SCIENCE SCREEN REPORT®

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3M TONAWANDA

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CHEMICAL ENGINEERING: Composites

SYNOPSIS

Composites are the result of combining two or more different materials to create a superior and unique material. When it comes to some of our most impressive structures on earth or out in space, and whether for work or for play, none of them would be possible without the use of composites. Typically, the design of composites consists of a binder or "matrix" material and one or more reinforcements. The binder functions to keep the reinforcement in a set position forming the backbone for the material. Composites have the advantage of not only being lightweight, but with a high strength-to-weight ratio. This is especially important in the design and manufacturing of automobiles, trucks, trains and airplanes. It will be an industry that along with the support of dedicated university programs and research institutions, will continue to develop improved materials and ways to manufacture them into products. This presents a unique opportunity to develop materials that are lighter, stronger, and more durable that will make the world a better place to live.

CURRICULUM UNITS

- CHEMISTRY
- ENGINEERING
- PHYSICAL SCIENCE

CAREER POSSIBILITIES

- CHEMIST
- ENGINEER
- MATERIALS SCIENTIST

NEXT GENERATION SCIENCE STANDARDS

NEXT GENERATION SCIENCE STANDARDS:www.nextgenscience.org

<u>3-5 ETS1-1: Engineering Design.</u> Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

Grades 5 - 8
Engineering Design
Defining and Delimiting Engineering Problems

<u>HS ETS1-3: Engineering Design.</u> Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Grades 9 - 12
Engineering Design
Defining and Delimiting Engineering Problems

CRITICAL THINKING EXERCISES

1. Research the topic of composites and report on major developments in its history.
2. Describe some lab procedures that you would use to test several properties of composites.
3. Compare and contrast the properties of composites versus metals.

BACKGROUND

The use of composites can be traced as far back as 1500 BC with the ancient Egyptian and Mesopotamians using composite materials in the form of a mud binder and straw reinforcement for building. In 1200 AD, the first composite bow was invented by the Mongols. They combined wood, bone and animal-glue pressed and wrapped in birch bark. These composite Mongolian bows enabled Genghis Khan to be the dominant military force of his era. Not much occurred in the development of composites until the 1870's through the 1890's, when a revolution was occurring in chemistry. Polymerization allowed new synthetic resins to be transformed from a liquid to solid state in a cross-linked molecular structure. Then in the early 1900's, plastics such as vinyl, polystyrene, phenolic and polyester were developed. Bakelite was developed by Belgian-born chemist Leo Baekeland in New York in 1907. In 1935, Owens Corning launched the fiber reinforce polymer (FRP) industry by introducing the first glass fiber. In 1936, unsaturated polyester resins were patented. Because of their curing properties, they would become the dominant choice for resins in manufacturing today. In 1938, other higher performance resin systems like epoxies also became available. World War II brought the FRP industry from research into actual production. In addition, the war effort developed first commercial grade boat hulls. By 1947 a fully composite body automobile had been made and tested. This car led to the development of the 1953 Corvette, which was made using fiberglass preforms impregnated with resin and molded in matched metal dies. In 1961, first carbon fiber was patented, but it was several years before carbon fiber composites were commercially available. Carbon fibers improved thermoset part stiffness to weight ratios, thereby opening even more applications in aerospace, automotive, sporting goods, and consumer goods. The marine market was the largest consumer of composite Fiber development in the late 1960's. Progress in advanced fibers led to breakthroughs in aerospace components, structural and personal armor, sporting equipment, medical devices, and many other applications. In the 1970's, the automotive market surpassed marine as the number one market – a position it retains today. By the mid 1990's, composites hit mainstream manufacturing and construction as a cost effective replacement for metals and engineered thermoplastics. In the mid-2000s, the development of the 787 Dreamliner validated composites for high-strength and rigid applications. The number of applications in automotive, appliances and consumer products industries continued to grow. Composites were just beginning to find their way into nanotechnologies. Composites research is attracting grants from governments, manufacturers and universities. These investments will find new fibers and resins to create even more applications for composites. Environmentally friendly resins will incorporate recycled plastics and bio-based polymers as composites the feed the demand for stronger, lighter and environmentally friendly products.

ADVANCED ORGANIZERS

Prior to viewing the video students should have some understanding of the following Science Benchmarks from AAAS, Project 2061. This is a long-term initiative focused on improving science education so that all Americans can become literate in science, mathematics, and technology.

Benchmark 8. The Designed World
Section B: Materials and Manufacturing, Grades 6-8
By the end of the 8th grade, students should know that

- Efforts to find replacements for existing materials are driven by an interest in finding materials that are cheaper to obtain or produce or that have more desirable properties. 8B/M5

Benchmark 8. The Designed World
Section B: Materials and Manufacturing, Grades 9-12
By the end of the 12th grade, students should know that

- Manufacturing processes have been changed by improved tools and techniques based on more thorough scientific understanding, increases in the forces that can be applied and the temperatures that can be reached, and the availability of electronic controls that make operations occur more rapidly and consistently. 8B/H1

