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MECHANICAL PROPERTIES OF LX-10-1

Herbert D. Johnson

DEVELOPMENT DIVISION

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ABSTRACT

Two Holston lots of LX-10-1 were evaluated for mechanical properties. The average 21 C tensile failure stress-strain values for Lot 711-1 and 711-2 were 2.32 MPa at 0.15% and 2.07 MPa at 0.18%, respectively. The failure stress range for both lots was approximately 0.4 MPa at 74 C to 5.6 MPa at -37 C.

Several additional pressing cycles were required to obtain a density of 1.865 Mg/m³ for Lot 711-1 material. The additional cycles appear to have increased the tensile failure stress of Lot 711-1 slightly.

DISCUSSION

LX-10-1, Lot 711-1 and 711-2, a plastic bonded explosive having a nominal by weight composition of 94.5/5.5 HMX/Viton A, was evaluated. LX-10-1 is white with blue-green spots. The molding powder is a 4 to 1 mixture of undyed (white) and dyed (blue-green) pellets. LX-10-1 has a theoretical maximum density of 1.895 Mg/m³. The nominal press density is approximately 1.865 Mg/m³.

The following pressing procedure is used to obtain the nominal density of LX-10-1:

1. Preheat molding powder to 104 C for 4 to 6 hours.

2. Press at 138 MPa for 5 minutes.
3. Open the sac and flood the billet with 88 C water (liquid full) and seal the assembly.
4. Repress the water-bag assembly at 138 MPa for 4 minutes and release the pressure for 4 minutes.
5. Repeat Step 4 twice and repress at 138 MPa for 10 minutes.
6. Allow the billet to cool for minimum of 48 hours and measure the density.

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The additional steps shown below are performed only if the required density (1.865 Mg/m^3) is not achieved:

7. Repress ambient part in ambient captive water at 138 MPa for 10 minutes, zero pressure for 5 minutes, and 138 MPa for 10 minutes.
8. The density is remeasured after 12 to 16 hours.
9. If the required density is not met, a final cycle of 138 MPa for 10 minute is made (ambient part in ambient water).

The LX-10-1, Lot 711-1 finished billet density of 1.866 Mg/m^3 was obtained by using Steps 1 through 9. However, Lot 711-2 required only Steps 1 through 6.

The standard mechanical tests for high explosives (tensile, tensile creep, compression, and compression creep tests at various temperatures) were performed. Results of the low, medium, and high (-37 , 21 , and 74°C) temperature tensile tests show that the failure stress of Lot 711-1 is slightly higher than Lot 711-2 (see Figs. 1, 2, and 3).

Failure envelope plots (see Fig. 4) of both lots were generated to describe the stress-strain behavior of LX-10-1 throughout the temperature range,

-37°C to 74°C . The failure envelopes were used to choose the stress and temperature for a creep test which will give failure strain in a reasonable time (longer than 10 minutes but less than 12 hours). The stress selected for the 49°C tensile creep and compression creep were 0.45 MPa and 0.90 MPa , respectively. Compression creep tests were conducted for a minimum of 24 hours. It should be noted that Lot 711-1 tensile creep specimens were fabricated from a different pressing (No. 78604Y3101).

The average compression test curves for Lots 711-1 and 711-2 are shown in Fig. 5. Individual test data for each specimen are given in Tables I through IX.

CONCLUSIONS AND COMMENTS

The additional pressing cycles needed to obtain the 1.865 Mg/m^3 density of Lot 711-1 may have produced the higher tensile stress. However, the failure strain was less than Lot 711-2 at all temperatures with the exception of the 49°C test. The trend of higher failure stress (Lot 711-1) and lower rupture strain was also noted in the compression test results.

There are no significant differences (at 95% confidence level) between the mechanical properties of Lots 711-1 and 711-2 even though some trends were observed.

