ABSTRACT:

Electro-Intrusion: Regenerative Shock Absorber based on Intrusion-extrusion Cycle

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Nanotriboelectric energy harvesting based on the intrusion and extrusion of non-wetting liquids provides a potential approach for recovering mechanical energy dissipated by vehicle suspension systems. However, experimental demonstrations at the scale of practical automotive components remain limited. In this study, a full-scale nanotriboelectric regenerative shock absorber was developed and evaluated through a progressive experimental programme combining laboratory bench characterisation with vehicle-based testing. The design was refined through three successive prototype stages, leading to a demonstrator incorporating functional intrusion–extrusion capsules within the hydraulic system. Controlled bench experiments showed that the device maintained repeatable damping performance while generating measurable electrical signals associated with pressure-induced liquid intrusion and extrusion. Electrical output was found to depend strongly on operating conditions and capsule configuration. Higher piston velocities and electrical load resistances generally resulted in increased voltage, whereas increasing excitation frequency reduced the output. Capsules containing CF3+C60 also exhibited greater electrical response than those containing CF3 alone. Following bench validation, the demonstrator was installed on an electric vehicle and assessed under controlled speed-bump excitations. The vehicle tests reproduced the pressure-dependent electrical response identified during laboratory testing, demonstrating consistent mechanical–electrical coupling under realistic suspension motion. Increasing bump height and vehicle speed enhanced the peak voltage, with values of approximately 20–23 mV obtained under the strongest tested excitations. Additional payload produced a more noticeable improvement for smaller bumps than for larger road inputs. These results demonstrate the feasibility of extending nanotriboelectric intrusion–extrusion energy harvesting to full-scale regenerative suspension systems and provide experimental guidance for the further optimisation of automotive nanotriboelectric shock absorbers.

Keywords
Nanotriboelectrification; Regenerative Shock Absorber; Non-Wetting Liquid Intrusion-Extrusion; Vibration Energy Harvesting; In Situ Bench Testing; In-Vehicle Validation