

Flywheel Energy Storage: An Overview

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COMMENTARY

Flywheel energy storage (FES) works by rapidly spinning a rotor (flywheel) and storing the energy as rotational energy in the system. As a result of the concept of conservation of energy, when energy is withdrawn from the system, the flywheel's rotating speed is lowered; when energy is added to the system, the flywheel's rotational speed is increased. The majority of FES systems use electricity to accelerate and decelerate the flywheel; however mechanical energy-based devices are being developed. Rotors composed of high-strength carbon-fiber composites are hung by magnetic bearings and spin at speeds ranging from 20,000 to over 50,000 rpm in a vacuum enclosure in advanced FES systems. Flywheels can get up to speed in minutes, allowing them to reach their energy capacity far faster than other types of storage. A flywheel supported by rolling-element bearings is coupled to a motor-generator in a typical setup. To reduce friction and energy waste, the flywheel and sometimes the motor-generator are encased in a vacuum chamber. A massive steel flywheel rotates on mechanical bearings in first-generation flywheel energy storage systems. Carbon-fiber composite rotors, which have a higher tensile strength than steel and can store significantly more energy for the same mass, are used in newer systems. Magnetic bearings are occasionally used instead of mechanical bearings to reduce friction.

Superconducting bearings could be used in the future

Low-temperature superconductors were initially dismissed for use in magnetic bearings due to the high cost of cooling. High-temperature superconductor (HTSC) bearings, on the other hand, may be cost-effective and expand the amount of time energy may be stored. The usage of hybrid bearing systems is most likely to come initially. Historically, high-temperature superconductor bearings struggled to deliver the lifting forces required for bigger designs, but they can easily supply a stabilizing force. As a result, permanent magnets support the load in hybrid bearings, while high-temperature superconductors stabilize it. Because superconductors are ideal diamagnets, they can perform effectively in load stabilization. If the rotor attempts to drift off centre, it is restored by a restoring force caused by flux pinning. This is referred to as the bearing's magnetic stiffness. Because of the poor stiffness and damping of superconducting magnets, rotational axis vibration might occur,

restricting the use of entirely superconducting magnetic bearings for flywheel applications. The HTSC can be produced considerably more readily for FES than for other uses since flux pinning is an essential aspect for delivering the stabilising and lifting force. As long as the flux pinning is strong, HTSC powders can be shaped into almost any shape. Finding a technique to prevent the decrease in levitation force and gradual fall of the rotor during operation caused by the flux creep of the superconducting material is an ongoing difficulty that must be overcome before superconductors can offer the entire lifting force for a FES system.

Tensile strength and modes of failure

The rotor's tensile strength is one of the key constraints on flywheel design. In general, the stronger the disc, the faster it can be spun and the more energy it can store in the system. (Increasing the weight of the flywheel without increasing its strength would reduce the maximum speed at which it can spin without rupturing, and hence will not increase the total amount of energy it can store.) When the tensile strength of a composite flywheel's outer binding cover is exceeded, the binding cover will fracture, and the wheel will shatter as the outer wheel compression is lost around the entire circumference, releasing all of the stored energy at once; this is known as "flywheel explosion" because wheel fragments can reach kinetic energy comparable to that of a bullet. Composite materials twisted and glued in layers disintegrate swiftly, first into small-diameter filaments that entangle and slow each other, then into red-hot powder; a cast metal flywheel spews massive chunks of high-speed shrapnel. The failure limit of a cast metal flywheel is the binding strength of the polycrystalline moulded metal grain boundaries.

Aluminum, in particular, is prone to fatigue and microfractures as a result of repeated low-energy stretching. Angular stresses can cause pieces of a metal flywheel to flex outward and drag on the outside containment vessel, or entirely separate and bounce around the interior. The rest of the flywheel is now dangerously imbalanced, which might result in quick bearing failure and stress fracturing of major sections of the flywheel. As a safety precaution, traditional flywheel systems require large containment tanks, which add to the device's overall mass. A gelatinous or encapsulated liquid inner housing liner, which will boil and absorb the energy of destruction, can decrease the energy release from failure.

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Mechanical bearings in flywheel energy storage systems might lose 20% to 50% of their energy in just two hours. The flywheel shifting direction owing to the earth's rotation causes a lot of the friction that causes this energy loss (an effect similar to that shown by a Foucault pendulum). The gyroscopic forces exerted by the flywheel's angular momentum resist this change in orientation, producing a push against the mechanical bearings. Friction is increased by this force. This can be prevented by aligning the flywheel's axis of rotation with the axis of rotation of the earth. Flywheels with magnetic bearings and a high vacuum, on the other hand, may maintain a mechanical efficiency of 97 percent and a round trip efficiency of 85 percent.

Vehicles and the effects of angular momentum

Flywheels operate as gyroscopes in cars because their angular momentum is often on the same order of magnitude as the forces acting on the moving vehicle. This attribute may affect the vehicle's handling qualities when turning or driving on rough terrain; for example, driving onto the side of a steep embankment may cause the wheels to partially lift off the ground as the flywheel resists sideways tilting forces. This characteristic, on the other hand, might be used to keep the car balanced and prevent it from rolling over during abrupt turns.