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Uniaxial Compression of GEM Reprocessed Experimental Gun Propellant

by Michael G. Leadore

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Abstract

The U.S. Army Research Laboratory (ARL) conducted the material test systems (MTS) servo-hydraulic tester (SHT) high-rate mechanical response of one lot of Naval Surface Warfare Center (NSWC)-manufactured high-energy gun propellant. The material was designated as GEM Reprocessed by the NSWC and given a lot number of IH94000WPB26-0116. The lot was a candidate propellant for the Navy 5-in/62 gun round (test sets 17–19/Fiscal 01).

Contents

List of Figures v

List of Tables vii

1. Background 1

2. Approach and Results 2

3. Conclusions 2

4. References 7

Appendix. The Mechanical Response of EX99 Gun Propellant 9

Distribution List 11

Report Documentation Page 27

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List of Figures

Figure 1. Navy cruiser with 5-in/62 gun. 1
Figure 2. Prepared test specimens.......... 2
Figure 3. Energetic material prepared for testing on the MTS load frame.......... 3
Figure 4. Tested specimens at 21°, 50°, and –20 °C.......... 4
Figure 5. Stress vs. strain plot at 21°, 50°, and –20 °C. 5
Figure A-1. Stress vs. strain plot of EX99 gun propellants at 21°, 50°, and –20 °C.......... 9

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List of Tables

Table 1. Mechanical properties of GEM reprocessed gun propellant at 21°, -20°, and 50 °C. 3

Table A-1. Mechanical properties of EX99 gun propellant at 21°, -20°, and 50 °C. 9

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1. Background

The U.S. Army Research Laboratory (ARL) received one lot of Naval Surface Warfare Center (NSWC)-manufactured gun propellant and testing instructions from Wayne Thomas of the NSWC. The lot was a candidate propellant for the Navy 5-in/62 gun round (Figure 1). The gun propellant was manufactured as 7-perforated granular propellants with a diameter of ~15.5 mm. The perforation diameter for the lot measured ~0.47 mm. Several grains from the lot of experimental gun propellant were shipped to Dr. Robert Lieb of ARL. Also, several lots of similar materials tested in October 2000 are included in the Appendix and the mechanical properties (Table A-1) and stress vs. strain plot (Figure A-1) of the tested material may be used for comparative purposes as the test conditions were similar. The lot of subject material was last tested for high-rate compressive mechanical response evaluation during February/ March 2001.

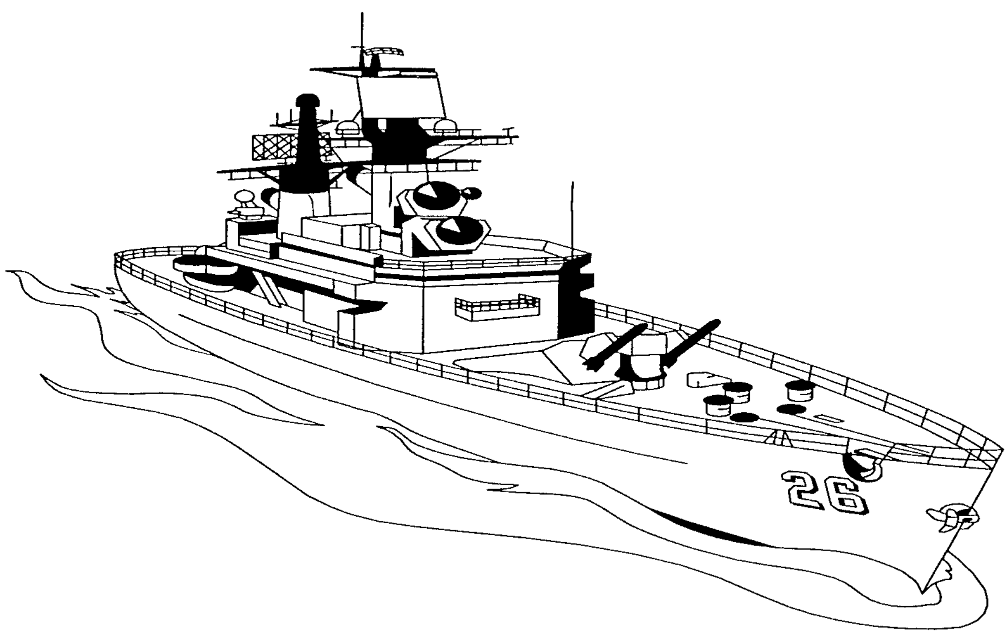

Figure 1. Navy cruiser with 5-in/62 gun.

