pattakon VVAs

–A solution for the idling problem of the known throttle-less VVAs.

–Mechanical VVAs with independently variable lift and duration.

–Mechanical VVAs without valve springs (desmodromic) for racing engines.

To the point

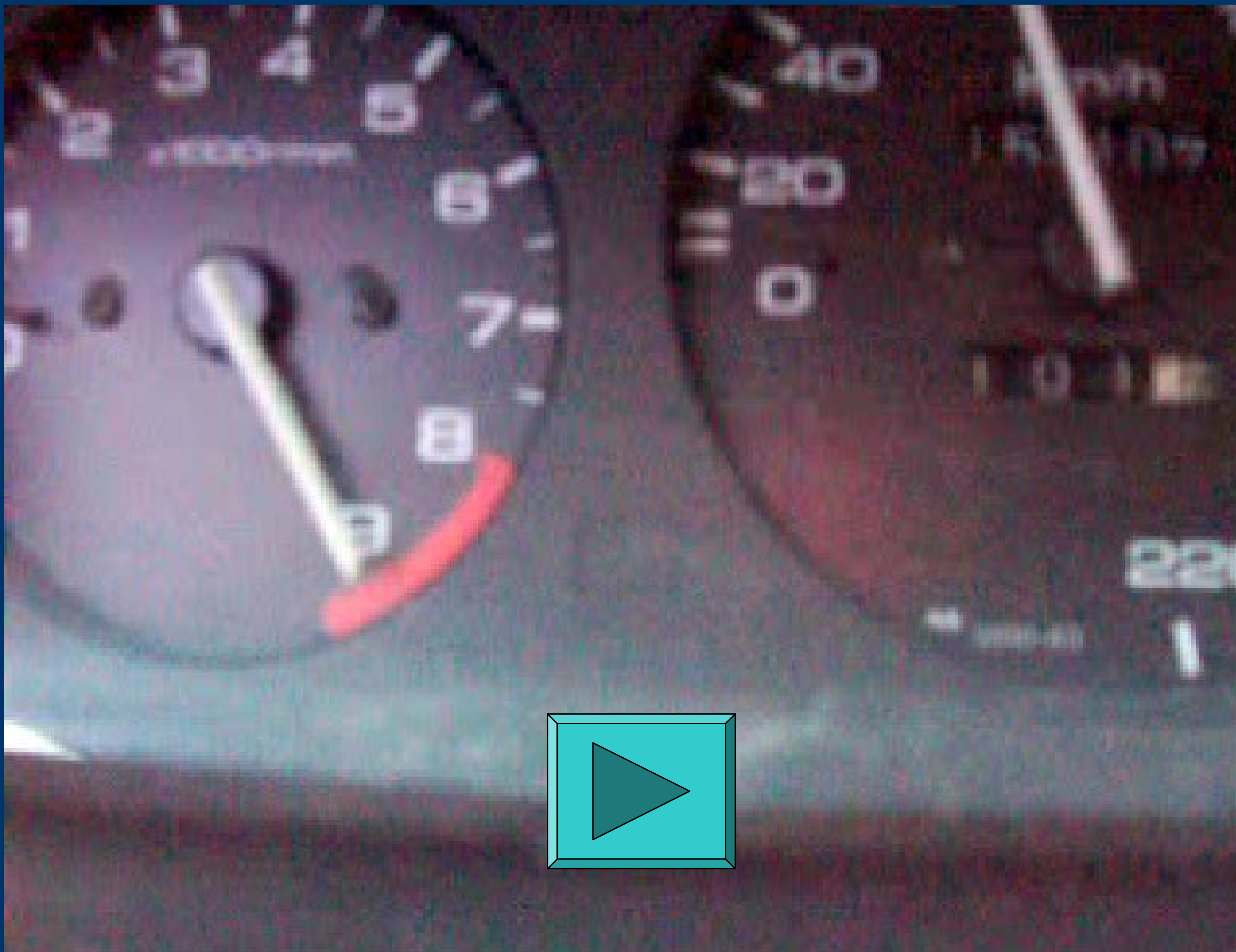
Every motorcycle maker has in production a 1,000cc bike engine with top power at around 12,000 rpm and red line at 13,000 rpm or even higher.

Such an engine cannot replace the engine of a heavy car. The peaky torque curve, the medium to low revs characteristics, the partial load response etc cannot meet the needs of a heavy vehicle.

Think of replacing the conventional valve train of the 1,000cc bike engine by a high revving VVA.

But, do high revving VVAs exist?

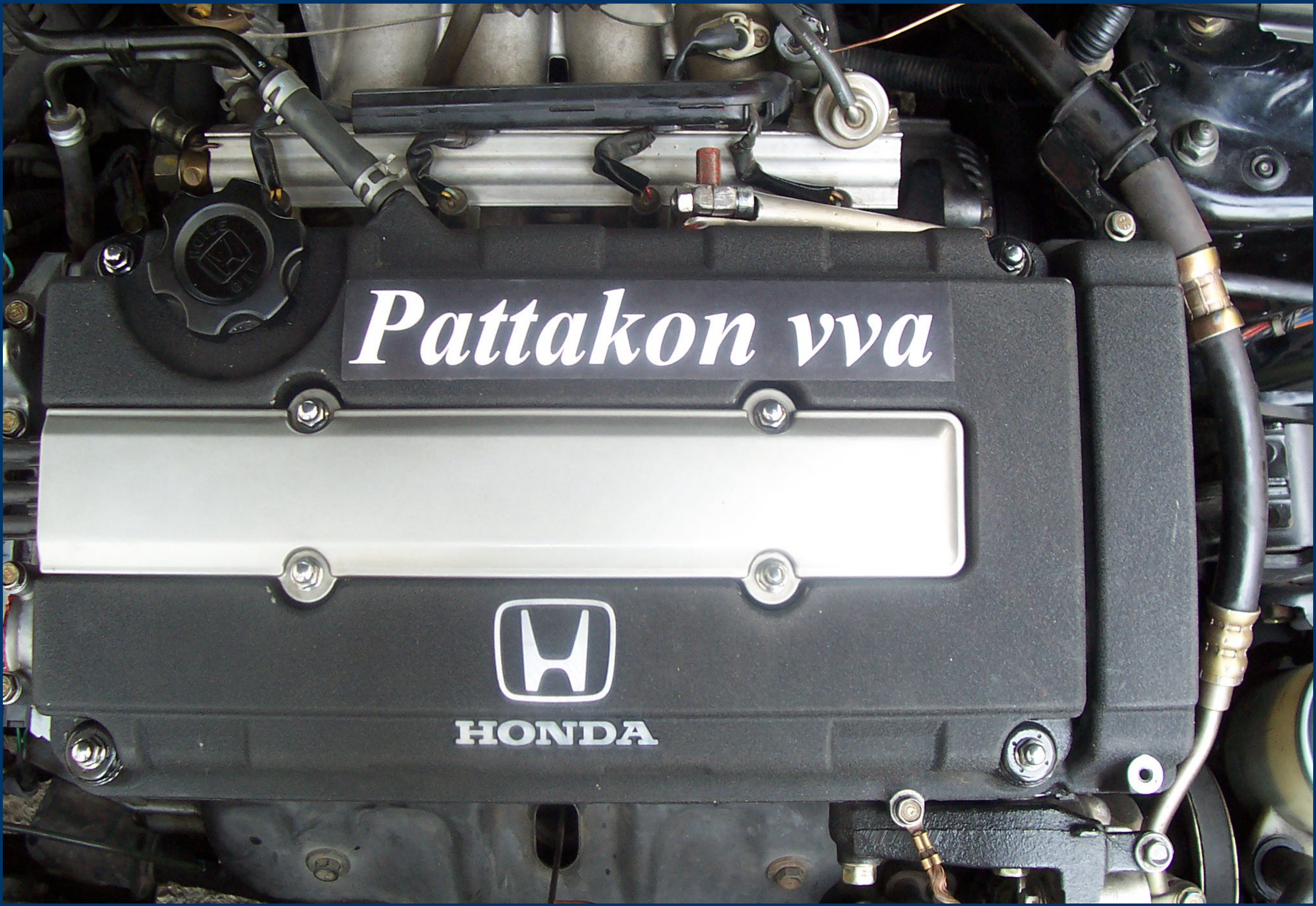
pattakon VVAr 4cylinder, 1600cc (9,000rpm rev limiter) accelerating on a highway (click on the button)



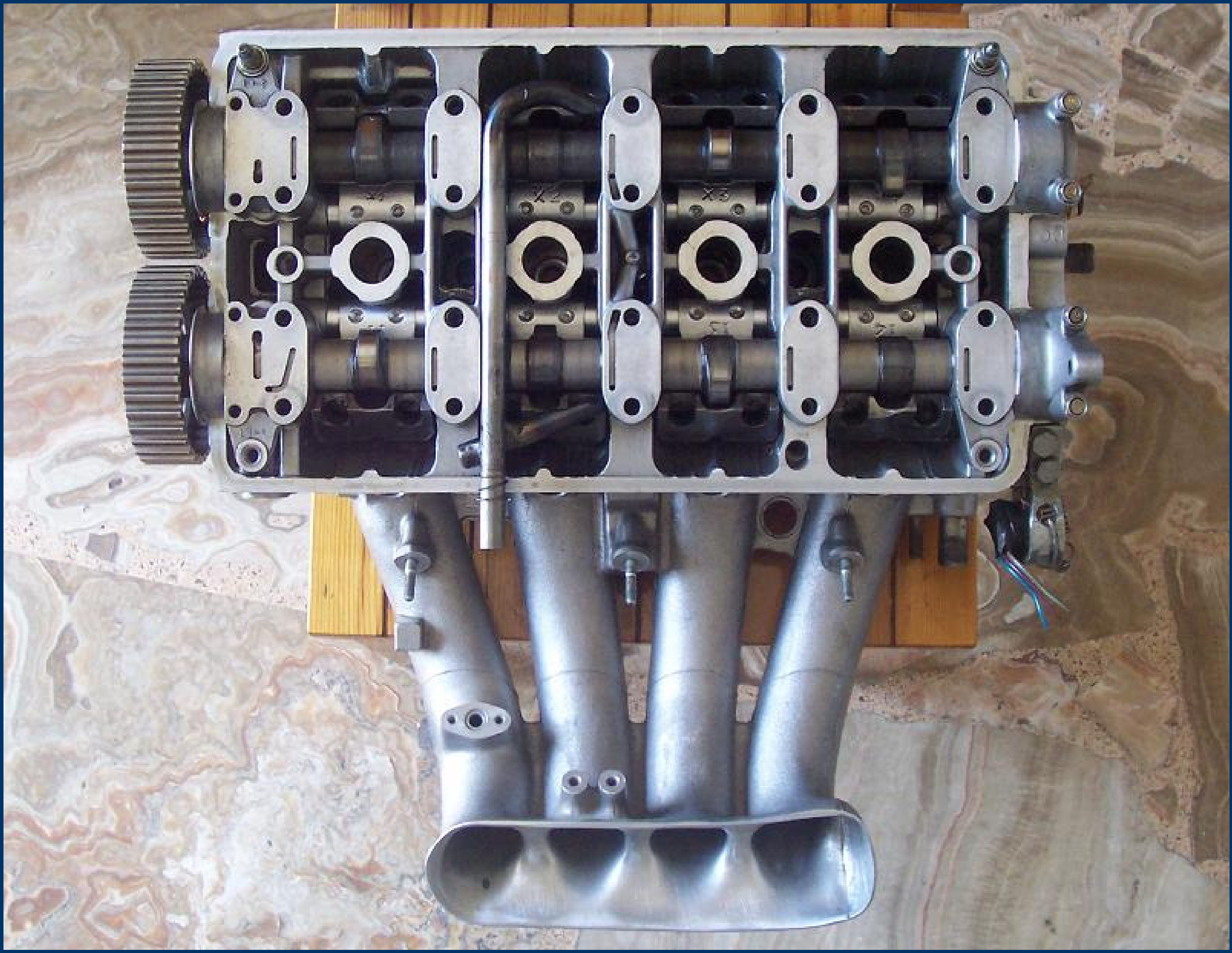
Rod-version and roller-version VVA prototypes

