UTC Spotlight

University Transportation Centers Program

University of Nevada, Las Vegas

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Quarterly
Issue 4
October 2021

An Energy-Harvesting Railroad Tie for Improving Track Condition Monitoring and Safety

Researchers at the Railway Technologies Laboratory (RTL) of the Center for Vehicle Systems and Safety (CVeSS) at Virginia Tech have designed and developed an energy harvesting railroad tie, shown in Figure 1, to power trackside electronics and sensors for improving track condition monitoring and safety. As a member of the Rail Transportation Engineering and Advance Maintenance (RailTEAM) consortium led by the University of Nevada Las Vegas (UNLV), RTL is funded by the U.S. Department of Transportation University Transportation Center program. RTL explores technologies that advance railroad sciences and enable the U.S. rail industry to become more efficient and globally competitive.

The shortage of electrical power along railroad tracks significantly limits the railroads' ability to apply intelligent solutions for improving rail safety and connectivity. Much advanced wayside electrical equipment desired by the U.S. railroads cannot be employed readily on tracks due to the absence of electrical power. For example, some railroads use drones as a preferred means of physical inspection of track conditions, but the average maximum battery life for most commercial drones is only 22 to 27 minutes, significantly limit their operational range and length of flight. Drone use is enabled to reduce interruptions to train traffic flow and safety risks associated with having personnel present on revenue service tracks. Lack of electricity along tracks is a limiting factor in broad implementation of drones for railroad applications. Therefore, finding a reliable way to efficiently power the advanced trackside electrical equipment and autonomously/wirelessly charge drones is necessary for achieving the goal of improving track safety and condition monitoring.

Figure 2 demonstrates the working principle and motion transmission of the embedded electromagnetic energy harvester. The red arrows represent the direction of movement when energy is harvested, while the green arrows shows the return to undeflected position. Under the force of a passing wheel, the tie moves downward with a small amplitude and compresses the harvester, causing the rotation of the ball screw shaft and the bevel gear pair, which in turn rotates the generator at high speeds. The direction of rotation for each component is shown by red arrows in Figure 2a.

Figure 1. (a) Design overview of energy harvesting tie; (b) various railway applications can be powered by energy harvesting ties to improve rail safety and connectivity.

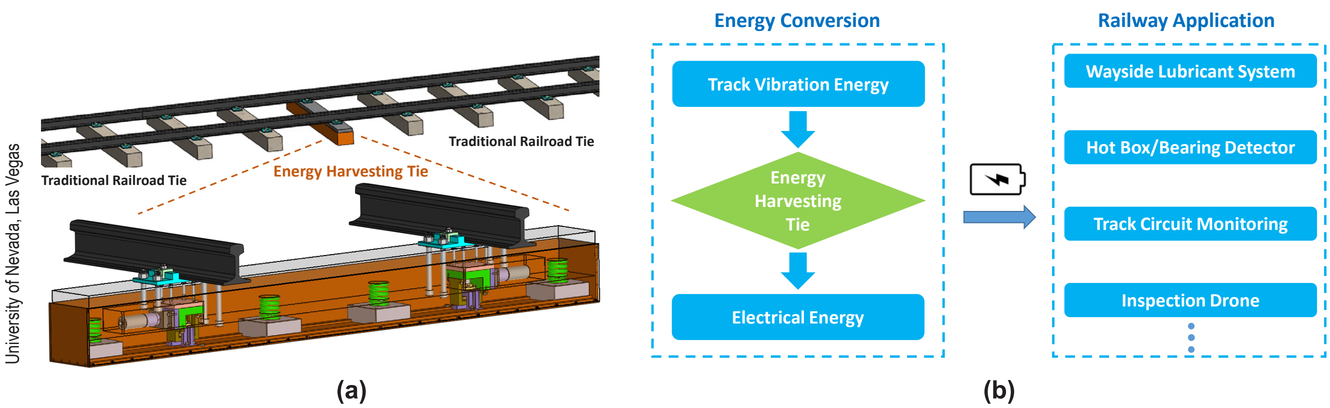
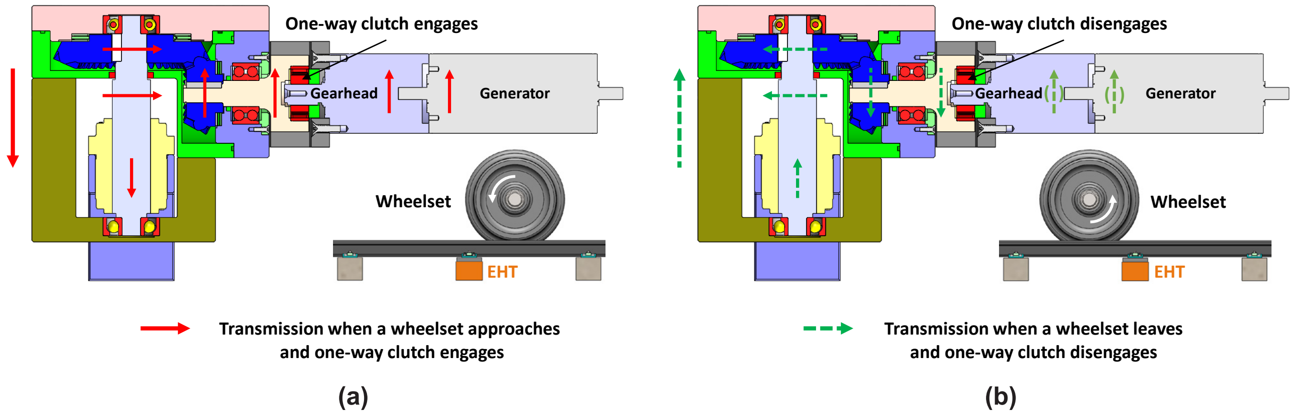


