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Future Brake Systems for Future Powertrain Technology

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ABSTRACT

Future Powertrains are challenged by reduced CO_2 and other exhaust emissions.

Thus auxiliary drives are vanishing including mechanical vacuum pumps. The creation of vacuum at SI engines will disappear temporarily or permanently due to start/stop functionality, intake valve control replacing throttle or due to hybrid/electric drives.

The increasing demand for safety improving driving assistance functions calls for control-by-wire ability of powertrain but also of brake systems. Today's conventional hydraulic brake systems with vacuum boosters and hydraulic units for ESP offer a high performance/cost ratio but may be pushed to their limits by above mentioned requirements.

Adaptive Cruise Control Systems featuring Stop & Go functionality or effective regenerative braking functions ask for high duty and low noise solutions that can exceed the possibilities of hydraulically controlled brake interventions by enhanced hydraulic units like ESP®*plus* or similar solutions.

A huge multitude of solutions are created or at least concepts are discussed that may help to overcome the described short comings of enhanced conventional solutions.

Electrohydraulic Brake Systems are in serial production and can cope with a. m. requirements but have proven to be rather costly and hardly scalable.

Brake-by-wire systems with electromechanical actuators with or without self-energizing functionality (wedge brakes) suffer from complexity and thus reduced reliability as well as high cost.

Systems with actively controlled vacuum boosters can be used for blending functions for regenerative braking but still rely on vacuum supply, whereas at the same time a high dependency on electronics introduces a fading effect on reliability.

Some proposals are made that have pedal decoupled electronic control on the rear axle only either by using electromechanic rear brakes or controlling them electrohydraulically. Those approaches offer a limited regeneration only since the front brakes always are engaged by

pushing the pedal and by that generating friction braking instead of generating electrical energy for battery recharging.

In addition those systems still require vacuum boost for the front hydraulic brakes whereas the rear seems to be more futuristic and by that independent from vacuum.

Bosch offers a system with pure mechanical pedal decoupling featuring full blending regenerative functionality with a so-called Pressure Controlled Actuation (PCA) in combination with its ESP systems (ESP®*plus,* ESP®*premium*). The system does not involve additional electronics complexity but still relies on vacuum supply.

There are several more or less complex solutions with full or limited blending functionality but all of them are lacking a reasonable scalability in case of hybrid and conventional drives on the same vehicle platform.

Therefore a system that could replace the standard vacuum booster offering control-by-wire and independence from vacuum can be considered as favourable.

In case of standard drives that create vacuum, a standard booster could be applied, being cost optimized. Start & stop systems, hybrid drives or other engine concepts without vacuum generation can be managed by an electrically driven and electronically controlled master cylinder with limited exposure to dependence on electronics and electric energy.

A comparison of systems is made using criteria for functionality, scalability and cost. A recommendation for a reasonable scaleable system at moderate cost is given that has the potential for a new mainstream industrial standard.