Table I. Tensile Test Results at a Constant Crosshead Speed of 0.002 mm/s at -37 C for LX-10-1

(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.866 Mg/m³)

Piece No.	Rupture* Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
67	2	337	5.79	0.05
68	2	281	5.86	0.06
69	-	319	5.63	0.04
Mean		312	5.76	0.05
Std. Dev.		28	0.12	0.01

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
11	4	155	5.40	0.06
21	2	172	5.39	0.07
30	6	209	5.69	0.04
Mean		179	5.49	0.06
Std. Dev.		28	0.17	0.01

*1 and 7 are in curved section, 2 and 6 are in the straight section outside the extensometer, 3 and 5 are at the knife edges and 4 is between the knife edges.

Table II. Tensile Test Results at a Constant Crosshead Speed of 0.002 mm/s at -7 C for LX-10-1

(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.867 Mg/m³)

Piece No.	Rupture* Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
65	2	227	3.65	0.20
71	2	285	3.79	0.21
72	2	253	3.81	0.22
73	5	252	3.49	0.22
Mean		254	3.80	0.21
Std. Dev.		24	0.12	0.01

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
10	2	228	4.28	0.30
35	6	174	3.57	0.24
39	4	174	3.75	0.28
Mean		192	3.86	0.27
Std. Dev.		31	0.37	0.03

*1 and 7 are in curved section, 2 and 6 are in the straight section outside the extensometer, 3 and 5 are at the knife edges and 4 is between the knife edges.

Table III. Tensile Test Results at a Constant Crosshead
Speed of 0.002 mm/s at 21 C for LX-10-1

(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.867 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
45	4	331	2.15	0.12
46	6	372	2.20	0.16
47	4	367	2.45	0.18
63	4	354	2.48	0.15
Mean		356	2.32	0.15
Std. Dev.		18	0.17	0.02

Table IV. Tensile Test Results at a Constant Crosshead
Speed of 0.002 mm/s at 35 C for LX-10-1

(Lot No. 711-1, Pressing No. 78604Y3101, Density 1.862 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
2	6	111	1.10	0.17
3	6	95	1.27	0.17
4	2	92	1.30	0.20
Mean		102	1.23	0.18
Std. Dev.		9	0.09	

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
1	4	131	2.12	0.19
36	4	126	2.06	0.18
37	6	120	2.04	0.16
Mean		126	2.07	0.18
Std. Dev.		7	0.14	0.01

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
3	6	120	1.22	0.20
9	6	114	1.46	0.19
34	2	131	1.50	0.24
Mean		122	1.39	0.21
Std. Dev.		9	0.15	0.03

Table V. Tensile Test Results at a Constant Crosshead
Speed of 0.002 mm/s at 49 C for LX-10-1

(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.867 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
41	2	325	0.80	0.32
51	4	250	0.92	0.25
52	4	244	0.88	0.37
54	4	284	0.88	0.30
Mean		276	0.87	0.31
Std. Dev.		37	0.05	0.05

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
2	4	153	0.99	0.33
16	2	123	1.02	0.26
32	2	124	0.95	0.27
Mean		133	0.99	0.29
Std. Dev.		17	0.04	0.04

Table VI. Tensile Test Results at a Constant Crosshead
Speed of 0.002 mm/s at 74 C for LX-10-1

(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.867 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
43	5	311	0.43	0.26
50	6	274	0.45	0.28
64	2	305	0.42	0.42
70	4	301	0.41	0.33
Mean		298	0.43	0.32
Std. Dev.		16	0.02	0.07

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m³)

Piece No.	Rupture Mode	Rupture		
		Time (s)	Stress (MPa)	Strain (%)
17	3	143	0.33	0.41
18	5	131	0.45	0.33
19	6	105	0.35	0.27
31	6	108	0.32	0.28
Mean		122	0.36	0.32
Std. Dev.		18	0.06	0.06

Table VII. Compression Test Results at a Constant Crosshead
Speed of 0.021 mm/s at Ambient Temperature (~ 22 C)
for LX-10

(Lot No. 711-1, Pressing No. 78646Y4601, Density 1.866 Mg/m³)

Piece No.	Time (s)	Failure		Time (s)	Rupture	
		Stress (MPa)	Strain (%)		Strain (%)	
29	39	12.52	1.01	69	2.62	
35	34	12.49	1.00	64	2.70	
36	38	12.38	1.08	67	2.73	
38	36	12.30	0.93	65	2.39	
Mean	37	12.42	1.00	66	2.61	
Std. Dev.	2	0.10	0.06	2	0.15	

