MECHANICAL ANALYSIS - DIFFERENT METHODS AND APPLICATIONS ON EM

Development of NATO standard | Wim de Klerk

TNO innovation for life

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MECHANICAL ANALYSIS

Mechanical analysis techniques in thermal analysis allow the measurement of transition by tracking changes in the physical properties of materials such as coefficient of thermal expansion, stiffness, modulus, and damping. Best solutions are both thermomechanical analysis (TMA) and dynamic mechanical analysis (DMA).

- **Dynamic Mechanical Analysis (DMA)**

A technique in which either the modulus or damping, or both, of a substance under oscillatory applied force or displacement is measured as a function of temperature, frequency, or time, or a combination thereof.

- **Thermomechanical Analysis (TMA)**

A technique where the deformation of the sample is measured under constant load as function of time and/or temperature.

AMMUNITION SAFETY

- *Eliminate Hazardous Consequences due to Unintended Reactions of Munitions and Energetic Materials throughout their Lifecycle”*

- The need to understand ageing and useable life is driven by the need to demonstrate continued safety and suitability over the munition lifecycle. It is also needed to inform decisions on operational life and limitations. Introduction of more complex and expensive munitions has driven the need to maintain availability by extending the life, ensuring maximum return on investment.

MOVIE

STANAGS ON MECHANICAL ANALYSIS OF ENERGETIC MATERIALS

- STANAG 4506, ed. 1, January 1998
  - Explosive Materials, Physical/Mechanical Properties, Uniaxial Tensile Test

- STANAG 4507, ed. 1, January 2002
  - Explosive Materials, Physical/Mechanical Properties, Stress relaxation Test in Tension

- STANAG 4525, ed. 1, October 2001
  - Explosives, Physical/Mechanical Properties, Thermomechanical Analysis for Determining Coefficient of Linear Thermal Expansion (TMA)

- STANAG 4540, ed. 1, September 2001
  - Explosives, Procedures for Dynamic Mechanical Analysis (DMA) and Determination of Glass Transition Temperature

  - These all originated in the Mechanical Properties EWG (1991-1994). Other tests were debated but thought less urgent e.g. adhesion/peel test, porosity test.

SUMMARIZED STARTING POINT

- STANAGs describe parameters (sometimes not equally defined)
- Sample preparation unclear / not consistent
- Several methods for determination glass transition temperature, thermodynamical (DSC) or mechanical (DMA)
- Current test equipment more sensitive and better thermal stability
- Tg and Coefficient of Thermal Expansion by TMA require different preparations
- More measure modes in current DMA apparatus methods

➔ *Need for consistent documents, with scientific background*

NEW DOCUMENT – AOP4717

- The test procedures provide information on the visco-elastic mechanical response of energetic materials as a function of temperature, strain rate, and any other parameter deemed necessary. This information can be used to establish mechanical properties, to determine mechanical response transitions, and for quality control.

- Dynamic Mechanical Analysis (DMA)
- Thermomechanical Analysis (TMA)
- Uniaxial Compression Test
- Uniaxial Tensile Test
- Stress Relaxation Test in Tension
- Surface Hardness Testing Shore Test
- Additional Mechanical Analysis

APPLICATIONS

- The methods as described in this AOP can be applied in part to the following energetic materials:

- Booster Explosives
- NC based Propellants
- Thermal Plastic Bonded Energetic Compositions
- Composite Propellants
- Bonded High Explosives
- Bonded Pyro Compositions

- Energetic Materials like primary explosives and/or liquid energetic materials can not be investigated with the methods as described in this document.

DESCRIPTIONS FOR EACH TECHNIQUE

3.1 Overview / Brief description
3.2 Test equipment
- 3.2.1 Tension
- 3.2.2 Dual Cantilever
- 3.2.3 Torsion
- 3.2.4 Shear
- 3.2.5 Single Cantilever
- 3.2.6 Compression
- 3.2.7 Others

3.3 Calibration
3.4 Sample preparation
3.5 Safety aspects
3.6 Test Methods (temperature / rate, etc.)
- 3.6.1 Temperature sweep
- 3.6.2 Frequency / Temperature sweep
- 3.6.3 Strain sweep
- 3.6.4 Time sweep
- 3.6.5 Stress Relaxation

