.230	0.237
17.86	0.273	0.266	18.00	0.304	0.291
18.36	0.349	0.344	18.64	0.384	0.400
18.84	0.428	0.428	18.90	0.457	0.451
19.08	0.478	0.488	19.18	0.550	0.555
19.30	0.577	0.575	19.38	0.654	0.656
19.42	0.688	0.651	19.50	0.781	0.785
19.50	0.715	0.712	19.52	0.958	1.017
19.46	0.846	0.801	19.40	1.069	1.079
19.46	0.874	0.856	19.34	1.208	1.313
19.48	1.041	1.003	19.02	1.270	1.402
19.36	1.086	1.054	18.94	1.423	1.528
19.30	1.232	1.163	18.72	1.630	1.723
19.10	1.352	1.321	18.26	1.676	1.764
18.90	1.500	1.549	18.22	1.868	1.936
18.60	1.730	1.656	17.82	2.123	2.164
18.22	1.965	1.857	17.38	2.449	2.432
17.30	2.199	2.093	16.58	2.671	2.754
17.28	2.253	2.254	16.00	3.014	3.177
16.98	2.350	2.321	15.02	3.760	3.203
16.28	2.572	2.544			
16.24	2.621	2.573			
16.10	2.902	2.621			
15.78	3.231	2.938			
14.88	3.617	3.551			
13.50	3.658	3.575			
13.58	4.094	3.604			

Table 11. Load and Crack Extension Measurements for 40-inch-Wide M(T) LT Test Specimens.

W=40 in., constrained 2a=13.334 in.			W=40 in., constrained 2a = 13.334 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
7.20	0.001	0.002	9.54	0.003	0.004
9.68	0.004	0.004	12.04	0.007	0.008
12.18	0.006	0.006	14.56	0.018	0.017
14.72	0.012	0.010	17.06	0.029	0.024
17.18	0.026	0.023	19.52	0.043	0.042
19.66	0.044	0.038	22.02	0.061	0.063
22.18	0.071	0.067	24.56	0.091	0.093
24.68	0.096	0.095	27.04	0.122	0.126
27.18	0.139	0.136	29.58	0.177	0.177
29.68	0.186	0.192	32.06	0.244	0.247
31.40	0.262	0.249	34.56	0.360	0.356
32.90	0.314	0.294	35.82	0.449	0.445
34.20	0.380	0.377	37.14	0.550	0.525
34.70	0.432	0.380	38.32	0.667	0.660
35.52	0.497	0.446	39.18	0.761	0.738
36.42	0.562	0.530	39.86	0.894	0.849
37.22	0.628	0.614	40.56	1.033	0.986
37.80	0.694	0.671	41.00	1.173	1.115
38.38	0.777	0.760	41.44	1.328	1.253
38.90	0.861	0.821	41.60	1.453	1.398
39.66	0.935	0.909	41.98	1.638	1.587
40.24	1.106	1.026	41.98	1.757	1.749
40.66	1.229	1.138	42.00	1.956	1.866
41.10	1.378	1.276	42.06	2.134	2.073
41.42	1.463	1.393	41.98	2.382	2.245
41.64	1.603	1.475	41.76	2.597	2.393
41.82	1.713	1.567	41.48	2.819	2.578
41.86	1.825	1.638	41.22	3.052	2.809
41.86	2.009	1.910	40.80	3.255	3.226
41.68	2.082	1.973	39.96	3.522	3.609
41.68	2.217	2.140	39.79	3.953	3.844
41.64	2.357	2.293	38.26	4.728	4.232
41.58	2.697	2.453			
41.08	2.862	2.648			
40.80	3.140	2.874			
40.36	3.268	2.935			
40.16	3.538	3.438			
39.06	3.837	3.616			
38.48	4.104	3.787			

Table 12. Load and Crack Extension Measurements for 40-inch-Wide M(T) LT Test Specimens.

W=40 in., unconstrained 2a=13.333 in.			W=40 in., unconstrained 2a=13.333 in.		
Load (kips)	Δa (inch)	Δa (inch)	Load (kips)	Δa (inch)	Δa (inch)
10.02	0.002	0.002	7.18	0.000	0.001
12.54	0.010	0.014	9.68	0.003	0.004
15.02	0.030	0.032	12.20	0.009	0.019
17.52	0.068	0.067	14.68	0.030	0.041
20.02	0.115	0.119	17.20	0.067	0.064
22.52	0.198	0.199	19.68	0.110	0.111
23.92	0.267	0.262	22.16	0.177	0.184
25.02	0.336	0.332	23.86	0.254	0.250
25.86	0.412	0.426	25.10	0.330	0.326
26.48	0.480	0.487	26.36	0.453	0.445
26.96	0.561	0.582	27.10	0.548	0.556
27.38	0.648	0.661	27.60	0.620	0.627
27.74	0.729	0.795	27.90	0.702	0.678
28.00	0.840	0.841	28.20	0.762	0.767
28.22	0.925	0.908	28.44	0.865	0.869
28.44	1.091	1.115	28.74	0.969	0.971
28.72	1.203	1.240	28.96	1.055	1.101
28.76	1.288	1.356	29.14	1.165	1.187
28.78	1.352	1.483	29.18	1.295	1.352
28.84	1.731	1.765	29.14	1.421	1.438
28.80	1.885	1.910	29.24	1.576	1.576
28.62	2.009	2.174	29.20	1.668	1.714
28.44	2.114	2.203	29.10	1.759	1.781
28.40	2.179	2.225	29.12	1.900	1.931
28.42	2.366	2.408	29.04	2.088	2.132
28.16	2.606	2.566	28.94	2.247	2.332
27.88	2.639	2.810	28.72	2.471	2.391
27.74	2.906	3.035	28.54	2.507	2.595
27.34	3.123	3.312	28.42	2.641	2.642
26.98	3.429	3.632	28.32	2.886	2.791
26.40	3.683	3.685	28.06	3.107	2.823
26.08	3.732	4.170	27.58	3.146	3.266
25.36	4.402	4.184	27.42	3.426	3.266
24.86	4.459	5.055	27.26	3.438	3.798
23.72	4.482	5.507	26.72	3.746	4.079
23.76	4.546	5.117	26.12	4.184	4.113

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13. ABSTRACT ***(Maximum 200 words)***
A series of fracture tests were conducted on Middle-crack tension M(T) and compact tension C(T) specimens to determine the effects of specimen type, specimen width, notch tip sharpness and buckling on the fracture behavior of cracked thin sheet (0.04 inch thick) 2024-T3 aluminum alloy material. A series of M(T) specimens were tested with three notch tip configurations: (1) a fatigue pre-cracked notch, (2) a 0.010-inch-diameter wire electrical discharge machined (EDM) notch. and (3) a EDM notch sharpened with a razor blade. The test procedures are discussed and the experimental results for failure stress, load vs. crack extension and the material stress-strain response are reported.

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