The Centre of Excellence in
Protection, Safety and Information Security
Performance through Research
PVTT

Accelerated ageing study of low sensitivity PBX formulation - FPX V40

IM & EM Symposium, May 11.-14. 2009
Tucson Arizona

FORCIT
DEFENCE

Introduction

Two common ways to achieve enhanced insensitivity properties

Melt Cast Formulations

PBX Formulations

Environmental impact
&
Ageing

Elastic binder matrix together with less sensitive high explosives → IM properties

Increased cross linking density

Degradation of mechanical properties of binder

Changes in mechanical properties of PBX

Possible changes on sensitivity properties of PBX

To predict these changes occurring during the life cycle, artificial ageing study is included in the qualification test program

Sample material – FPX V40

- FPX V40…

  …is produced by Forcit Defence

  …is isocyanate cured HTPB based PBX

  …has shown very good insensitivity properties

  …is a multipurpose explosive

  …is used for example in army engineering charges (charges fulfill the IM requirements)

Experimental

Ageing

- STANAG 4581
  - At 60 °C for 3 and 6 months
  - According to van'T Hoffs rule this represents storage for
    - 10 years at 20 °C
      or
    - 20 years at 10 °C
  - Samples were wrapped in plastic foil during ageing
  - Outer surfaces were removed before machining the test specimens

Testing

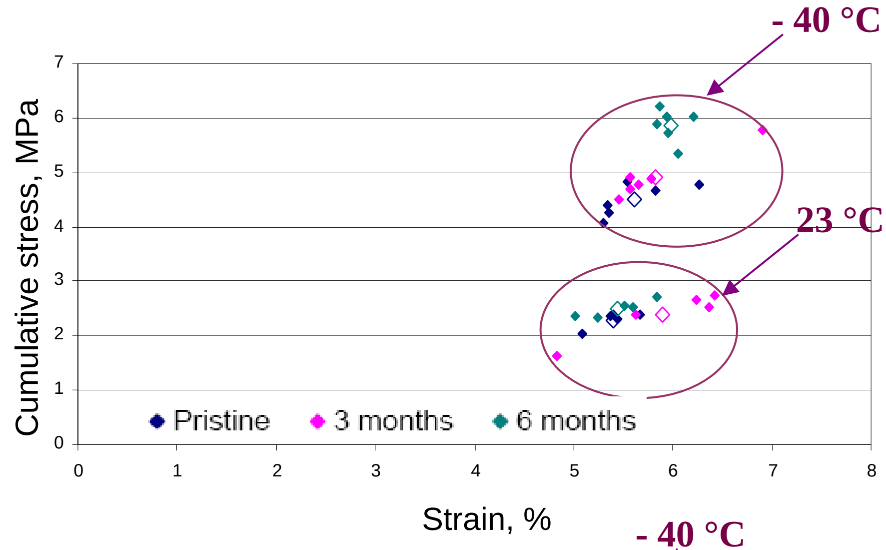
- Pristine and aged samples were tested
- Two test temperatures
  - + 23 °C
  - - 40 °C
- Mechanical test were done with Lloyd LR5k Plus
  - Uniaxial tensile test
  - Compression test
  - Stress relaxations test
- Other tests were included in qualification procedure

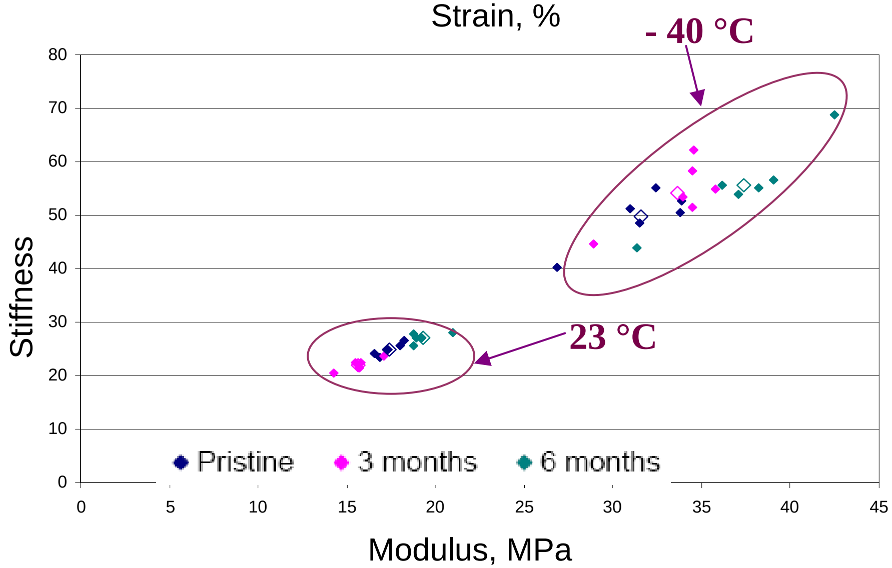
Results – Tensile test

- **Low temperature behavior**
  - Stress, modulus and even strain increased -> cumulative stress is increased
  - Tensile properties were maintained also after ageing
- **Ageing effect**

