Kinetic Energy Storage and Power Generation

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In kinetic energy storage, power and energy are separate design choices.
Fundamental limits to maximum energy density for various energy Storage approaches

Suggests that chemical and kinetic energy storage have high energy density
Pragmatic Considerations

- The best technology may not be the short term driver.
- Approximate order of research investment:
  
  Fuel cell > Batteries >> Inertial ≈ Electrical > Magnetic

Research investment will limit technology choices
Range of Applications Leads to Range of Sizes

Utilities

Trains

Defense

Vehicles

UPS

Space
Flywheel Highlights

- Conducted flywheel tests, including:
  - Flywheel-only tests to identify failure modes and structural margins
  - Flywheel burst tests to test candidate containment designs
- Demonstrated life of more than 110,000 cycles with a 50% DOD
Flywheel Spin Tests

• Flywheel tests to-date:
  – Numerous burst tests (modified design for containment proof tests)
  – Loss of vacuum test
  – Overspeed “As Built” Test
    - Preload loss
    - 1120 m/s
    - Benign and recoverable
  – Fatigue tests
Technical Success - Flywheel

- New record speed for composite flywheel assembly (1.4 km/s)

- Key features
  - Composite arbor design
  - Quality fabrication
Largest Composite Flywheel

- ~ 500 MJ
- 15,000 rpm
- 2 MW for 3 minutes
- Testing with high input and output power
For storage to be economical, $\, (\text{stored}) < $ (generated)

Cost to produce power and the cost of energy storage are both complex functions.
Economic Considerations

Analysis Relates:

\[
\frac{\left(\frac{\xi_1}{\xi_2}\right) - 1}{\beta^{-1} \frac{\text{Energy loss}}{\text{Energy stored}}} >
\]

Turnaround efficiency for kinetic energy storage $>>$ for batteries

Remaining kinetic challenge: Energy loss
Research Opportunity

• Achieve minimal loss for 12 hours +
  – Superconducting bearings
    - MRI systems make cryo-coolers robust commercial devices
    - Research promising
    - Experiments needed to guide future research

• Success opens door reliable use of intermittent generation sources
  – Wind
  – Solar
    - Either off or on grid
Conclusions

• Kinetic energy storage is a viable alternative to chemical storage for high energy density needs
• Kinetic energy storage is being used today in niche markets
• Additional research and development could exploit the high turnaround efficiency to improve energy storage and usage