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High-Rate Mechanical Response of BAMO/GAP/RDX High-Energy Gun Propellant

by Michael G. Leadore

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High-Rate Mechanical Response of BAMO/GAP/RDX High-Energy Gun Propellant

Michael G. Leadore

Weapons and Materials Research Directorate, ARL

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Abstract

One lot of BAMO/GAP/RDX (3,3-bis[azidomethyl] oxetane/glycidyl azide polymer/cyclotrimethylenetrinatraine) next-generation gun propellant was tested in uniaxial compression at strain rates of 100 s^{-1} . The material was conditioned at temperatures of 21° , 50° , and -20° C . End strain of the tested material was $\sim 60\%$. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density, and the fracture assessment values were recorded for each test.

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1. Introduction

The following is the U.S. Army Research Laboratory's (ARL's) report of the material test systems (MTS) servo-hydraulic tester (SHT) high-rate mechanical response of one lot of Thiokol Propulsion-manufactured next-generation high-energy gun propellants (Test Sets 21-23/Fiscal 00). The BAMO/GAP/RDX (3,3-bis[azidomethyl] oxetane/glycidyl azide polymer/cyclotrimethylenetrinitramine) material was designated TGD-019 by Thiokol Propulsion and given a lot number of M56-4-001. The lot is a candidate propellant for the Abrams M829E3 120-mm tank gun round (Figure 1).

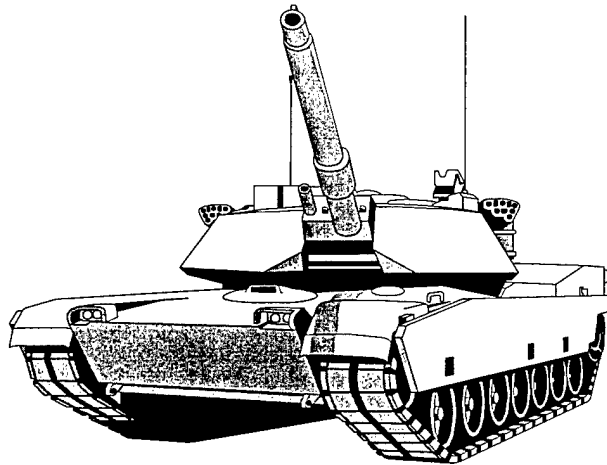


Figure 1. M1 Abrams tank with 120-mm gun.

2. Background

ARL received one lot of Thiokol Propulsion next-generation 120-mm gun propellant and testing instructions from Ms. Thelma Manning of the U.S. Army Armament Research, Development, and Engineering Center (ARDEC). Lot M56-4-001 was manufactured as solid-stick propellant with a diameter of 12.50 mm. A stick from the lot of the experimental gun propellant was shipped to Dr. Robert Lieb of ARL. Several lots of similar materials previously tested are included in the Appendix; the mechanical properties 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 September 2000.

3. Approach and Results

The propellant TGD-019, lot no. M56-4-001, was composed of a mixture of BAMO/GAP/RDX and was received in solid-stick form and was without perforations. The material was prepared into test specimens using an Isomet double-bladed diamond saw and the sample ends were machined flat. The prepared test specimens (Figure 2) had an average length-to-diameter (L/D) ratio of 1.74. MTS SHT Mechanical Properties Tests [1-7] were conducted on several specimens under each test condition. Strain rates of 118.6 s^{-1} were achieved. The specimens were taken to failure at ambient pressure to ~60% end strain while conditioned at temperatures of 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.