Figure 2. Downward track motion is transmitted and converted into generator rotation: (a) the red arrows show the direcction of motion in response to track deflection due to a passing wheel; (b) the green arrows represent the motion in rebound to return to undeflected track position.



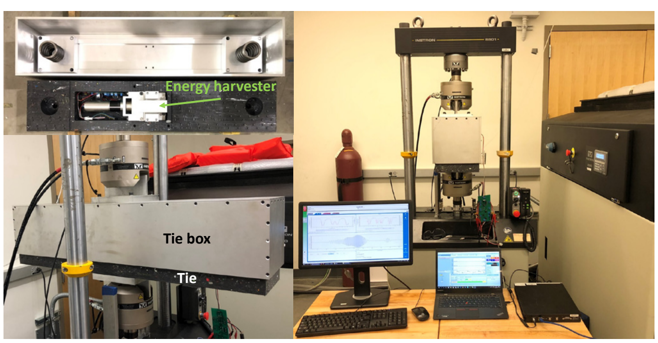
University of Nevada, Las Vegas

In rebound, the preloaded springs rotate the output shaft, bevel gear, and ball screw shaft in the opposite direction, along the green arrows in Figure 2b. The one-way clutch is disengaged from the gearhead's shaft in rebound, disconnecting the generator from the gearbox. The generator can continue spinning with its momentum but momentarily receives no additional torque until the next compression cycle by the next railcar's wheel shortly later.

A ½-tie prototype, shown in Figure 3, was developed and fabricated to fit in a hydraulic load frame for testing. Comprehensive bench testing was performed in the lab with both sinusoidal excitation and field-recorded tie displacement on a ballasted track at 40 mph train speed. Testing with the sinusoidal excitation testing yielded average electrical power of up to 150 W. The mechanical efficiency of the energy harvester proved to be as large as 78.1%. The test results proved the energy harvesting tie to have a highly efficient, promising, and practical design.

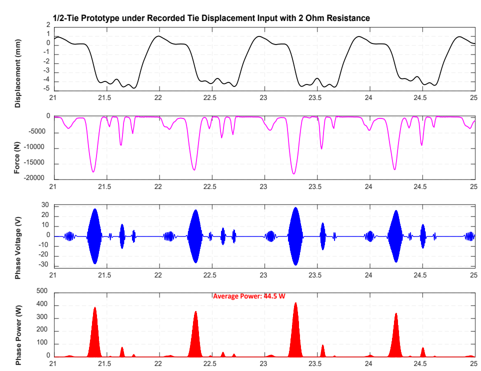
With a recorded tie displacement input, an average 44.5 W power output was obtained, as shown in Figure 4. The test demonstrates that the proposed system can generate sufficient power for powering various trackside electronics effectively. The implementation of such electronics promises to have a great influence on in situ track condition monitoring, which is essential for track safety and reducing maintenance costs.

Figure 3. A half-size energy harvesting tie prototype was fabricated and tested in the lab



University of Nevada, Las Vegas

Figure 4. Experimental results under recorded tie displacement excitation with 2-ohm resistive loads



University of Nevada, Las Vegas

About This Project

This project is being conducted under the auspices of the RailTEAM UTC, a consortium of universities led by the University of Nevada, Las Vegas (https://www.unlv.edu/railTEAM). The research is led by Dr. Mehdi Ahmadian, J. Bernard Jones Chair of Mechanical Engineering and Director of the Center for Vehicle Systems and Safety at the Virginia Tech Railway Technologies Laboratory. The project resulted in an innovative energy harvesting railroad tie that can convert track deflection under passing wheels' load into electricity, which can be installed readily on revenue-service tracks for powering various trackside electronics that are critical to improving track condition monitoring and safety. The energy harvesting tie can also be used to set up remote power stations that extend the flight range of drones that are highly desired by the U.S. railroads for track inspection.