The Promise Of Energetic TPE Gun Propellants – From Notebook To Full Scale Verification

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P. Braithwaite, G. Dixon, M. Rose, and R. Wardle
Acknowledgements

• Advances in these new propellants are the results of cooperative efforts with many organizations including:
  • ARL
  • TACOM-ARDEC
  • DTRA
  • NSWC/IH
  • ONR
  • GD
  • SAIC
  • United Defense
Outline

• Background
• Typical ETPE propellant ingredients
• Propellant processing
• Propellant characterization
• Gun testing
• Summary and conclusions
The potential advantages of TPE gun propellants were seriously discussed in the early 1980’s

- Performance
- Environmental benefits - R3
- Superior burning rate control
  - No plasticizers are used
  - No sensitivity to moisture

Early feasibility studies were successfully performed in coordination with ARL/ONR and others

- Identified areas of critical technical needs
- Developed initial data to verify attractiveness

Recent efforts have demonstrated these propellants on a larger scale
• Early calculations using ETPE propellant formulations indicated they had performance advantages when compared with NC based compositions

• Burning rate tailorability suggested by early low pressure tests indicated these propellants could be used in conventional and layered geometries
Oxetane Thermoplastic Elastomers

Below Tm of Hard Block
- Hard Block Crystalline Spheres
- Soft Block Elastomers

Above Tm of Hard Block
- Hard Block Melts
- Blocks phase separated

Flows and Mixes under Shear
- Hard and Soft Blocks Mix
- Annealing needed for phase separation

- Melting materials behavior critical to energetic processing
  - Need narrow transition from hard to processible
  - M.p. too low and won't survive environment (<65°C)
  - M.p. too high and energetic solids can't be processed safely (>90°C)
  - Dynamic viscosity data show attractiveness of crystalline hard block oxetane TPE (green line)
- Novel TPEs allow continuous processing and recycling
  - Production scrap can be well below 1 percent
- TPE nature allows unusual geometries
  - Better energy management maximizes performance
Thiokol Propulsion

**TPE’s Offer Formulation Flexibility**

![Chemical Formulas]

**BAMO/NMMO**

![Chemical Structure Image]

**BAMO/BAMO-AMMO**

![Chemical Structure Image]

**BAMO/AMMO**

![Chemical Structure Image]

**BEMO/AMMO**

![Chemical Structure Image]
New Energetic Solids

• Energetic solids provide additional burning rate and energy tailoring capability

  • Burning rates at 40 kpsi from less than 4 in/sec to over 15 in/sec
  • Impetus levels above 1350 J/g
Twin Screw Extrusion

- Twin screw extrusion has been found to be the best way to mix and extrude pilot scale lots of ETPE based propellants
- No solvents are required during mixing and extrusion
- Multiple formulations have been extruded into a wide range of geometries
Multiple Geometries Have Been Successfully Manufactured
SEM Evaluation

• Careful examination indicates excellent adhesion between solid ingredients and ETPE
Gun Testing

- ETPE propellants have been tested in multiple gun systems
  - 30 mm
  - 35 mm
  - 40 mm
  - 60 mm
  - 120 mm
  - 5-inch
  - 155 mm
120 mm Firings

- ETPE propellants have been tested in 120 mm gun systems using advanced geometries

- Results were great!!!
Summary

- ETPE propellants have matured significantly during the past several years
  - Formulation
  - Processing
  - Testing and characterization
  - Quality control
  - Recycle and reclamation
  - Grain design

- Multiple gun test firings unequivocally demonstrated the performance potential of these promising new propellants