Improved Efficiency of Mobile Machinery Through Joint Hydraulic and Electric Actuation

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Abstract:

The needs of a growing society lead naturally to a growing demand for highly productive off-road machinery. Simultaneously, increasing interest in emission reduction and rising fuel costs demand a reduction in machine fuel consumption. To rectify these two requirements, efficient actuation architectures for off-road machinery are required. Electrification is one popular approach to achieve this efficiency, but the cost and logistical weight of its implementation makes it infeasible for large machines. Analysis of the state of the art technology for off-road actuation, hydraulics, demonstrate several gaps that electrical actuation is particularly suited to fill. By pairing electric actuation with hydraulic actuation to allow for efficient energy recovery and straightforward system decentralization, joint electric-hydraulic actuation architectures can be developed that are both efficient and practical.

This work aims to demonstrate this point by following two reference cases-an agricultural case and a mining case- through the process of designing an efficient EH architecture. First, reference machines for both cases are selected along with representative drive cycles. Data on the baseline machines is gathered and analyzed to identify the sources of inefficiency in these systems. Based on these insights, a pair of electric-hydraulic actuation architectures are proposed. For the agricultural case, the capability to spread prime movers throughout the system is used to separate a problematic high load actuator from the main system, allowing for the overall system to operate more efficiently. For the mining case, the ability to control flow without any intrinsic losses is utilized to investigate the potential of load recovery in primary controlled systems.

After the proposal of these architectures, analytical models are used to estimate system performance under the same conditions as the baseline test, to assess savings potential. Lumped parameter simulation models are then used to validate the dynamic feasibility of the architectures. Finally, selected subsystems of the proposed architectures are tested experimentally. For the agricultural case this is done through the assembly of a full-scale test machine, while for the mining case a stationary test-rig is used. The agricultural architecture demonstrates a 40% reduction in system power consumption for the most common use case, while the mining system demonstrates a 51% improvement in efficiency for a common use cycle. These results demonstrate the potential of joint electric-hydraulic actuation to power the next generation of off-road vehicles.