pattakon VVAr, 4cylinder, 1600cc, 9000 rpm

full version



pattakon VVAr, 1600cc, 9000 rpm, full version

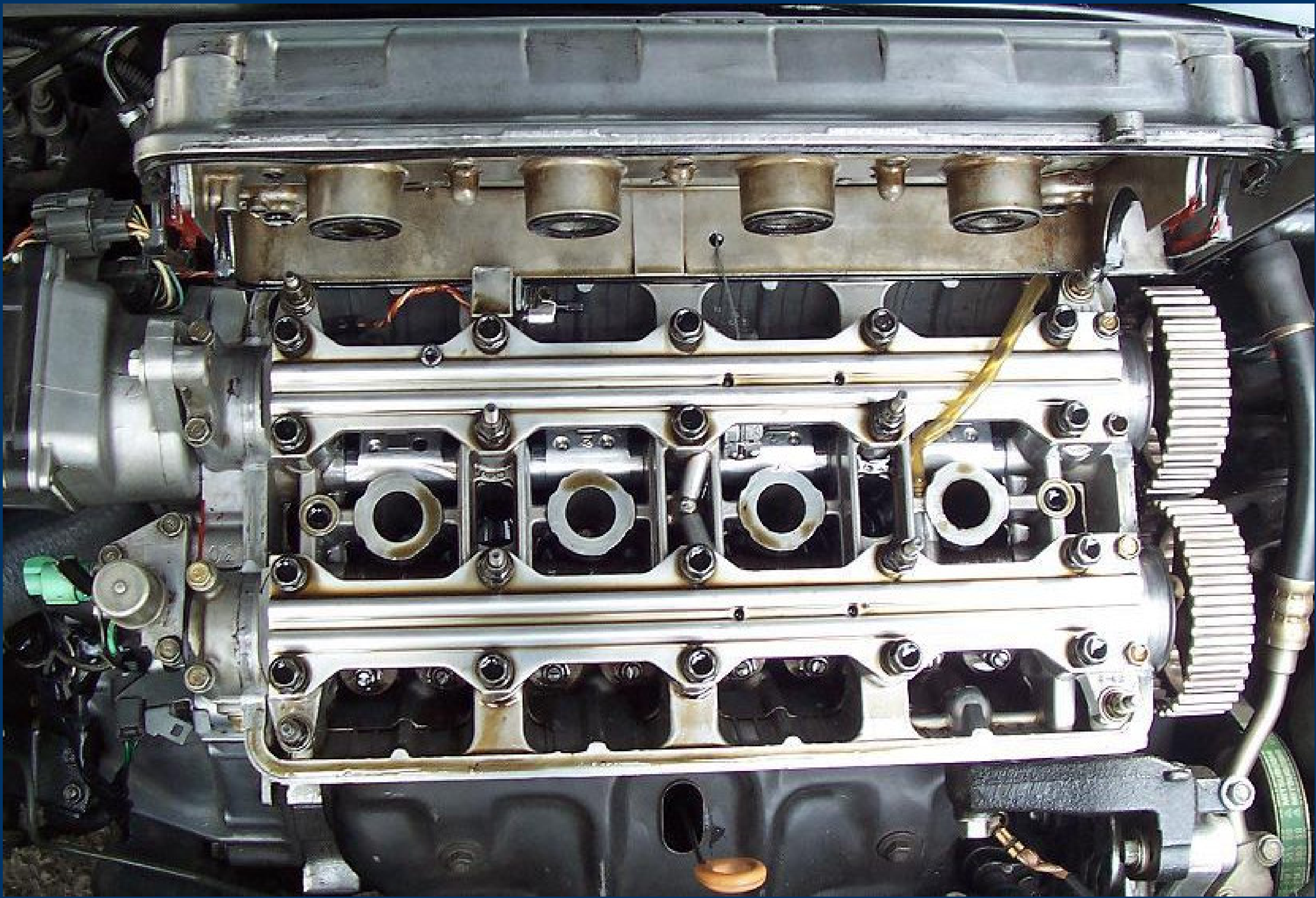


pattakon VVAr, 4cylinder, 1600cc, 9000 rpm

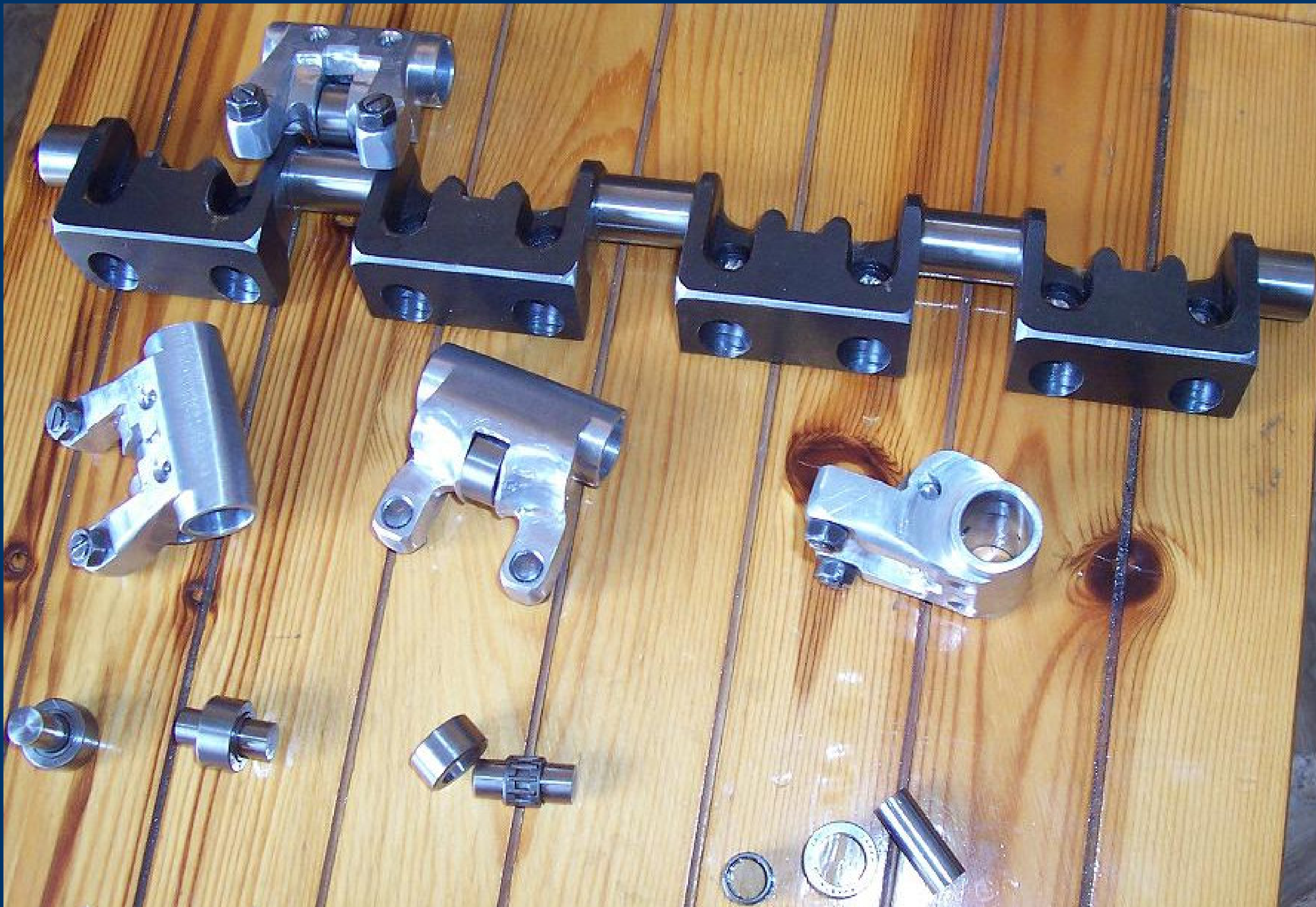
light version (intake side only)

pattakon VVAr, 4cylinder, 1600cc, 9000 rpm

light version (intake side only)



VVAr parts. 0.150 Kp each "complete new rocker arm" versus 0.260 Kp of the original 2-mode.



Control of the VVAr prototype engine (a modified B16A 1600cc)

The rotation of the intake control shaft defines the lift of the intake valves.

A rheostat is displaced by the intake control shaft and its signal is fed to the MAP input of the ECU (the original MAP sensor is removed: without a throttle valve the pressure just before the intake valves is always atmospheric).

To increase the sensitivity of the system at low valve lifts, the rheostat is exponential.

The original engine uses the revs and the MAP (manifold absolute pressure) signal as the basic parameters for the ECU, while the modified VVA engine uses the revs and the valve lift as the basic parameters for the same ECU. Modifying properly the injection and ignition tables (a wide band lambda sensor and a data logger is all it takes) the VVA engine is ready to operate.

The system in practice:

The driver presses the gas pedal. The gas pedal, through the gas cable, rotates the control shaft(s) changing the valve lift. The rheostat, displaced by the intake control shaft, signals to the ECU for the new valve lift.

The ECU, based on the present revs value X and on the present valve lift value Y (which, for the ECU, is nothing more than the original MAP signal), reads the injection duration and the spark advance at the (X, Y) cell of the modified injection and ignition tables.

The ECU modifies the injection duration and the spark advance according the signals from the rest sensors of the engine (the air temperature sensor, the exhaust oxygen sensor, the water temperature sensor etc) and triggers properly the injectors and the spark plugs.

The ECU at medium – low revs operates in closed loop mode (based on the feedback from the exhaust oxygen sensor), while at high revs it operates in open loop mode.

With 0.15mm intake valve lift the engine idles at 300 rpm.

Any valve lift from 0.15mm to 12 mm is directly available.

The engine breaths efficiently from below 1000 rpm to 9000 rpm, without steps.

The rev limiter is set to only 9000 rpm not to protect the valve train but to protect the rest engine (connecting rods, pistons, crankshaft and block).

There is no VVT (to phase the camshafts) yet the VVA system manages to control efficiently the "actual overlap": as the lift of intake and exhaust valves lowers, the actual overlap decreases (at very sort lifts, the actual overlap is reduced to zero).

The cam lobe profiles have been designed according the new geometry of the valve kinematic mechanism: the valve lash is constant, no matter what the valve lift is, while the maximum acceleration and jerk are kept acceptably small, i.e. the valve – no matter what the valve lift is – performs a smooth and controllable motion.

The response of the engine is direct – instant.

There is nothing between the valves and driver's right foot except the gas cable.

Neither "drive by wire" nor "time delays" between driver's decision and engine's response.

Even the intake manifold "capacitor" is missing now: the intake is a high flow (and zero cost) ITB, and the pressure just before the intake valves is always atmospheric.

Side effect: the heavy gas pedal.

Valve springs:

The original valve springs of the VVAr prototype engine (B16A2 VTEC 1600cc) cannot provide valve lift above 11mm neither reliable operation at 9000 rpm (1000 rpm above the factory rev limiter setting).

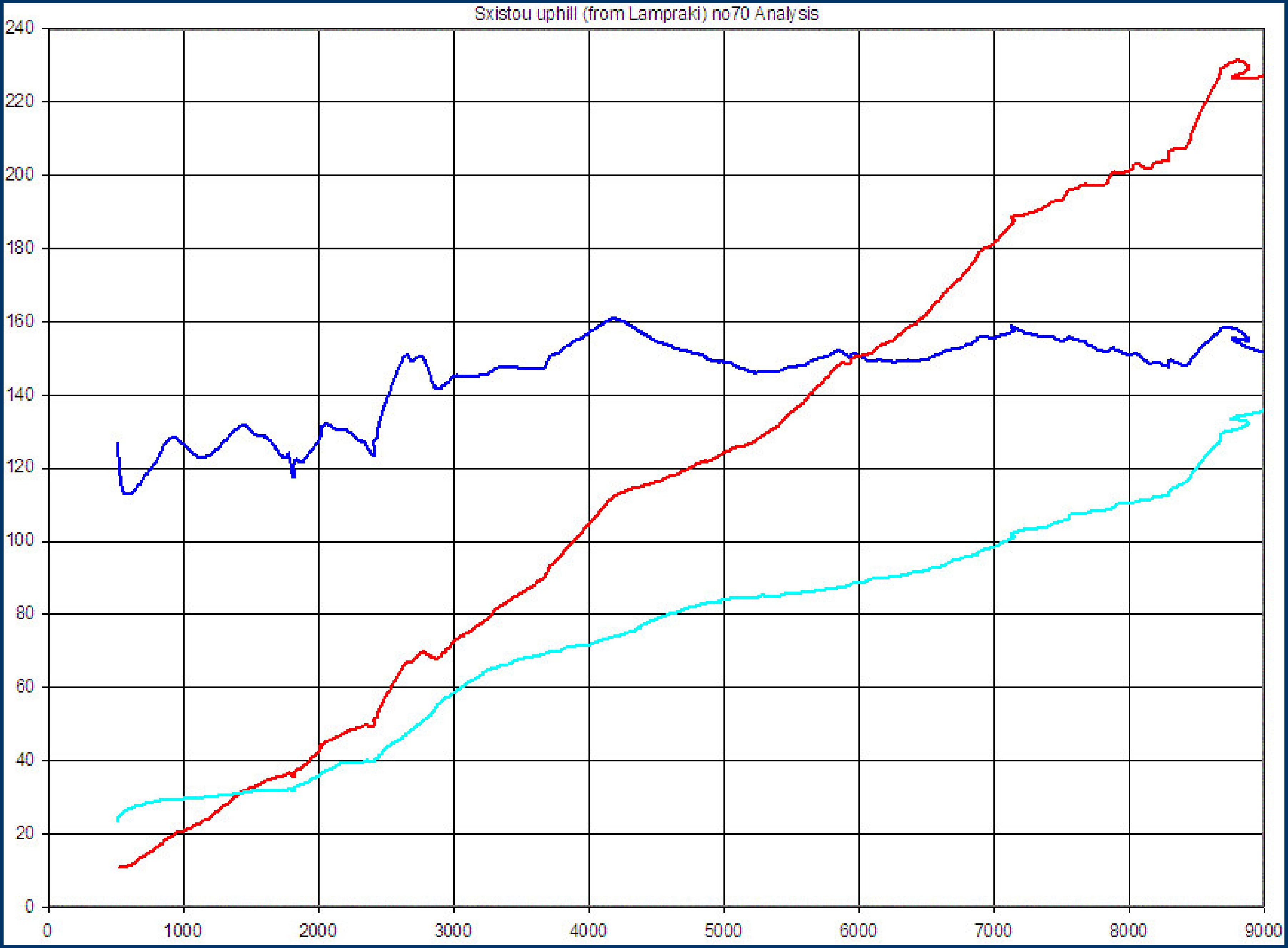
So, a set of harder valve springs, capable to provide valve lift of 12+ mm and reliability at 9000 rpm was purchased ("egg shape", unreasonably expensive).

A side effect of the harder valve springs is the "heavier" gas pedal.

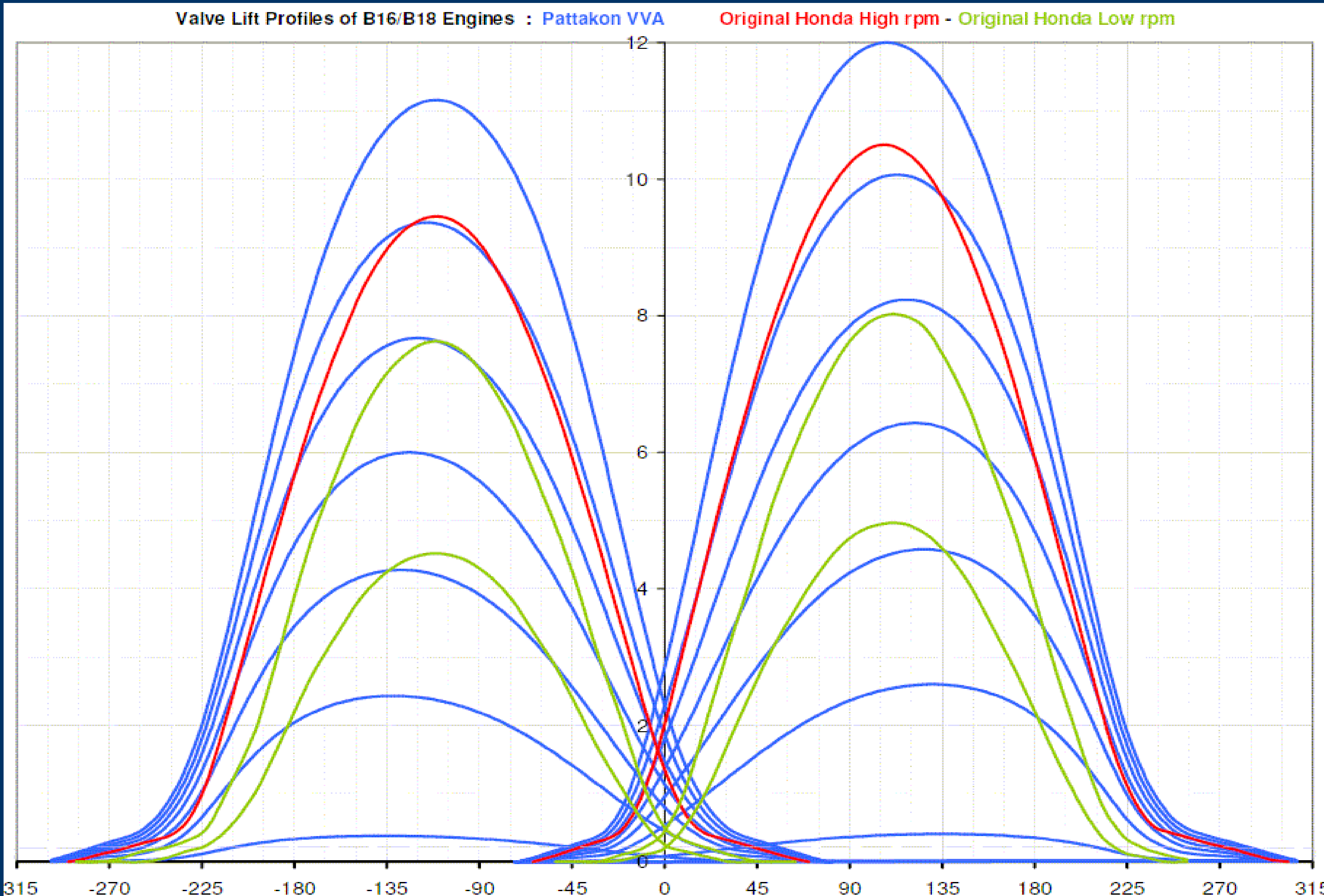
Intake manifold:

The VVAr prototype is rid of throttle valve (the throttling is done by the intake valves themselves, because they can operate at lifts continuously variable from zero to a maximum). Cutting the backside of the original intake manifold (plenum), what is left is a true free flow ITB (independent throttle bodies rid of throttle valves), and this without any cost (2000 euros is a "reasonable" price for a good ITB for this specific engine).

