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Regenerative, Semi-active Shock Absorber Technology "GenShock®" for Improved Ride Handling and Fuel Economy on Combat and Tactical Vehicles

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ABSTRACT

GenShock is an energy-harvesting, semi-active shock absorber. The device converts vertical travel of a vehicle suspension system to useful electricity. On defense platforms, this power ranges from a few hundred watts to several kilowatts. Conventional shock absorbers provide damping by dissipating suspension energy as heat, while GenShock provides damping by generating electricity. For an internal combustion engine (ICE) vehicle, the energy harvested by GenShock is used for reducing alternator load. The energy can also be conditioned for battery charging to address vehicle hotel loads. GenShock is also semi-active capable, in which each unit can stiffen or loosen in concert with the terrain, vehicle speed and load conditions for improved maneuverability. This paper presents a characterization of GenShock technology in its form and function of a direct replacement shock absorber that has regenerative and semi-active capabilities.

INTRODUCTION

As the U.S. Military projects power to more regions around the world, the cost to support and maintain that power rises dramatically. The farther troops are from safe havens, the more extended, vulnerable and expensive the supply line becomes. Some estimates put the fully-burdened cost of diesel at over $400/gallon[1] when airlift, convoy protection, support, logistics, and personnel expenses are factored in, and the National Automotive Center, an arm of the Army's TARDEC, estimates that a 1% improvement in military-fleet fuel economy would remove 6,400 military personnel from harm's way in the extended supply chain.[2]

GenShock is a regenerative suspension system that harvests waste energy on any vehicle platform, turning suspension motion into usable electrical power. In doing so, GenShock extends vehicle range, improves fuel economy, and increases the readiness and survivability of the force. Simultaneously and without sacrificing power generation, GenShock improves the stability, safety, maximum all-terrain speed, and ride quality of ground vehicles and weapons platforms. In semi-active mode, GenShock stiffens and softens the suspension in concert with the terrain, vehicle speed, road and load conditions and a variety of other factors to ensure that ride, handling, stability and safety are optimized for each situation.

In active and semi-active modes, GenShock can extend or compress the suspension upon command to accelerate airlift, tie-down, maintenance, emergency-repair and shipping operations and enable safe travel and operation while in defilade, inclined defilade, reconnaissance and firing positions.

BACKGROUND

Shock absorbers (dampers) can be categorized into three broad categories: a) passive, b) semi-active, c) active. Dampers of all types have historically been comprised of a cylinder filled with oil through which a piston travels, aided by a hole that permits oil to flow from one side of the piston to the other. If the hole is large, the piston moves rapidly and with little input force. If the hole is small, the piston moves slowly and requires a large input force. By managing the viscosity of the fluid, the size of the hole and the size of the entire assembly (cylinder bore and stroke), damper manufacturers can achieve a wide range of damping force and operational characteristics.

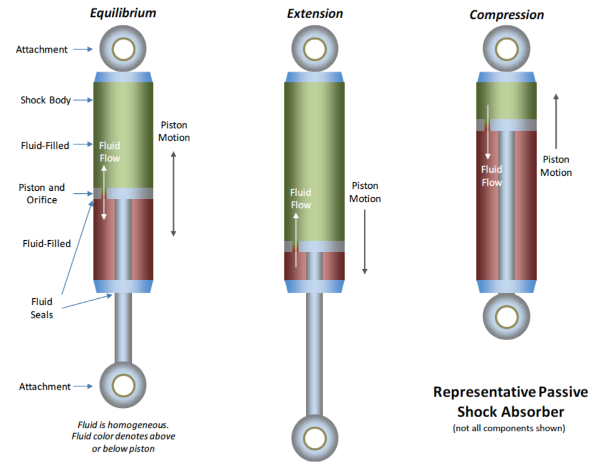

Figure 1: Diagram of basic passive damper technology

GENSHOCK TECHNOLOGY

GenShock eliminates the simple piston and valve concept, replacing it with an integrated-piston hydraulic motor and electric motor generator system. Instead of forcing the oil to flow from one side of the piston to the other, GenShock makes the fluid do work by channeling the fluid through a valve block and hydraulic motor. As it spins, its shaft is shared with an integrated electric motor generator. The generator produces electricity in direct proportion to its rotational velocity. Mated to power electronics, the electricity is buffered and regulated to 13.8VDC, 28VDC or other appropriate voltages (and currents) for the power bus of the host vehicle. This energy can then be employed to fulfill a wide variety of useful purposes from hybrid range extension, to fuel economy improvement to operation of on-board electronic systems. GenShock supplemental power reduces alternator load, relieving strain on the alternator drive belt.