(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.862 Mg/m³)

Piece No.	Failure			Rupture	
	Time (s)	Stress (MPa)	Strain (%)	Time (s)	Strain (%)
43	37	11.63	1.03	71	2.91
44	35	11.89	1.06	73	3.08
47	34	11.75	1.04	70	2.94
49	35	11.80	0.98	73	2.84
Mean	35	11.77	1.03	72	2.94
Std. Dev.	1	0.11	0.04	1	0.10

Table VIII. Tensile Creep Test Results at 49 C at 0.45 MPa for LX-10

Piece No.	Rupture Mode	30 Min Creep ($\mu\text{m/m}$)	T1 (hrs)	S1 ($\mu\text{m/m}$)	T3 (hrs)	S3 ($\mu\text{m/m}$)	First Transition		Failure		90% Rupture	
							T2 (hrs)	S2 ($\mu\text{m/m}$)	T4 (hrs)	S4 ($\mu\text{m/m}$)	T5 (hrs)	S5 ($\mu\text{m/m}$)
(Lot No. 711-1, Pressing No. 78604Y3101, Density 1.862 Mg/m ³)												
11	6	1650	0.04	590	0.14	940	0.48	1620	1.30	2600	1.17	2410
12	6	1570	0.04	625	0.12	925	0.36	1360	0.90	2050	0.81	1950
Mean		1610	0.04	608	0.13	932	0.42	1490	1.10	2325	0.99	2180
Std. Dev.		57	-	25	0.01	11	0.09	184	0.28	389	0.26	325
(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m ³)												
22	2	1240	0.18	854	0.57	1300	1.80	2000	4.50	3070	4.14	2920
23	4	1390	0.11	733	0.36	1170	1.13	1790	3.10	3260	3.05	3240
29	6	1300	0.15	850	0.48	1280	1.51	1850	3.96	2870	3.56	2700
Mean		1310	0.15	812	0.47	1250	1.48	1880	3.85	3067	3.58	2953
Std. Dev.		75	0.03	69	0.11	70	0.34	108	0.71	195	0.55	272

Table IX. Compression Creep Test Results at 49 C at 0.896 MPa for LX-10

Piece No.	30 Min Creep ($\mu\text{m/m}$)	T1 (hrs)	S1 ($\mu\text{m/m}$)	T3 (hrs)	S3 ($\mu\text{m/m}$)	First Transition		24-Hr Creep ($\mu\text{m/m}$)
						T2 (hrs)	S2 ($\mu\text{m/m}$)	
(Lot No. 711-1, Pressing No. 78240Y4601, Density 1.866 Mg/m ³)								
30	1668	0.67	1692	2.12	1836	6.69	1900	2008
31	1592	0.68	1620	2.15	1700	6.79	1888	2020
32	1480	0.68	1485	2.14	1510	6.75	1555	1600
Mean	1580	0.68	1602	2.13	1711	6.74	1781	1876
Std. Dev.	95		106	0.02	176	0.05	196	239
(Lot No. 711-2, Pressing No. 78646Y4601, Density 1.863 Mg/m ³)								
52	856	0.74	910	2.35	1098	7.43	1340	1442
53	1193	0.66	1222	2.09	1330	6.60	1420	1460
54	1482	0.66	1530	2.10	1696	6.65	1826	2004
Mean	1177	0.69	1221	2.18	1375	6.89	1529	1635
Std. Dev.	313	0.05	310	0.15	301	0.47	261	319

Fig. 1. LX-10-1 Tensile Results at -37 C and a Constant Crosshead Velocity of 0.002 mm/sec

Fig. 2. LX-10-1 Tensile Results at 21 C and a Constant Velocity of 0.002 mm/sec

Fig. 3. LX-10-1 Tensile Results at 74 C and a Constant Crosshead Speed of 0.002 mm/sec

Fig. 4. Failure Envelopes for LX-10-1, Lots 711-1 and 711-2

Fig. 5. LX-10-1 Compression Test Results at Ambient Temperature (~ 22 C) and a Constant Crosshead Speed of 0.021 mm/sec

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