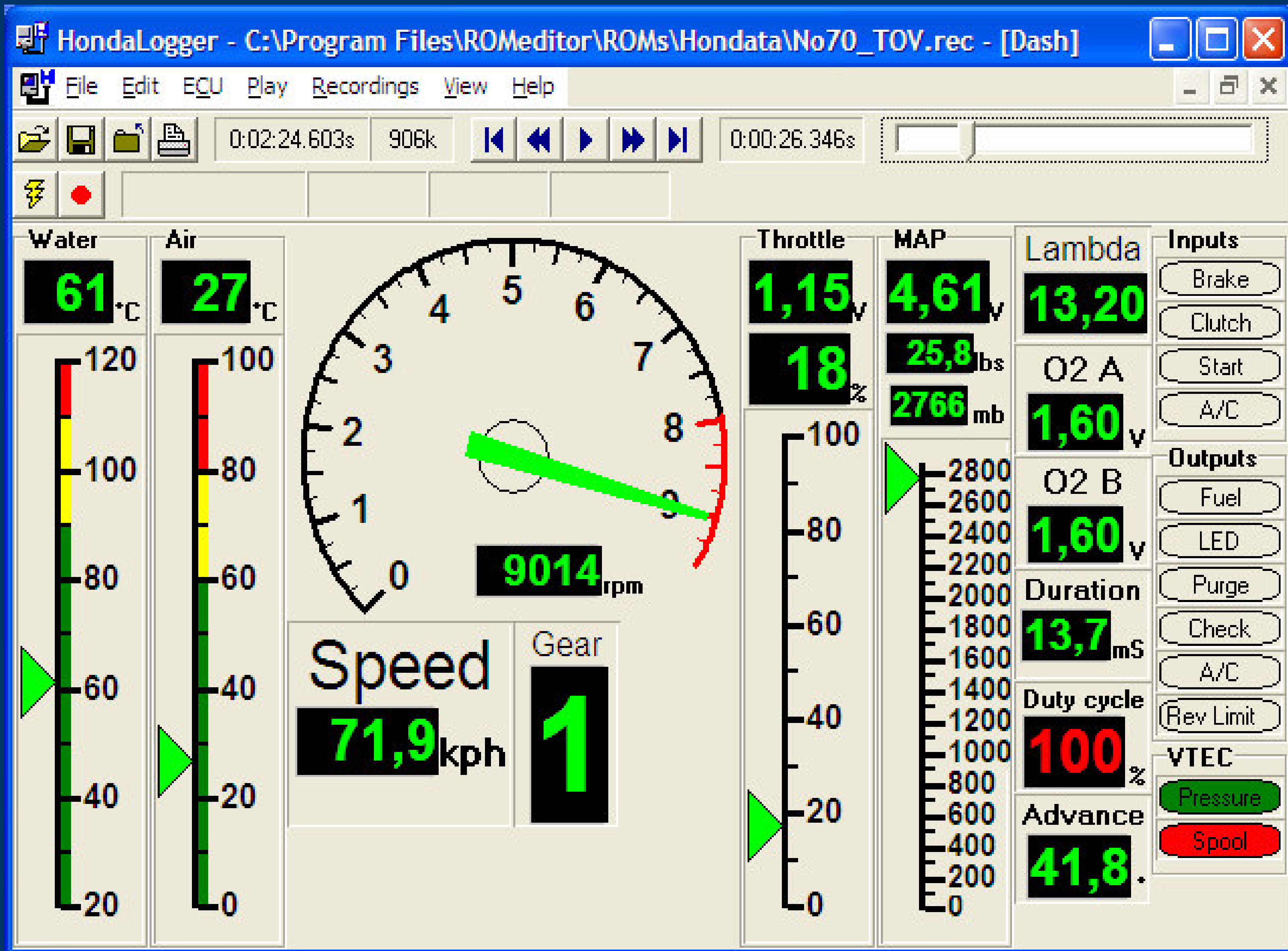
Flat air flow (torque) all the way to rev limiter



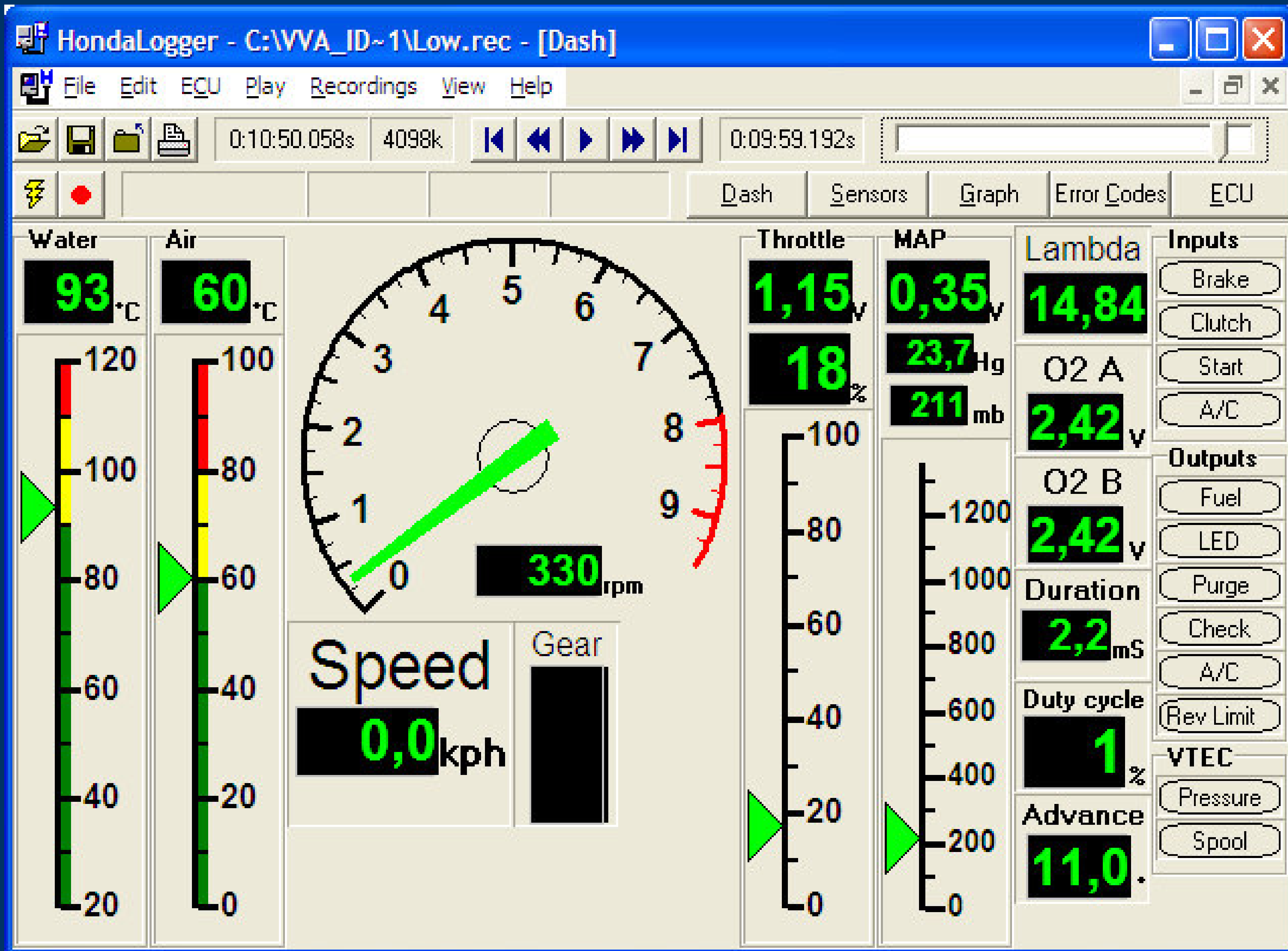
Infinite available versus the two original modes



High revving



Low idling


HondaLogger - C:\VVA_ID~1\Low.rec - [Dash]
File Edit ECU Play Recordings View Help
0:10:50.058s 4098k 0:09:59.192s
Dash Sensors Graph Error Codes ECU
Water 93 °C
Air 60 °C
330 rpm
Speed 0,0 kph
Gear
Throttle 1,15 V 18 %
MAP 0,35 V 23,7 Hg 211 mb
Lambda 14,84
O2 A 2,42 V
O2 B 2,42 V
Duration 2,2 mS
Duty cycle 1 %
Advance 11,0 °
Inputs Brake Clutch Start A/C
Outputs Fuel LED Purge Check A/C Rev Limit
VTEC Pressure Spool

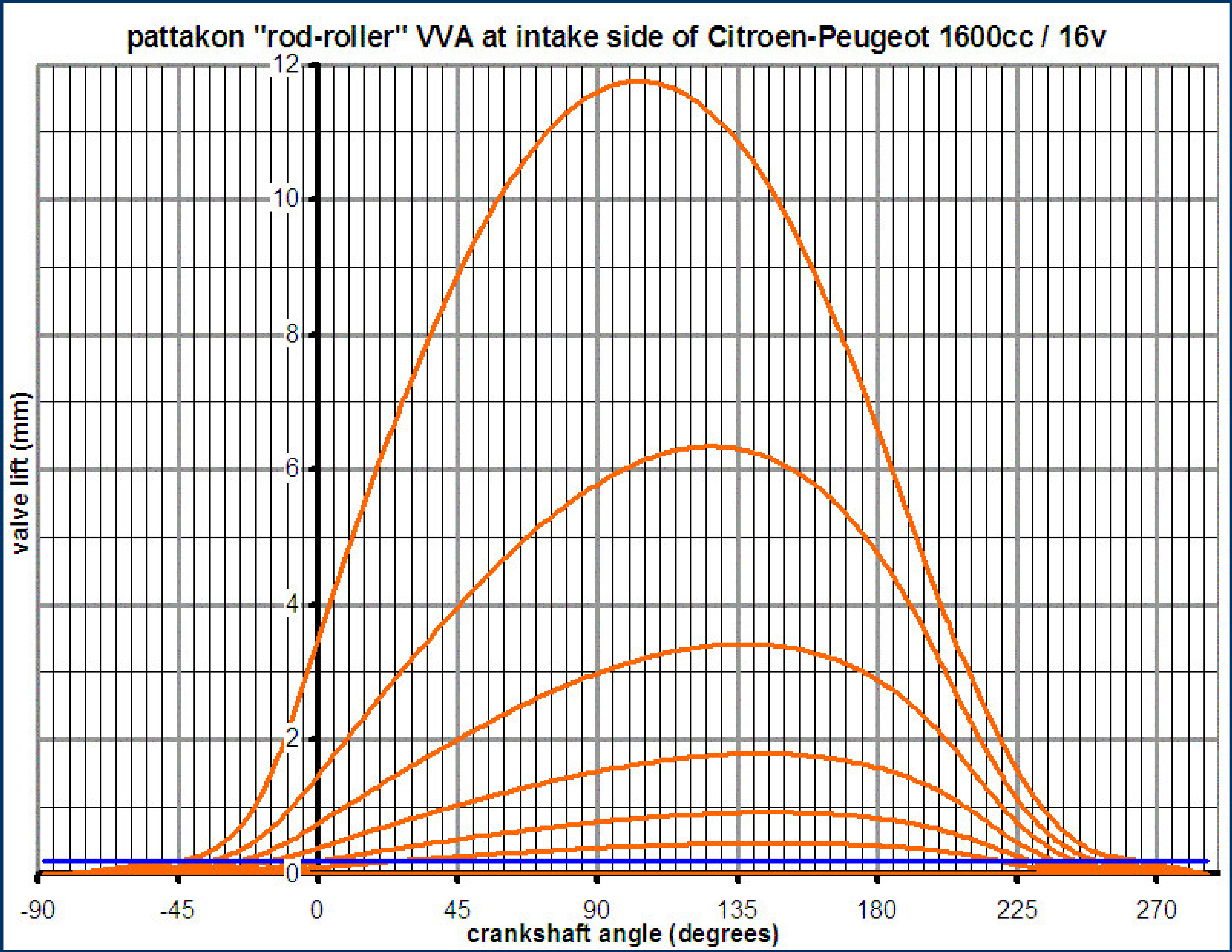
Throttle-less

Throttle-less

Throttle-less ITB

pattakon rod-roller VVA, 4cylinder, 1600cc

pattakon rod-roller VVA, 4cylinder, 1600cc


pattakon "rod-roller" VVA at intake side of Citroen-Peugeot 1600cc / 16v
valve lift (mm)
0
2
4
6
8
10
12
-90
-45
0
45
90
135
180
225
270
crankshaft angle (degrees)

pattakon rod-roller VVA, 4cylinder, 1600cc necessary force to rotate the control shaft

Back to the 1000cc bike engine.

Choose the design details of the pattakon DVVA (desmodromic VVA, details later) in order to provide (at around 90% of its maximum valve lift – valve duration "capacity") the valve lift profile of the original 1,000cc engine (securing at proper angles the two control shafts, the engine cannot see difference from the original to the DVVA valve train).

*Some 10 Kp*m of torque are available from bellow 1,000 rpm to over 13,000 rpm (~70 PS at 5,000 rpm, ~140 PS at 10,000 rpm, ~180 PS at 13,000 rpm).*

Replace the 2 litter engine of a car by the modified 1000cc DVVA moto engine and change properly the differential transmission ratio.

No need for variable compression.

The extra wide (efficient) rev range allows the small engine operate permanently at heavy load (where the thermal efficiency is better).

Flat torque and optimized breathing allows the driver to use low revs (fuel economy, low emissions, low noise, reliability etc) until the -rare- case he needs more or the peak power.

Compare to the original car, where a bulky and heavy engine, inefficient at partial loads (where the engine spends almost all its life) is used.

Compare to the Hybrid cars. Hybrids efficiency is based on spark ignition engines' inefficiency at partial loads.

A small / light / high-revving engine with the correct VVA is the way for economy, emission control, performance, driver friendly operation and more.

State of the art VVAs

A look at BMW's valvetronic, the only VVA in mass production, reveals the problems.

It improves economy and emissions, it has better response, it changes continuously the valve lift and the valve duration from zero to a maximum, it idles smoother than conventional.

It is not used in sport cars (where the VVA can show its big difference from the conventional valve train, providing flat torque from very low to very high revs) because valvetronic cannot withstand high revving.

The idling revs (and consumption/emissions there) cannot go too low: the system cannot balance the feeding of the cylinders of throttle-less engines.

The available “valve lift profiles” are infinite. But the valve lift and the valve duration determine one another, i.e. they cannot vary independently.

The electromagnetic VVAs claim their full variability: the desirable valve lift can be combined to the desirable valve duration. But they still have their own problems to overcome.

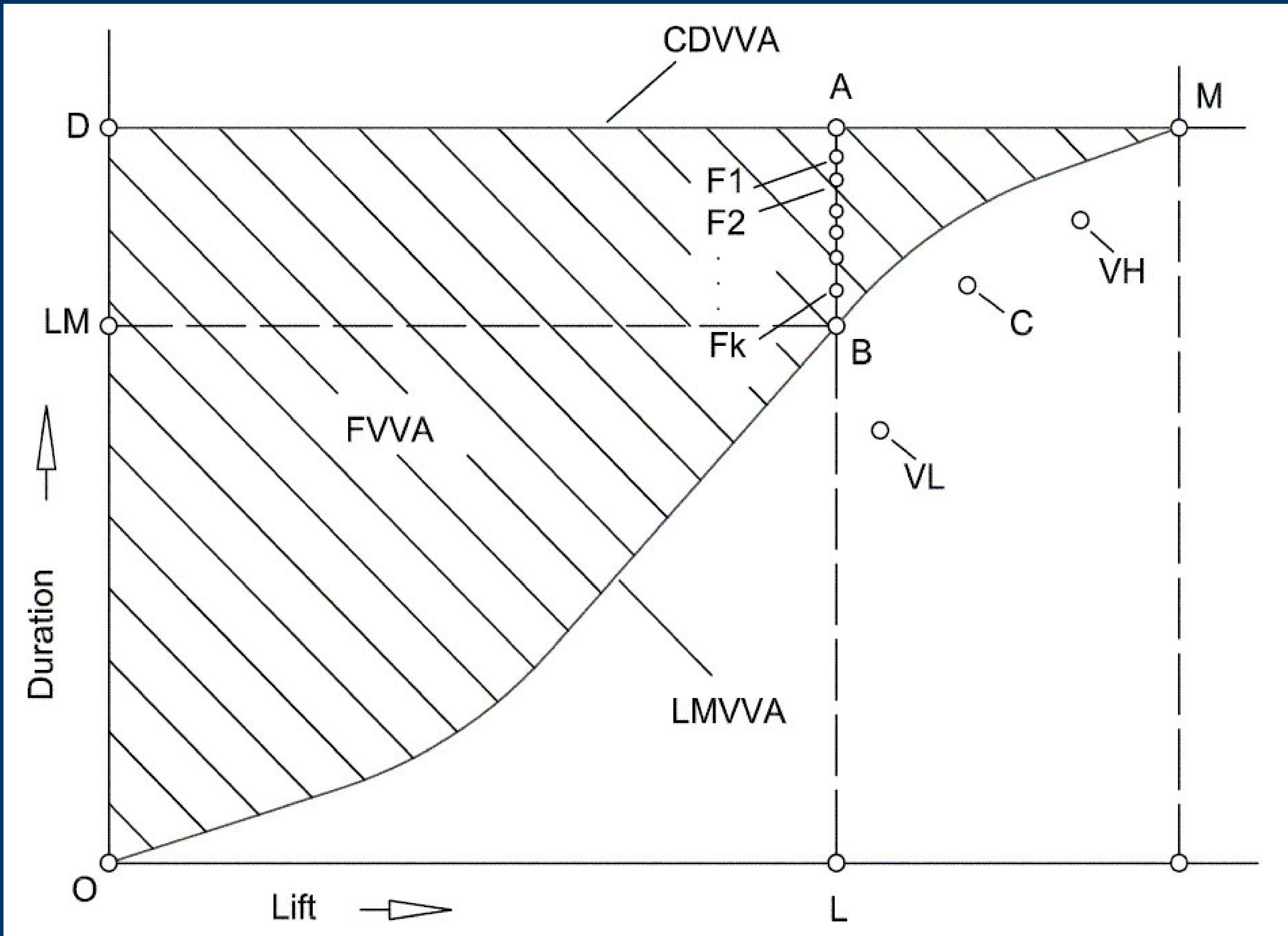
Variability

The pattakon FVVA (fully variable VVA) is a mechanical VVA providing infinite times more valve lift profiles than the state of the art mechanical VVAs.