  After 3 months
  - Stress and modulus, thus stiffness was decreased (23 °C)

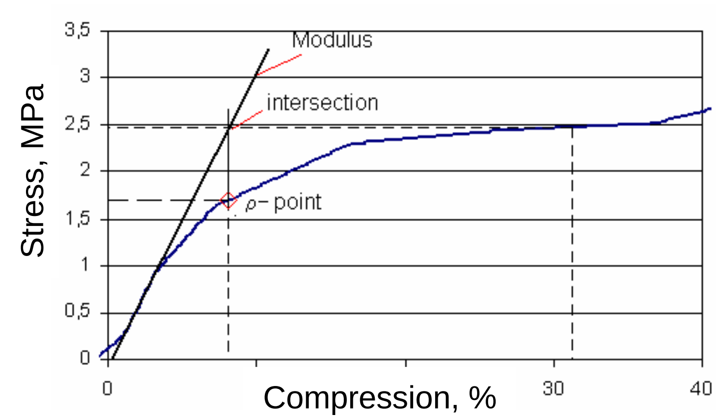
  After 6 months
  - Stress, modulus and stiffness were increased and strain remained or even increased -> higher cumulative stress and thus tougher material

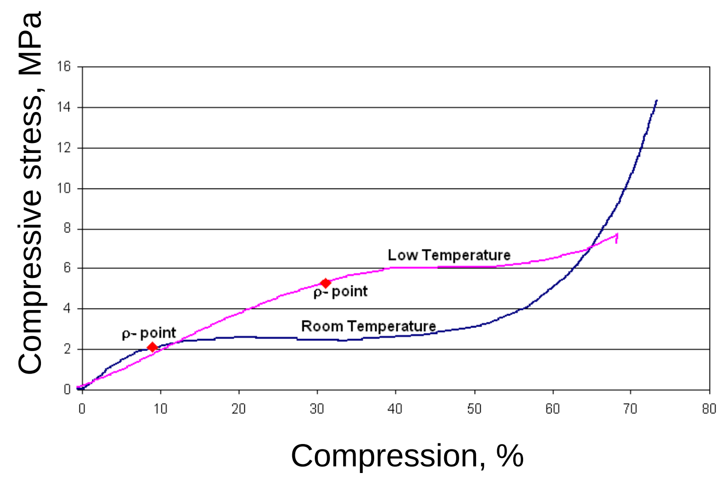




Results – Compression test

- **Low temperature behavior**
  - Remarkable different compression behavior
    - higher compressions
    - stress level is increased
    - linear part lasts longer
    - determined ρ-point moved towards higher compressions
  - Toughening behavior was seen in test specimens after compression test – samples were not fractured
  - Behavior was consistent with tensile test observations





