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Annual Technical Report for FY99

Project Title: Solventless Manufacture Of Artillery Propellant Using Thermoplastic Elastomer Binder PP-867

Performing organizations:

Lead laboratory: Naval Air Warfare Center Weapons Division, China Lake, CA

Other performing organizations:
Naval Surface Warfare Center Indian Head Division
Army Armament Research, Development and Engineering Center
Stevens Institute of Technology

Project background:

The manufacture of multi-base gun propellant for artillery ammunition creates 0.3 lb of solvent emissions per lb of propellant produced. At expected production rates of 3 million lb/yr, this represents the largest source of volatile organic compound (VOC) emissions resulting from gun propellant manufacture. Thermoplastic elastomer (TPE) binders are now available which should allow the development and production of gun propellants without solvent emissions. TPE binders may also be in a variety of other energetic material applications, including rocket propellants, explosives and pyrotechnics. In addition to solvent reduction or elimination, the use of TPE binders may permit recovery and recycling of propellant ingredients for additional pollution prevention. To date, these TPEs have not been qualified for use in military ordnance systems, mainly due to the perceived risk of using novel materials and manufacturing processes. A demonstration of the feasibility of using TPEs in a solventless process will lower the perceived risk and accelerate acceptance and use of these promising materials and processes.

Manufacture of propellants by continuous, twin screw extrusion has been considered as an alternative to conventional, batch processing (Husband, 1989; Murphy et al, 1991). As material flow properties are critical to TSE processing, both rheological characteristics and ballistic performance must be evaluated. Important considerations for gun propellant manufacture in twin screw extruders include control of the feed rate of raw materials, proper configuration of the screws, and predictable, stable flow through the extrusion die.

Objective:

The objective of this project is to demonstrate the production of TPE-based gun propellants using TSE processing. The use of TPE-based processing will significantly reduce or eliminate the emission of VOCs and solvents associated with propellant processing. New propellant formulations based on TPE technology will be developed and evaluated for potential replacement of current propellants that require solvents to manufacture. This project will demonstrate at a pilot plant scale the production of TPE gun propellant by using solventless continuous processing.

Technical approach:

New TPE propellant formulations are being designed to permit solventless processing while simultaneously meeting performance and safety requirements. This requires evaluating the most promising TPEs, determining the proper composition and molecular weight of the TPE, and optimizing the choice and amount of oxidizer in the propellant. A solventless manufacturing process is being developed for this propellant by modifying and adapting existing continuous twin screw extrusion technology. Manufacture of the new TPE propellant by the solventless process will be demonstrated at a pilot plant scale. The manufacturability, safety, sensitivity and performance properties of the propellant produced will be evaluated in proof of principle tests.

For leveraging cost of testing and evaluation this project is closely coordinated with efforts to develop a propellant charge for the Crusader 155-mm howitzer. Other related projects include the ARDEC 6.2 Technology Base Program, the Green Energetics Affordability Initiative, and other efforts to develop propellants for naval guns and tank guns. Developments are communicated to the user community through briefings, workshops, and professional society presentations and publications. Under leveraged funds, sufficient propellant for approximately fifteen rounds is being manufactured, and these rounds will be fired in a 155-mm gun to evaluate actual propellant performance. These results will guide further improvement of the propellant composition and manufacturing process. Technology developed under this SERDP project will be transferred through briefings and reports to the Crusader Program and through discussions with representatives of the Army ammunition plants and the Army Single Manager for Conventional Ammunition.

Technical accomplishments

In FY99 this program had two primary area of focus. The first of these was to resolve the remaining processing issues with the NSWC Indian Head twin-screw extruder system. The second was to produce 500 pounds of TPE propellant and to test fire this in a 155mm artillery gun system. Significant progress was made on both of these fronts, culminating in a series of 155mm gun firings in the fall of 1999. It should be noted that to the best of our knowledge, this is the first time a TPE-based gun propellant has been fired under other than ambient temperatures, and as such this is a significant milestone in the development of TPE gun propellants.