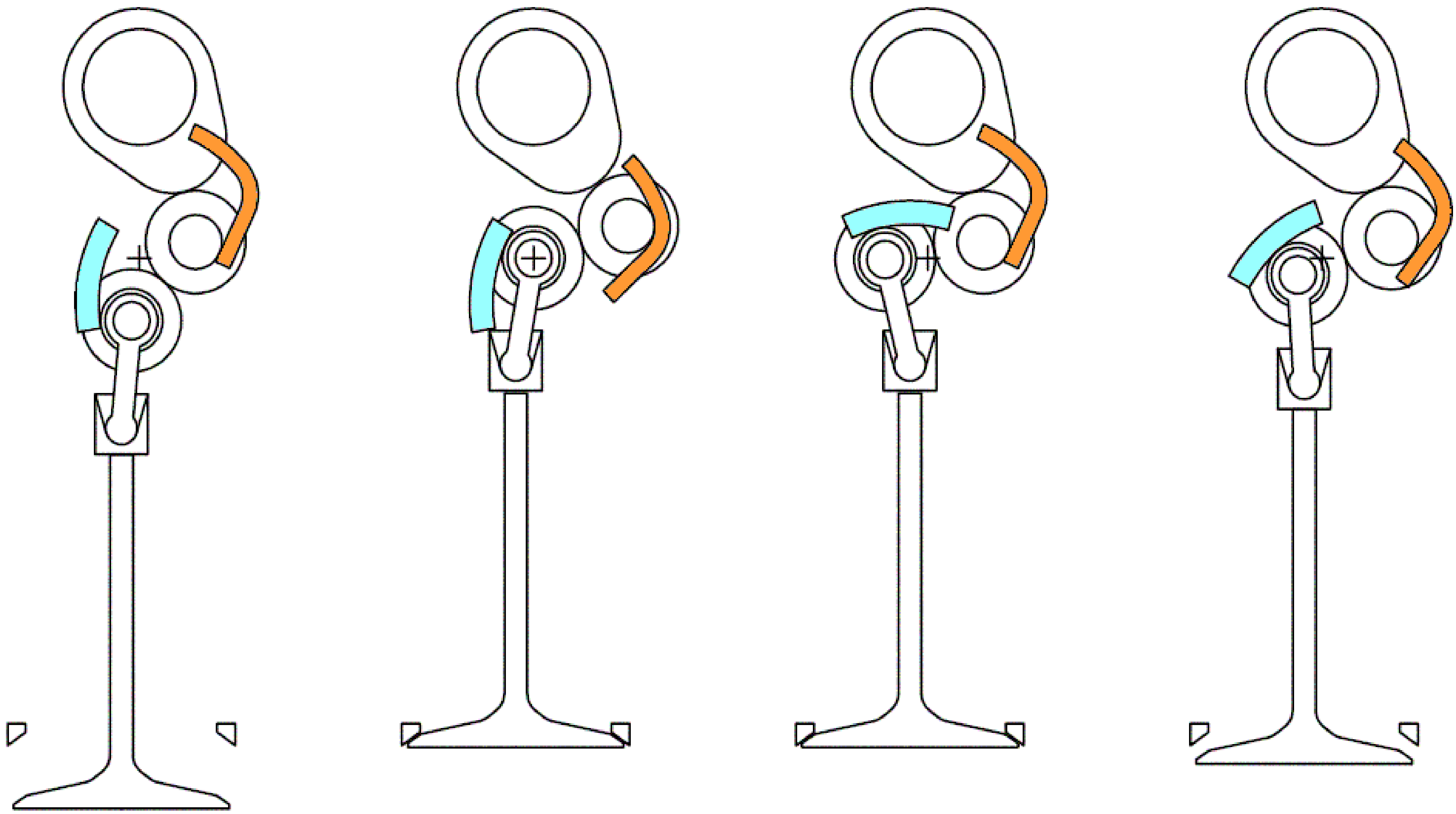
In the valve lift versus valve duration plot, valvetronic moves exclusively along a curve changing continuously, but not independently, the valve lift and the valve duration.

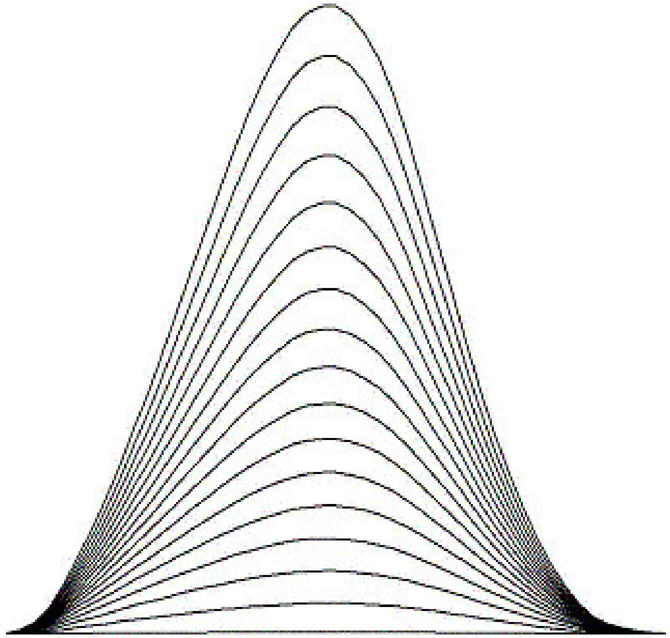
*In FVVA case, for a specific valve lift there are infinite valve durations to combine with, **and** vice versa.*

From one (state of the art) to two dimensions

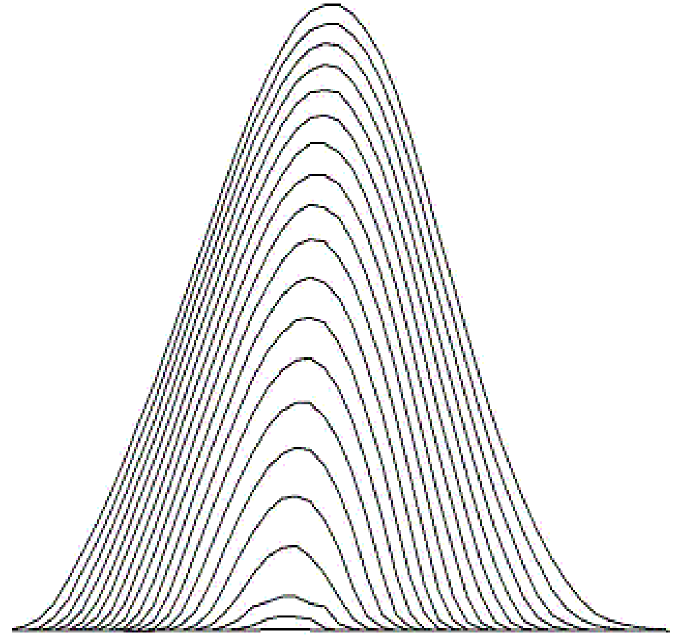


FVVA mechanism / principle

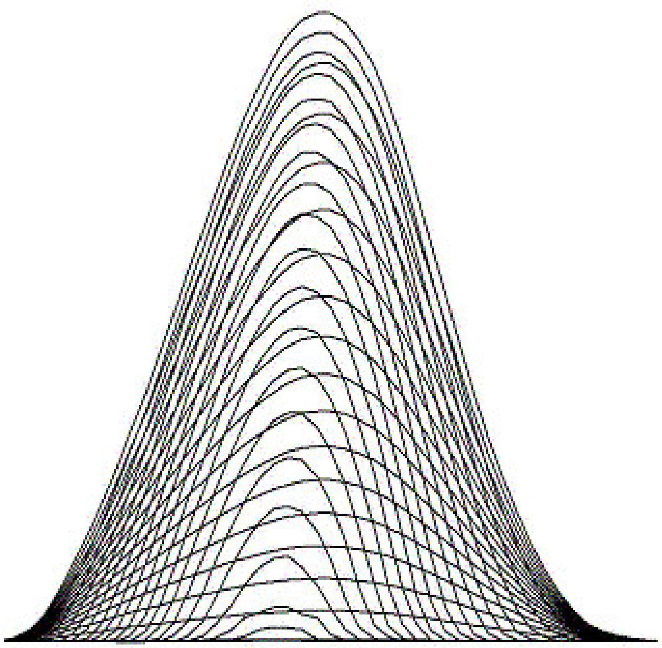




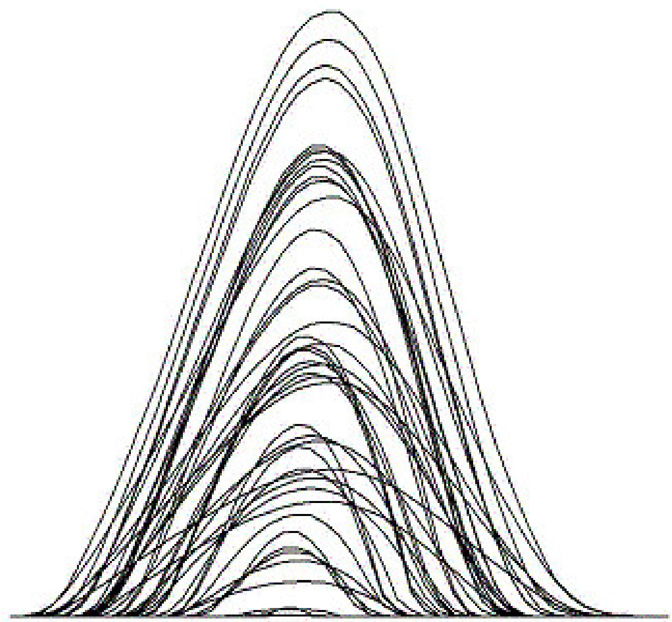
Constant Duration VVA (CDVVA)



Lost Motion VVA (LMVVA)



Lost Motion and Constant Duration curves



Fully Variable Valve Actuation (FVVA)

Securing at an angle the "duration" control shaft (orange) the FVVA system "degrades" to a Constant Duration VVA (CDVVA) like pattakon's prototypes.

Securing at an angle the "lift" control shaft (cyan), the FVVA system "degrades" to a Lost Motion VVA (LMVVA) like BMW's valvetronic.

Securing both control shafts, the FVVA system "degrades" to a conventional single mode valve train.

Instead of being bound to move along a curve, with FVVA we are free to move on a surface area.

From one dimension (curve) we go to two (area).

In other words, the pattakon FVVA can approach much better the ideal valve lift profile (ideal for the instant operational conditions of the engine) than the state of the art mechanical VVAs.

To justify the additional complexity and cost a VVA brings to an engine, the gains must be worthy.

The only gain a VVA brings is the optimization of the engine breathing.

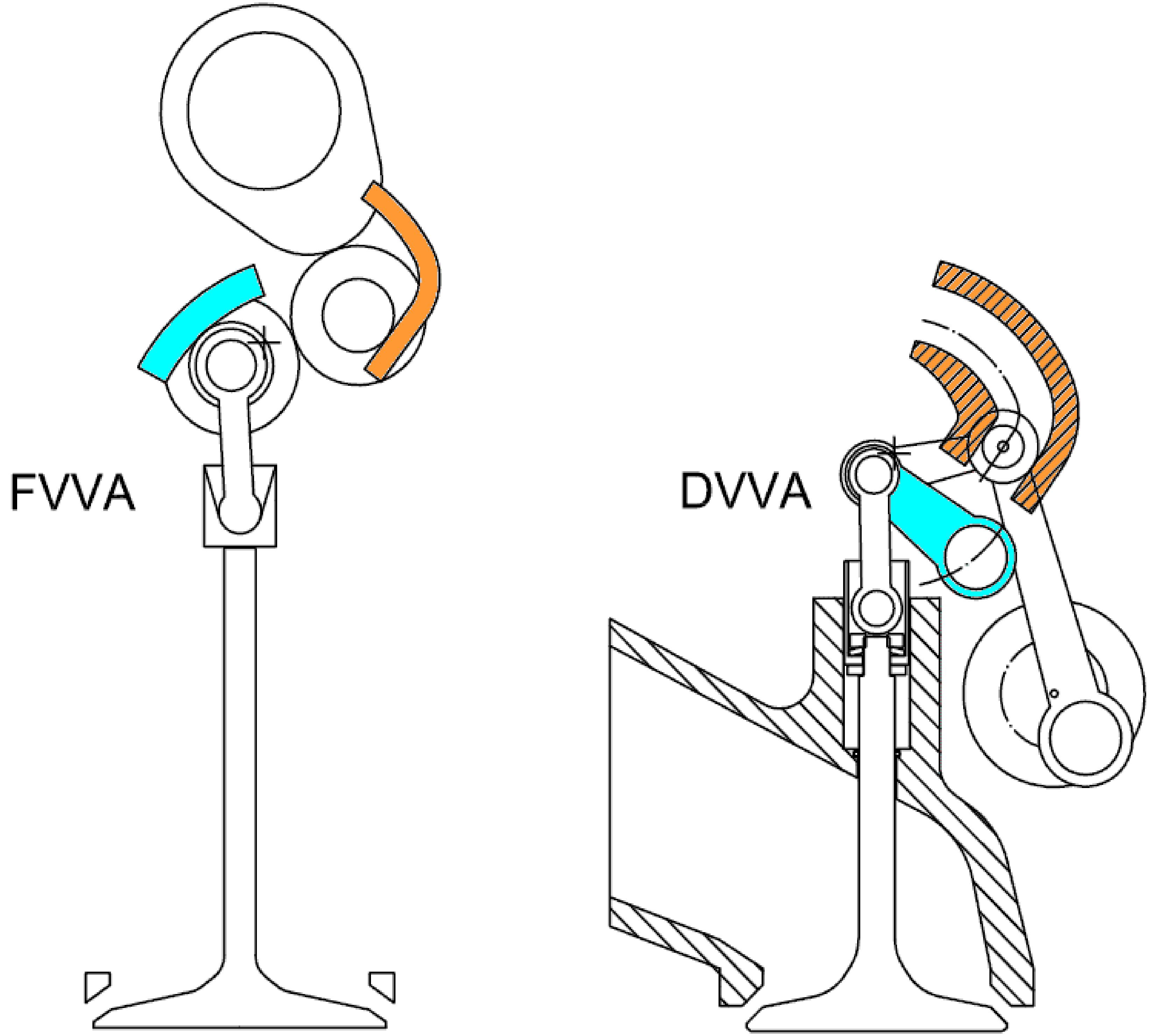
The closer to the optimum valve lift profile a VVA can approach, the better.

And the pattakon FVVA can approach much better the optimum valve lift profile keeping at the same time the advantages of the mechanical VVAs.

High revving

The state of the art VVAs cannot rev high because, among others, their mechanisms are heavy generating strong inertia loads and because they, of necessity, involve additional restoring springs that further increase the inertia loads and the friction-wear.

The usual statement during new VVA design advertisement is that the specific design is indented for emissions control, rather, than for increased power. Which really means: "forget high specific power".