3.7 Data recording
3.8 Data analysis
- 3.8.1 Mastercurve

3.9 Report form

MEASUREMENTS

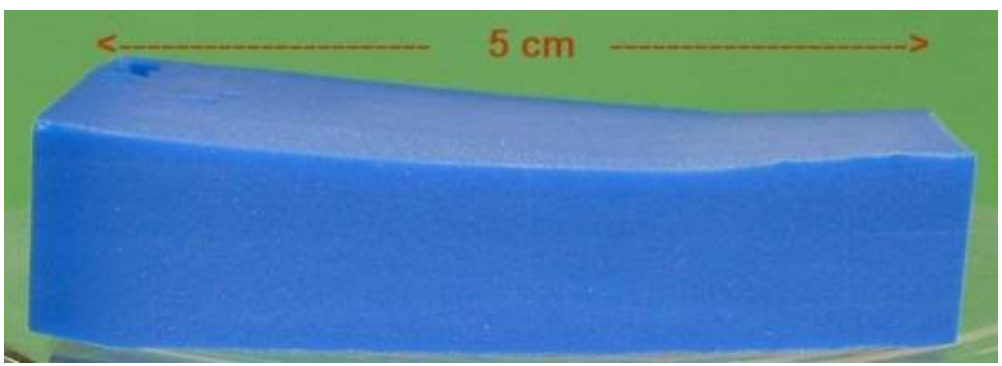
ON-GOING ROUND-ROBIN (1)

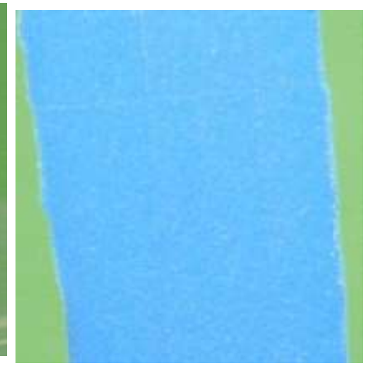
- 12 laboratories work in DMA program
- Two samples; one from USA:

Ingredients
Ballontini Impact Bead AG (53 to 125 µm)
Spheriglass 3000A (30 to 50 µm)
Sphericel 110P8 (2 to 25 µm)
Hydroxyl terminated polybutadiene (HTPB) R45HTLO
Dioctyl Adipate (DOA)
Isophorone diisocyanate (IPDI)
(N,N'-di(2-hydroxyethyl) dimethylhydantoin (Dantocol DHE)
Cyanox
Triphenyl Bismuth (TPB)
Cyan Blue

ON-GOING ROUND-ROBIN (2)

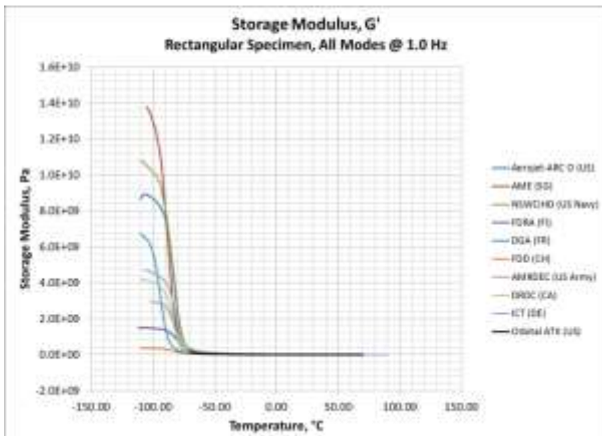
- Sample of DGA, France:
  - HTPB-IPDI binder filled with Aluminium oxide- hydroxide, bi-modal, about 73 mass %, 15µm and 6 µm
  - Using excess IPDI to bond the particles to the binder, DOAZ as plasticizer
  - Antioxidant and a colorant added

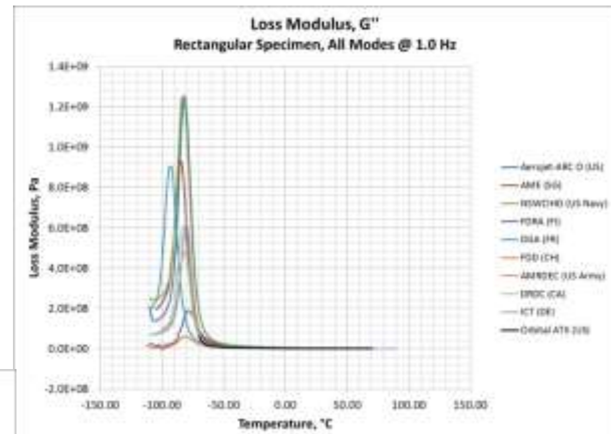


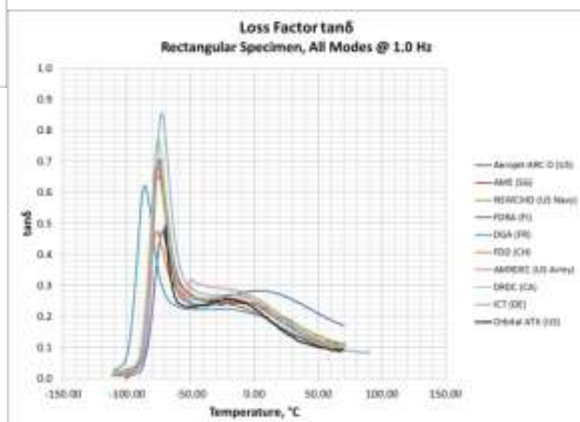


ON-GOING ROUND-ROBIN (3)

