# THE PROBLEM OF CONTROLLING FOUR-STROKE ENGINES; THE NEED TO ALTER THE CONVENTIONAL METHOD, AS JUSTIFIED BY THE EXAMPLE OF OTTO ENGINE

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**A reasoned proposal for the modification of the controlling method of four-stroke engines, and motivation of the importance of and the need for such modification**

Below, I want to outline the controlling techniques presently applied in operating four-stroke internal combustion engines, together with the enumeration of their distinctive features, as well as to present a completely new control concept, which, based on some innovative features, is capable of properly operating four-stroke engines, and may offer an alternative to the conventional controlling methods. First of all, however, mention must be made of the importance of engine control, of its precision, and of the control parameters to be applied to ensure proper functioning of the engine.

*Said issues are outlined in accordance with the below aspects:*

I. Proper engine control as precondition of good functioning, and the importance of precision
II. Engine controlling techniques presently applied, and their basic features
III. An alterantive to the presently applied control approach, and its basic features
IV. Summary

## I. Proper engine control as precondition of good functioning, and the importance of precision

The principle of operation of four-stroke engines, as suggested by the name, is based on the continuous succession of four cycles, i.e, their operation is realized by the succession of the individual cycles.

<u>*These are:*</u>
- Suction
- Compression
- Power cycle (firing stroke, combustion and expansion)
- Exhaust

In order to achieve that the consecutive continuity of these four strokes or cycles is transformed into a rotary movement and to obtain thereby some source of power, it is necessary to regulate - by utilizing the movement of the piston - the pressure conditions inside the cylinder. The four basic cycles are generated in function of the controlled pressure conditions within the cylinder. In fact, the proper control of pressure conditions in each cycle, equals to safeguarding the perfect functioning of the engine. This **regulation of pressure conditions** is referred to as **engine control**. With internal combustion engines, kinetic energy is obtained by ensuring the fulfilment of the above criteria. The development of pressure conditions can be represented in a diagram. The formation of pressure conditions regularly required for ensuring correct motor operation, is safeguarded by certain components.

Also the position of said components, expressed in degrees, can be visualized by means of diagrams. They are referred to as **valve timing diagrams**. Parameters that can be read off of the valve timing diagram are used to guarantee the development of pressure conditions inside the cylinder, required for the economic operation of the engine.

Accordingly, **the suction valve opens at the end of exhaust stroke, 15 to 50 degrees before top dead center, then it closes at the beginning of compression stroke, 50 to 70 degrees after bottom dead center.**

**In suction stroke,** the piston travels from the top dead center position towards the bottom dead center position. Until the piston reaches bottom dead center, a continuous volume gain is observed, as a result of which, the cylinder gets filled up with a gaseous mixture made up of gasoline and air, entering the cylinder through the now open suction valve. Upon the piston arriving at the bottom dead center, the pressure within the cylinder will have reached a value of **0,5 to 0,6 bar**. Closing of the valve after bottom dead center is necessary, as the build-up of **1 bar** pressure in the cylinder must be waited for, to allow the engine and the cylinder, respectively, to go on getting filled up with gases even during that time **(pressure compensation within the cylinder).**

This phase is followed by that of **compression.** The piston travels from bottom dead center towards top dead center. A continuous volume reduction is taking place within the cylinder, as a result of which, the mixture of gasoline and air gases that have been sucked into the cylinder is condensed until (the piston) reaching top dead center.

At the end of compression cycle, at the moment of firing, pressure inside the cylinder will have risen to **10-11 bar**. The cylinder is kept closed by the suction valves and the exhaust valves.

**At combustion,** the pressure suddenly rises to a value of **30 to 33 bar**, and the force thereby resulting, will cause the piston to move from the top dead center position towards the bottom dead center position.

Now, **the exhaust valve can be opened, 90 degrees before the piston's bottom dead center position.** At bottom dead center, the pressure measured in the cylinder will have dropped to **3 to 5** bar.

**In exhaust stroke,** the piston will travel from its bottom dead center position towards top dead center position, while causing exhaust gases to escape from the cylinder into the atmosphere, through the now open exhaust valve and exhaust system, respectively. **The exhaust valve will close at the beginning of suction cycle, 5 to 10 degrees after top dead center.**

It is appearant, that at this point, some sort of **'intercommunication of valves'** is taking place at the end of the exhaust stroke (the suction valve already in progress of opening), and at the beginning of the suction stroke, respectively (the exhaust valve still in progress of closing). This phenomenon is referred to as the **scavenging** of the engine.