FVVA
DVVA

Pattakon Desmodromic VVA (or DVVA)

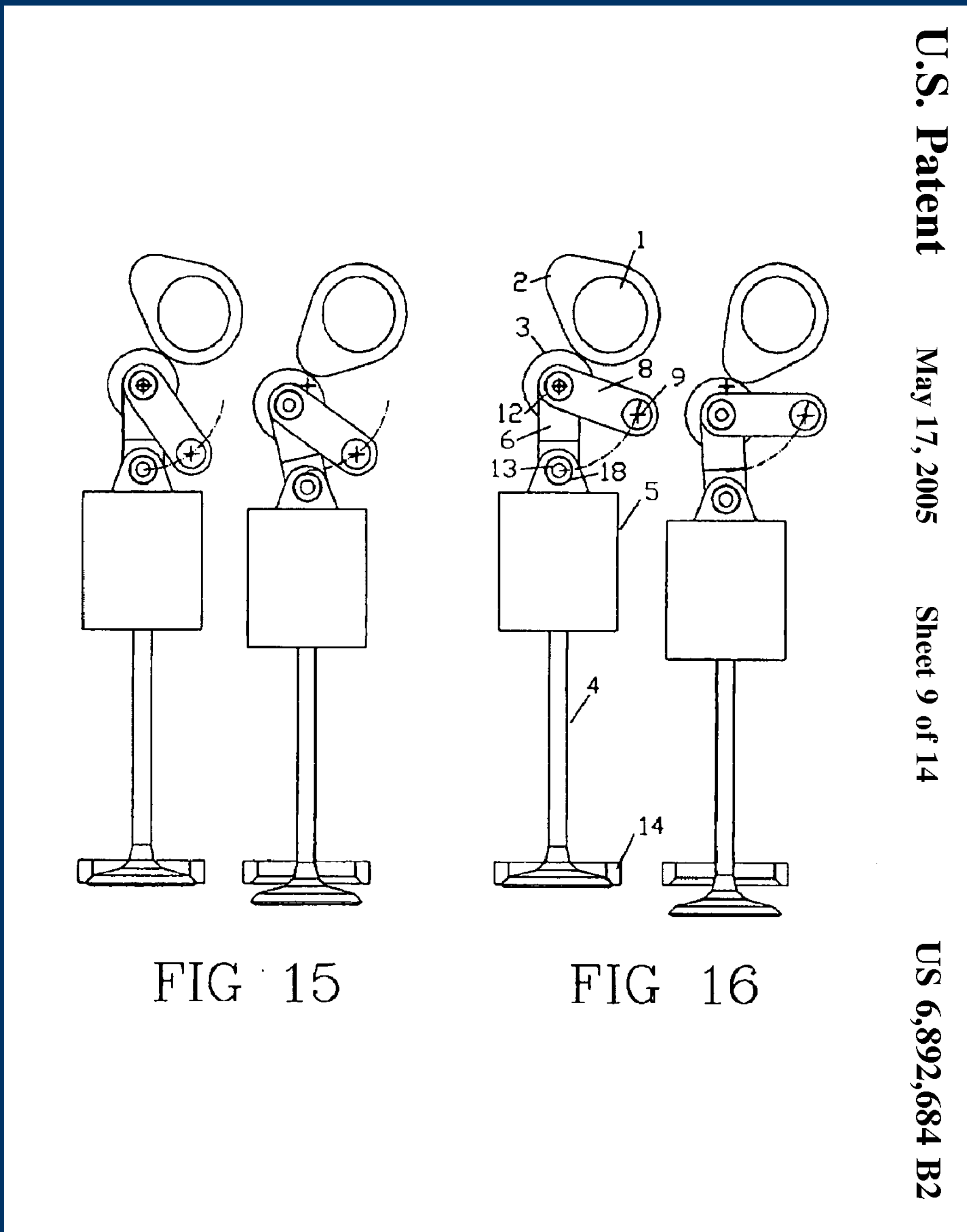
Continuously variable (from zero to a maximum) valve lift AND continuously variable (from zero to a maximum) valve duration AND independently variable "lift – duration" (i.e. for each valve lift there are infinite available valve durations AND for each valve duration there are infinite available valve lifts).

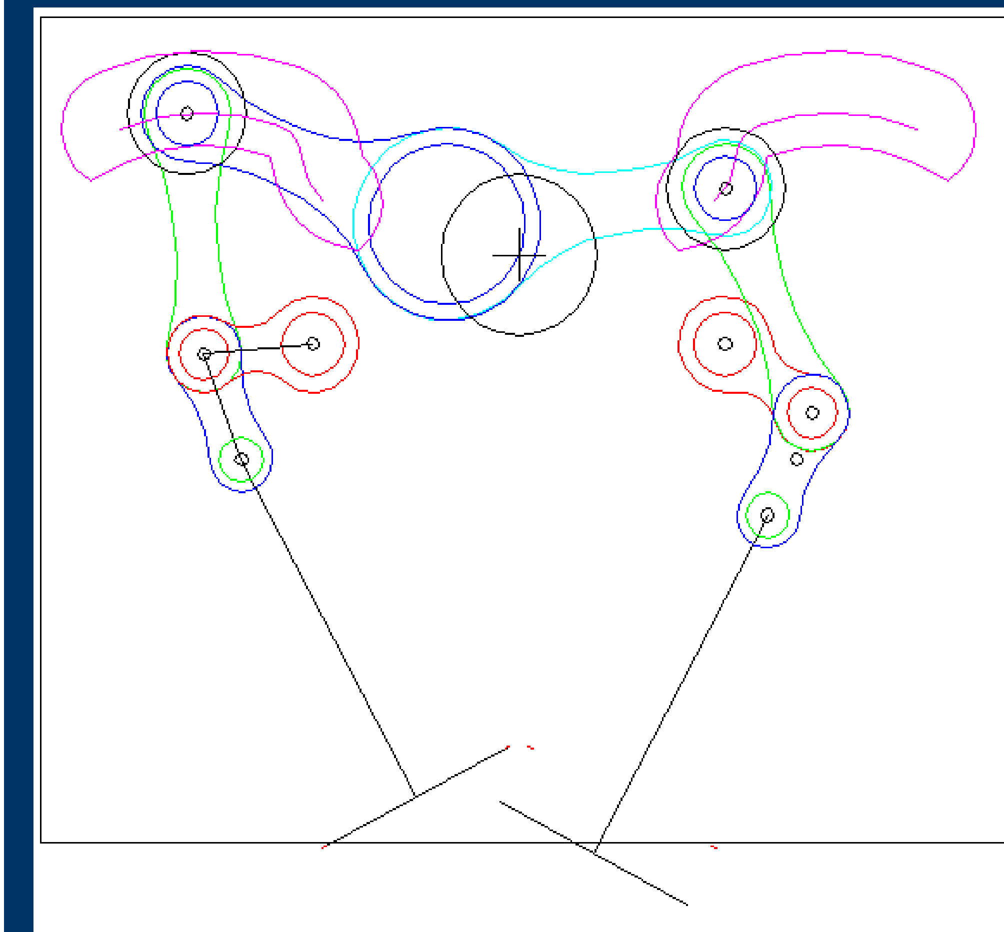
Rid of valve springs and any other restoring springs.

Compact, robust and light.

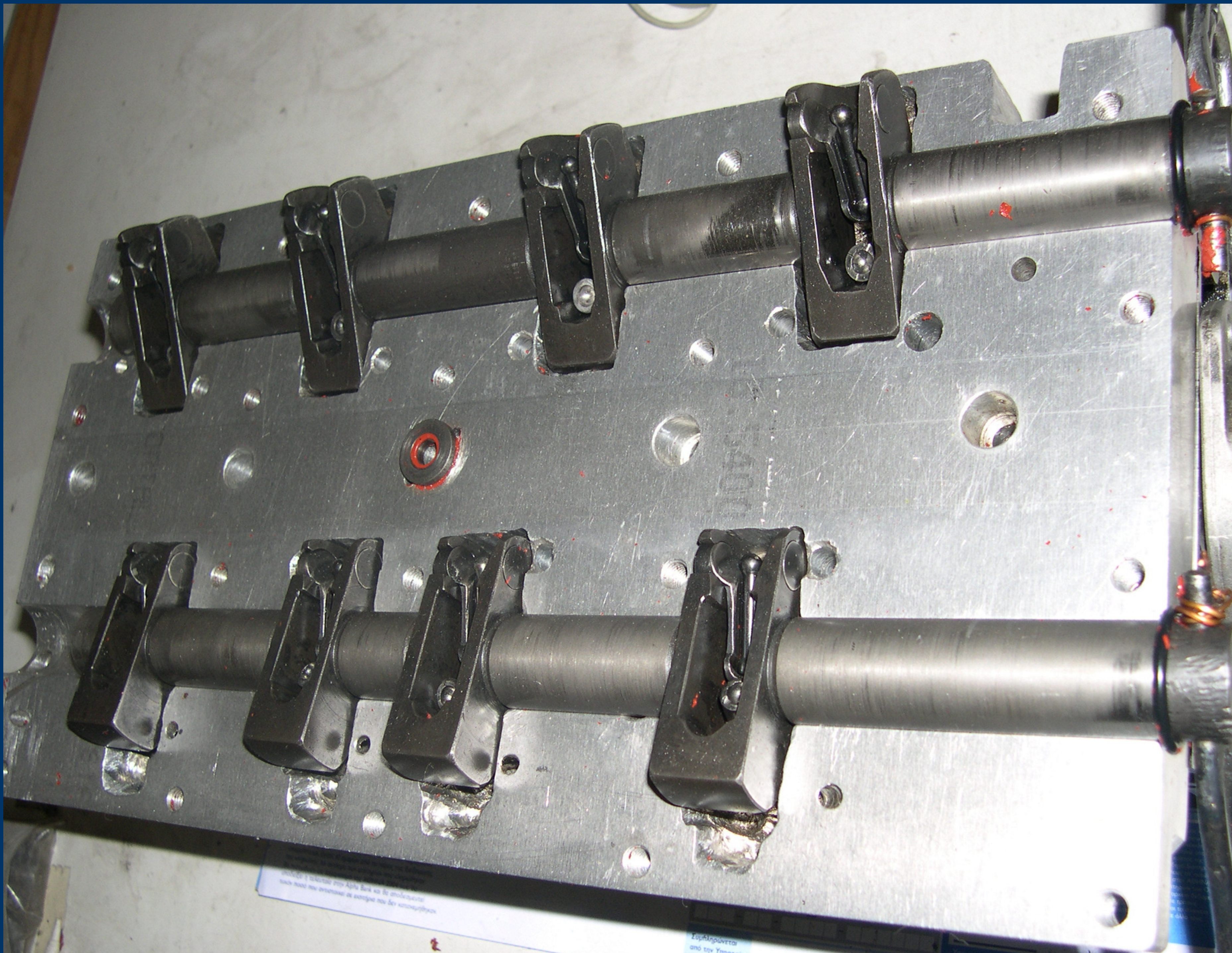
From pure mechanical to pure "drive by wire" control.

At left is the first pattakon VVA, at right is the pattakon DVVA mechanism. Compare.

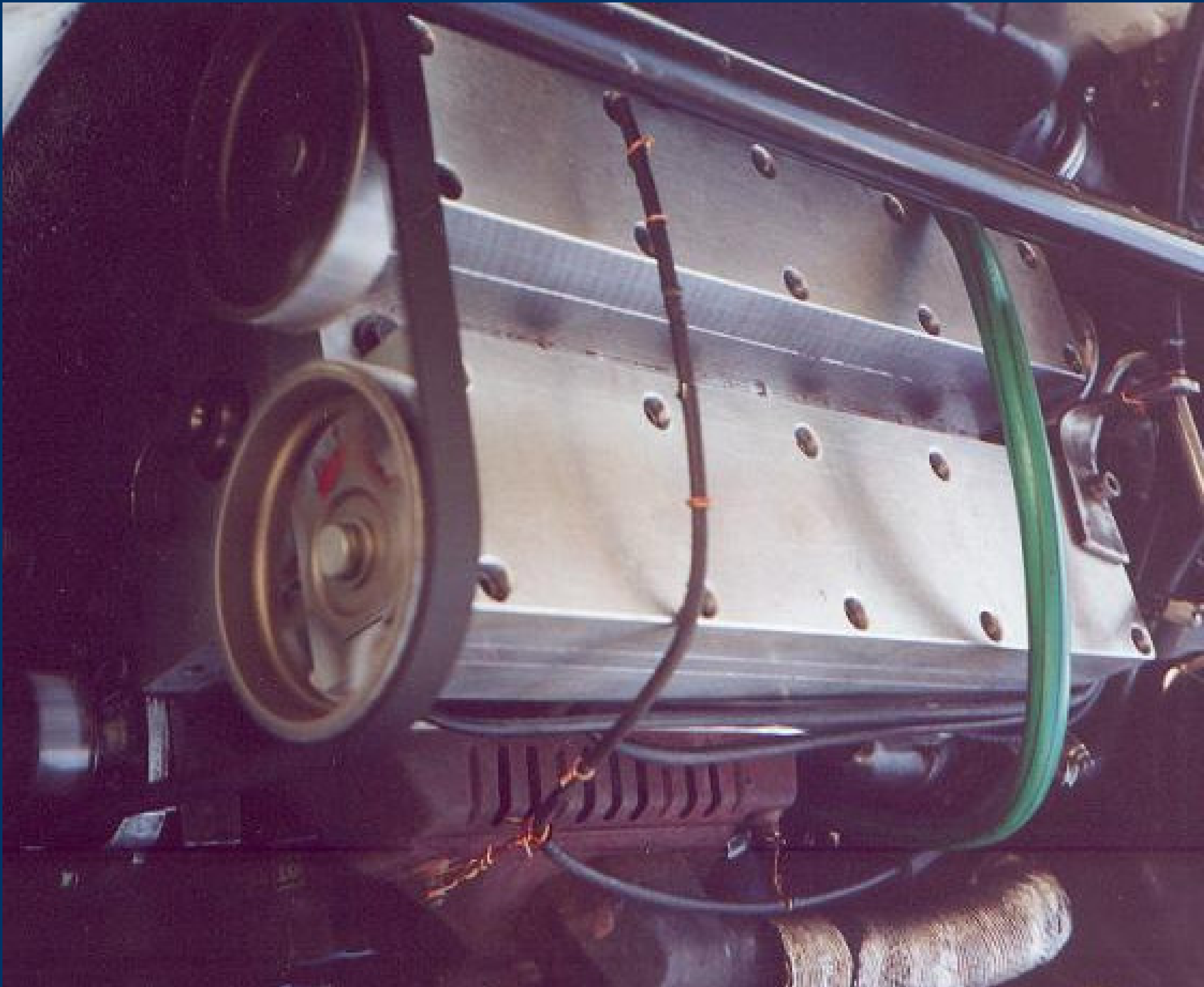




Basic parts of the 1st pattakon prototype VVA

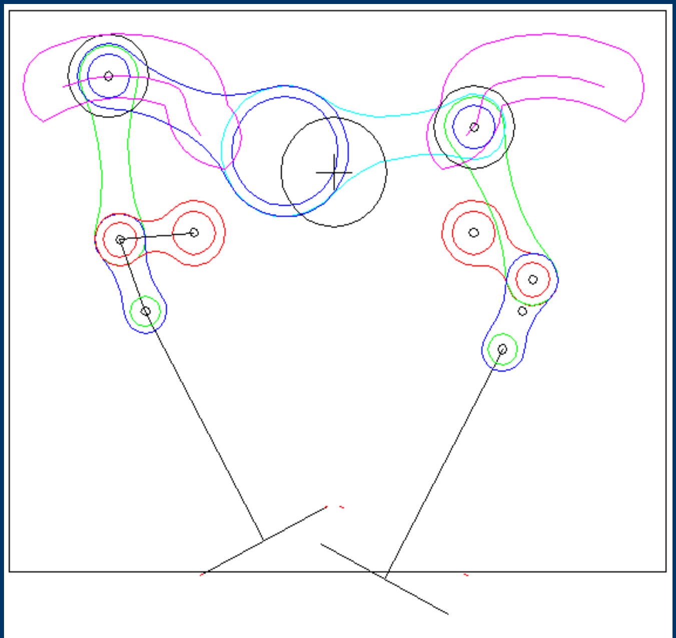
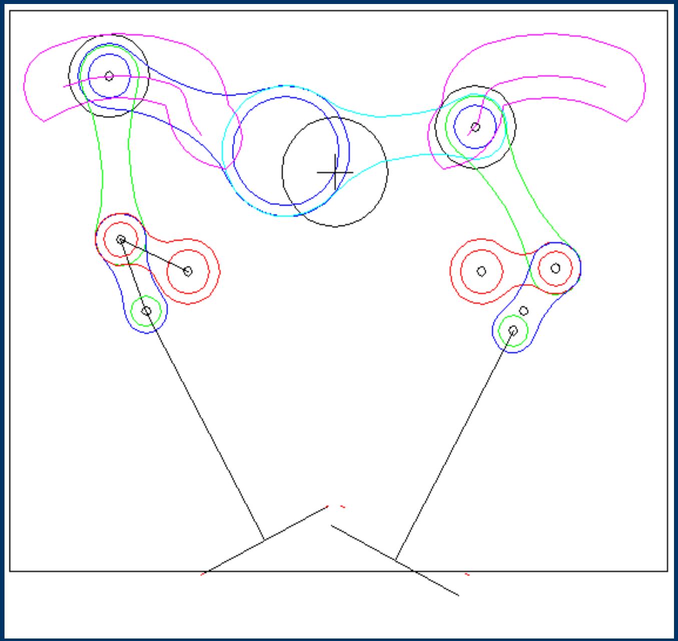
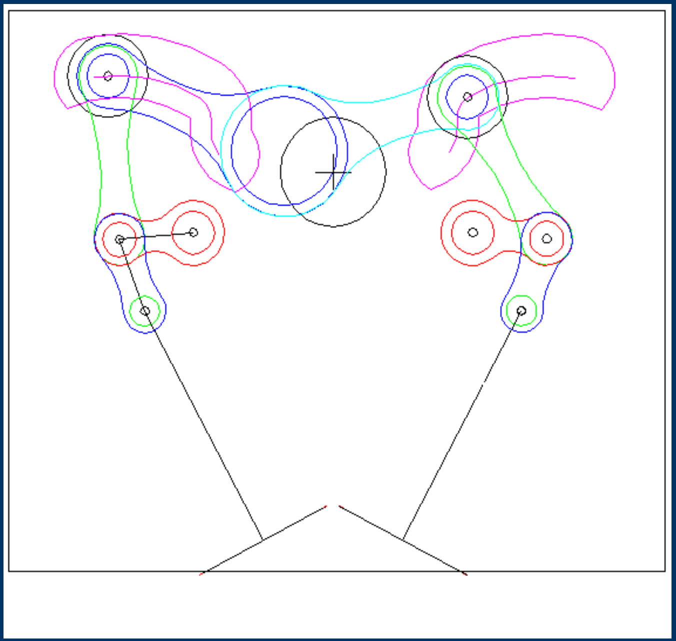


The cylinder head of the 1st pattakon prototype VVA



The first pattakon VVA, hand made, runs on Athens roads for five years without any maintenance.

pattakon Desmodromic VVA at three* different modes

Long duration High lift	Long duration Medium lift	Short duration Small lift
		

* three from the infinite infinities available

A Formula1 engine (or a motoGP or a racing engine in general) pollutes a lot, consumes a lot, idles unstably at a few thousand revs, is difficult to start, is almost "dead" at low to medium revs and at partial loads. All these sound reasonable, today.

