Esterline
Defense Technologies

NC Characterization for Felted Fiber Cases

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Outline

- Felted Fiber Combustible Cases
- The challenge of NC Specification
- Discussion of unusual test methods to evaluate NC
- Future work

COMBUSTIBLE CASE BENEFITS

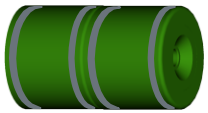
- Rigid combustible cases provide:
- Fixed containment of the propellant charge
- Structure to the charge configuration
- Performance Additives [wear reduction, etc]
- Additional propulsive energy
- Combustible Cases aid gun crews:
- Improved charge identification features
- Improved charge handling characteristics
- Reduced gun gases in confined crew compartments

COMBUSTIBLE ORDNANCE PRODUCTS

ARTILLERY
155mm

MACS (MODULAR ARTILLERY CHARGE SYSTEM)

M231



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FIXED AMMUNITION

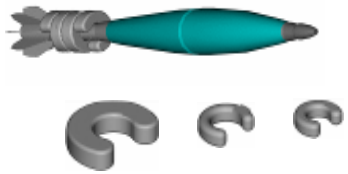
KINETIC ENERGY (KE)

HIGH EXPLOSIVE ANTI-TANK (HEAT)

TANK
120mm

MORTARS
60mm, 81mm, 120mm

MORTAR AMMUNITION



COMBUSTIBLE CASE MANUFACTURE

Batch Preparation (Composition)

Component Rough Forming (Weight Control)

Component Molding (Density Control)

Trimming & Finishing (Final Shape)

Inspection, Packing & Shipment

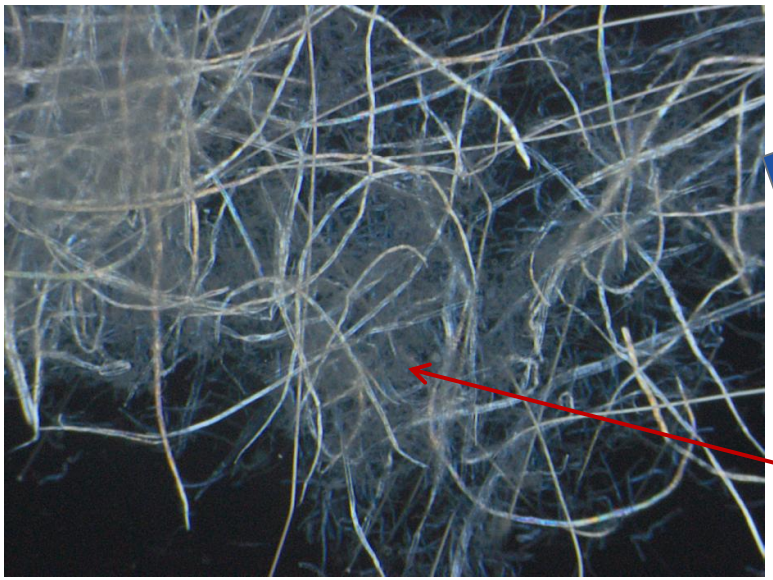
CELLULOSE FIBER PREPARATION

- Original sources of cellulose:
  - Cotton linters (fuzz scraped from cotton seeds)
    - Baled form – best for nitration
    - Sheeted form – easiest to handle
  - Sulphite processed wood pulp
  - Kraft processed wood pulp (sulfate)
- Cellulose preparation for nitration:
  - Bale breaker maximizes ‘free fiber’
  - Sheeted form requires the sheet ‘deconstruction’
  - Cutting (Waldron, Bowas, etc) increases surface area for nitration but does reduce hard ‘knit’ lumps
  - Milling reduces ‘knits’ produces more dusty fines

NC IMPACTS CASE PERFORMANCE

- NC materials are compatible with in the EDT manufacturing process and can be used to produce CCC components
- NC Quality has a major effect on the processing and performance characteristics of combustible cases
  - Different NC materials have shown differing processing behaviour
  - Testing of combustible cases from different NC has shown different levels of acceptability in key areas:
    - Rough Handling
    - Ballistic performance

Felted Fiber



- Fiber matrix is a web of cellulose and synthetic fibers that trap NC and provide structural strength
- However, since NC is a large component of the formulation, the fiber properties also influence physical properties of the felt

What can we learn from papermaking?