- PBX-S Temperature Sweep – All Modes (1.0 Hz)

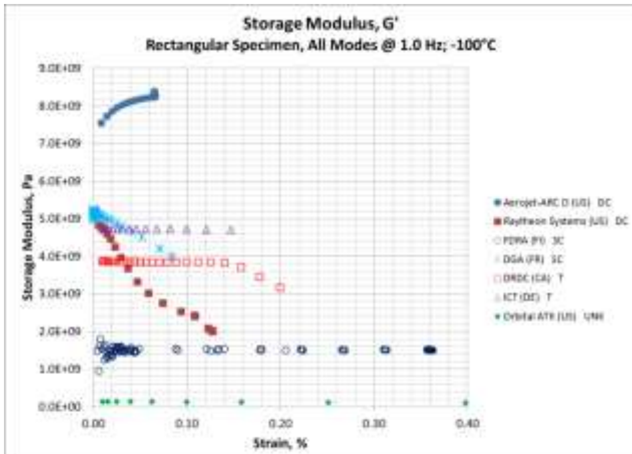


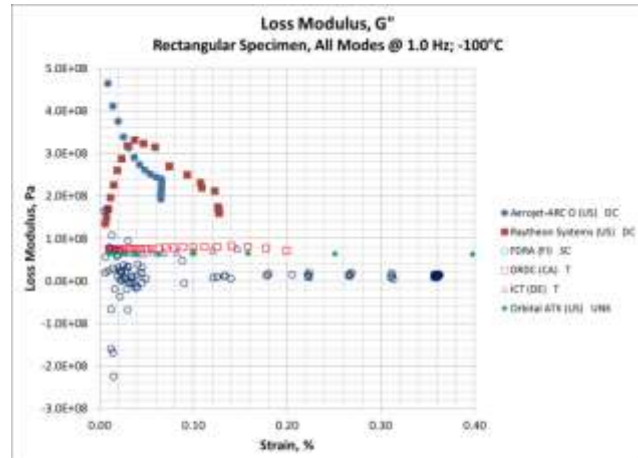


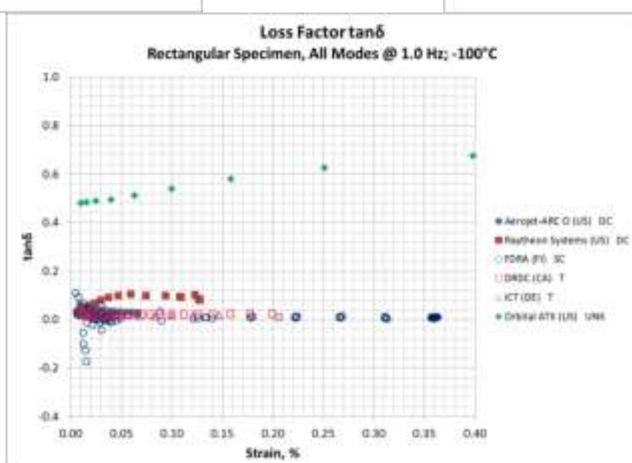


ON-GOING ROUND-ROBIN (4)

- PBX-S Strain Sweep – All Modes (1.0 Hz, -100°C)







CONCLUSION

- Critical parameters needs to be described and validated, like
  - Sample geometry & size
  - Way of preparing
  - Clamping
- Standardized document is under development, and will give a scientific overview of methods and way to use it
- Correct mechanical analyses is a key parameter for correct stress calculations on larger (IM) systems

SAFETY OF EM – HFC TECHNIQUE

9th TAMPERE

INTERNATIONAL
HEAT FLOW CALORIMETRY SYMPOSIUM
ON ENERGETIC MATERIALS

International Heat Flow Calorimetry Symposium on Energetic Materials
HFCS-EM

Three Days of Inspiration
8-10 September 2015, Tampere, Finland

Main topics are:

- Decomposition kinetics of energetic material – mechanisms, kinetic descriptions
- Experimental methods, problems, solutions, developments
- Instrumental improvements and innovations
- Measuring heat changes from chemical reactions or physical events
- Surveillance study using HFC
- Testing high explosives, propellants and pyrotechnics by HFC
- HFC for stability and compatibility testing of explosives and materials
- Regulations and standards
- Other thermal methods (DSC, ARC etc)

=> www.hfcs2015.com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