Think of a Formula1 engine capable of sustaining its peak torque all the way down to 1000 rpm, idling at 500 rpm, having partial load response and fuel efficiency better than family car engines. All these sound like science fiction today.

DVVA : technical details.

Beyond being a pure mechanical VVA, it is also a true fully variable VVA: it can change independently the valve lift and the valve duration, providing infinite times the valve lift profiles provided by the state of the art mechanical VVAs.

Securing the "lift" control shaft, the DVVA "degrades" down to a Lost Motion VVA (LMVVA) like BMW's valvetronic (yet rid of valve springs and any other restoring springs).

Securing the "duration" control shaft, the DVVA "degrades" down to a Constant Duration VVA (CDVVA) like pattakon's prototypes (yet rid of valve springs and any other restoring springs).

Securing both control shafts, the DVVA "degrades" down to a single mode, spring-less, valve train, like Ducati's desmodromic valve train.

The valve springs are eliminated giving room for the intake ports.

A common assumption, in valve train dynamic analysis, is that half of the valve spring weight is immovable, while the other half performs the reciprocation of the valve.

In the original B16A2 engine:

Intake valve: 45 gr

Intake valve springs : 50 gr

Intake valve + (Intake valve springs)/2 + Retainer = 85 gr

Releasing the valve train from the valve springs' reciprocating weight, the red line of the valve train goes higher.

It is also the valve stem's weight, flexibility and thermal expansion. Reducing the valve stem length to half (i.e. as much as the length of the springs), the reciprocating mass is further reduced, as well as its flexibility and heat expansion.

The cost is also reduced: in order to increase the valve lift to 12mm and to shift reliably the red line to 9000 rpm, 460 euros were paid for a set of harder valve springs for the VVAr prototype engine (original engine: B16A2 1600 cc).

It is also the friction.

It is stupid, yet it is the rule today, to operate an engine at idling or at 1000 rpm using many times harder restoring springs than what is really necessary.

A valve spring capable of restoring a valve at 7000 rpm (typical rev limiter setting) is some 50 times harder than what is necessary to restore the same valve at only 1000 rpm, provided either at 7000 or at 1000 rpm the valve lift profile is the same.

Using reduced valve lift at low revs, the necessary hardness of the valve spring is even lower (some 200 times at 1000 rpm and full load).

A restoring force many times heavier than what is really necessary, means friction, wear and reduced smoothness.

The DVVA, on the other hand, imparts to the valve only the necessary force to perform its reciprocation: from light at low revs to extreme at red line.

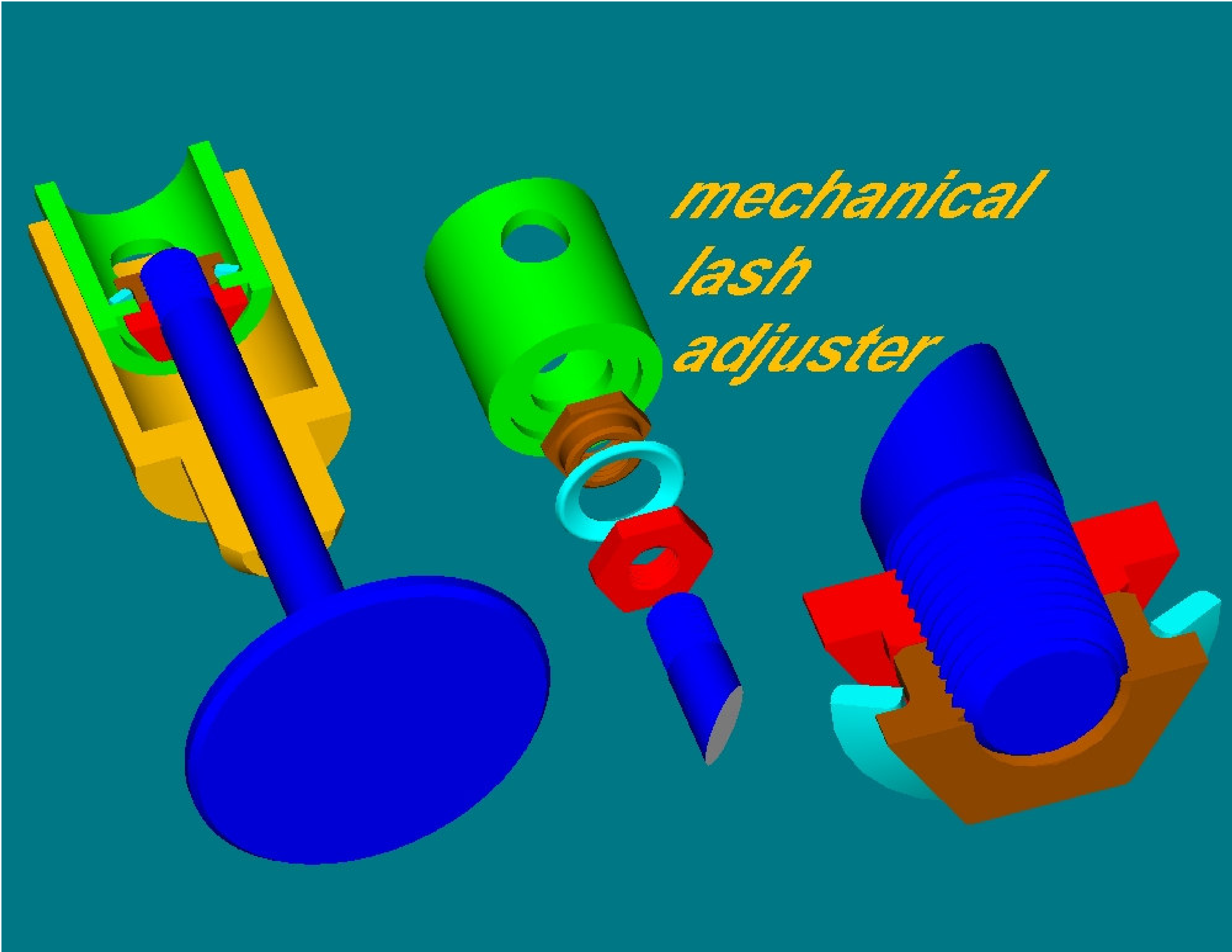
Similarly light is the gas pedal of the DVVA (especially at low lifts and low to medium revs).

Pure "drive by wire" can be the case.

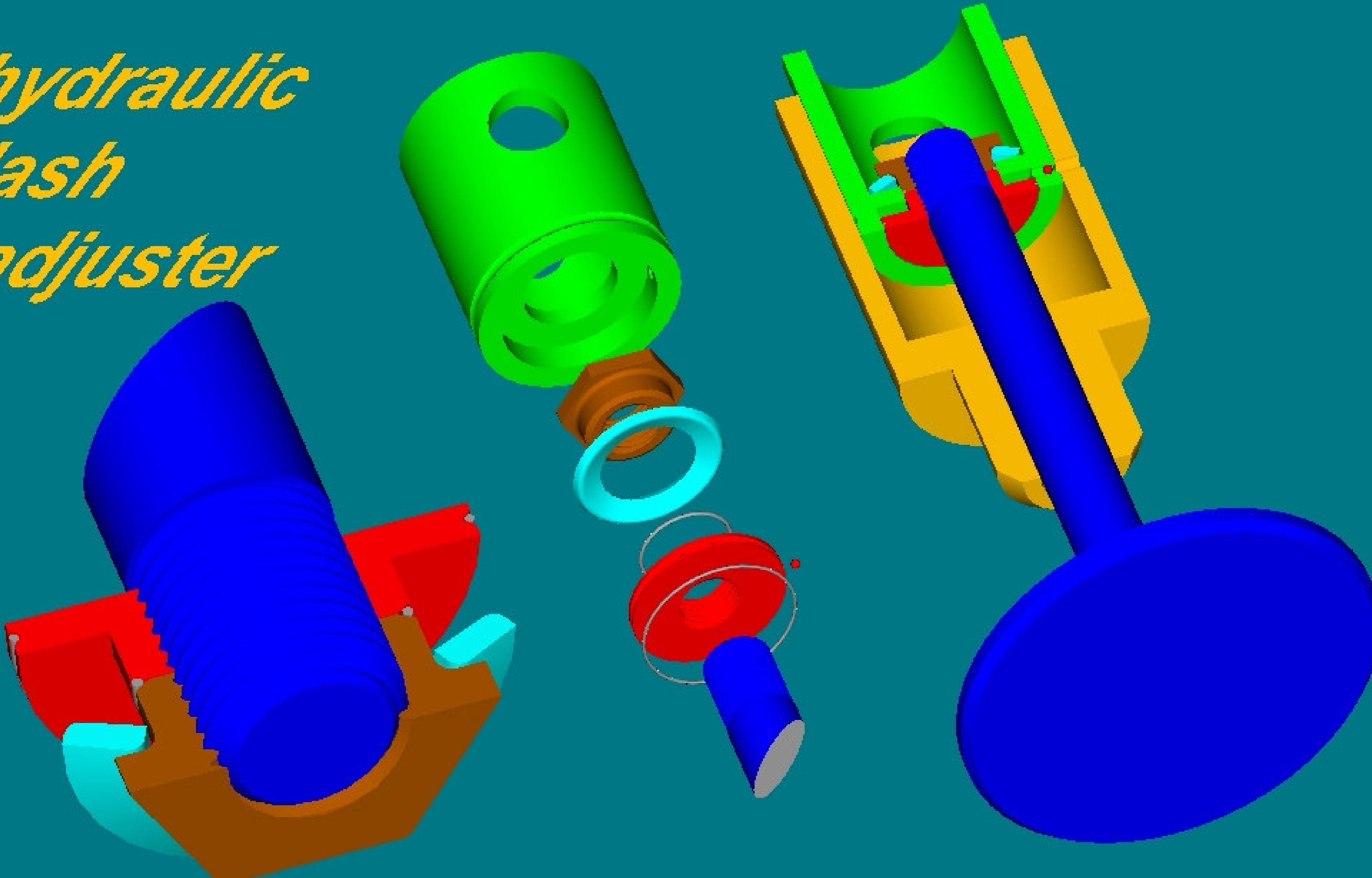
Partial "drive by wire" has advantages, too: the driver can directly control (through the gas cable) the "lift" intake control shaft to get the best in direct response, while servo motors can rotate the rest control shafts according ECU's commands.

Pure mechanical control can also work: the driver rotates directly (through the gas cable) the "lift" intake control shaft, while the rest control shafts are "linked" (mechanically or in other way) to the primary "lift" intake control shaft.

For racing use, the lash adjustment is mechanical. For normal applications (like mass production cars) the DVVA can use hydraulic lash adjusters in order to avoid the need for valve lash adjustment.


mechanical
lash
adjuster

hydraulic lash adjuster



An application:

The DVVA applied on a motoGP engine can be "degraded" down to fit the reliability, performance, direct response and "easy of control" needed in a race.

The rider rotates (by the grip) the intake "lift" control shaft, while he has a lever to change – when he decides so – the angular position of the intake "duration" control shaft (the way, for instance, he now controls his suspension characteristics).

The exhaust can be single mode desmodromic (both exhaust control shafts are blocked), or variable lift (for instance by linking the exhaust "lift" control shaft to the intake "lift" control shaft) or independently variable lift and duration.

Depending on race conditions (dry or wet race-way, last lap, need for more than top power for a few seconds etc) the rider has the way to align instantly his engine characteristics of torque and power.

In a more simplified edition of the DVVA, all control shafts are fixed. This way the DVVA "degrades" down to a single mode desmodromic valve train (like the current motoGP champion Ducati) with throttle valve and conventional control.

Besides saving space and weight from the cylinder head, the improved breathing and combustion reduce the fuel weight necessary for the race.

The existing electronics are more than adequate: memory space to store additional injection and ignition tables, depending on the angular position of the control shafts.

The reduced reciprocating "valve" mass,

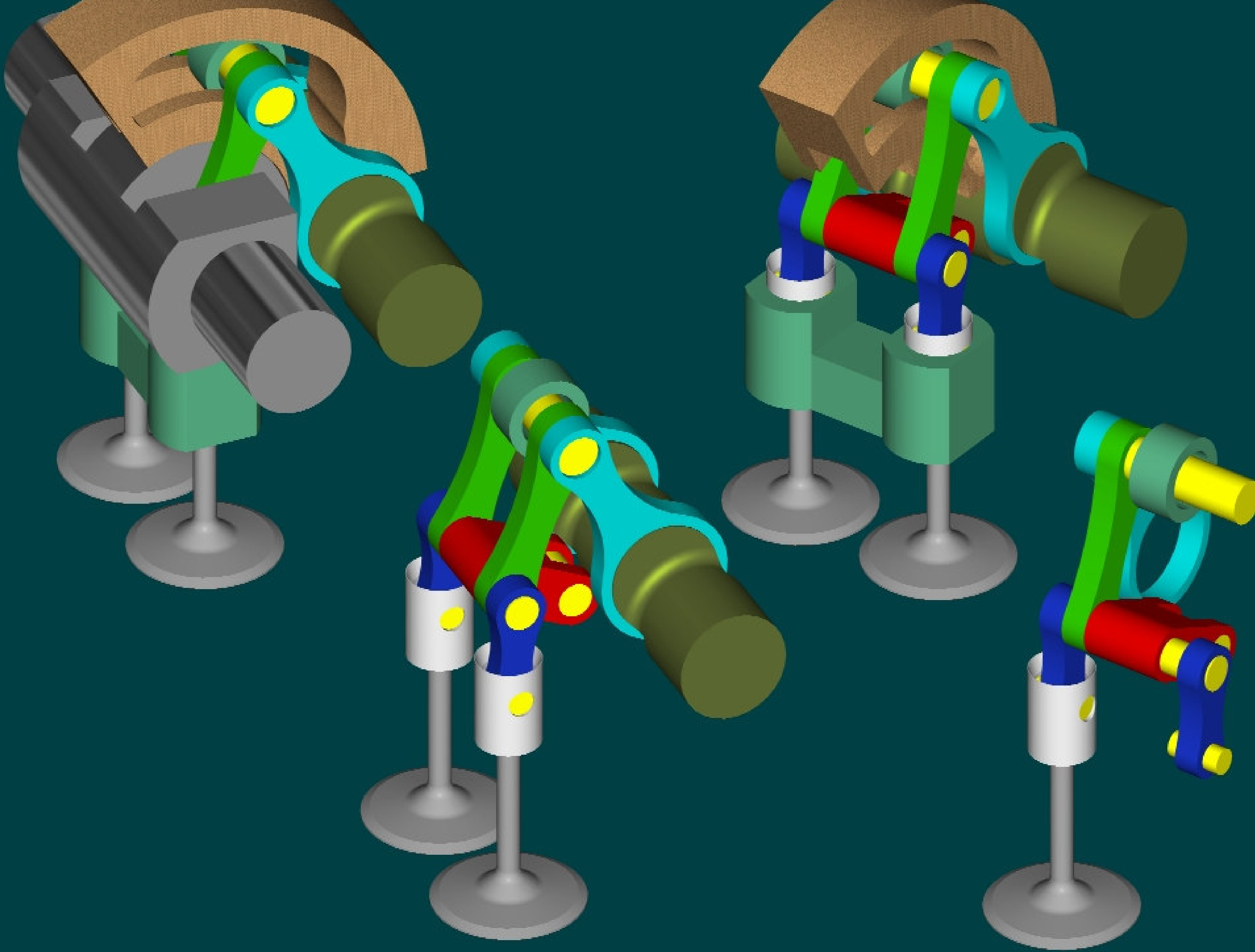
the absence of valve springs,

the reduced flexibility and thermal sensitivity of the valve train (halving valve stem length and having all "rods" of the DVVA linkage rid of bending moments),

