Milestones on the R&D path to VCSR ICE solution

The main thrust of my lifetime of work in R&D was to improve the efficiency and enhance the sustainability of Internal Combustion Engines ICEs (see Home Page).

1. R&D field modeling and simulating ICE processes, especially the gas exchange (s. SAE and FISITA) and mixture formation in diesel engines (s. CIMAC), all as offline simulations (time span 1975-2004).
2. R&D field reduction and control of exhaust emissions using modeling, simulation, HIL, SIL, NMPC control algorithms and their implementations for real-time applications. All these R&D areas have required real-time simulations and corresponding process modeling methods (time span 1992-2007), (see: List of Publications).
3. In 2002, the VW Group commissioned BorgWarner (BW) Turbo Systems to develop a new way of simultaneously controlling boost pressure and exhaust gas recirculation (EGR) for diesel engines. This time the control had to work without a great number of convoluted PID controllers, with several maps of pre-control, control, and adaptation parameters. Specifically, the control had to be based on the NMPC (Nonlinear Model-based Predictive Controller), although it was known that such controllers were only implemented for power plants with hourly sampling rates. Nevertheless, this unsolvable task (from VW's point of view) was given to BW for solving and implementing. BW commissioned me, between 2003 and 2005, to develop an NMPC controller with a sampling rate of only 10 ms (milliseconds). The NMPC controller was developed by me, implemented by BW on a VW diesel engine with the final support of IAV, and successfully tested on the engine test bench. (see: ATK 2005, SAE 2005, SAE 2007). Nevertheless, VW did not adopt and implement the realized NMPC control. Instead, VW activated the so-called acoustic function in the control units of its diesel engines in order to be able to continue exporting them to the USA despite clearly exceeding the NO_x emission caps. This deception was discovered in the USA, which led to the diesel emissions scandal, also known as Dieselgate.
4. R&D field regarding solutions for the simultaneous reduction of CO_2 and NO_x emissions in ICEs. Based on the realization that the process control of the classic combustion engines is not optimally set up and therefore has to be fundamentally changed, I have tried to improve it in several attempts.
    a. First, between 1998 and 2000, I invented and patented a sensor suitable for continuous real-time monitoring and control of soot emissions and therefore also appropriate for onboard diagnosis. Its development lasted until 2012 (see SAE).
    b. At the same time, i.e. in 1998, I made a first attempt to invent a crankshaft drive with variable compression (variable VCR, i.e. Volumetric Compression Ratio) (see Patent application). I implemented this solution in a piston compressor and presented it at the Hanover Fair 2000. This particular solution was not sufficiently mature and, therefore, I stopped pursuing it.
    c. Meanwhile, Toyota launched the Prius II hybrid vehicle. According to Toyota, the Prius II engine operates on a **quasi-Atkinson cycle**, closing the intake valves much later to simulate a shortened compression stroke. First, out of curiosity, I investigated this solution (see Papers from 2007 to 2015, under List of Publications). In SAE of 2015, Appendix 3, I definitively proved that the so-called "Intake Valve Opening Time" (IVOT) control of the quasi Atkinson cycle brings no increase of efficiency.
    d. For this reason, I have invented a solution for crank drives that simultaneously feature true Atkinson cycles (first with geometrically shortened strokes, for suction and compression, and second with extended strokes, for expansion and exhaust) and a continuous variation of the compression ratio (VCR). For these VCSR crank drives, I applied for patents in 2013 and 2014, and they were granted in 2018 (DE) and 2020 (EU), respectively.
    e. In addition to the VCSR crank drives, I have invented a suitable, optimal load control (LC, Load Control) of the VCSR engines and named it Ultra Downsizing (UD LC).
    f. A third load control variant has thus been realized. This third load control variant on VCSR engines takes over the positive features of I. and II. (see below) while eliminating the negative ones:
        I. Quantity control of stoichiometrically operated gasoline engines by throttling the intake gas mass. Disadvantageous for efficiency but advantageous for simple exhaust gas aftertreatment using only 3-way catalysts.

II. Quality control mostly under-stoichiometric diesel engines, based on the leaning of the mixture and intensive external EGR. Advantageous for efficiency, but disadvantageous for exhaust aftertreatment of NO_x and soot emissions. This makes the use of SCR catalysts with Addblue etc. and soot filters DPFs absolutely necessary.

III. Regardless of whether the VCSR engine is powered by gasoline, CNG, hydrogen or similar fuels, the engine is always operated stoichiometrically and unthrottled. The control of the aspirated gas mass is mainly done by varying the VCR and turbocharging, i.e. boost pressure level. Patent claim 8 of 2018 (DE) and 2020 (EU), respectively, expresses this control strategy of the engine load in a very compressed manner. If a thermodynamic cylinder deactivation, as an extension of the engine load control strategy, is desired, it can be evaluated under the patent claim 9, where is presented in detail.

g. In 2013, I presented this invention to the VW and BMW groups, as well as to IAV GmbH, and proposed a plan to cooperate.

I. The VW engineers were convinced to varying degrees. Specialists in thermodynamics were enthusiastic about the invention, specialist in mechanics complained that, because of the extended expansion and apparently larger engine displacement, vehicle owners would have to pay more in taxes.

II. The BMW engineers were enthusiastic, but the BMW group was undergoing restructuring and the proposal did not get any traction.

III. IAV GmbH engineers were also enthusiastic, but the plan requires a vehicle manufacturer to place orders and pay for this development.

IV. Daimler Group engineers were skeptical from the outset about noise, vibration, harshness (NVH) development in the planetary gearboxes of the VCSR crankshaft drive.

V. An inquiry to the transmission specialists ZF AG Friedrichshafen and the Schaeffler Group showed that the fears of the Daimler specialists proved to be unjustified. As with IAV GmbH, further cooperation requires the involvement of a vehicle manufacturer.