Beginning with the first focus area, significant progress was made in the definition of process conditions and parameter for processing TPE propellants in a twin-screw extruder (TSE). Data from flow measurements taken on an 8 pound batch of BAMO/AMMO-based TPE propellant were analyzed by Stevens Institute of Technology, and viscosity as a function of shear rate and temperature were determined. Numerical simulations were performed to support subsequent extrusion die design. NSWC Indian Head Division successfully processed 10 pounds of TPE propellant (BAMO/AMMO/RDX/HBNQ(high bulk-density nitroguanidine)) from individual feedstreams on a 40mm twin screw extruder. The material was extruded into approximately 1 1/2 inch strands through the die holder door. The inlet temperature set point was 130°F, remaining set points were 200°F. Actual temperatures: Melting/kneading of BAMO/AMMO ~211-214°F, mixing zone (after addition of RDX & HBNQ): 242°F, die holder temperature ~215°F. The pressure at the die holder door ran between 175-200 psi.

NSWC Indian Head has subsequently worked to resolve remaining processing issues with the 40mm twin-screw extruder system. Further modifications were made to delivery hoppers to insure feed control of HBNQ. The new setup was run and HBNQ feed rates calibrated. Final revised material feed parameters were determined and cleared through safety. Detailed plans for an extended TSE run have been completed; however, a tight TSE schedule has resulted in a further delay. It is expected that this run will be completed by the end of February.

Work in the second area of focus has proceeded under leveraged funding from the ARDEC 6.2 Technology Base Program and the Crusader program office. Extensive technical details including polymer composition and properties and propellant composition and properties (safety, burning rate, interior ballistics and mechanical) for a series of formulations may be found in the latest JANNAF report of this work (See publications list attached). A summary of important milestones follows.

An 8 lb test batch of BAMO/ AMMO / HBNQ / RDX propellant was extruded at Thiokol in November, 1998 using the 19mm TSE in a semi-batch process. The propellant was extruded from a 7 perf die; however, under the extrusion conditions used the perforations closed. Another 8 lb test batch was extruded in December using slightly different extrusion conditions including a lowered extrusion pressure. Data from this test batch was analyzed and indicated that the burning rate had an increased coefficient and lowered slope (0.78) as compared to previous batch-produced test lots and a lowered temperature sensitivity compared to standard M30 propellant. This data indicated that the propellant could be successfully test fired.

A second 7-perf test lot was produced in March using a 35/65% BAMO/AMMO TPE for comparison to the 25% BAMO used to produce the previous test batches. Burning rate data on the new lot was taken in March and analyzed at both ARDEC and Thiokol. The burning rate was used in interior ballistic calculations to redesign the propellant grain for 155mm test firings. A 19mm Twin-Screw Extrusion (TSE) die for manufacture of the propellant grain was designed at ARDEC and manufactured at Thiokol in April. The redesigned die was used to manufacture 500 lb of propellant which was delivered to ARDEC in late August. Safety, mechanical, and interior ballistics calculations were subsequently performed prior to gun charge manufacture.

Firings of 155mm artillery zone charges at ARDEC began in late September 1999 and continued to early October 1999. Charge assessment was carried out with the results shown in Table 1.

Table 1 TGD-008 Charge Assessment

Charge	Propellant weight (lb)	Temp (°F)	Pressure (Kpsi)
XM23 z6	4	70	24.95
	4.25	70	25.55
	4.5	70	31.25
	4.6	70	32.55
	4.6	70	33.15

Additional firings were performed with hot (145° F), cold (-60° F) and ambient (70° F) temperature conditioning. The results are given in Table 2, and the pressure-time trace for the first charge at low temperature is given in Figure 1. The maximum pressure and the smoothness of the curve shown in Figure 1 give no indication of grain breakup.

These gun firings, conducted under several temperature conditions, have given encouraging results for this TPE-based propellant. The data indicate that required performance may be achieved through continued improvements in charge design. Based on the current gun firing data, the grain is currently being redesigned to achieve required performance.