- Physical properties of cellulosic felts are influenced by:
  - Fiber properties
    - Fiber length/diameter/thickness
    - Fibril angle
  - Inter-fiber interactions
    - Hydrogen bonding

Focus here for 1st part of research

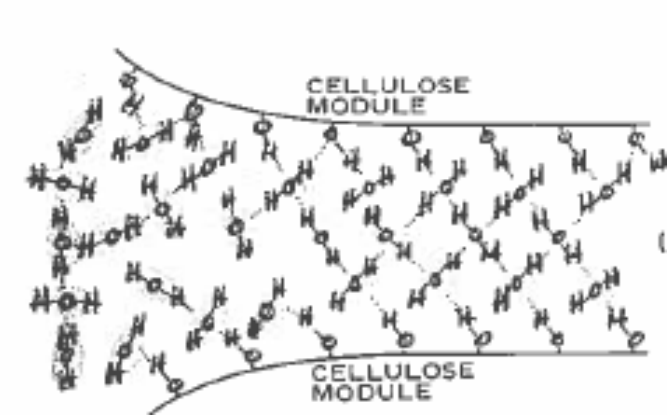
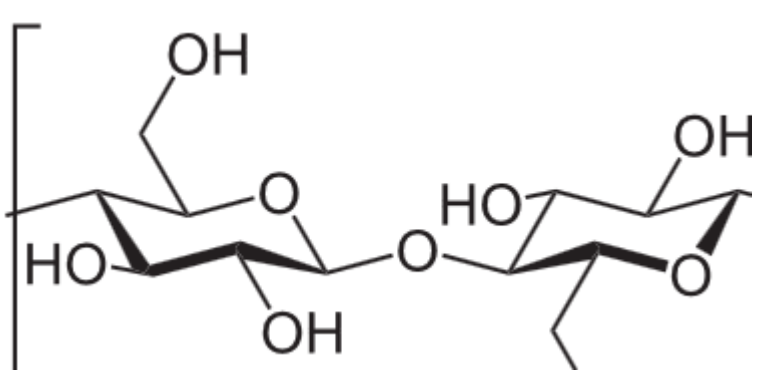
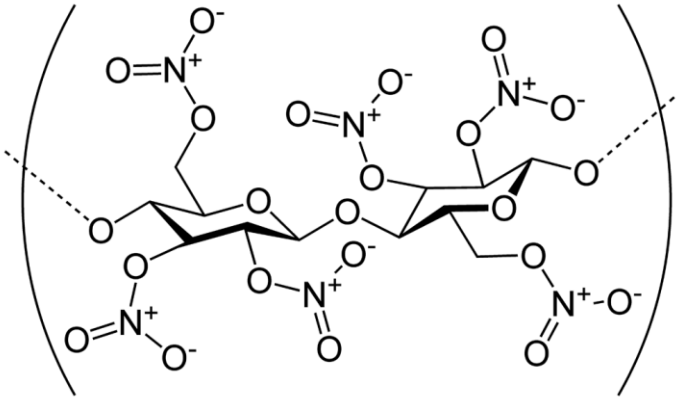


Image from Handbook for Pulp& Paper Technologies, G.A. Smook

Hydrogen bonding



vs.



- In nitrocellulose, hydroxyl groups are replaced by nitro groups (but never fully nitrated)
- Is hydrogen bonding still an important part of inter-fiber interactions?

Inter-fiber interaction characterization methods

- Canadian Standard Freeness
  - Measures drainability of pulp. Indirectly measures fiber length and fiber interactions.
- Water Retention Value
  - Measures water remaining in a pad after centrifugation. Measures water bonded or trapped in fibers.
- Handsheet characterization
  - Measures properties such as tear resistance, fold resistance, tensile strength, burst strength, etc. on handsheets made with the given fiber.

Objective—measure hard-to-remove water in nitrocellulose and compare results to Canadian Standard Freeness, Water Retention Value, and Handsheet Properties

- Hard-to-remove water
  - Bound water (associated with fiber surface through hydrogen bonds)
  - Trapped water (trapped in nano-scale pores)
- Use isothermal thermogravimetric method described by Park et. al. to characterize

Park S, Venditti, RA, Jameel H, and Pawlak JJ,. 2005. Hard to remove water in cellulose fibers characterized by high resolution thermogravimetric analysis—methods development. Cellulose. 13:23-30.