At 23 ºC tested samples

At -40 ºC tested samples

Results – Compression test *(continues)*

- **Ageing effect**

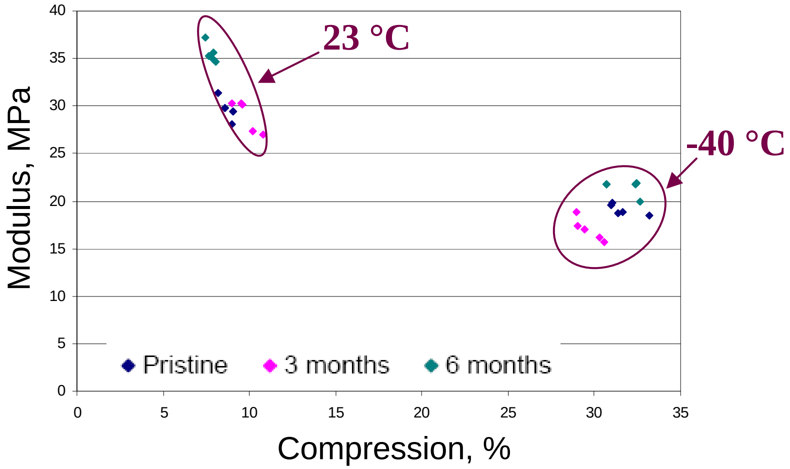
  After 3 months

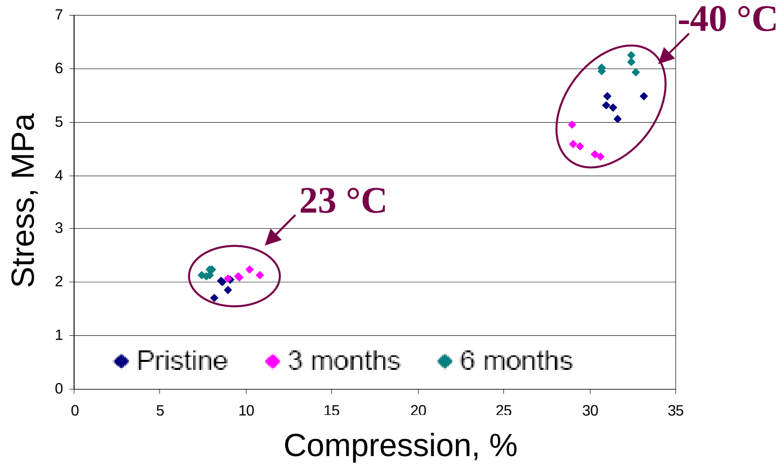
  - Decreased modulus
  - Slight loose in compression capability was observed at low temperature

  After 6 months

  - Increased modulus
  - No significant change on compression values at room temperature
  - Some increase in compression capability at low temperature
  - Thought behavior at low temperatures was maintained also after ageing

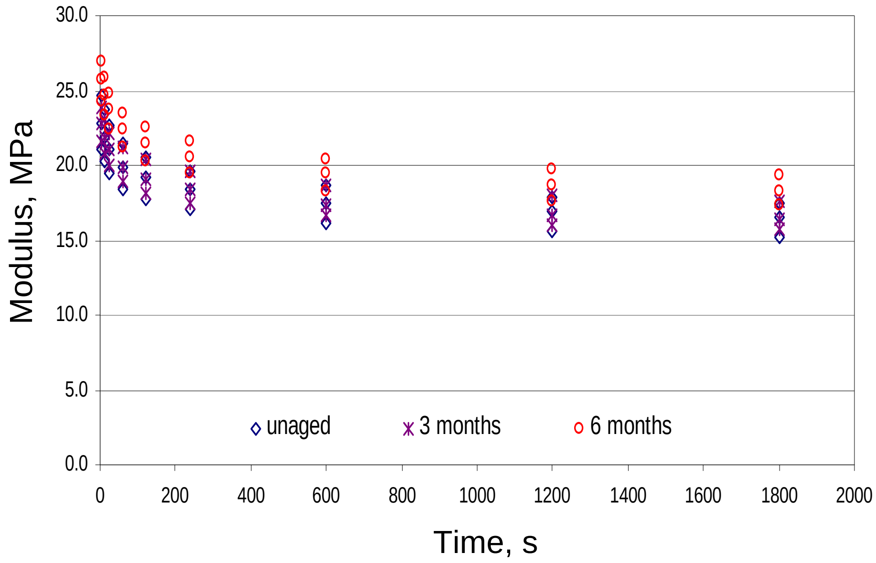
✓ Test results were congruent with tensile test results

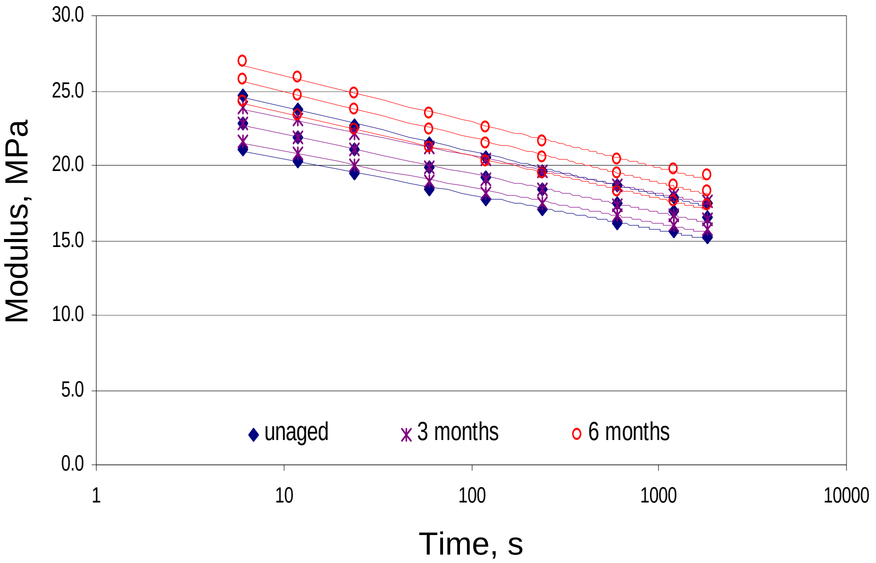




PUOLUSTUSVOIMAT I FÖRSVARSMAKTEN I THE FINNISH DEFENCEFORCES

Results – Relaxation test





- Modulus difference between 6-1800 seconds was determined
  - No significant changes can be observed
    - Ageing has a slight effect on relaxation tendency
    - Relaxation tendency was lower samples aged for 3 months