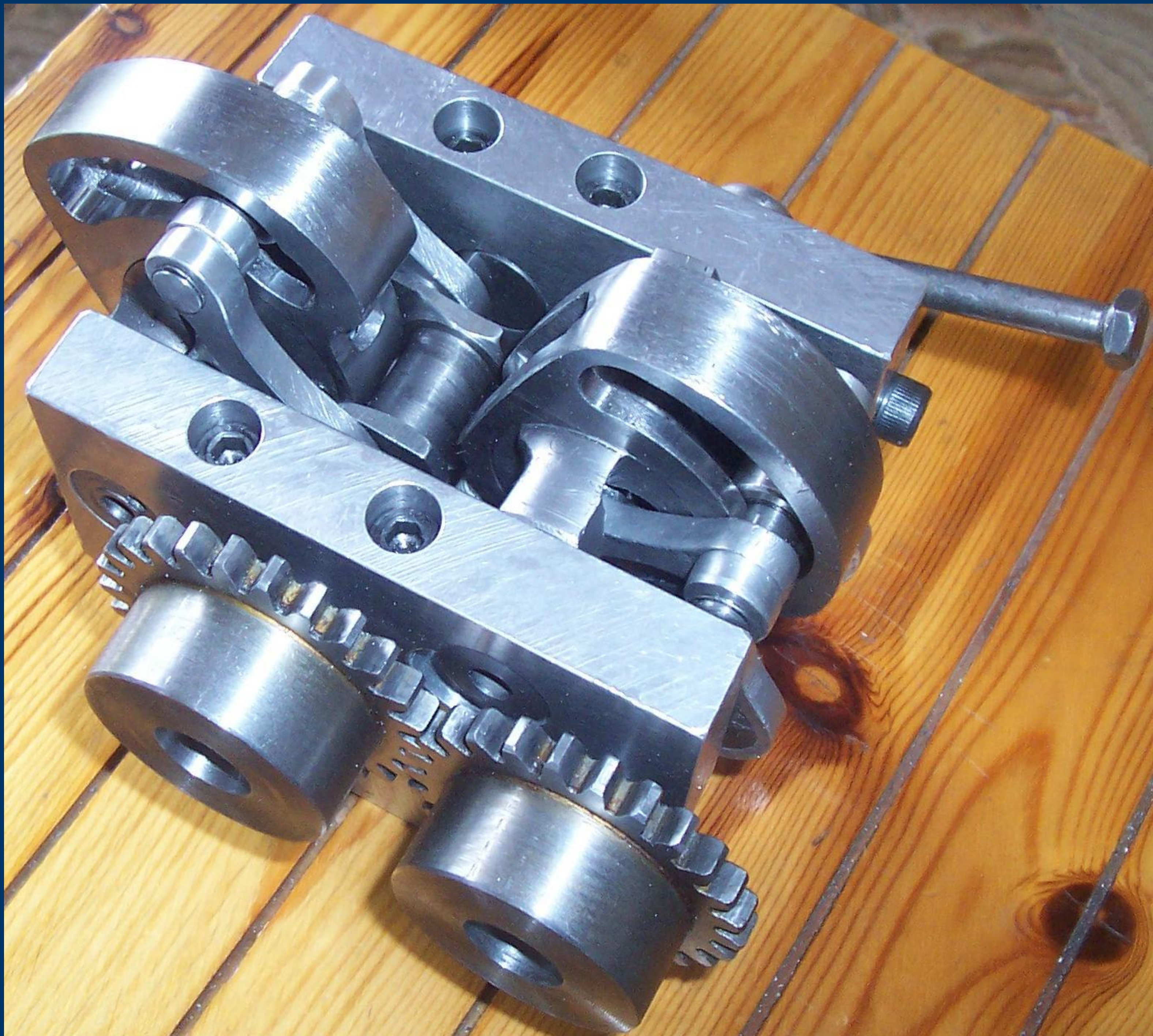
allow true high revving and more specific power, which also means improved economy and emissions (remember the 1000cc moto engine this presentation started with).

The infinite, directly available, valve lift profiles improve the torque output throughout the entire rev range as well as the partial load characteristics, the easy cranking, the low rev idling.

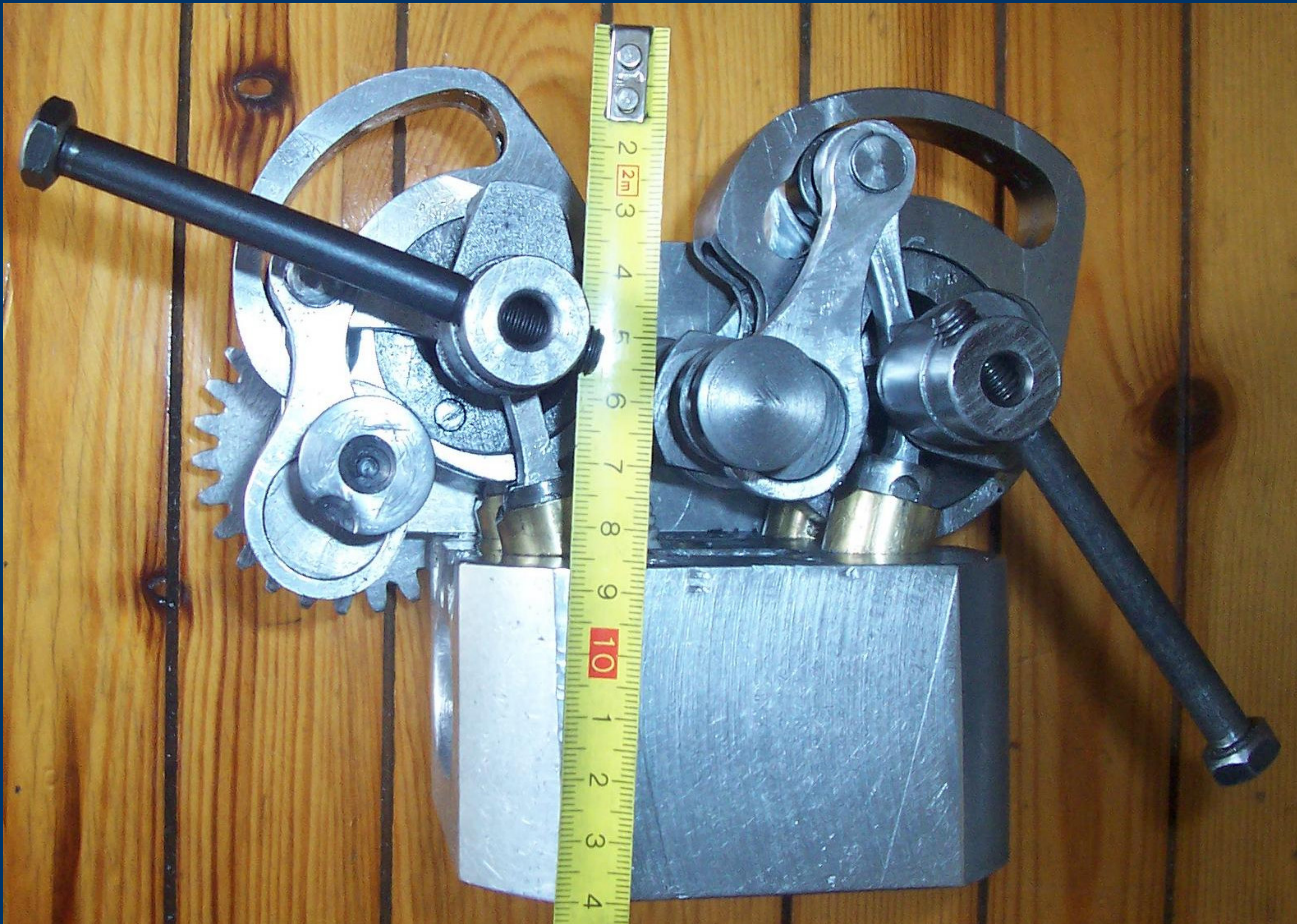
DVVA mechanism



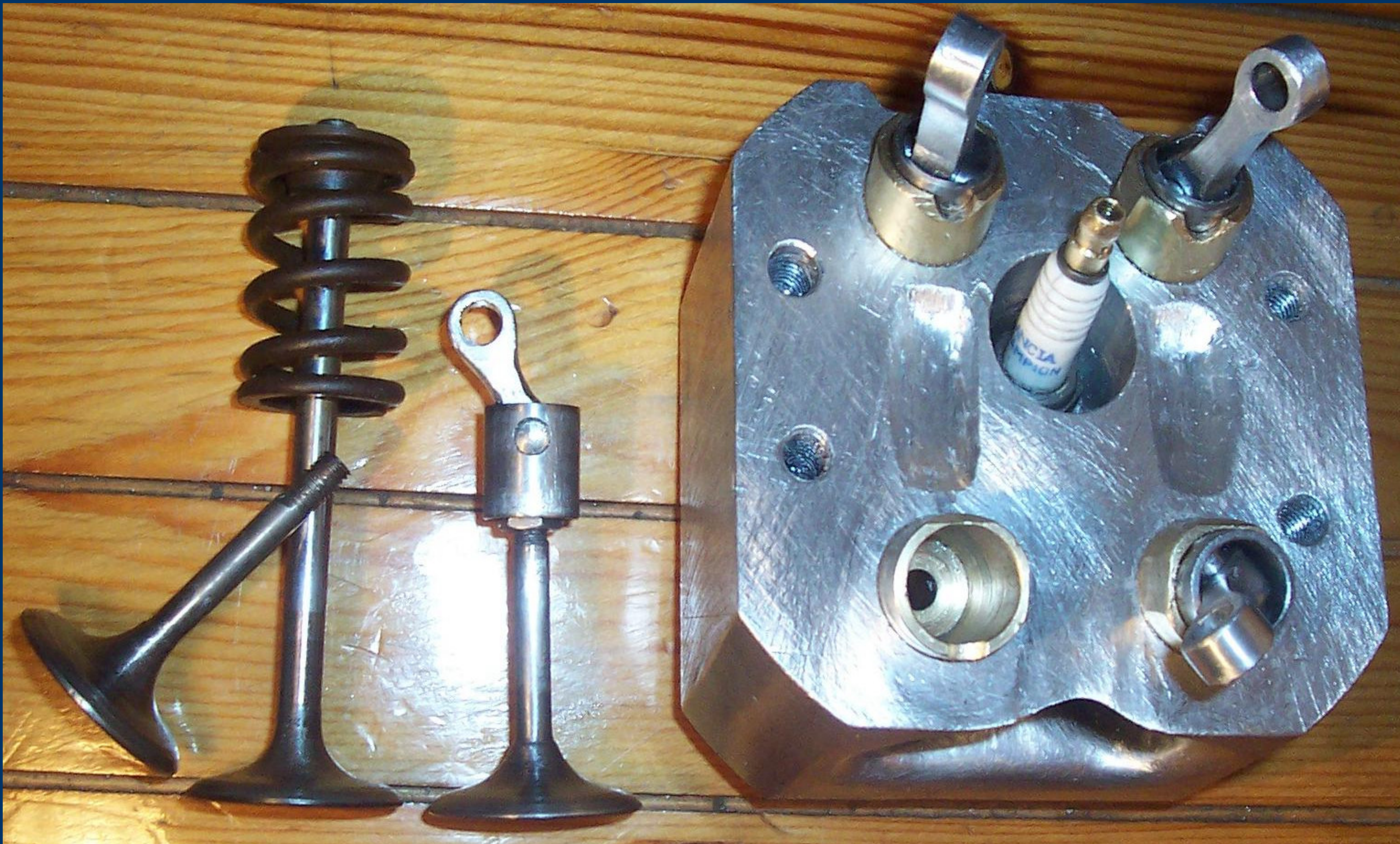
DVVA head for single cylinder engine (87mm bore). 35mm intake valves (14mm maximum lift), 30mm exhaust valves (12 mm maximum lift).



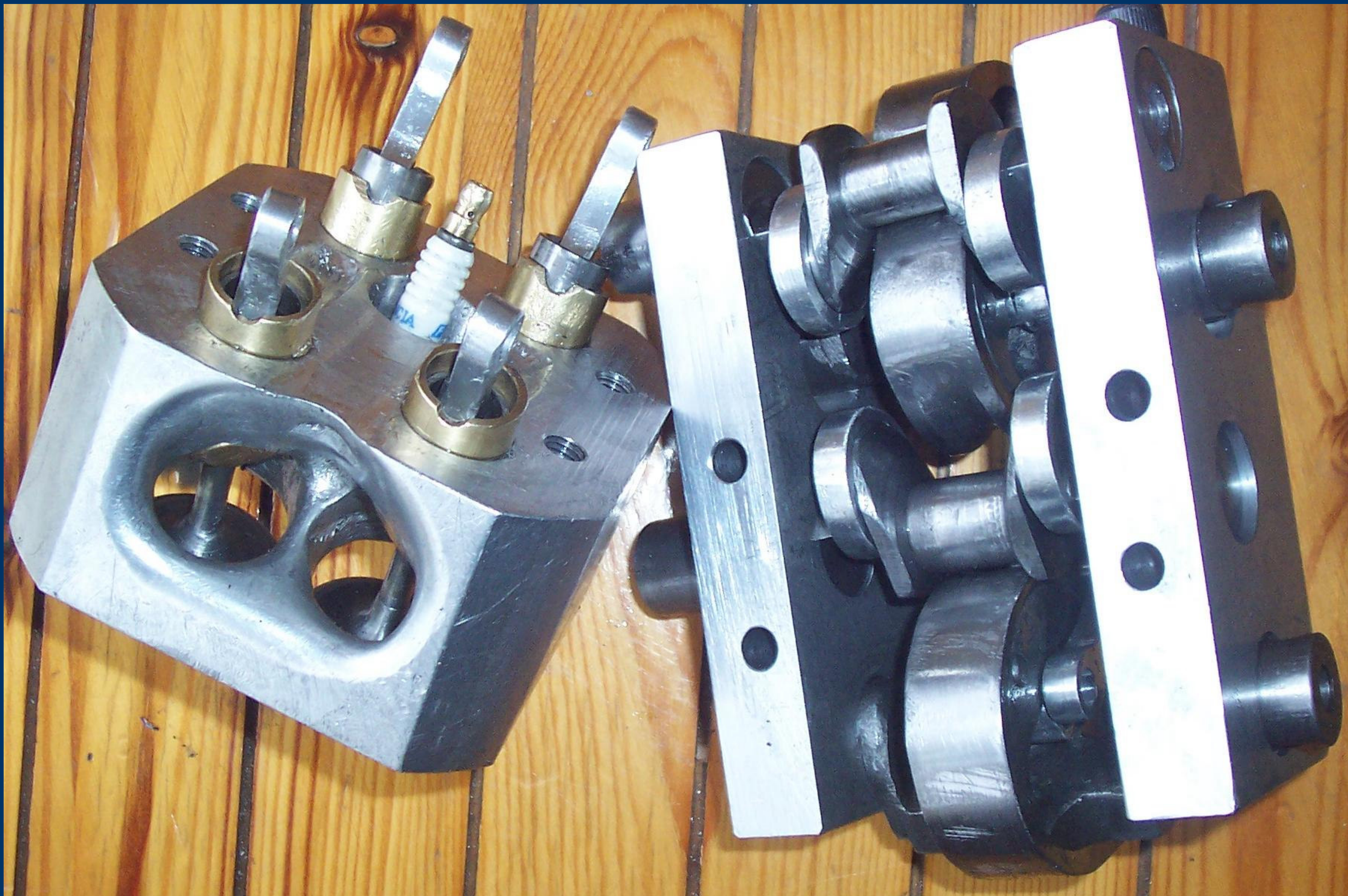
DVVA head for single cylinder engine. Total height 140 mm



The conventional intake valve with its valve spring versus the DVVA valve. Centrally located spark plug.