The maximum pressure and the smoothness of the curve shown in figure 7 give no indication of grain breakup. Apparently, the mechanical properties of this formulation, while not all that could be desired, do prevent brittle fracture under these conditions.

SUMMARY AND CONCLUSIONS

Efforts are now underway to tailor BAMO/ AMMO oxetanes for use in artillery. Five hundred pounds of a formulation similar to O3 has been manufactured using the 19 mm TSE at Thiokol, Brigham City, UT, This formulation designated TGD-008 has undergone both safety, theological and closed bomb ballistic testing. 155 mm gun firings at hot, cold and ambient conditions indicate that with suitable charge design desired performance may be achieved. This formulation provides an opportunity to develop manufacturing processes such as the continuous TSE process that are appropriate to TPE propellant. The characterization of these TSE processed propellants and the correlation of the determined properties with the results of gun firings should greatly accelerate the development of TPE gun propellants. During the process of developing TPE formulations to meet performance requirements every opportunity will be taken to substitute lower cost ingredients to increase the affordability of the final TPE propellant candidates for production.

Development of solventless TPE formulations for artillery has the potential to eliminate 800,000 Kg per year of VOC emissions from Army Ammunition Plants (AAPs). NG contamination carried by the VOCs would also be eliminated. Cost savings would result from the elimination of facility modifications needed at Radford AAP to contain VOCs, purchase of solvents for propellant processing, operation of propellant dryhouses and disposal of waste propellant and munitions (demilitarization)

REFERENCES

1. R. L. Willer, R. A. Biddle, P. I. Kaste, D. L. Henry, A. W. Williams and G. K. Hoeschele, "Semi-Commercial TPEs for LOVA Propellant Binders," 1990 JANNAF Propulsion Meeting, Anaheim, CA, October, 1990.

2. A. Juhasz, F. Robbins, S. Moy, T. Manning, J. Hartwell and R. Wardle, "The Promise of Advanced Solid Gun Propellants," 1995 JANNAF Propulsion Meeting, Tampa, FL, December, 1995.

3. R. B. Wardle, W. W. Edwards, J. C. Hinshaw and J. A. Hartwell, "Polyoxetane Thermoplastic Elastomers as Gun Propellant Binders," 6th International Gun Propellant Symposium, Parsippany, NJ, November, 1994.

4. L. E. Harris, S. Moy, T. Manning, R. B. Wardle, A. Haaland, J. A. Hartwell, T. Stephens, C. Murphy and S. Prickett, "TPE Artillery Propellants," 33rd JANNAF Combustion Meeting, Monterey, CA, Oct 1996.

5. L. E. Harris, S. Moy, T. Manning, R. B. Wardle, A. Haaland, J. A. Hartwell, T. Stephens, C. Murphy and S. Prickett, "Thermoplastic Elastomer (TPE) Artillery Propellant," 1996 JANNAF Propulsion Meeting, Albuquerque, NM, December 1996.

6. L. E. Harris, T. Manning, K. Klingaman, R. B. Wardle, P. Braithwaite, T. Stephens, S. Prickett, "Thermoplastic Elastomer Gun Propellant, "Proceedings of the ADPA Insensitive Munitions and Energetics Technology Symposium, Tampa, Florida, Oct., 1997.

7. L. E. Harris, T. Manning, K. Klingaman, R. B. Wardle, P. Braithwaite, T. Stephens, S. Prickett, "Thermoplastic Elastomer Gun Propellant," 34th JANNAF Combustion Meeting, West Palm Beach,

Florida, Oct., 1997.

8. L. E. Harris, T. Manning, K. Klingaman, R. B. Wardle, J. P. Braithwaite, G.W. Dixon, T. Stephens and S. Prickett, "Thermoplastic Elastomer gun Propellant," 35th JANNAF Combustion Meeting, Albuquerque, NM, Dec, 1998.