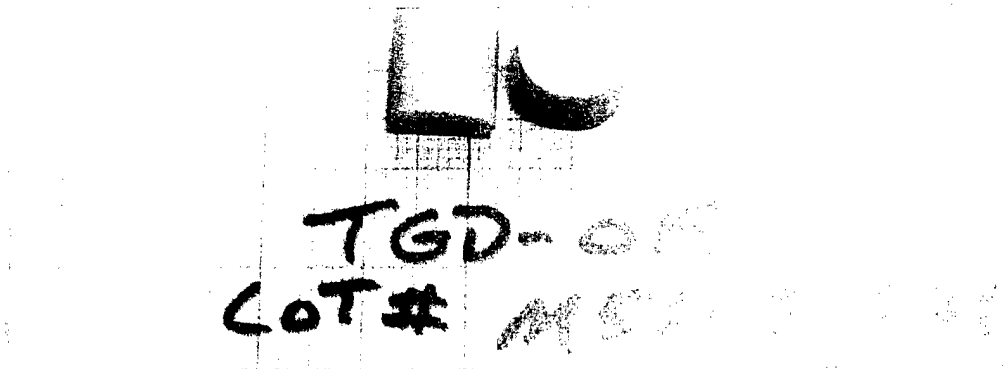


Figure 2. Prepared test specimens.

4. Conclusions

One lot of Thiokol Propulsion-manufactured TGD-019, lot no. M56-4-001, next-generation gun propellant containing a mixture of BAMO/GAP/RDX was tested in uniaxial compression at an average 1.32 m/s deformation rate. The material was taken to ~60% end strain while conditioned at 21°, 50°, and -20 °C. Several lots of similar materials tested using like conditions are included in the Appendix and their values may be used for comparative purposes.

Table 1. Mechanical properties of TGD-019 gun propellant at 21°, 50°, and -20 °C.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus ^a (GPa)	IED ^b (MPa)	FAV ^c (MPa)
at 21 °C						
TGD-019 Lot M56-4-001 BAMO/GAP/RDX solid stick	31.10	9.40	0.460	-0.013	15.16	2AB
at 50 °C						
TGD-019 Lot M56-4-001 BAMO/GAP/RDX solid stick	16.50	8.82	0.27	-0.009	6.11	1B
at -20 °C						
TGD-019 Lot M56-4-001 BAMO/GAP/RDX solid stick	97.09	4.82	2.59	-0.71	11.12	7AS

^aThe failure modulus (slope of the curve after failure) has been added. Generally, the lower the value, the worse the material (i.e., 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).

^bThe IED (incremental energy density) 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.

^cThe 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).

At 21 °C, the mechanical properties of the Thiokol propellant was most impressive. Note the compressive and failure modulus values, which indicate the material provided a ductile response and was better able at sustaining load than the propellant lots contained in the Appendix. Also, the tested specimens at 21 °C showed some permanent deformation and barreling of the material, but only minimal axial fracture was observed.

At 50 °C, the stress at failure and compressive modulus values indicate some softening of the material as would be expected at 50 °C. The tested specimens at 50 °C showed permanent deformation and/or barreling of the material, but no fracture was observed.

At -20 °C, the compressive modulus values showed a factor of 5.6 increase when compared with the 21 °C modulus values. The tested specimens (Figure 3) from TGD-019 lot M56-4-001 suffered moderate to severe axial and shear fracture damage that likely caused significant increases in the surface area of this material. The stress/strain plots (Figure 4) for the materials also correlate with the physical damage observed. Note the sharp stress vs. strain pulse for the lot which indicates the material had likely glass transitioned as a result of the -20 °C exposure. The negative failure modulus values achieved for lot M56-4-001 also indicated the material's inability to sustain load at -20 °C.

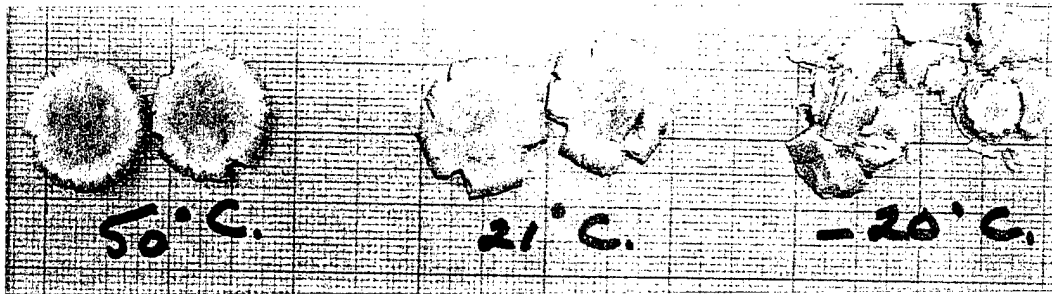


Figure 3. Tested specimens at 50°, 21°, and -20 °C.

