NC Ageing; Effects on a High Explosive Formulation

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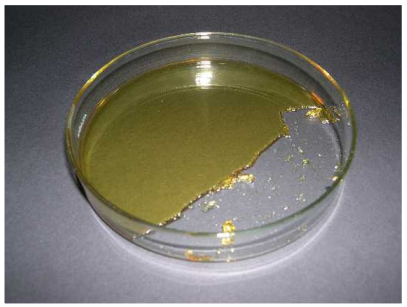
Introduction

- 'PBX(A)'
  - HMX explosive filler
  - Gelatinous binder containing NC
  - Requirement for through life mechanical integrity
- Molecular mass of NC reduces with age
- Mechanical strength of a consolidated, high density pressing also reduces with age
- Molecular mass of NC is quick and relatively easy to measure
  - Mechanical strength can be predicted

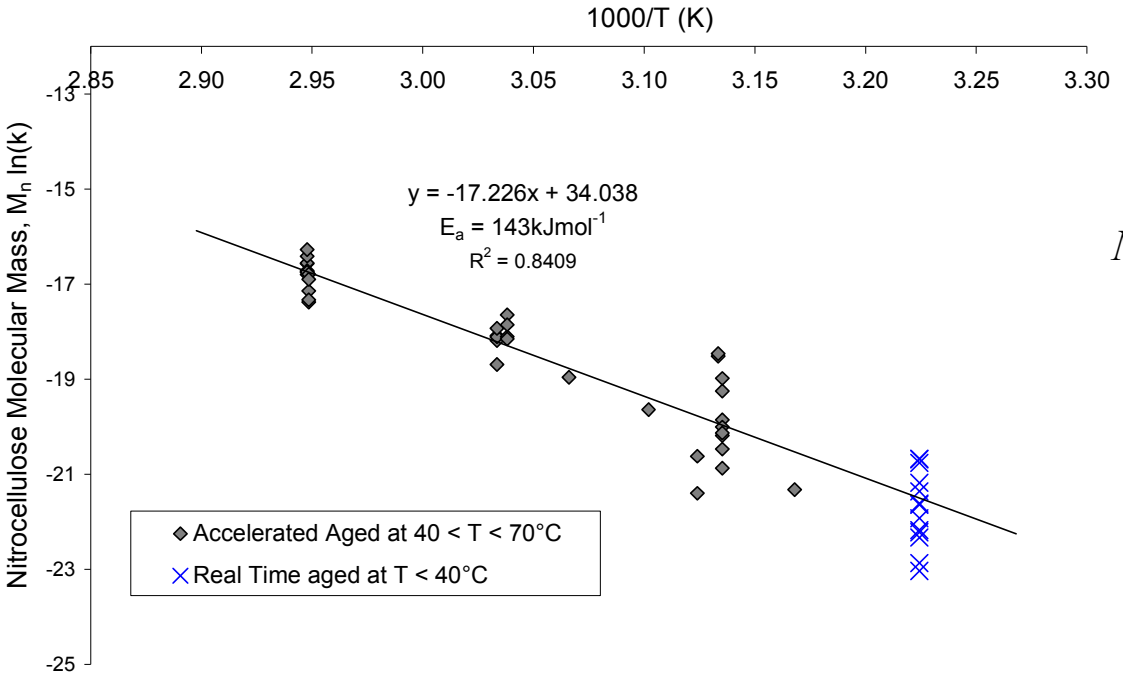
Sources of Evidence

- Pristine PBX(A)
  - Multiple sources of NC
    - Different molecular mass
    - Cotton linter & wood pulp cellulose
- Aged PBX(A)
  - Real-time aged at T < 40°C
  - Accelerated aged at 40°C < T < 70°C
- Aged gelatinous binder
  - Sealed glass vessels
  - Atmospheric control
  - Study chemistry of binder ageing



NC Ageing Model

- Arrhenius plot verifies that real time ageing is consistent with accelerated ageing
  - Consistent with single mechanism and a dominant thermolytic process