Now, I want to discuss this particular function of the engine in somewhat greater detail. To my view, this is important, as little attention is paid to this specific issue, and even in the technical literature this question is treated marginally. Here and there mention is made of the phenomenon but no in-depth studies are available. In my opinion, however, in addition to the four basic cycles, the state (phase) of scavenging constitutes a sort of 'background stroke'. In said position, **the inlet (suction) side, the cylinder and the exhaust side,** in other words the whole system that is responsible for the development of rotary motion, is entering **a state of 'confluence' or 'communication'**.

This is of special significance from the point of view of ensuring that **pressure compensation may take place** in all three units supportive of engine operation **(in the entire system).** The state of scavenging during engine operation is of decisive importance, and is practically of the same rank as any of the four basic strokes, constituting an essential aspect of functionability.The absence of said state would render continuous engine operation impossible, by causing the engine to 'choke'. Said interconnection and confluence of the complete system that is responsible for engine operation, ensure proper scavenging (rewashing or interflushing), in a phase between the end (exhaust) and the beginning (suction) of engine operation. At the end of scavenging (exhaust valve closes), processes responsible for smooth engine operation, restart in a 'refreshed' condition. For an engine, the state of scavenging is like having a breath of invigorating fresh air for a living organism.

The longer the scavenging takes, the 'fresher' the engine will become. In other words, the wider choice of scavenging is provided, the more air ('breather') is supplied to the system maintaining engine operation.

With valve-controlled engines, said 'communication' of the cooperative sections is limited, due to the determined motion of the individual components. In case of valve-control, said parameter expressed in degrees will indicate an **angular displacement of maximum 30 degrees** in relation to the **main shaft** (crankshaft) and that of **15 degrees** in relation to the **camshaft.** However, in exhaust cycle, the suction side could be opened as early as in the last third of the travelling phase of the piston (**60 degrees** before reaching top TDC), while the closing of the exhaust side could be extended (up to **30 degrees** after the upper TDC), at the start of the suction cycle.

Thus, the duration of scavenging would correspond to an angular displacement of **90 degrees** in relation to the **main shaft,** and **45 degrees** in relation to the **camshaft**. These values represent, in case of four-stroke engines, **the extreme the limits of scavenging** possibility. However, as mentioned earlier, such a wide scavenging possibility cannot be realized with the valve-controlled approach, due to the determined position of the engine components.

What has been said above, refer to the control parameters ensuring the operation of four-stroke Otto engines. These parameters must be extremely precise within each speed range of engine operation, such precision representing a sort of guarantee of maintaining perfect and economic operation. In fact, a good control is the pivot ('the soul') of the proper engine functioning.

Any change of the values of the engine control diagram (valve timing diagram), has an influence on the development of pressure conditions within the cylinder, and is closely related with the possibility of faulty coaction of the individual components. A faulty and inaccurate control will result in engine malfunction, implying significant loss of power and moment, as well as excessive fuel consumption.

As a result of inaccurate regulation, operating temperature may rise to a level the permanent presence of which leading to damage to the engine and its components. An inaccurate control will render engine operation unecomomical, while causing increased polluttant emissions

## II. Engine controlling techniques presently applied, and their basic features

With four-stroke engines commonly used today, a certain method of **valve control** is applied to regulate pressure conditions within the cylinder. The essence of the method is public knowledge, nonetheless, the question does arise, whether due considerations have been given in the course of R&D activities to the limits and constraints of that control method? Said control is of the same age as four-stroke engines themselves, and the basic approach has not been altered ever since.

True, there have been some experiments and trials to realize certain sorts of port control, however, next to all of those attempts were limited to controlling friction only. But there is more than that to it, and as the trials have not been extended to a wider scope, even today the same, over hundred year old technique is being applied to control four-stroke engines. Besides bringing about a huge friction and compression spring force resistance during engine operation, this engine control approach has another drawback,

*namely:*

The **opening of the valves** is **subject to speed** (rpm), regarding that valve opening is performed by the camshaft, whereas **valve closing** is **subject to spring force**, with the speed of closing being the function of mechanical force stored by the compression spring.

