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Exploring novel transmission mechanisms for rotary electromagnetic shock absorbers

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In recent years, active suspensions have seen a substantial growth in the automotive sector. This trend is aligned with vehicle electrification and the increasingly stringent requirements for passenger comfort and safety. Among the possible solutions, electromagnetic ones are preferred, as they integrate an electric machine that can be easily controlled to attain a desired output force. In this regard, rotary electric motors are preferred over linear ones due to their higher torque and power density. Then, actuators require a suitable transmission mechanism to convert rotations into linear displacements, which are more natural in a vehicle suspension mechanism. Furthermore, electromechanical actuator ones are preferred to those employing hydraulic technologies since they are oil-free and more efficient.

In this context, previous experiences in our research group have led to the development of rotary actuation technologies for suspensions, where an electric machine coupled to a speed multiplier drives the angular position of a lever mechanism to provide linear actuation for the suspension arms. This setup has led to favorable results in terms of packaging, efficiency, responsiveness and force output. However, the main bottleneck of this solution lies in the multiplier, as it must accomplish an elevated reduction ratio (>50) in limited space. In previous projects, this has led to the development of a double-stage planetary gearbox with low module spur gears. This design choice introduces negative impacts in terms of economic cost and mechanical issues, the latter arising from the very harsh duty cycle that the device must accomplish. Furthermore, the alternating motion of the suspension also raises concerns about backlash, which becomes the primary source of noise, particularly in the high-speed stage.

To deal with this scenario, this research aims at replacing the planetary gearbox with an innovative transmission compound. The high-speed stage could be replaced by a parallel axis high-strength polymer gear couple. By reducing the number of meshing gears and using a material with more intrinsic damping, a strong noise reduction is expected. Conversely, the low-speed stage could be replaced by contactless magnetic gears. Leveraging the intrinsic properties of magnetic coupling, the system would provide a fail-safe mechanism, enabling torque decoupling when the applied torque exceeds the design limits. This feature helps prevent mechanical failure and enhances system reliability. Furthermore, the contactless nature of the magnetic gearbox improves durability and minimizes component wear, contributing to a more efficient and maintenance-friendly solution.

This work will provide a feasibility study for this novel compound and the final solution will be compared against the steel-made planetary baseline, in terms of efficiency, economic cost, and size. While the plastic stage of the reducer will follow traditional mechanical design tools, the magnetic stage will integrate electromagnetic analysis to quantify benchmark quantities.

The expected outcome is an electromagnetic damper with an overall efficiency comparable to the planetary benchmark (up to 70%). This work will be the baseline for future prototype manufacturing with the final goal of an experimental comparison.

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