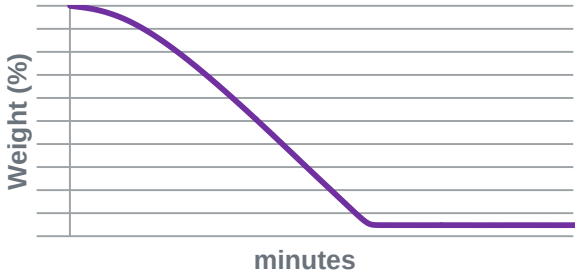
TGA method

- Heat wet NC isothermally and measure when the rate of water evaporation changes. Define hard to remove water as the ratio of water mass to fiber mass at the transition between the *constant rate zone* and the *falling rate zone*
- Measurements were taken by using 8-14 mg of wet NC, and heating at 90 ºC for 15 minutes

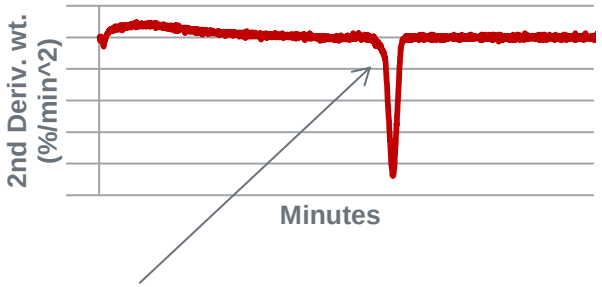
TGA curves

HRW=Mass at transition to falling rate zone/mass of dry fiber

Weight loss curve

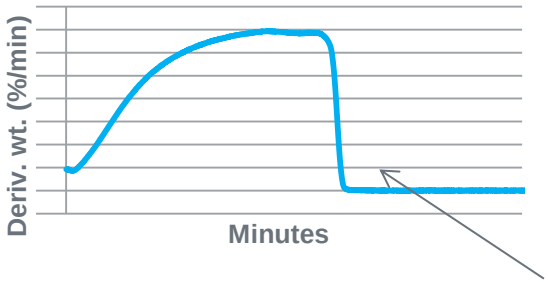


Second Derivative



Mass at transition to falling rate zone is defined as mass when DDTG is less than 3x the standard deviation of the constant rate zone

First Derivative



Mass when DTG is 0.0001% was used as mass of dry fiber

TGA summary

NC lot	%N	TGA HRW
Grade A lot 1	12.64	1.65
Grade A lot 2	12.57	1.54
Grade B lot 1	13.64	1.53
Grade B lot 2	13.62	1.78

- If hard to remove water (HRW) correlates to hydrogen bonding, less nitrated NC would have higher HRW values
  - Does not appear to be the case for our NC
- HRW values for cellulose fibers determined by Park et al. were typically between 2-3
  - The lower values for NC fibers compared to cellulose are probably due to the lower amount of hydrogen bonding

Comparison with Canadian Standard Freeness

- Larger freeness numbers mean better drainability. Smaller fibers and more fiber-to-fiber interaction should reduce freeness

NC lot	TGA HRW	Freeness
Grade A lot 1	1.65	785
Grade A lot 2	1.54	833
Grade B lot 1	1.53	757
Grade B lot 2	1.78	786
Grade B lot 2 +60 mesh -40 mesh	1.23	821

Fines removed

Freeness does not appear to correlate with HRW value. However, it may correlate with fiber length because a sample where the fines were removed gave a larger freeness value

NC Fiber Analysis by Water Elutriation

Cellulose Source	Baled Cotton Linters	Sheeted Cotton Linters	Sheeted Cotton Linters
Fiber Prep	Bale Breaker	Cutter	Hammer Mill
Test Samples	5	9	10
Percent Knits	0.573	1.863	0.581
Standard Deviation	0.213	0.791	0.404
Ballistic Test	Passed	Failed	Passed

Water Elutriation Test Method , and Apparatus developed by Mario Paquet

Future work

- Determine hard to remove water by standardized TAPPI water retention value method (centrifugal method)
- Prepare and characterize handsheets both of NC-only pulps and combustible ordnance formulations
- Characterize fibers by SEM and fiber quality analyzer