Thus, it can be stated that the biggest failure, drawback and difficulty of said control method consist in the very approach referred to above, and not in the friction resistance brought about by it, or in the compressive force resistance due compression springs, said phenomenon significantly loading the engine while in operation.

**With overhead valve and square engines gaining ground, the control method referred to above had grown obsolate, as (using that obsolate method) the power the engine is rated for cannot be fully utilized.** Namely because spring force is constant. That is why each compression spring has a so-called speed follow-up limit.

When the speed of the camshaft exceeds the potential of mechanical force stored by the spring, the spring has no power nor time enough to return the valve onto the valve seat. That is when the phenomenon of 'float' of the valve and the valves involved in the control, respectively sets in, with test-bench characteristics pointing to engine-wear at high rpm, and even with new engines! As a consequence, a drop in moment and a loss of power are observed, and fuel consumption starts to rise to an excessive level, all this coupled with increased pollutant emission. Only lube oil will preserve its level stability.

Upon reaching medium speed, the valve timing diagram starts to get 'distorted', then upon reaching higher speed, it simply 'disappears' (from the engine). One could put: the engine has become 'soulless'. That is when the inaccuracy of the control system becomes apparent, reflected in a significant deviation, with respect to the development of the prescribed values of pressure conditions. **As from this speed range, the function of the system responsible for generating rotary movement, is determined by the compression final pressure only. With the speed increasing, the compression final pressure within the cylinder gradually decreases, keeping the engine operating, as long as the pressure is above 7 bar.**

**A Remark:**

It is public knowledge that the fuel consumption of motor vehicles that have run several hundreds of thousands of kilometers is markedly different from the fuel consumption of new cars. This deficiency is commonly attributed to the worn-down condition of a much-used engine.

It can be stated, however, that following any engine overhaul, the somewhat elevated fuel consumption level of the engine, as compared to a new engine, will continue to exist, no matter the top overhaul has taken place.

One may assume with good reason that this is because, when repairing an engine, the replacement of valve springs is hardly taken in consideration, but instead, the valves are re-fitted (wedged) while retaining the old, fatigued springs. What a big mistake!

I have tested valve springs of 10 to 20 years of age, that have served vehicles that having run several hundreds of thousands of kilometers, while measuring the maximum pretensioning of new springs, at the same time. As a matter of course, I have compared all of them with their matching pairs of the same type. As a result of the probe, it could be stated that during full pretensioning, the old, much-operated springs indicated a drawback of several kilograms - (4-6)kg(39,24-58,86)N –. Thus, the resulting loss of power, as compared to new springs, amounted to an order of magnitude of approximately 10%.

Based on the above considerations, the conclusion can be drawn that compression springs fatigue over time, after prolonged use, and here, the phenomenon of 'valve float' may be observed at lower speed than with new engines.

Therefore, with valve-controlled engines, it is recommended to replace existing vave springs after the vehicle has run 150,000 to 200,000 kilometers, and it is also advised that, upon overhauls justified by the natural wear and tear of the engine, the valves should be refitted (wedged) with new valve springs.

*Summerizing what has been said about valve-control methods, the following can be established:*

- The components of the control section do not form a unity (The opening and closing, respectively of the valves are taken care of by unrelated components).
- The method referred to, causes significant friction and compression spring force resistance (load) to the motor.
- The engine is severly damaged, should a sudden interruption take place in the connection line between the main shaft and the camshaft.
- The possibility of scavenging, expressed in degrees of angular dispacement, is very small and narrow (Only one-third of the full scavenging potential can be covered by this method).
- In suction stroke, gases entering the cylinder are confronted with the resistance by the valve disc, causing – in terms of the potential of the cylinder getting filled up with gases and subject to the prevailing pressure conditions -, a filling loss of 25 to 30 %.
- Exceeding medium speed range, pollutant emission by the engine will grow at the same rate as the rpm is increasing. A drop in moment and a loss of power, as well as an elevated fuel consumption can be observed.
- At high rpm, the control fails to perform its basic duty, it loses its importance.
- It is made up of over-elaborate components.
- Considerable exposure of the parts to wear and tear, hence an elevated risk of control breakdown.
- It requires continuous inspection and maintenance.
- Equipping the control with automatic tappet adjusting device increases the complicatedness of the system, and involves an elevated risk of failure and breakdown.
- Due to the need to ensure proper matching and adaptability of components, the process of manufacturing of said control device is over-elaborate and complex.
- System operation is inevitably accompanied by an elevated noise level, which will further increase in case of malfunction.
- Due to the enhanced load and stress, valve springs get fatigued following a certain period of duty, resulting in reduced speed follow-up capacity.