VOCABULARY

Aramid-fibers: A class of heat-resistant, strong synthetic fibers normally used in armor due to their hard density.
Binder: The matrix material that binds the filler in a composite.
Carbon fiber: A material consisting of fibers about 5–10 μm in diameter and composed mostly of carbon atoms.
Composites: The result of combining two or more different materials to create a superior and unique material.
Conductor: Materials that easily transfer heat, electricity, or sound..
Epoxy: A type of strong adhesive, also used for covering surfaces, characterized by Oxygen atoms linked to Carbon atoms formed when two resins are mixed together before use.
Fiberglass: Plastic reinforced with thin glass fibers.
Fiber Reinforced Polymer or F-R-P: A composite material made of a polymer matrix reinforced with fibers.
Insulator: Materials that don't easily conduct heat, electricity, or sound.
Kevlar: A high-strength, aramid synthetic fiber.
Nano-materials: Materials too small to be seen even with conventional microscopes.
Part-consolidation: A single piece made of composite materials that can replace an entire assembly of metal parts.
Pultrusion: A manufacturing process that involves pulling a resin mixture through a heated steel forming die for producing continuous lengths of reinforced polymer structural shapes with constant cross-sections.
Polymer: Any of a class of natural or synthetic substances composed of very large molecules that are multiples of simpler chemical units called monomers.
Radar transparent: Property of composites in that radar signals pass right through them.
Reinforcement: The strong, stiff backbone of a composite kept in a set position by the binder.
Resins: Natural or synthetic compounds that begin in a highly viscous state and harden with treatment.
Strength-to-weight ratio: How strong a material is relative to its weight.
Stress: Force per unit area, measured in lbs/in^2 or N/m^2.
Tensile strength: The ability of a material to resist breaking when under tension.
Tension: Force applied to a cable, chain, or column.
Thermal conductivity: The ability of a material to conduct heat.

Vocabulary Learning Tool: Make a Jeopardy Game. **http://www.superteachertools.us/jeopardyx/brandnewgame.php**

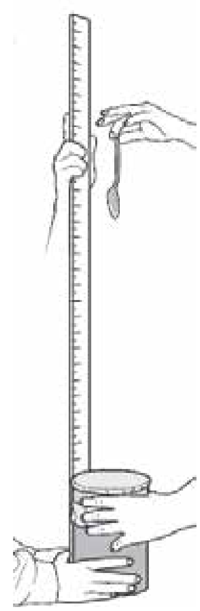
SUGGESTED REFERENCES

- Latest News About Advanced Composites: **http://www.compositestoday.com/**
- AAAS, Project 2061: **http://www.aaas.org/program/project2061**
- Interactive Periodic Table: **http://www.ptable.com/**
- Composite Technologies: **http://www.hexcel.com/**
- Plastics Analysis: **http://plastics.americanchemistry.com/Education-Resources/Hands-on-Plastics/Activities**
- Performance Composites: **http://www.performancecomposites.com/about-composites-technical-info/122-designing-with-fiberglass.html**

INQUIRY ACTIVITIES

- **Grades 6-8: Spoon Drop Strength Test**

  Overview: Students learn about the physical properties of materials and how scientists their properties, including how to measure toughness, a type of strength. Toughness is how much energy a material can absorb before breaking. In this activity, the toughness of everyday materials will be tested by dropping a spoon from different heights. The greater the height, the more potential energy the spoon has and the more kinetic energy it has when it hits the material.

  Procedure: Explain to the students that they will be predicting, and then testing, the strength of everyday materials (wax paper, aluminum foil, plastic wrap, brown paper, freezer paper).

  1. Demonstrate the spoon drop activity by securing a square of newspaper over the opening of one of the containers with a rubber band and then place a long piece of tape, over the rubber band, around the container.
  2. Ask a volunteer to come up and help you. Have him or her hold a meterstick next to the can. Drop the spoon from 10 cm above the can. The paper may not break. Ask kids what they observed. Continue the test, increasing the drop height until the newspaper tears.
  3. Kids will set-up a data table in their lab notebooks, explore the materials, predict which ones will be the easiest and hardest to break, and rank them.
  4. Students select a material to test. They place it over the top of the canister and secure it with a rubber band putting a strip of tape over the rubber band, around the container.
  5. A spoon is dropped from 10 cm above the can. Students observed what happens. Increase the distance by 10 cm each time until the material breaks. Record all observations.
  6. Continue testing all materials and write the final drop height in your data table.
  7. Discuss what was learned by comparing your predictions to the results of the activity.

- **Grades 9-12: Simplified Vertical Rebound Testing**

  Overview: This activity involves rebound testing of elastomers. Students will produce rebound data and determine the kinetic energy transformed by the impact of a free falling ball. When choosing a material for an application, the designer must take into consideration the inherent physical properties of the material in comparison to the service requirements. Think what athletic shoes would be like if the materials used for soles and inside linings did not have good rebound characteristics.

  Procedure: Explain to the students that resilience or rebound is an inherent property of rubber materials. Objects to be tested include various balls made of polymeric materials including a golf ball, a cotton ball, a Nerf ball, a croquet ball, a billiard ball, etc. The type of testing in this activity is based on the Law of Conservation of Energy within a closed system.

  1. Tape the meter stick or tape measure to a wall such that the zero mark touches the floor.
  2. Hold the first ball to be tested so the bottom of the ball is level with the 100 cm mark.
  3. Release the ball, and note the rebound height, recording to 0.1 cm. (Take all measurements from the underside of the ball.) Note that it may take some practice to be able to read the rebound height accurately.
  4. Repeat with the same ball four more times for averaging in Step 6.
  5. Assuming a close to perfectly elastic system, the loss in height of the rebound is due to the energy which is dissipated and transformed. Derive an equation for the percent of the original energy which is transformed.
  6. Create and complete a data chart to display the rebound heights, % energy transformed, and the averages and standard deviations for each ball to be tested. Record all data and results in lab notebook. Discuss findings.

REFERENCES

- Spoon Drop: **http://d43fweuh3sg51.cloudfront.net/media/assets/wgbh/nvms/nvms_doc_strongeract/nvms_doc_strongeract.pdf**
- Vertical Rebound Test: **http://www.terrificscience.org/freebies/lessonexchange/polymers/#238**