Technician Education in Additive Manufacturing & Materials
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Materials Recycling

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Abstract

Materials recycling has become popular not only to save the environment, but it has also become big business. Recyclable materials include: fibers, plastics, glass (a type of ceramic), and metals. Paper (a fiber made from a cellulose composite) recycling is probably the most widely known and common type of recycling. This module introduces concepts of material processing (called pulping) used in recycling paper to create pulp out of post-consumer paper products. The hands-on activity takes the student through the full pulping process from selecting and collecting the material to the ultimate transformation into a new product. Recycled pulp and fiber products can be found everywhere today. It's important for materials technologists to understand the processes involved and the mechanics responsible for the transformation (recyclability) of the material.

Module Objective

Develop knowledge about the processes and need for material recycling and the materials that can be recycled.

Student Learning Objectives

Students will be able to:

- Describe the pulping process.
- Describe the mechanics (the science) of pulping.
- Explain the effects of pulping at the macro and micro level.
- Explain change in material properties after pulping.
- Define: feedstock, pulp, viscosity.

MatEdU Core Competencies Covered

0B – Prepare Tests and Analyze Data
6A – Apply basic concepts of mechanics
7J, J2 – Describe how the grain structure of material can affect properties
8A – Demonstrate the planning and execution of materials experiments
8C, c3 – Describe the effects of processing on the microstructure of materials

Key Words:

Pre- and post- consumer recyclables, recycling, reuse, material treatment

Type of Module/Mode of Presentation

PART 1 – Interactive presentation (using slides and resources) to introduce concepts to be learned.
PART 2 – Hands-on activity that demonstrates the processes of recycling paper.
PART 3 – Observations and testing. A presentation to help assess knowledge gained and encourage further learning.

Time Required

60 minutes in class time for material processing, 2 days for soaking and 3 days for material curing.

Pre-requisites

None

Target Grade Levels

High school

Table of Contents

Equipment and Supplies Needed

☐ Examples of recycled products

Per person/team:

☐ Newspaper
☐ 3 – 5 gal Bucket
☐ Screened frame, 6” x 6” minimum
☐ Unframed screen (same size as screen frame)
☐ Pan, must be larger than the screened frame and deep enough to submerge the screen
☐ Water (use water from soaking, must be about 75ºC) about 18 oz of water is needed for a 12” screen
☐ Blender
☐ Digital scale, tabletop type such as a kitchen/food scale
☐ Sponge
☐ Paper towels or other absorbent material to lay sample on to dry

The screening and pressing equipment and the emulsifier, a.k.a. a blender

Curriculum Overview and Instructor Notes

There are three parts to this module:

PART 1 – An interactive presentation

… introduces key concepts and terms such as emulsification, screening, curing, viscosity. Included in the presentation is a verbal pre-evaluation to assess how much students know about paper and materials recycling.

PART 2 – The hands-on activity

…demonstrates the pulping process and related mechanics.

Discussion suggestions:
During sample preparation:

- Separation of fibers from bulk material (recycled newspaper).
- Well-dispersed fibers decreases viscosity (resistance to flow) of the substance phase of pulping/papermaking, improves segregation resistance (homogenization) and uniformity.
- Consistency standards, indication that the pulp is ready to pour, are only that the emulsified substance be free of “clumps”.

During drying:

- Hydration accelerated?
- Water retention (discoloration on the sample)?
- General, overall color, texture, etc.
- Dry time can vary; allow at least 3 days.

PART 3 – Observations and testing

…suggests ways for students to test material and learn from observations. A verbal post-evaluation can be used to assess how much students learned about paper and materials recycling.

Safety

Take any necessary precautions before you start. There are no known dangers with the pulp mixture as described. If a bleaching agent is used to remove ink, read the label and take necessary precautions. Instruct students to refrain from putting any dangerous objects in the blender e.g. pencils, metal, etc., or from reaching in to the blender while on. Take care in cutting and handling the screen.

Terms to know (and use)

- Recycling is the procedure of making used or unwanted products into new manufactured products.
- Composite is one of the material types classified as having 2 or more constituents that together are stronger/”better” than when alone. Example

is the airplane wing, typically layers of wood, foam, fiberglass sandwiched (glued) together.