## III. An alterantive to the presently applied control approach, and its basic features

Below, I want to outline an alternative approach to the conventional valve control system, representing entirely different characteristics. I did not try to approach the problem of valve control by striving for the minimization of friction as I did not consider it to be the primary problem. What I was striving to achieve as primary objective, consisted in trying to unite **the tasks of the camshaft, the valves as well as of the compression springs** to form a compact assembly. We may also term this aim an attempt to **'amalgamate'** the functions of the components involved. The main point about my approach is **to have the duties of the camshaft, of the valves and of the compression springs performed by a single component** located above the given cylinder, representing each parameter of the valve-control approach and each requirement to ensure proper system function. Hereby I have achieved that **also the closing of the cylinder has become subject to speed (rpm).**

And that is the point, because by applying this approach, the control continues to be 'diagram-conform' even at high rpm., i.e. the pressure conditions inside the engine will not change even at high speed.

The resulting decreased friction is merely regarded as a concomitant advantage of this control approach. Being a 'by-product' of of said effort, it might as well be considered a secondary aspect. Nonetheless, said advantage certainly adds to the positive features of this particular control method.

The idea is based on the so-called **'tube in the tube'** theory, which can be summarized as follows: if placing a (loose) tube in another fixed tube, and **cutting - in overlapping position - a window in the mantle of both tubes, then the window cut in the mantle of the inner tube that can be freely turned inside the fixed (outer) tube, will periodically coincide with the window cut in the mantle of the outer tube.** In other words, by turning the inside tube, **said windows** will periodically **coincide and communicate with one another**. The same principle can be utilized for the control of four-stroke engines. Nothing special needs to be done but consequently applying the instructions and parameters defined to ensure proper operation. **The component** thus formed is termed **diagram shaft, in which pre-sealing is ensured by a labyrinth system.**

**Features of the above-mentioned shaft:**

1. It performs the task of cylinder opening and closing as a single component (the opening and closing of the window and the windows, respectively are both speed- dependent, hence, no function delay is encountered).
2. The system is entirely free of any friction.
3. No engine damage occurs, even if a sudden interruption takes place in the connection between the main shaft and the diagram shaft.
4. Expressed in degrees of angular displacement, much wider possibility of scavenging is provided in this case than the possibility of scavenging provided by the valve-control approach (the duration of scavenging of 90/45 degrees angular displacement can be realized here). The 'width' of scavenging may be altered in function of the speed.
5. The gases entering the cylinder in the suction stroke encounter no resistance. The potential of the cylinder getting filled up is of 100 %, subject to the prevailing pressure conditions.
6. At any speed, the system remains conform with the valve timing diagram.
7. This approach ensures considerable fuel economy.
8. It is coupled with power increase.
9. No loss of moment takes place at high speed.
10. No excessive pollutant emission takes place even when operating the system at a speed higher than the medium speed range.
11. Forming a single unit, the cylinder head incorporates the diagram shaft, and thus the full control system.
12. Noiseless operation.
13. Uncomplicated structure and setup.
14. No regular maintenance and supervision is required.
15. The risk of wear of the components is reduced to the minimum.
16. Lower manufacturing costs, higher material savings.
17. It is coupled with weight reduction.
18. Easier to assemble, hence, higher transparency.
19. Its complicatedness is reduced in terms of manufacture technology.

I can demonstrate the practical features and aspects of the new control system outlined above by means of a model.

Patent is pending for the idea with the Hungarian Patent Office.

**IV. Summary**

Based on what has been described above, I consider efforts aimed to alter the present conception of controlling four-stroke engines well-founded and necessary. **With the development of infrastructure - with the continuous upgrading of motorways -, we may reach almost any locations by driving our cars at high speed and high power. However, the engine control system presently applied, is simply unable to keep the engine running at the required output values above the medium range of speed. It has become obsolete.** Due to the high pollutant emission at high speed, it is harmful to the environment. It is no coincidence that when testing environmental-friendliness, the rate of pollutant emission of the engines is measured up to medium speed-range only (and never in the high-speed range), as the presently applied concept of engine control is capable of safeguarding proper enging operation up to that range of speed only.

