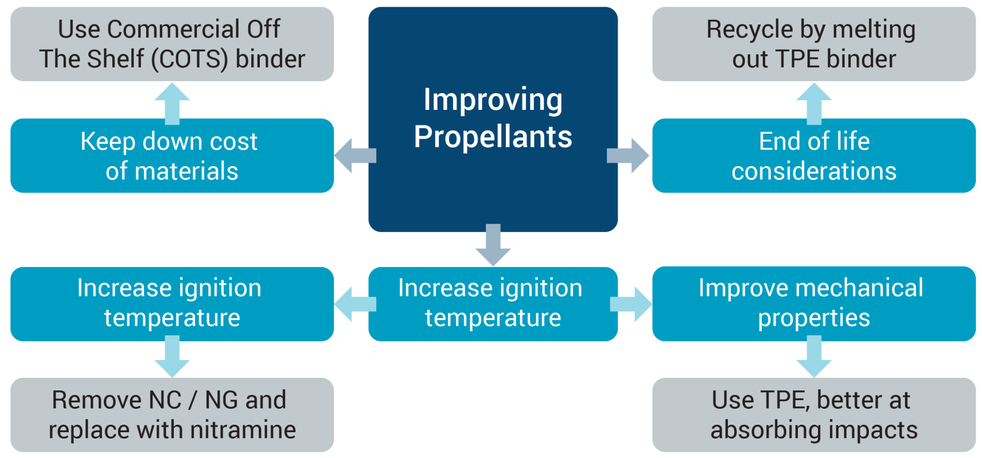
Future Sustainable Propellants

KEY WORDS: Resonant Acoustic Mixer (RAM), Commercial off the Shelf (COTS) Binders, Thermoplastic Elastomers (TPE)

Introduction

Obsolescence is a key factor for the sustainability of gun and rocket propellants. The factors that drive obsolescence can be economic; environmental; legislative; or safety driven.

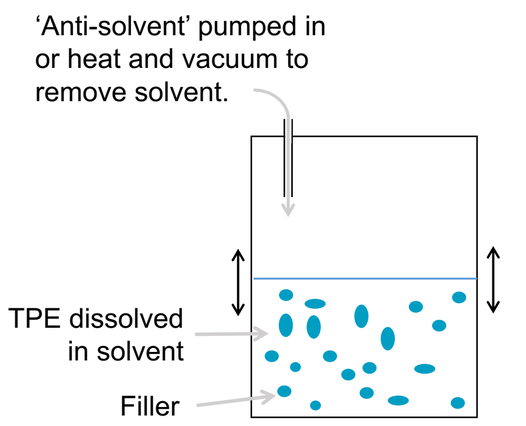
This research aims to make sustainable propellants by using commercially available off the shelf (COTS) polymers and has investigated new mixing/manufacturing techniques. The focus has been on using thermoplastic elastomers (TPE) as the binder, these are commercially made on a large scale giving a sustainable source of binder.



Formulation

The aim was to develop an environmentally sustainable manufacturing process. We have developed a small scale slurry coating method using a Resonant Acoustic Mixer (RAM). This has the advantages of more uniform mixing, faster mixing and ease of scale-up. Custom mixing vessels allow heating and addition of liquids during mixing.

The new RAM method uses either addition of an 'anti-solvent' or vacuum and heat to remove solvent causing the TPE to precipitate, coating filler. The aim for the future is to recycle or eliminate the need for processing solvents.



Mixing vessel shaken on RAM

Hot Pressing

Samples are hot pressed (to replicate rolling or extrusion) at 125 °C under 2 ton load into rectangular slabs using an oil fluid heater plate.

Propellant moulding powder

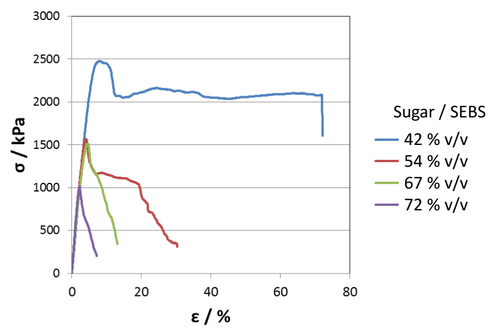
Pressed propellant

Mechanical Testing

Has been undertaken to evaluate the mechanical properties of SEBS (TPE) based propellants.

Tensile Testing at -40 °C, 20 °C and +74 °C, used to calculate the Initial Modulus (E_0), Maximum Stress (σ_{max}) and Strain (ε_{max}).

Tensile Testing a Sample*



Dynamic Mechanical Analysis (DMA) from -120 °C to + 120 °C to ascertain the Storage Modulus (E'), Loss Modulus (E''), tan δ and Glass Transition (T_g)

Results/Future Work

- New RAM slurry coating manufacturing method successfully developed.
- AP/SEBS propellants has been successful made.
- RDX/SEBS moulding powder successful made, propellant to be pressed soon.
- Small scale (powder) safety testing of propellants successfully completed.
- Mechanical testing of propellants ongoing.
- Ballistic testing of RDX/SEBS propellants pending.

Conclusions

In this PhD we have successful used a new binder and a new manufacturing process to produce a new LOVA gun propellant formulation. The propellant uses a relatively inexpensive binder in good supply, furthermore we used Resonant Acoustic Mixing (RAM) as an effective and efficient manufacture method. The thermoplastic properties of the binder means the propellant can be recycled, by melting it out of the munition. It should also have improved safety characteristic due to increased ignition temperature and improved mechanical properties over traditional nitrocellulose based gun propellants.

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* Image from https://www.imrtest.com/tests/tensile-testing