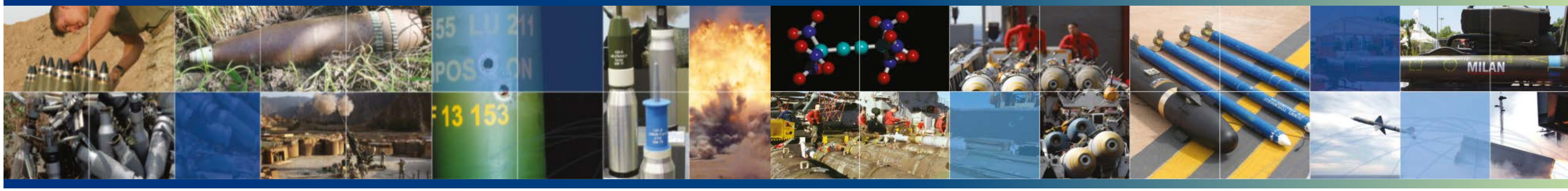
Munitions Safety Information Analysis Center

Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety



Aging and Mechanical Damage of Munition Materials

An MSIAC Limited Report

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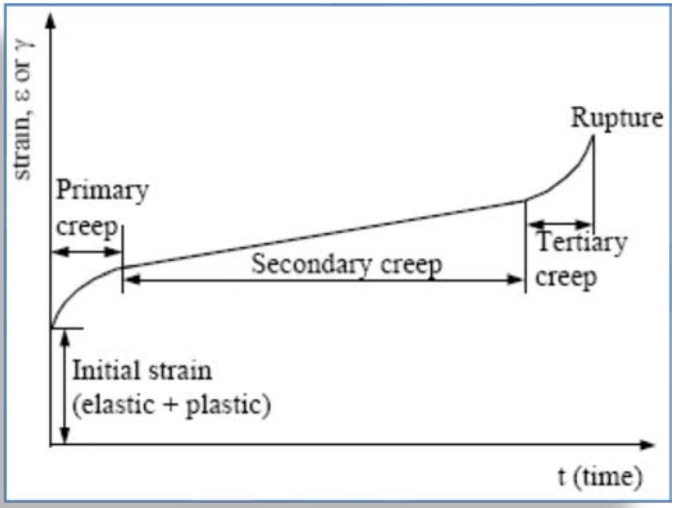
MSIAC Objectives

- Two work element objectives:
  - Kno-Und-8 – Age-related Mechanical Damage
    - Mechanisms such as cracking, delamination, fiber breakage, particle/matrix and fiber/matrix debonding, etc.
  - Kno-Met-3 – Effect of Ageing on Materials and Munitions Safety
    - Review of IM and ageing studies, and applicability of latest R&D techniques to evaluate ageing
- Significant overlap of these two topics
  - Currently treating as one topic, with multiple distinct sub-sections

What is Material Degradation?

- Alteration of properties caused by exposure to service conditions
  - Sometimes routine, sometimes abnormal
- Aging alters properties gradually, over time
- Other insults may cause degradation suddenly or in “jumps”
- Implication is that aging is detrimental



DESIGN IMPLICATION

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- Aging → not always detrimental
  - I.e., if stiffness is critical to a component's performance and aging mechanisms cause the material's stiffness to increase over time…
- But, most changes in one property are accompanied by changes in another
  - Increasing stiffness is usually matched with reduced ductility
- The engineering design challenge: select appropriate materials, plan for changes

Report Structure

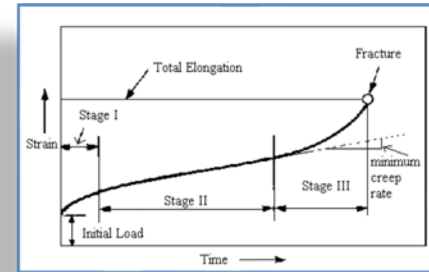
Multiple subsections based on material classes

- Polymers
  - Primer
  - Organic fluid contamination
  - Photo-induced degradation
  - Chemical degradation
  - Solvolysis
  - Ozonolysis
  - Oxidation
  - Creep, fatigue
  - Galvanic action

- Metals
  - Primer
  - Environmental stress fractu
  - Corrosion
  - Fatigue, cyclic loading, vibration
  - Irreversible deformation
  - Stress-corrosion cracking
  - Hydrogen embrittlement
  - Hysteretic elastic/plastic deformation
  - Galvanic action

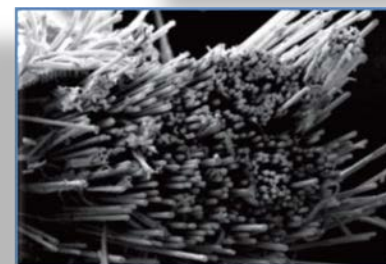
- Composites
  - Primer
  - Constituents (polymer matrix, fiber, particulates, etc)
  - Delamination, interlaminar cracks
  - Fiber breakage
  - Fiber pull-out
  - Voids, bubbles
  - Incomplete matrix penetration
  - Stress concentrations at thickness changes, holes

Report Structure



Additional section on damage mechanisms referencing back to material damage morphologies

(Following structure of
Ordnance Board Pillar P123(1)
“Scientific Basis for the
Whole Life Assessment of Munitions”)



