Making Stuff – Stronger Video KEY
The Science of Materials

Steel

1. How does the "life saving piece of equipment" work? How do the plane and wire interact?

   Plane land under full power, hook on the plane catches the wire. Hydraulic piston pools out wire at a speed that counteracts the momentum of the plane.

2. What are the characteristics of the wire?

   Thick, strong, made out of iron and carbon

3. Why is this important?

   So the cable does not break

4. What is the breaking strength of the wire? Compare both parts of the wire.

   Replace the cable underneath the deck every 2000 landings and the one on the deck every 125 landings. The one on the deck wears out faster because of the metal from the plane rubbing the metal of the wire causes it to wear out faster.

5. Where does the material come from?

   Iron and carbon

6. What is tensile strength?

   The ability to withstand pulling forces

7. What happens if the wire fails?

   The planes go off of the deck of the ship and into the ocean ☹

8. Can we make it stronger?

   Unknown at this time. A new material that is stronger than steel has not been found/created yet.

9. Who is trying to improve the wire? What are they doing to try to improve the wire?

   Ellwood Steel. Trying to find the right balance between the steels strength and flexibity.

10. How is tensile strength tested?

    Piece of material is stretched until it snaps/breaks. The amount of force used to pull is its tensile strength.

11. Where does the strength of steel come from?

    The carbon in it

12. What makes car bodies strong?

    Steel

13. What does "strong as steel" mean?

    Combination of properties (tensile strength and toughness together)

14. What is toughness? Why is toughness important?

    How much energy materials can absorb without breaking. Important because it tells how much impact it can take.

15. Why do metals fail under fire?

    The impact of a bullet is too great for metal because the force is concentrated in a small area.

16. Explain the energy of impact?

    Atoms move allowing the metal to bend, but not break. The atoms absorb the force.

17. What happens if metal is too thin?

    It breaks because the atoms do not have enough other atoms to bond to in order to remain in place. They move enough to create cracking. Therefore, a bullet would tear through the material.

Kevlar

18. What is Kevlar?

    A strong woven fabric, the strongest fiber ever produced

19. What can it do?

    Take a lot of impact, hard to rip/break

20. Who invented Kevlar?

    Stephanie Kwolek, a chemist with Dupont

21. What makes Kevlar so strong?

    It is a polymer made up of long repeating chains of atoms. It is like stiff spaghetti. It has high tensile strength and high toughness.

22. How many layers of Kevlar are needed to stop a bullet? What is the function of the remaining layers?

    4 to stop a bullet (each layer is <4 mm each). The remaining 7 layers keep the hole from getting any deeper.

23. What characteristics might make Kevlar a good replacement for steel?

    Extremely high tensile strength and enough toughness to stop a bullet

Nanotubes

24. What are nanotubes?

    Pure carbon atoms arranged in a chicken wire pattern. Used as strength additives in tennis racquets, bike frames, and high-end car bumpers.

25. Where does their strength come from?

    Extremely strong bonds between carbon atoms

26. Describe the nanotube forest?

    ~200 billion nanotubes (like tall, thin bamboo trees)

Animal Engineering: Toucan

27. What is the function of a toucan's beak?

    Tool used to get and eat food, dagger for protection

28. Why is the toucan's beak as strong as it is?

    Made of 2 materials (thin shell and airy bone). Neither one is strong on its own, but together they are strong.

Animal Engineering: Abalone

29. What is an abalone shell made out of?

    Chalk (calcium carbonate- calcium, carbon and oxygen atoms). The atoms are bonded together tightly (no wiggle room).

30. If the tensile strength of this compound is low and the toughness of this material is low, what characteristic makes it so strong?

    Compressive strength

31. If calcium carbonate (chalk) and glass are both fragile, how is it possible that they can hold a great deal of weight?

    High compressive strengths

32. The abalone shell is comprised of 95% of the same elements as chalk. Abalone shells are not fragile. Explain what comprises the remaining 5% of an abalone shell that makes it so much stronger.

    Protein, a long biological chain. This acts as an absorber of force.

Animal Engineering: Spiders

33. What are the characteristics of spider silk that make it such a desirable material?

    Strong, light (1 lb could stretch around the world), flexible

34. Compared to steel and Kevlar, explain the tensile strength of spider silk.

    Stronger than steel and Kevlar

35. How can spider silk be harvested? How is spider silk mass produced? Is it abundant? Explain.

    It is pulled from the spider as it is being produced. 1,063,000 spiders 20 minutes for each spider to produce a total of 400 yards. Not abundant. It is very difficult to harvest.

36. Why is a *dragline* so important?

    Spiders release dragline to catch them if they fall. They create it whenever they move.

37. How are goats important in the production of spider silk?

    Transgenic goats- gene from spider is spliced into a goat's chromosomes. This way goats make spider silk in their milk.

38. What is the tensile strength of spider silk?

    Greater than steel and Kevlar, not as strong as nanotubes, but more flexible. Not quite as strong as natural spider silk.

39. What percent of spider silk is in the milk of transgenic goats?

    1-2%

40. How is the protein responsible for the strength of spider silk coaxed out of goat's milk?

    Separate the milk from the silk protein

41. What is the milk to protein ratio?

    2-3 meters of silk out of a quart of milk

42. How is man-made spider silk created?

    Alcohol bath causes protein to solidify into silk.

43. Compare the tensile strength of steel, Kevlar, and spider silk using a line graph – label each material.

44. Explain the importance of the various parts of spider silk working together to produce a strong and flexible material. (Hint: the analogy of Legos and zippers)

Legos provide strength (proteins), Springs provide elasticity/stretching (molecular spring), zippers hold them together

Summary

How can these materials improve the design of the future? What is the next chapter in making strong materials? How will this be accomplished?