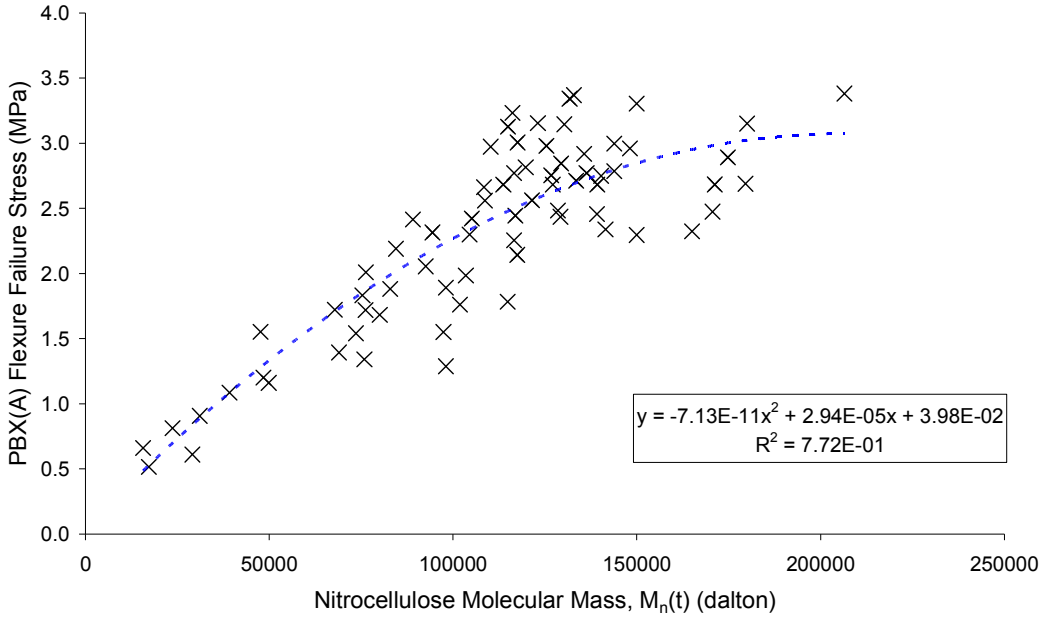


$$M_n(t) = \frac{1}{\frac{1}{M_n(0)} + kt}$$

$$k = Ae^{-\frac{E_a}{RT}}$$

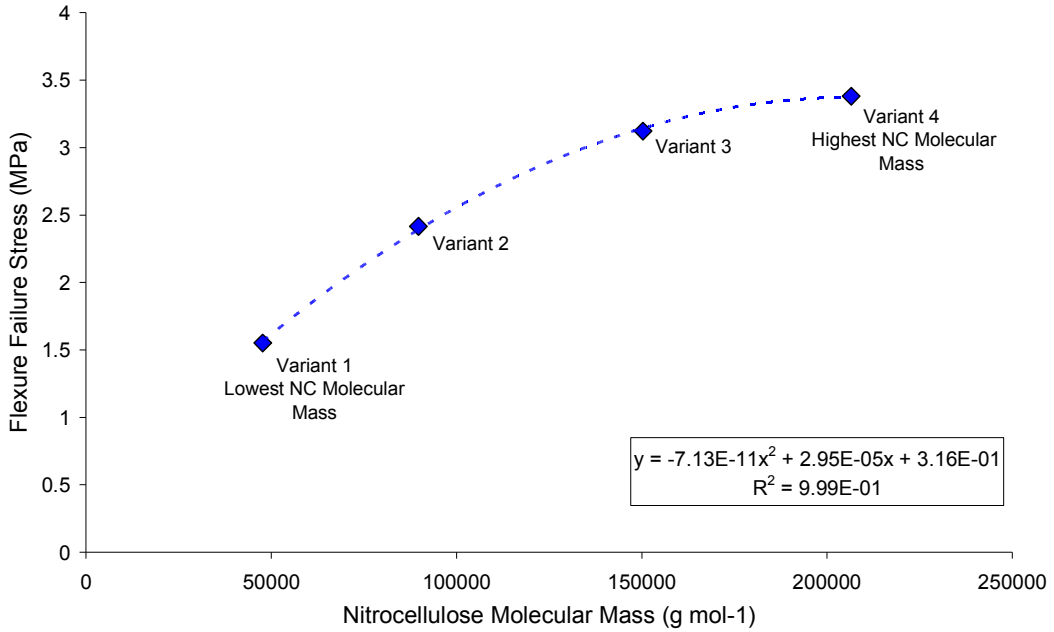
Empirical Correlation of Properties

- NC molecular mass empirically correlated with PBX(A) flexure failure stress
  - Pristine virgin, real-time aged and accelerated aged PBX
  - Minor component of the composition affecting bulk properties



Testing the Correlation

- Four PBX(A) variants manufactured to test the empirical correlation
