Mechanical motion rectifier leads to better energy harvesting

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(Phys.org) -- Mechanical energy is all around us, whether in the form of a vehicle's vibrations, ocean waves, or vibrating train tracks. However, much of this energy is irregular and oscillatory - for example, road bumps cause a vehicle to move up and down at random intervals - but energy harvesting works best with regular, unidirectional motion. To address this problem, a team of engineers from the State University of New York (SUNY) at Stony Brook has developed a new type of energy harvester that converts irregular, oscillatory motion into regular, unidirectional motion, in the same way that an electric voltage rectifier converts AC voltage into DC. Among its applications, the energy harvester could be used in regenerative shock absorbers, which have the potential to save US drivers billions of dollars per year in fuel costs.

The engineers, led by SUNY Mechanical Engineering Professor Lei Zuo, have been working on energy harvesting devices for the past decade. Their regenerative shock absorber, which harvests a vehicle's vibrational energy that would otherwise be wasted as heat, can generate enough electricity to charge the vehicle's battery and power its electronics. By reducing the load on the alternator and engine, the device improves fuel efficiency by 2-8%, depending on the type of vehicle, vehicle speed, and road conditions. The shock absorber can be retrofitted in the suspension systems of cars, trucks, buses, and military vehicles, as well as installed on train tracks.

WIth the new ability to convert irregular vibrations into regular motion, the engineers predict that the benefits of this device could increase further.

“We've developed a new type of energy harvester, based on a mechanism which I call mechanical motion rectifier (MMR),” Zuo told *Phys.org*. “It will convert the irregular oscillatory vibration into regular unidirectional rotation, just like the way that an electric voltage rectifier converts the AC voltage into DC. I believe it will solve the fundamental challenge of large-scale vibration energy harvesting due to irregular oscillations, and offers significant advantages of high efficiency and high reliability. Based on the MMR, we have recently developed and tested new energy harvesters for applications in vehicle suspensions, railroads, and ocean wave energy converters.”

In prototype tests, the researchers achieved 60-70% efficiency with the MMR-based energy harvester. This advantage stems from several changes in the way that the new regenerative absorber harvests energy and generates electricity. For example, the new shock absorber's motion produces less friction and can produce direct current without electric diodes and a capacitor, which are usually required. Because of its smoother operation, the new absorber is also more reliable and less prone to damage compared with regenerative absorbers that operate with irregular reciprocating motion.

What does this mean for drivers? A typical car, for example, has an energy harvesting potential of 100-400 watts using the regenerative shock absorber. Since a car uses about 250-350 watts (not including optional accessories such as the radio), the researchers estimate a fuel savings of up to 4% in vehicles with internal combustion engines and up to 8% in hybrid vehicles. If just 5% of the vehicles in the US used the device, driving an average of one hour per day and saving 3% in fuel costs, drivers could save an estimated $1 billion of gasoline per year.

The researchers estimate that it would take 3-4 years to recoup the installation costs for conventional vehicles, and 2-3 years for hybrid and electric cars. Trucks and buses, due to their larger sizes, could recoup costs in just 1-2 years. Military vehicles could reap large benefits, as well, considering the cost of oil in Afghanistan is around $400 per gallon. As a side benefit, vehicles with regenerative shock absorbers would also have improved comfort and maneuverability since more of the vibrations are absorbed than normal.

By implementing the MMR design into energy harvesters attached to railroad tracks, hundreds of watts of vibrational energy can be harnessed from passing trains. With support from the US Department of Transportation and the New York State of Energy Research and Development Authority, the researchers are designing the MMR energy harvesters to power track-side electrical devices such as lights, crossing gates, and monitoring sensors, which could be especially valuable in remote areas. Zuo explained how both railroads and ocean wave energy applications could benefit from the MMR design in a similar way as vehicles.

“The train-induced rail track vibrations are in pulse form and very irregular,” he said. “And ocean wave energy is concentrated at low frequencies and at low, alternating velocities. These irregular oscillatory motions make the vibration energy harvesting particularly challenging, much more than the wind energy, where the turbines rotate in one direction at relatively steady speed. The MMR directly converts the irregular oscillatory vibration into regular unidirectional rotation, therefore solving the fundamental challenge of vibration energy harvesting.”

The engineers have recently taken steps toward commercializing the energy harvesting devices, having licensed the technology to a new company called Harvest Energy, which is co-founded by investment banker Henry Mariano. Already seeing some interest from bus and truck manufacturers, the team's next steps will involve marketing, commercial testing, and large-scale manufacturing.