- Wood as a Composite, the 2 main constituents are cellulose and lignin.
- Feedstock is the bulk material chosen to treat during paper recycling. It can be wood chips or post-consumer paper.
- Pulp is the fibrous consistence of the material after processing/treatment.
- Viscosity is the resistance to flow.
- Emulsifying/disintegrating: the mechanics of how a material is broken down during processing.
- Dispersement is the separation of the granular pulp material to reveal "fibers/grains."
- Screening, Pressing, Drying/curing are three steps in the process for papermaking.
- Catalyst: something that increases the rate of a reaction (chemical/molecular, etc.).
- Post-consumer waste is any discarded material after being consumed.
- Pre-consumer waste is typically found in manufacturing and refers to the "scrap" created during production of a part/product (e.g.: trimmings from paper products, shavings from pencil making).

Module Procedures

PART 1 – Interactive Presentation

Resources (slides) have been provided to introduce key concepts and terms used in the module. Included in the presentation is a verbal pre-evaluation to assess how much students know about paper and materials recycling, this is known as the KWLD Chart (what you KNOW, WANT to know, what did you LEARN, and what you can DO with what you learned). The first half of the KWLD chart is done to assess readiness, the second half is done later to assess learning and motivation. Directions for the KWLD are in the slide show.

Directions	**Resource**
Tell: The universal recycling symbol, the three "chasing" arrows, represents the vision and core principles: Reduce, Reuse, Recycle.	Slide Universal recycling symbol
Provide examples of recyclable items. Discuss the importance and impact of each one.	Slide Picture of recyclable items
Use the slide to discuss composites and cellulose composites.	Slide Cellulose composites
Tell: As it turns out, the same process used	Slide Pulping Equipment & Process

in papermaking can be used to recycle it too. Pulping equipment includes many of these things used for complex processes: hydrochloric acid to break down the material, crushing and grinding equipment to homogenize the material (decrease viscosity).	
Explain recyclable material and the classifications. Selection (first step in pulping) between: • Post-consumer waste is any discarded material after being consumed • Pre-consumer waste is typically found in manufacturing and refers to the "scrap" created during production of a part/product (e.g.: trimmings from paper products, shavings from pencil making)	Slide What Gets Processed?
Begin the KWLD Chart	Slide KWLD Chart and Example KWLD Chart
Explain what will take place in the hands-on activity using the terms for the pulping process: ▪ Treatment (second step in pulping) Water is key to the pulping process. So are certain chemicals (catalysts) that help the breakdown of fibers. Equipment is used to emulsify the feedstock. ▪ Curing (third step in pulping) Whether assisted or unassisted curing takes place and the material is transformed.	Slide Pulping Equipment & Process

PART 2 - Hands-on Activity

The hands-on activity takes the student through the pulping and screening process in papermaking. They emulsify a feedstock to create a pulp slurry. The slurry is then cured to recreate a new paper product.

Pre-preparation:
It is highly recommended that the teacher complete all of the procedures prior to conducting the activity.

1) Locate/purchase supplies.
2) Prepare feedstock (at least 2 days ahead). Tear newspaper into 1-inch squares, completely cover the paper with water, soak in water (recommend 2 days). Save excess water for use later.
3) Prepare screen frames. The frames can be square, made of wood or other material, In this module a plastic frame (needle point hoop) was fitted with the screen.
4) Prepare screens. Use aluminum screening material (used in screen door repair) that can be found at most home improvement stores.
    - Cut a piece of screening material about 1" larger than the frame diameter.
    - Lay the screening material down on top of the larger hoop. Use the tension screw on the hoop to enlarge it slightly.
    - Press the smaller hoop inside the larger until it snaps in place. Tighten the tension screw.
5) The crease between the frame and screen must be sealed to prevent seepage. Hot glue or silicone glue works well for this.
6) Cut unframed screen, same size as the inside border of the screened frame. Set aside.

Prepare station(s) for the activity:

1) Spread several layers of paper towel or newspaper flat on a table/bench top.
2) Fill pan(s) with water.
3) Place sponge(s), screened frame(s), unframed screen(s), plenty of paper towels at each station.

Activity procedure:

1) Provide list of supplies and lab directions for the students. A blank slide has been provided for insertion of the list.
2) Taking a handful of soaked newspaper, squeeze it to release excess water.
3) Place 1 unit of the wet newspaper on a scale.
4) Place newspaper (call it, "feedstock,") in blender.
5) Add water. Use a 1:9 mix ratio (newspaper to water), you need to make enough pulp to fill the frame. For example, a 9x9 screen requires 2oz:18oz mix ratio of feedstock to water).

