Kinetic Energy Storage and Power Generation

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- The Need – Structural composites with revolutionary strength and modulus increases
  - Composite materials and relationship to inertial energy storage and power generators
- Overview of application areas
- Example
  - Large energy storage (GJ) for grid connection
  - Sizing using today’s composites
- Structured nanocomposites – Path to the future?
Composite Materials Relationship to Inertial Energy Storage and Power Generation

Kinetic energy storage
- Stored energy ~ $J\omega^2$
- Specific Energy (wh/kg)
  - Proportional to $\sigma_t/\rho$
  - Current composites offer a factor of about 6 over steel
  - Higher performance will be realized by higher strength, stiffer composites

PM Generators
- PM generator’s power can be described by $P \sim D^2 \omega$, where
  - $D$ is mean air gap diameter
  - $\omega$ is shaft speed
- Higher performance machines require
  - Increased $D$ and $\omega$
  - Higher strength composites
  - Higher stiffness composites

5 MW PM Generator

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Application Areas of Technology

**Space**
- Dual mode use
  - Space Power
  - Satellite Attitude Control

**Electric Power**
- Advanced Generators for Distributed and Remote Power
  - MW class machines
  - PM generators with composite overwrap

**Transportation**
- Advanced Hybrid Trains
- Hybrid Passenger Cars

**Defense**
- Advanced Hybrid Vehicles
- MW Class PM Generators for Directed Energy Systems

**Electric Power**
- Large Scale Energy Storage for Power Generation
Example: Energy Storage for Grid Connection

- 8 GJ, 2.2 MW-hours stored energy
- Composite energy storage rim
  - Using today’s materials
  - Rim weight is 65,000 lbs
- System performance/cost driven by
  - Cost of materials
  - Amount of materials needed ($J\omega^2$)
    - Operating speed dependence upon materials strength and modulus
- Performance vs cost improvement directly related to
  - Price of materials
  - Enhanced material properties
An Approach to Structured Nanocomposites (Sponsored Activity)

• Identify leading organizations developing
  – Fiber: Revolutionary property improvements
  – Matrix: Compatible with these new fibers

• Maturation Issues
  First set of milestones:
  ➢ Demonstration of beneficial properties on R&D scale
  ➢ Independent verification of properties

  Second Milestone:
  ➢ “Out of the Lab” Processing
  ➢ Material availability in a form useable for kinetic energy storage, power generators
Summary of Initial Findings: Matrix (Literature Search)

- Matrix (Resin) fillers
  - Most widely used is montmorillonite, MMT (nanoclay)
  - Enhances both structural and thermal properties in neat resin (polymers)
    - Increased strength, impact resistance
    - Additional resistance to microcracking and increased Tg
  - These resin enhancements translate into reinforced polymer composites, but on a reduced scale
Summary of Initial Findings: Fiber (Literature Search)

- Fiber
  - Magellan’s M5 fiber (incremental improvement)
  - Carbon nanotubes (revolutionary improvement)
    - Embedded CNT in thermosets has had mixed results
      - Problems with alignment, NT/matrix adhesion
      - Both surface treatments and alignment techniques are improving
  - Emerging technologies
    - Polymer wrapping
      - In-situ polymerization, or co-polymerization
Fiber Technology: Carbon Nanotubes - In-situ polymerization

- NT embedded and aligned with PAN fiber precursor
  - Strong NT interfacial strength
- Two approaches are possible
  - Carbonize PAN precursor to produce PAN/NT fibril
    - Generate fibril roving
    - Impregnate with B-stage thermoset
    - Filament wind laminate structure
  - Carbonize PAN precursor to produce carbon/carbon NT structure
- In-situ polymerization: Encouraging results
  - Tensile strength doubled over PAN fiber
  - Modulus strength doubled over PAN fiber
  - Some development has begun
    - Army (AMCOM) is funding to develop light-weight, high-strength missile cases
Path to the Future?

• What is the next enabling technology for structured composites?
  – Offers revolutionary improvements
  – Benefits kinetic devices and generators

• Need further understanding of technologies and maturation issues

• Begin direct communication with leading organizations