- Virgin material
- Control of:
  - Ingredients
  - Manufacturing process
  - Composition
  - Density
  - Testing methods

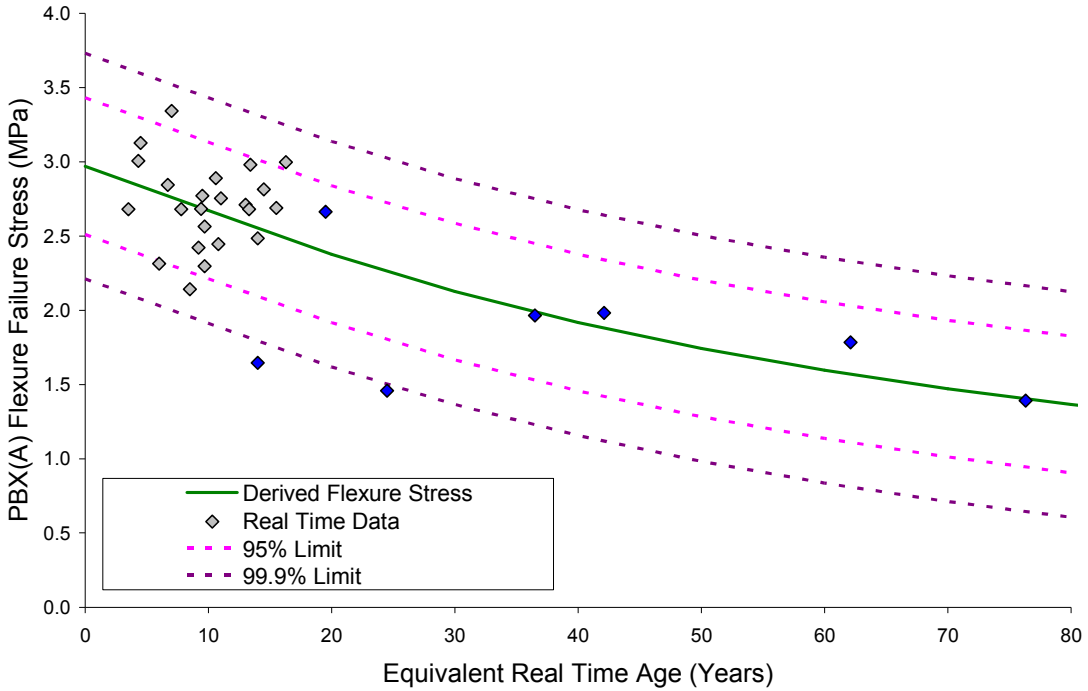


- Confirmed NC molecular mass affects PBX mechanical strength

Predicted Mechanical Properties

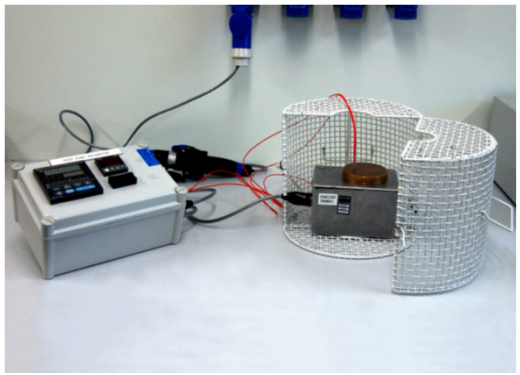
- NC ageing model used to predict reduction in number average molecular mass, M_n
- Correlated properties used to derive reduction in PBX(A) mechanical strength
- Trials verification
  - Equivalent ages