And a few case studies

- Case Studies
  - Case I
  - Case II
  - Case III

- Munitions Ageing
  - Insults
  - Transport
  - Rough Handling
  - Vibration
  - Climatic Conditions
  - Thermal Changes
  - Electromagnetic Insults

Details of the Polymer Section

- Three most common uses for polymers in munitions:
  - – Structural materials, pure form, with minor additives
    - Examples: brackets, straps, lugs, plugs, seals
  - – Matrix for structural composites
    - Example: “(G)FRP” or (glass-)fiber-reinforced-polymer(epoxy)
  - – Binders, components, and/or additives within energetics (aggregate composites)
    - Examples: plasticizers, coatings, binders

A Primer on Polymer Materials

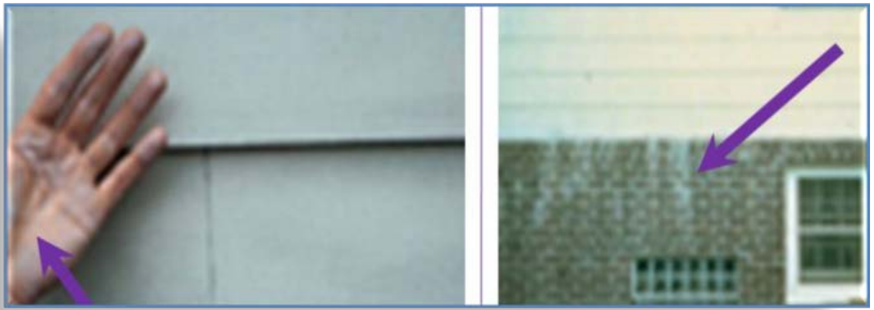
- Basics of polymer chemistry and nomenclature
- An understanding of chain architecture and interaction
- How bulk properties derive from molecular characteristics
- Common industrial polymers

Polymers of Interest

- 97% of plastics in daily life
  - polyethylene (PE)
  - polypropylene (PP)
  - polyvinyl chloride (PVC)
  - polyethylene terephthalate (PET)
  - polystyrene (PS)
  - polycarbonate (PC)
  - polymethylmethacrylate (PMMA)
  - silicones (polysiloxanes)
- Plus, discussion of polymers typically used in energetics, such as hydroxyl-terminated polybutadiene (HTPB)

Polymer Degradation

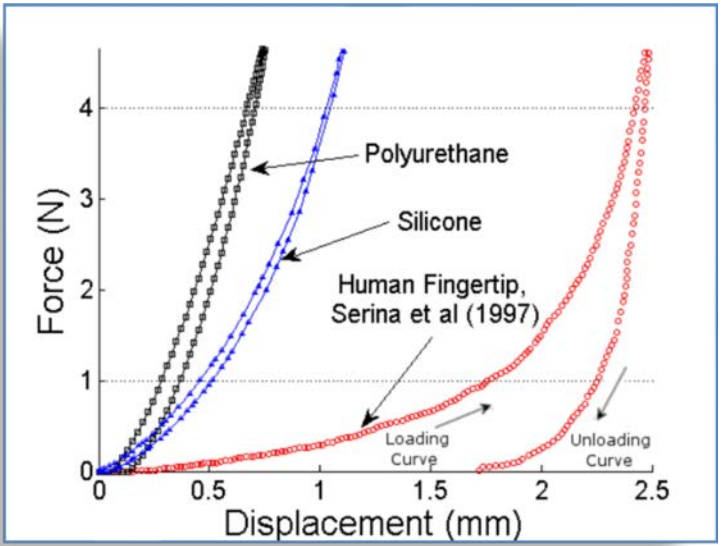
- Engineering properties
  - Strength, ductility, toughness
- Cosmetic / Appearance
  - Color, surface residue (chalking), cracking



- Examples:
  - Random chain scission in polyethylene
  - Specific chain scission in polyalphamethylstyrene

DEGRADATION MECHANISMS

- Liquid-borne
  - Organic fluids
  - Chemical attack
  - Solvation / solvolysis
- Radiant Energy
  - Photo-induced damage
  - Thermally induced
- Gas-phase
  - Gaseous
  - Ozonolysis
  - Oxidation
  - Chlorine cracking
- Mechanically-borne
  - Creep / relaxation
  - Fatigue
  - Hysteretic elasticity reduction



“Towards Humanlike Social Touch for Sociable Robotics and Prosthetics: Comparisons on the Compliance, Conformance and Hysteresis of Synthetic and Human Fingertip Skins.” J. Cabibihan, S. Pattofatto, M. Jomaa, M. C. Carrozza, International Journal of Social Robotics 1(1):29-40 Jan 2009.

Organic Fluid Contamination

- Swelling, debonding, loss of strength
  - When exposed to organic fluids and other corrosive environments, such as acids and alkali solutions
- Applied stress can accelerate process
- High strength polymers particularly sensitive
  - May become brittle and lose fracture resistance
  - Fracture toughness doesn't change but threshold stress intensity factor for crack propagation may be considerably lowered
  - Become prone to premature fracture because of sub-critical crack growth.

Progress

- Presentation here at IMEMTS
  - Includes overview of content and scope
  - Paper provides extract of Polymer section
- Final report published and available this summer