2. Approach and Results

The GEM Reprocessed propellant lot number IH94000WPB26-0116 was received in granular form with 7-perforations. The material was prepared into test specimens using an Isomet double-bladed diamond saw and the sample ends were cut flat and square. The prepared test specimens (Figure 2) had an average length-to-diameter ratio (L/D) of 1.21.

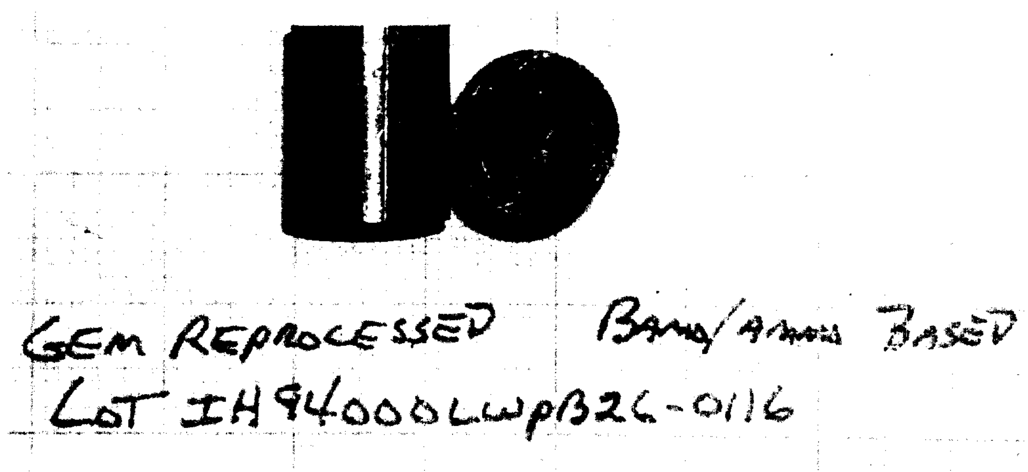

Figure 2. Prepared test specimens.

Material test systems (MTS) servo-hydraulic tester (SHT) mechanical properties tests [1–7] were conducted on several specimens under each test condition (Figure 3). Strain rates of 108.3 s^{-1} were achieved. The specimens were taken to failure at ambient pressure to ~60% end strain while conditioned at 21°, 50°, and –20 °C. The stress at failure, strain at failure, modulus, failure modulus, incremental energy density, and fracture assessment value were recorded for each test. The average values achieved from the tests are listed in Table 1.

3. Conclusions

One lot of NSWC–manufactured GEM Reprocessed Bamo/Ammo-based 7-perforated gun propellant, lot number IH94000WPB26-0116 was tested in uniaxial compression at an average 1.33 m/s deformation rate. The material was taken to ~50% end strain while conditioned at 21°, 50°, and –20 °C. Two lots of

Figure 3. Energetic material prepared for testing on the MTS load frame.

Table 1. Mechanical properties of GEM reprocessed gun propellant at 21°, –20°, and 50 °C.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus[a] (GPa)	IED[b] (MPa)	FAV[c] (MPa)
at 21 °C						
IH94000WPB260116	33.5	6.03	0.801	0.0510	8.95	2ABR
at –20 °C						
IH94000WPB260116	100.3	5.56	2.33	-0.55	15.02	7AS
at 50 °C						
IH94000WPB260116	16.6	6.25	0.342	0.275	4.05	0B

[a] The failure modulus (slope of the curve after failure) has been added. Generally, the lower the value, the worse the material (i.e., a negative value indicates the material is unable to sustain load). A positive value indicates a positive failure slope (i.e., the material is better able to support load after failure).

[b] The incremental energy density (IED) value reported is the amount of energy per unit volume absorbed at 25% strain; this includes a portion of the area located beneath the stress/strain curve.

[c] The tested specimens were assigned a fracture assessment value (FAV). The values range from 0 (no observed fracturing) through 9 (severe fracturing observed). The type of fracture was also characterized using the following methodology: A = axial fracture, S = shear fracture, B = barreling/deformation, and R = radial splitting (i.e., 9A indicates the tested specimens showed a severe amount of axial fracture).

similar materials tested using like conditions are included in the Appendix (Table A-1 and Figure A-1) and this information may be used for comparative purposes as similar test conditions were used.

