Twin-Screw Processing of GEM Gun Propellant

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Affordable Green Energetic Materials (GEM)

- High Performance, Minimum Life-Cycle Environmental Impact Materials
- Meet Naval Surface Fire Support (NSFS) Extended-Range Guided Munition (ERGM) 5-inch Projectile Mission Requirements
- Warhead, Rocket Motor, and Gun Propellant
- Manufactured at Lower Total Life Cycle Cost Than Current Materials

Develop a New Continuously Processed Gun Propellant

Accomplished the First Five Goals

- Devise Feeding Method for Virgin Polymer
- Melt, Mix & Extrude Quality Strands Using a Twin-Screw Extruder
- Design Take-Away Equipment & Integrate Bofors Cutter
- Rheological Characterization & Die Design
- Produce 200 lbs. Test Quantity
- Develop Recycling Scheme Including Reduction, Feeding, Melting, & Extruding

Live Processing Trials

Single Strand Batch LOVA Die

- Conserve Polymer - Run at Very Low Throughput
- Design Screw for Vacuum Processing (Degree of Fill)
- Minimize Viscous Heating in Solids Mixing Section
- Evaluate Effect of Process Parameters on Extrudate Quality
- (show video)

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Feed Locations

Side View of ZSK Set-up for GEM Gun Propellant

Processing Conditions Screening Study

Four-Fold Objective

- Screw Design for Vacuum Processing (Low Throughput)
  - Surging: Function of Screw Fill, Geometry, and RPM
  - Screw Fill: Throughput and RPM
- Screw Design to Minimize Viscous Heating (VDH)
  - Function of Screw Fill, Screw Geometry, and Barrel temperature
- Melting & Mixing Efficiencies
  - Temperature, Throughput & RPM Effects
- Extent to Which Conditions Affect Extrudate Quality

Rheology Drives the Train

Indian Head is Building an In-House Capability

- Modern Energetic Materials Increasingly Non-Newtonian
- NSWC Characterized Rheology Using Capillary Dies (Dr. Prickett)
  - Various Diameters and Lengths
  - 2" Press with Vacuum & Temperature Control (1.5 kg)
- Purchasing a Laboratory Scale Capillary Rheometer (100 g)
- Evaluating Poly3D™ – Mold & Die Design Software (Code 590)

Smart Die Design

Drs. Kalyon, Rallkar, & Lawal, NJIT/SIT

- Designed a Dual Strand Die Based on Rheological Characteristics
  - Yield Stress 151,000 Pa
  - Slip Velocity Asymptote 230,000 Pa
  - Material of Die Construction Increases the Ceiling
  - Dual Strand Allows Higher Output
- NSWC LOVA Die 300,000 Pa

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Show vu-graphs of design, modeling and hardware

- (vu-graphs of Modeling)
- (vu-graph of design sketch)
- (vu-graphs of finished design)

Die Implementation

Wrong Assumptions & Poor Conventional Wisdom

- Keep Strand as Cold as Practical: Chilled Water in Take-Away
  - Ensure Best Perforation Formation
  - Best for Cutting
- Mix at Low Barrel Temperatures
- Extrude at Low Die Temperature: Air Cool Extrudate

Successful Extrusion

No Die Air-conditioning for Extrudate

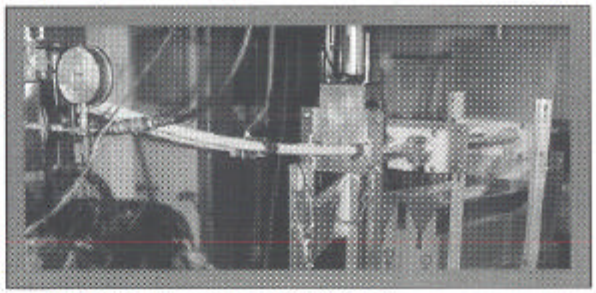
Raised Die Temperature (+15°F)

Independent Heat Control for Die Zone

Location of Controlling Thermocouple

Strand Handling x 2

Designed by Bill Newton (father of the Newtomatic)



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Successful Take-away

- Initial Cut and Remote Capture
- Warm Water: Issue is Strand Hardness
- Best to Pelletize On-line

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Conclusion

- Ingredients to Grains in One Facility
  - Continuous
  - Robust Design
  - On-line Pelletizing Possible
- No Solvents
- Rheological Characterization Critical for Extrusion Success
- Dual Strand Die - Higher Overall Throughput Possible
- Vacuum Processing at Very Low Throughput
- Excellent Dimensional Stability – 0.600" dia. ± 0.0042"
- Gun Firings Last Spring

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