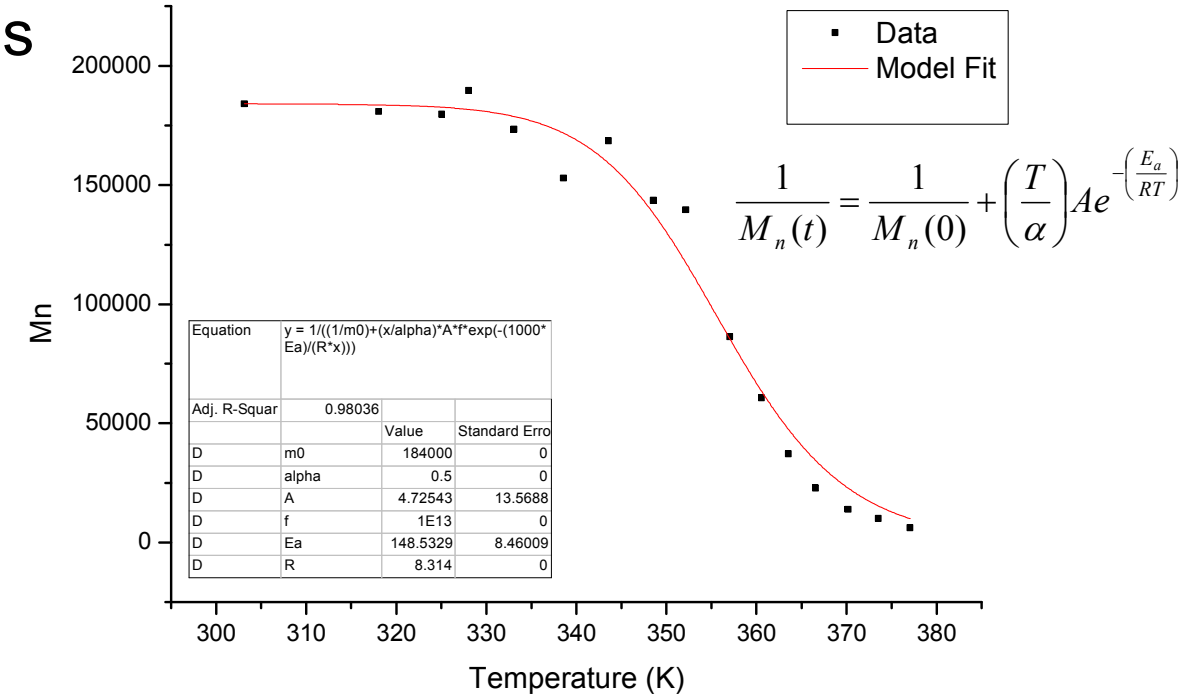
$$F = \frac{Ae^{-\frac{E_a}{RT_2}}}{Ae^{-\frac{E_a}{RT_1}}}$$



Additional Evidence

- Non-isothermal ‘thermal ramp’ ageing experiments performed to further verify Arrhenius parameters
- 30 – 105°C at linear ramp rate (α) 0.5°C day^{-1}
- Periodic withdrawals
- NC analysed
  - E_a ~ 148kJmol^{-1}





Conclusions

- NC is a minor component of HMX-filled PBX(A)
  - NC molecular mass has been shown to correlate with mechanical strength of the pressed PBX(A)
  - Virgin materials using different NCs verifies correlation
- Arrhenius ageing model predicts molecular mass which allows mechanical strength to be derived
  - Predicted properties are verified with long term storage Trials
- The NC ageing model has been further verified with a ‘thermal ramp’ ageing experiment