At 21 °C, the mechanical properties of the GEM Reprocessed propellant was very good. Note the compressive and failure modulus values, which indicate the material provided plastic response and was able to sustain loads beyond 40% strain, thus workhardening. When comparing these values with the propellant lots contained in the Appendix, the large difference in compressive and failure modulus values becomes clearer. The tested specimens at 21 °C (Figure 4) showed permanent deformation and only minimal axial fracture/splitting.

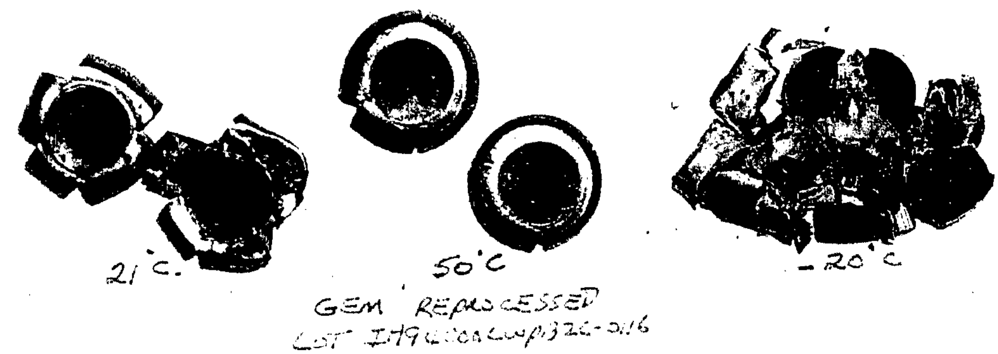

Figure 4. Tested specimens at 21°, 50°, and –20 °C.

At 50 °C, the stress at failure and compressive modulus values showed some softening of the material, as would be expected from the higher testing temperature. The tested specimens at 50 °C showed only deformation of the material, without apparent fracture or splitting.

At –20 °C, the tested specimens (Figure 4) suffered moderate to severe axial and shear fracture damage that would likely cause significant increases in the surface area of this material, thus, likely increasing the burning rate. The stress/strain plots (Figure 5) for the materials also correlate with the physical damage observed. Note the negative failure slope for the lot that indicates the material had likely glass transitioned as a result of the –20 °C exposure. The negative failure modulus values also indicated the material's inability to sustain load at –20 °C beyond 6% strain.

Overall, the GEM Reprocessed 7-perforated gun propellant showed very good mechanical properties at 21° and 50 °C when compared with the Appendix lots. The –20 °C mechanical response of the reprocessed material was poor; however, the mechanical properties were better than the lots contained in the Appendix. Note the factor of 5 improvement in the failure modulus values when comparing the subject and Appendix lots at –20 °C.

