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FlexWork – Fully Variable and Efficient Valve Train for Internal Combustion Engines

By increasing the valve train's variability the internal combustion engine is optimized in terms of efficiency and emissions and the engine's functionality is expanded by e.g.

- Cylinder deactivation
- Switching operation mode between 2-, 4-, and 6-strokes
- Increasing efficiency by avoiding throttling losses in SI engines

By the use of a camless solution the amount of catalyst-poisoning additives in the engine oil can be significantly reduced. Hence, the catalytic converter's precious metal loading can be decreased.

The main challenges in developing a fully variable valve train were keeping the system's complexity, its energy demand, and cost as low as possible.

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Introduction

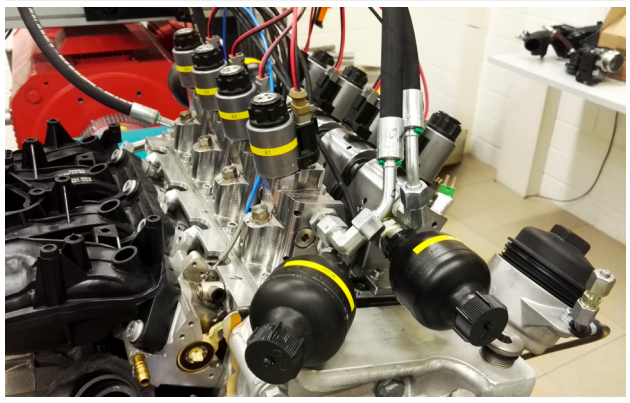

Fig. 1: Fully variable valve train on engine test bench.

A novel, fully, flexible valve train has been invented[1], simulated, developed and built. A 1.4 liter SI engine has been fully equipped for the intake and exhaust side. Fig. 1 shows the experimental setup installed on Empa's engine test bench and Fig. 3 shows an intake module. Currently, preparations are ongoing for the first fired operation.

The Mechanism

- Spring-mass-system with one conventional solenoid actuating two engine valves.
- Water-ethylene-glycol mixture (coolant liquid) as hydraulic fluid due to its high stiffness.
- Valve lift (Fig. 2) is controlled by the hydraulic pressure level.
- Hydraulic recuperation and soft valve seating are ensured automatically.
- No displacement sensors necessary and no feedback control required.

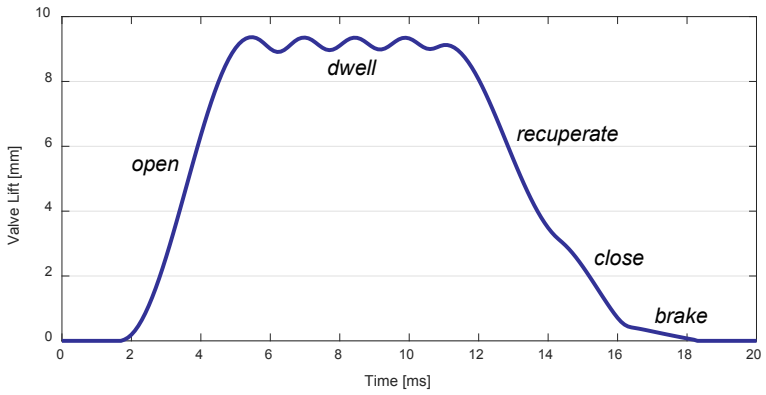

Fig. 2: Valve lift curve with indication of different phases.

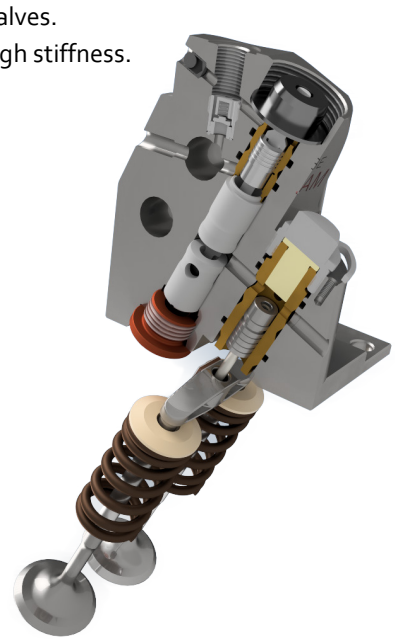

Fig. 3: Intake module with engine valves and springs.

Current Research

The experimental validation of the valve train and its potential started in summer 2018. Tab. 1 lists the methods which will be investigated.

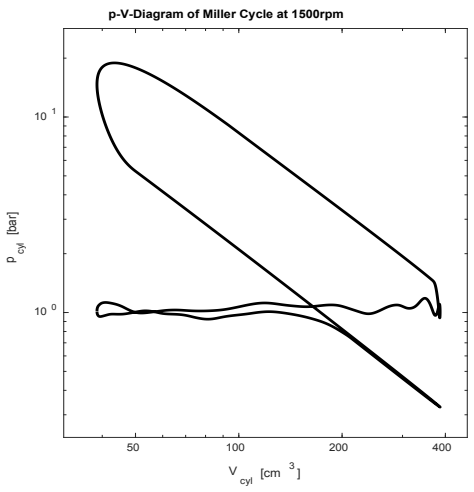

Fig. 4: Simulated combustion process illustrated as a p-V-diagram. Unthrottled part-load operation and Miller valve timing.

Tab. 1: Methods being validated simulative and experimental.

Measure	Method	Goal
Unthrottled operation	Control load by valve lift & timing	Improve part-load efficiency, see Fig. 4
Atkinson / Miller cycle	Late / early IVC	Decrease knock tendency, longer expansion than compression stroke, see Fig. 4
Internal EGR	Early EVC	Improve part-load efficiency[4]
2-Stroke operation	Double actuation frequency	Increase output
Cylinder de-activation[2]	Turn off solenoids	Downsizing, increase load[2]
Turbulence generation	Minimize valve lift	Faster combustion[3]

Expected Impact

Our fully variable valve train does not require fast switching solenoids, displacement sensors, feedback control, or expensive materials. Hence, it can be competitive with camshafts from a cost point of view. Simulations predict a similar drive power demand as for conventional mechanical valve trains at high rotational speeds and high engine load. However, at low engine load and speed the power demand is considerably lower. In sum, by applying methods listed in Tab. 1 fuel savings in driving cycles in the order of 15-20%, dependent on the chosen operation strategy, are achievable[3,4]. If the experimental validation will be successful, the intention is to transfer this technology to industry.

References

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3 Maas, G., Neukirchner, H., Dingel, O., and Predelli, O., " Potential of an Innovative, Fully Variable Valvetrain ", SAE Int.: 2004-01-1393

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