6) Turn on blender to high, grind/crush/pulverize until pulp is fluid enough (emulsified) to be able to see fibers and it holds no clumps.
7) Place screen frame in large flat pan of water, submerge briefly.
8) With screen frame floating in the water and while moving screen gently in circular motion, pour pulp to fill the screen frame area and maintain the circular motion to spread the pulp evenly.
9) Remove entire frame assembly from the water and place on paper towels/flat newspaper.
10) Place piece of unframed screen over the pulp.
11) Gently and evenly press the sponge to remove water, squeeze excess water out of the sponge and repeat several times. As the pulp dries it will begin to adhere to the unframed screen; this is a sign that it is drying properly.
12) Continue drying. Leave the pulp in the frame and set in a safe place to dry. NOTE: You may be able to lift the pulp out of the frame at this point, if it holds its shape without tearing, that is ok to do too, do the same: set in a safe place to dry. To speed up drying you can place the pulp between paper towels and roll with a rolling pin to squeeze more moisture out.

NOTE: depending on the feedstock used, a step to remove ink (de-inking) or other contaminants can be added. This can be accomplished by adding a catalyst (hydrogen peroxide or chlorine) to the pulp. The chemical reaction that takes place separates/disintegrates the ink from the pulp. A “skin” or foam may appear on the surface of the pulp slurry. This can be “skimmed off” using a paper towel and dragging it gently across the top. Or a surfacant (dishwashing detergent) can be added (just a drop or two) to de-foam the water. The water should be much clearer.

PART 3 – Observations and testing

It is difficult to do any kind of materials testing on the samples. Suggestions for observing some of the changes/results of the pulping process and collecting data:

1) Review material properties and what to look for, provide a list.
2) Tear the newspaper. Notice the tearing pattern. Tear the pulped paper; compare the patterns, what are the differences?
3) What happens when you write on it, fold it? Discuss observations.
4) Examine the fiber of the newly formed paper product. Micrographs are helpful for this discussion.

Optional – Disintegrate it:

1) Paper cannot be infinitely recycled. To test this, have students tear up their recycled paper, weigh it and record the measurement.
2) Place the paper in the blender and add water in the same 1:9 mix ratio.
3) Continue with the same screening process.

4) After the pulp has dried, weigh it again.
5) Continue the process several more times. The paper after pulping 6-7 times will be almost transparent and probably brittle.
6) Keep track of amount of water used to feedstock.
7) Form a discussion around the amount of water, energy, etc. required for this process. Discuss: would it be worth it to recycle paper over and over?

Finish the KWLD

8) Return to the chart started in Part 1.
9) Ask:
   What has been learned?
   What can you do with what you learned?
   NOTE: it is helpful to have several examples of recycled fiber/paper products to encourage discussion.

References

What materials can be recycled?
http://www.benefits-of-recycling.com/whatmaterialscanberecycled/

Recycling
https://en.wikipedia.org/wiki/Recycling
http://www.paperrecycles.org/recycling-resources/school-recycling

What is waste?
www.iso.org

Paper making HQ
http://www.hqpapermaker.com/paper-history/

Paper Making
http://en.wikipedia.org/wiki/Papermaking
http://www.ehow.com/info_8740412_cellulose-papers-made.html

Paper Density (instructions for measuring)
http://en.wikipedia.org/wiki/Paper_density

KWL Chart Information
https://en.wikipedia.org/wiki/KWL_table

Evaluation Packet

Student evaluation questions (discussion/quiz)

1) Describe the pulping process.

   - Answer should include descriptions of: Selection (pre- and post-consumer), Treatment (emulsifying, screening, pressing), and Curing.
2) Describe the mechanics (the science) of pulping.
   - Answer should include the breakdown and separation of the fibers/grains during emulsification.
3) Explain the effects of pulping at the macro and micro level.
   - Answer should include viscosity and separation of fiber/grains.
4) Explain change in material properties after pulping.
   - Answer should include properties such as: more ductile when bent, tougher when torn, etc.
5) Define: feedstock, pulp, viscosity.
   - Answer should include definitions provide.

Instructor evaluation questions:

1) At what grade level was this module used?
2) Was the level and rigor of the module what you expected? If not, how can it be improved?
3) Did the demonstration work as presented? Did they add to student learning? Please note any problems or suggestions.
4) Was the background material sufficient? Please comment.
5) Did the demonstration/lab generate interest among the students? Please explain.
6) Please provide comments on how to improve this module including concerns about the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the student):

1) Was the experimental procedure clear and understandable?
2) Was the instructor's explanation comprehensive and thorough?
3) Was the instructor interested in your questions?
4) Was the instructor able to answer your questions?
5) Was the importance of materials testing made clear?
6) What was the most interesting thing that you learned?