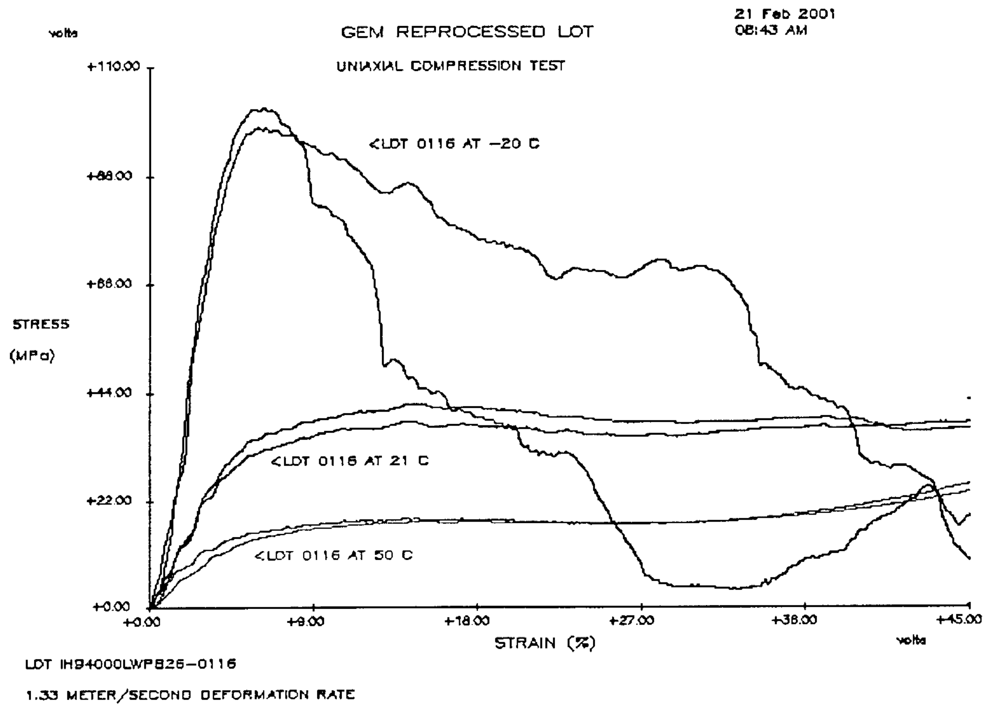

Figure 5. Stress vs. strain plot at 21°, 50°, and -20 °C.

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Appendix. The Mechanical Response of EX99 Gun Propellant

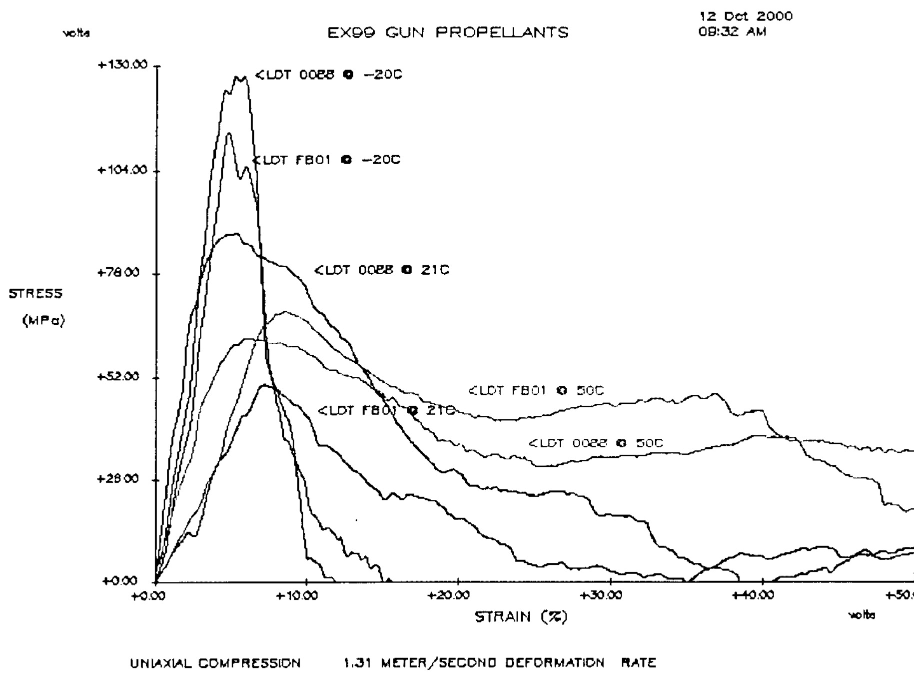

Figure A-1. Stress vs. strain plot of EX99 gun propellants at 21°, 50°, and -20 °C.

Table A-1. Mechanical properties of EX99 gun propellant at 21°, -20°, and 50 °C.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus (GPa)	IED (MPa)	FAV (MPa)
at 21 °C						
IH94X990088	98.1	4.40	1.940	-0.320	16.60	8A
Lot IH23X99FB01	56.10	7.20	0.590	-0.310	8.30	8A
at -20 °C						
IH94X990088	128.0	5.40	2.54	-2.85	7.13	9A
Lot IH23X99FB01	108.1	5.25	2.30	-1.90	5.56	9A
at 50 °C						
IH94X990088	59.19	5.10	1.19	-0.120	11.9	7A
Lot IH23X99FB01	67.33	8.40	0.700	-0.230	11.8	7A

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13. ABSTRACT*(Maximum 200 words)*

The U.S. Army Research Laboratory (ARL) conducted the material test systems (MTS) servo-hydraulic tester (SHT) high-rate mechanical response of one lot of Naval Surface Warfare Center (NSWC)-manufactured high-energy gun propellant. The material was designated as GEM Reprocessed by the NSWC and given a lot number of IH94000WPB26-0116. The lot was a candidate propellant for the Navy 5-in/62 gun round (test sets 17–19/Fiscal 01).

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