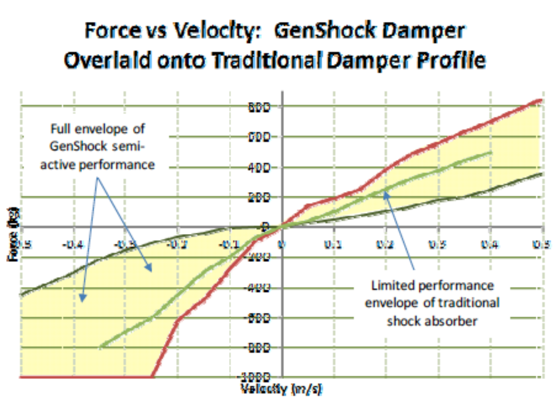

Figure 2: Damping plot of GenShock (LP0002) range, with standard passive shock (Tenneco 12340071) curve superposed

GenShock design takes advantage of counter electromotive force (CEMF) or back EMF, a phenomenon experienced with most electric motors. With open terminals, the electric generator will freewheel and rotate with little applied force, and low friction. When the terminals are shorted however, the generator will quickly cease spinning due to CEMF that retards motion. Open terminals represent minimum damping force and shorted terminals represent maximum damping force. GenShock uses this phenomenon to rapidly vary the damping transfer function via pulse width modulation (PWM) by quickly adjusting the resistance across the generator terminals to deliver a true electronically controlled, rapid-acting semi-active damping capability. GenShock has the ability to mirror a set damping curve within its range of damping forces at a given velocity.

GENSHOCK BENEFITS

The technology serves to harvest energy previously wasted in conventional suspension systems. With conversion efficiency losses considered, suspension energy has potential to increase fuel economy by 1-6%, determined by the vehicle GVW, speed of travel, and terrain roughness.

By sapping suspension energy out of a vehicle's suspension system as electricity rather than heat, GenShock technology also reduces the thermal signature of the vehicle. This minimizes long-term wear and variability in the selection of damping force for the vehicle platform. Some alternative semi-active approaches mechanically vary the orifice diameter or fluid viscosity to alter damping force, but mechanical systems often cannot react as rapidly or as seamlessly as a continuously variable electronic system like GenShock. Furthermore, several existing systems are prone to wear or fluid fatigue with performance gradually degrading over time. Since GenShock is continuously variable, each shock can continuously adjust for wear ensuring like-new performance throughout the product's service life.

This approach to capturing energy stored or wasted in the suspension system takes advantage of technical advances in hydraulic motor design and ability to integrate multiple devices within a single enclosure. Fundamental to the GenShock design, linear motion is converted to rotary motion which permits the use of highly efficient electric motors optimized for rotary power generation, and proven motor designs. Attempting to capture the same energy with a linear system (such as a linear motor) is more efficient, however it requires the use of large coils that add to system cost and weight. When magnetics are employed in such a way to minimize the number of needed coils there is still the need for expensive and sizeable coils in order to create damping levels required in military vehicle suspensions.

The amount of power available in military vehicle suspension systems is a function of the vehicle's GVW, speed of travel, and terrain roughness. Data from various military proving grounds throughout the U.S. indicate available suspension energy ranging from few hundred watts on level dirt road to several kilowatts on rough terrain. Outfits include Aberdeen, NATC, and Yuma. Data monitoring tests on medium and heavy combat vehicles demonstrated a range of power output (hundreds of watts to several kilowatts) while the vehicles traversed Perryman 1, Perryman 2 and Perryman 3 at various speeds up to 30 mph. Figure 3 is a demonstration of GenShock technology retrofitted on a Hummer H1.

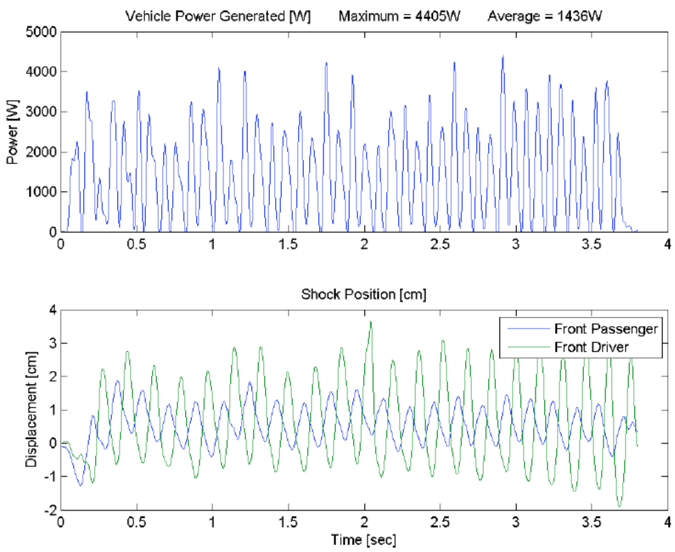

Figure 3: Hummer H1 GenShock power output (upper) and corresponding displacement data, off-road testing.

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