✓ Results are congruent with other tests

Conclusions

- Behavior of 3 months aged samples were unexpected
    - Loss of modulus
    - Decreased stress values and stiffness
    - Increased strain values
  - Similar behavior was observed in all conducted tests

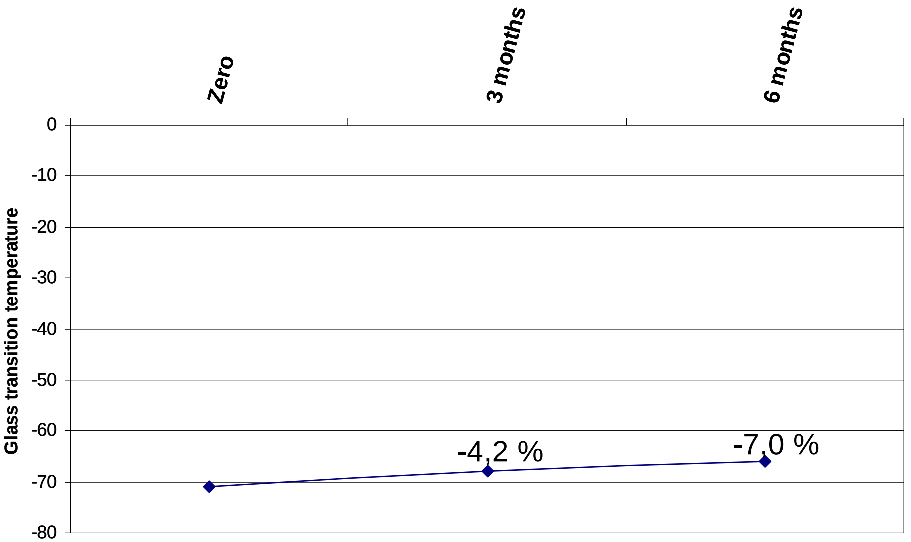
- Explanation
  - Result of recovery or stress relaxation process occurred during short period ageing at temperature which is close to the curing temperature
    - At the curing temperature the internal stresses are at minimum level
    - Relaxation or recovery processes compensates the changes caused by ageing

Conclusions *(continues)*

- ✓ Ageing has an effect on mechanical properties although these effects are quite minor
- ✓ During the ageing the sample explosive became tougher and stiffer without losing its elasticity
  - indicating some degree increase in cross linking density but only to such degree that it does not affect strain values.
- ✓ Tendency to relaxation is highest for most aged samples
  - during the initial stretching phase the stiffened structure hinders the movements of molecules and thus relaxation of the polymer
  - chain relaxation occurs slowly in constant strain phase as a function of time.

Correlations to other tests

- Glass Transition Temperature
  - Glass transition temperature (T_g) describes the behavior of the binder and its structure also
    - T_g was determined with DMA according to STANAG 4515
  - Ageing causes the shift of T_g values
  - For aged samples the glass transition occurs at higher temperatures
    - smaller mobility of molecules due to increased cross linking



✓ T_g results support the conclusions made based on mechanical tests

Effect on insensitivity properties

- Test program showed that ageing at 60 ºC for 6 months has an slight effect on mechanical properties of sample explosives.

Even so:

- No changes in shock sensitivity (LSGT)
- No changes in thermal sensitivity
  - deflagration temperature - maintained
  - decomposition temperature - maintained
  - slow cook off temperature - maintained

Test	Pristine	3 months	6 months
LSGT	31 mm 41 kbar	31 mm 41 kbar	31 mm 41 kbar
Deflagration Temperature	211 °C	213 °C	213 °C
Decomposition Temperature (DSC)	227 °C	226 °C	224 °C
SCO	176 °C	172 °C	172 °C

Summary

- ✓ Minor changes in mechanical properties was seen
- ✓ No evidence of change in sensitivity properties
- ✓ Test program however did not take into account the impact sensitivity properties which should be tested in future

Acknowledgements

- Explosives Technology staff at PVTT
- M.Sc Matti Muilu
- Senior Mechanics:
  - Jukka Nenonen
  - Kari Reinola
- Forcit Defence

PUOLUSTUSVOIMAT I FÖRSVARSMAKTEN I THE FINNISH DEFENCEFORCES