Upper and lower part of the DVVA head



idling

The pattakon Civic 1600 cc prototype makes its peak power at 9000 rpm (12mm valve lift) and idles at 300 rpm where the necessary lift of the (33 mm diameter) intake valves is only 0.15 mm (throttle-less).

At idling the passage through which the mixture enters the cylinder is like a rectangle having long side to sort side ratio more than 1300 !

Think the effect of the slightest difference between the lifts of the intake valves.

The state of the art throttle-less VVAs cannot idle correctly at very low revs. It is a matter of feeding-balance between the cylinders. It is also a matter of air-mixture swirl and turbulence "the right moment".

In order to improve the idling of ***any throttle-less VVA engine****, pattakon's solution is the* ***idle valve****: during idling the big intake valves of a cylinder are completely deactivated (i.e. they stay close) while the feeding of the cylinder is realized by an additional intake valve of small flow capacity (idle valve).*

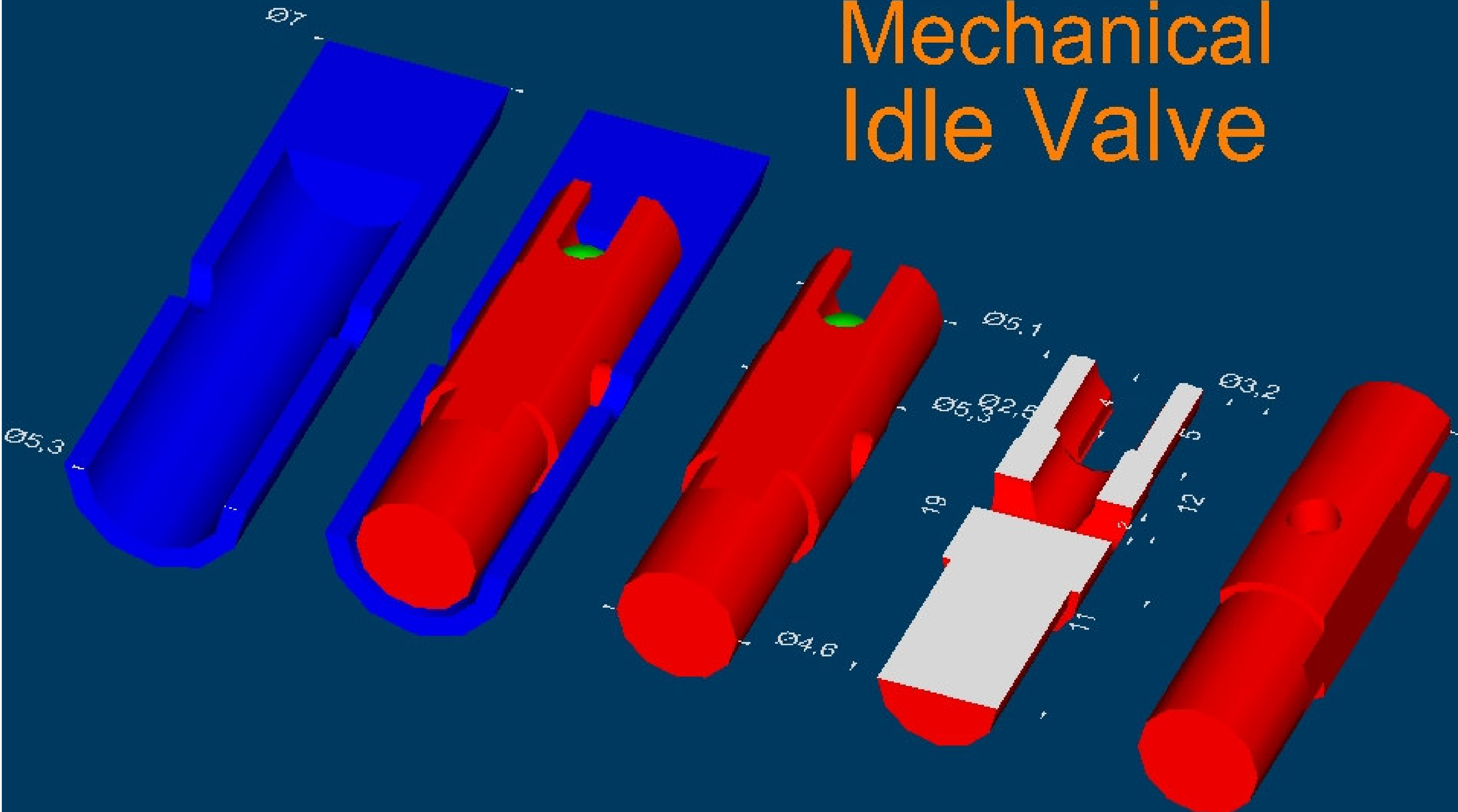
pattakon ***idle valve*** *is the ideal application for* ***electromagnetic valves*** *because an* ***idle valve*** *is a few times lighter than the normal intake valve, because an* ***idle valve*** *performs a stroke a few times shorter than the normal intake valve stroke, because an* ***idle valve*** *operates at revs a few times lower than redline.*

The idle valve control can be similar to the control of the typical injectors. The ECU signals each idle valve to open at the optimum crankshaft angle and, after some milliseconds, signals the idle valve to close.

mechanical idle valves (3 hours/litter at 330 rpm)

3 hours/litter at 330 rpm idling, top specific power at 9000rpm

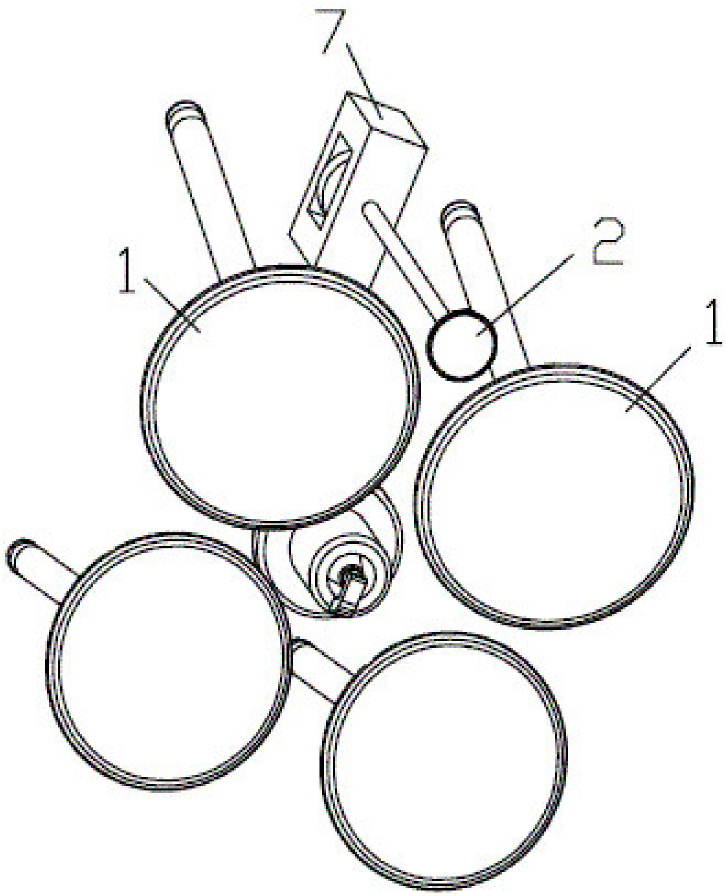
Mechanical Idle Valve

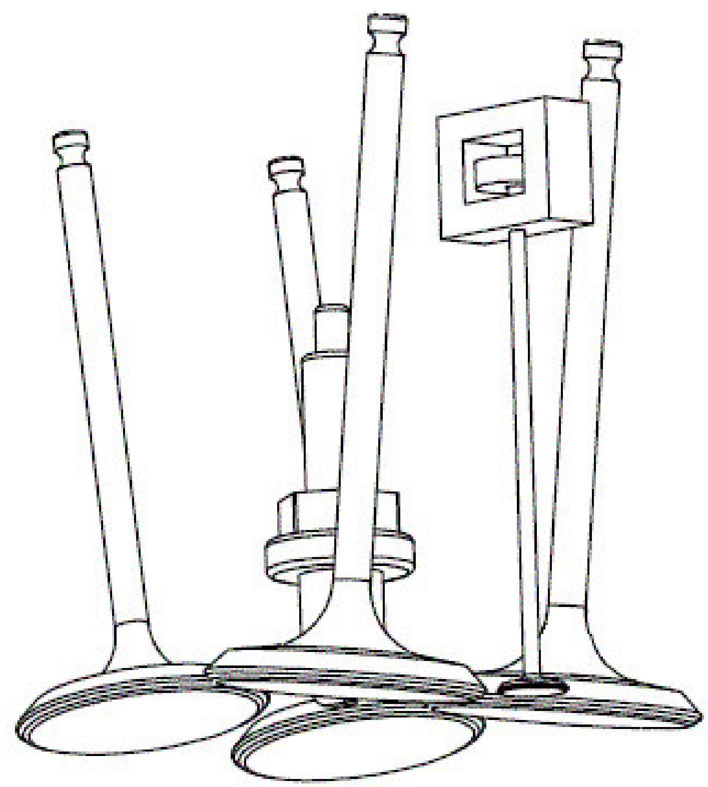


Changing the duration the idle valves stay open, changing also the idle valve advance, the engine keeps control on idling in order to drive various appliances (loads), like air condition, power steering etc.

With smart control (different idle-valve-advance and idle-valve-duration from cylinder to cylinder) and feedback from the oxygen sensor, the ECU can easily balance all cylinders to optimize idling consumption, idling emissions, idling smoothness etc.

electromagnetic idle valve





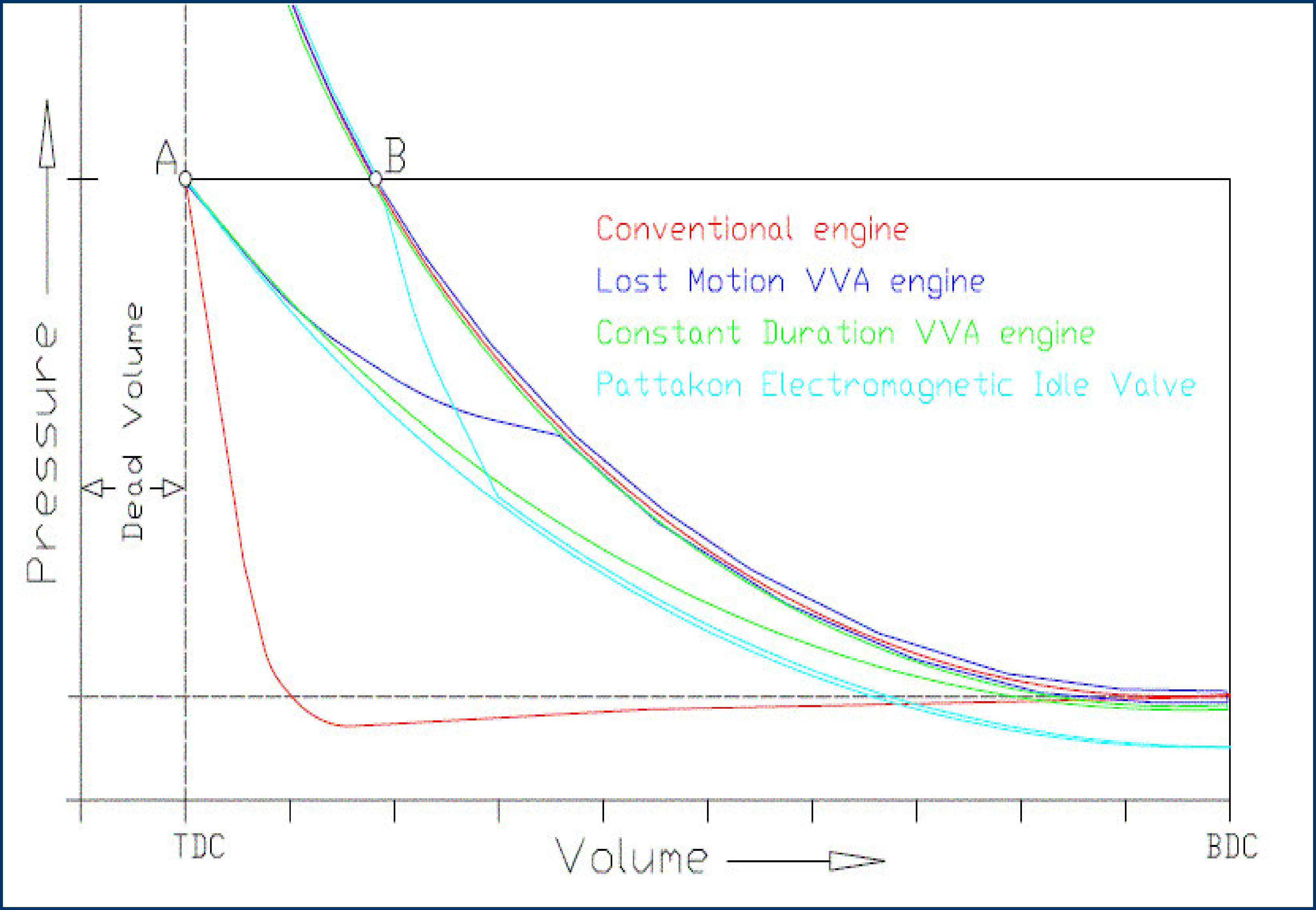
The slightest difference between the lifts of the normal intake valves, let say a +/- 0.02mm valve-lash-difference from valve to valve (which, by the way, is the increase of the valve length when temperature increases by 17 degrees centigrade) causes, during idling, an intolerable difference in the quantity of mixture entering the cylinders during suction cycle.

To expect from the same intake valve to operate the one moment at 9000 rpm and 12 mm valve lift and the next moment to control the idling performing a precise stroke of 0.15mm is overoptimistic.

Besides controlling idling, the idle valves can also control the operation of the VVA engine at low revs – partial loads (for instance at down-town traffic): as long as the flow capacity of the idle valves is adequate to provide the power necessary for the vehicle, the normal intake valves can stay close.

The following indicative plot reveals the idling problems of the various valve trains. It is significant to reduce the pumping loss, indeed. But it is more significant to keep the combustion efficiency good. From all systems only the "electromagnetic idle valve" combines the minimization of the pumping loss with the optimization of the mixture homogeny, turbulence and swirl ***at the combustion time.*** *The electromagnetic idle valves optimize all: idling smoothness, consumption and emissions.*

More significant than the pumping loss reduction is the swirl and turbulence boost at combustion time



The typical VVA approach is to open slightly, just after TDC, the normal intake valves and to close them before middle stroke. This reduces the pumping loss in expense of turbulence and swirl. Having a long "dead period" (some 270 crankshaft degrees) from the moment the intake valves close to the moment the ignition occurs is no good.

The small electromagnetic idle valves, on the other hand, share equally the charge between the cylinders, demanding neither extreme construction accuracy, nor special cooling system, nor periodic adjustments. They also improve the consequent combustion because they freely phase the opening and closing of the idle valves, optimizing the turbulence and the swirl during combustion (even with zero "dead period").

VVA: great idea, poor results

VVAs are used to optimize the breathing of the internal combustion engines.

Unable to operate reliably at high revs, VVA engines became synonymous to poor performance engines.

Unable to approach closely the ideal (for the existing conditions) valve lift profile, VVA engines did not achieve yet to show their great superiority (smoothness, response, consumption, emissions etc) compared to conventional.

VVAs can do more

Top power needs true high revving VVA.

Optimization of economy, emissions, response etc needs fully variable VVA.

Smooth, stable, economic idling needs idle valves.

pattakon VVAs do more

Offer infinite times the "valve lift profiles" offered by the state of the art mechanical VVAs.

Operate at racing revs.

Idle perfectly.

thank you

for more details:

www.pattakon.com