I must point out in this context that when testing engines on a test bench in car factories, engines are tested up to the medium speed-range only. Thus, when purchasing a new car, the technical data specified in the manual supplied with the vehicle, necessarily include test values obtained by the above test methods.

All claims made in this paper with respect to valve control, may be proven and verified in practice. To demonstrate this, to model control conditions, I have constructed an electro-mechanical measuring device to be used with the help of a lathe. By gradually increasing the speed of the lathe, the speed follow-up limit of the compression spring and the starting point of 'valve float' condition can be measured, these points being indicated by a lamp going out. It can be observed that by increasing the speed (rpm), the gap between valve seat and the closing/sealing surface of the valve disc will grow in direct proportion to the speed increase, while the compression final pressure within the cylinder will decrease in the same ratio**. When compression final pressure within the cylinder has dropped below 7 bar, the engine is unable to perform its function even at minimum level,** it becomes 'lifeless', in fact that is when the 'death' of the engine sets in.

All this is due to the substantial deformation of the compulsorily prescribed pressure conditions essential for ensuring perfect engine function, considering that the conventional valve-control approach is unable to safeguard the development in the high speed range of pressure parameters necessary for economical engine operation.

Until the presently applied engine control concept is succeeded by some egy new approach, no breakthrough may be expected in the field of four-stroke engine development. At high speed, the present method of valve-control simply causes the engine to become a 'waster', until the engine itself is turned into a piece of waste too.

I am able to support the truth of my statement by theoretical means, by physical equality comparison and by providing some formulae too.

The diagram shaft represents an alternative solution ensuring reliable control of internal combustion engines, by ensuring perfect accuracy required for the development of pressure conditions within the cylinder, and hence for an economical engine operation even above the medium speed-range. Said method may be applied both in two-stroke engines and in four-stroke engines, both in single window and in double window versions.

The presently applied conventional method of valve-control is coupled with variable fuel consumption of the engine, whereas the fuel consumption of an engine controlled by means of diagram shaft would reduce by one-third of the fuel consumption of the conventional valve-controlled engine, and the level of consumption would remain constant on a stretch of 100 kilometer, at no matter how high speed!

This involves that a valve-controlled engine with average fuel consumption of 9 litres/100 km, would require a mere 3 litres of fuel to cover a distance of 100 kilometers, even if driving at a speed of 200 km/hour, were the conventional control replaced by diagram shaft control! Due to its accuracy (synchronity) and frictionless operation, the diagram shaft endows the engine with stabil fuel consumption (with the so-called consumption constant).

Some 60 to 70 % of those interested in buying a car have no idea of, nor do they care about characteristics like moment curve, performance curve, carbon dioxide emission etc. (When trying to choose a car, they will ask about the maximum power or fuel consumption of the vehicle, at best).

In fact, these latter parameters correspond to a sort of veiled communication of facts to them, far from being a plain speech, whereas the truth is that valve-controlled engines are a fuel waster when run above the medium speed-range, actually, they are a scrap with high pollutant emission.

That is why testing engines up to the medium speed-range only is nothing but self-deceit on the part of the car manufacturer, self-deceit whenever environmental protection supervisions take place, and the deception of all those wanting to purchase a car!

Building some navigation system into the car is not a sign of the development of the car or of the engine, but certainly a sign of the development of informatics and computer technique. Again, altering the design of the car is not a sign of the perfection of the engine but that of the design techniques, and one could go on enumerating the examples. Those purchasing a car do purchase mere brands for substantial amounts of money representing a multiple (financial) cover for the technical essence that is offered in exchange for them.

Any amount spent for the development of valve-controlled engines is nothing but waste of money. Simply because the condition of 'valve float' will certainly set in upon having gone beyond the medium speed-range, frustrating and reducing to nothing any intention of modernization and further development! After all, any development engineer trying to perfect valve-controlled four-stroke engines does not do nothing else than what the engine itself does above the medium speed-range: He is WASTING time and energy! And if that is how the engine and the development engineer acts, no choice is left for the car purchaser either to act differently.

For all of the above reasons, I want to propose to motor vehicle manufacturers to set themselves the objective of creating a four-stroke engine that applies a basically different control than the one presently applied. In pursuing development and research work to such an end, one could measure the operational parameters of the engine, and comparing the data thus obtained with those of valve-controlled engines, the question whether to justify or to reject the innovative efforts referred to above could be unanimously decided upon