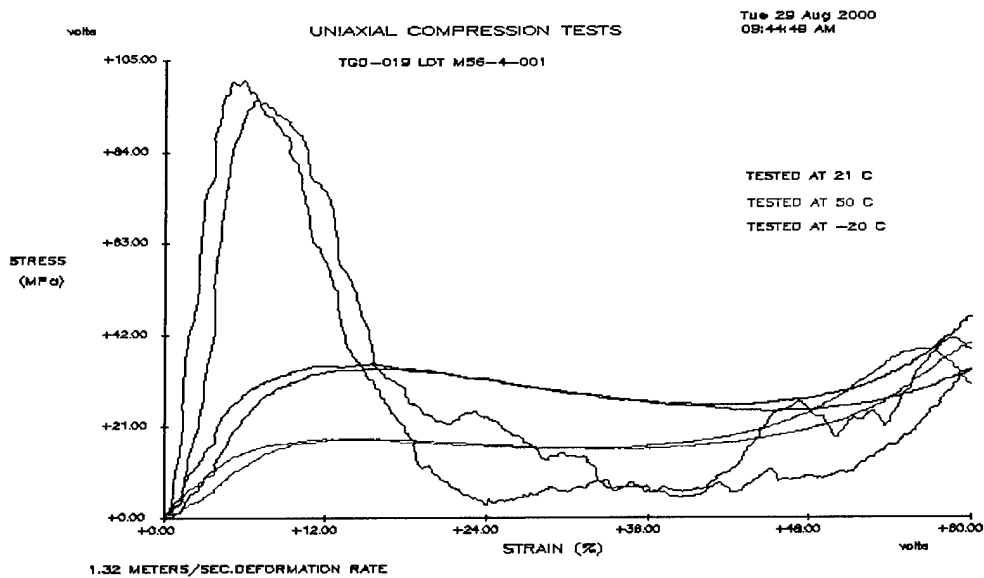


Figure 4. Stress vs. strain plot at 21°, 50°, and -20 °C.

Overall, TGD-019 lot M56-4-001 BAMO/GAP/RDX-based solid-stick material showed very good mechanical properties at 21° and 50 °C when compared with the Appendix lots. The -20 °C values are a bit disturbing; however, as the test results indicated, the lot was sensitive to the colder testing temperature and became “brittle” at -20 °C suffering prolific fracture.

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Appendix. Mechanical Properties of AXF 3663, AXF 3736, and AXF 3744.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus (GPa)	IED (MPa)	FAV (MPa)
at 21 °C						
AXF 3663 Lot 10TPG-41	37.30	6.30	0.855	-0.0426	7.02	1AB
AXF 3736 Lot 10TPG-40	58.01	5.75	1.27	-0.261	10.09	2AB
AXF 3744 Lot 10TPG-39	36.16	4.21	1.17	-0.471	2.02	2AB
at 50 °C						
AXF 3663 Lot 10TPG-41	21.10	6.00	0.485	-0.0260	4.34	1B
AXF 3736 Lot 10TPG-40	25.05	5.50	0.752	-0.0213	5.63	1B
AXF 3744 Lot 10TPG-39	26.66	5.61	0.982	-0.0488	5.24	1B
at -20 °C						
AXF 3663 Lot 10TPG-41	89.56	6.02	3.73	-6.92	1.37	8AS
AXF 3736 Lot 10TPG-40	35.10	6.35	1.77	-1.45	0.990	9AS
AXF 3744 Lot 10TPG-39	13.50	4.27	1.75	-0.934	0.911	9AS

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