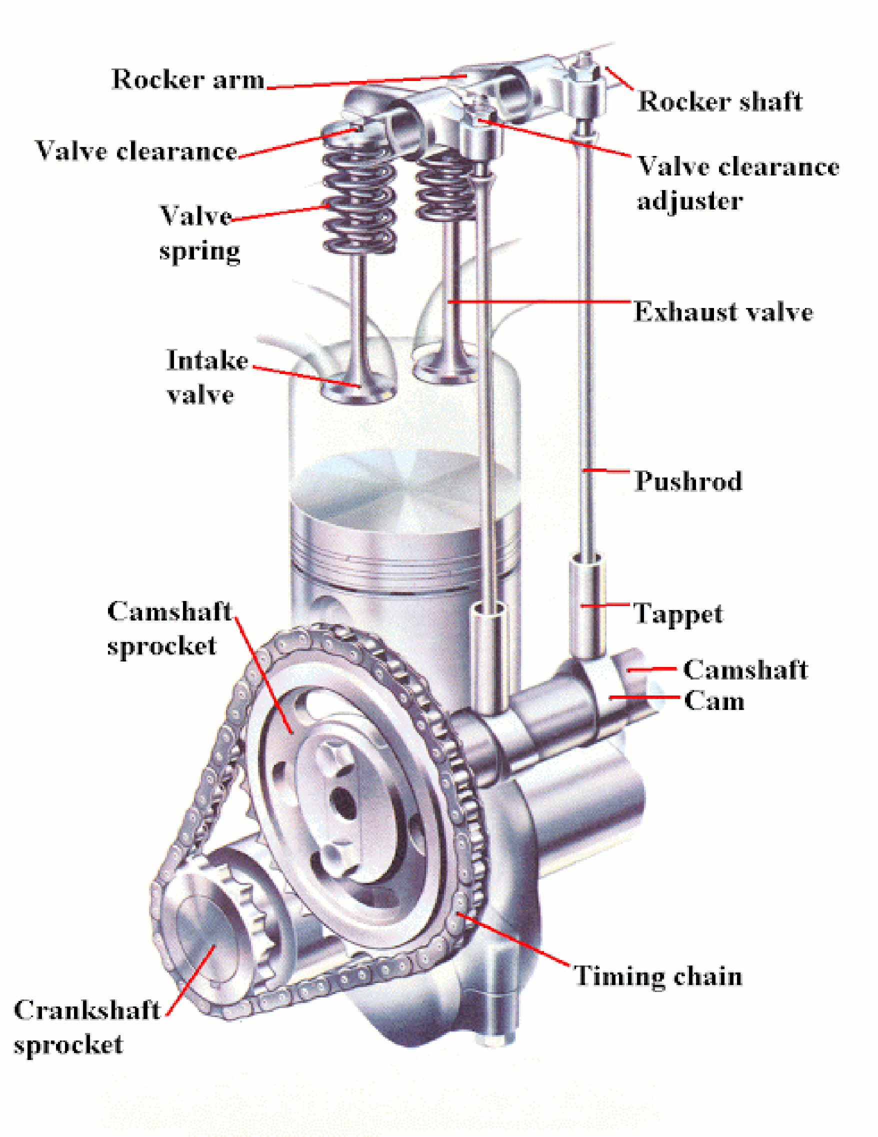
# Valve Mechanism and Valve timing

The Valve Mechanism of internal combustion engines must ensure the best possible discharge and filling of the compression space of the cylinder. This process precedes at precisely defined time points - due to the rotation of the crankshaft (and the position of the piston). Modern internal combustion engines require variable valve timing that responds to engine loads.
The Valve Mechanism of internal combustion engines is structurally divided into:

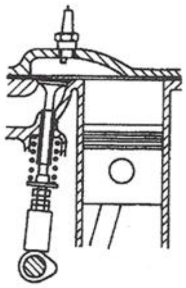
- valve
- channel
- rotary disc valves
- combined.

**Main parts of Valve Mechanism**

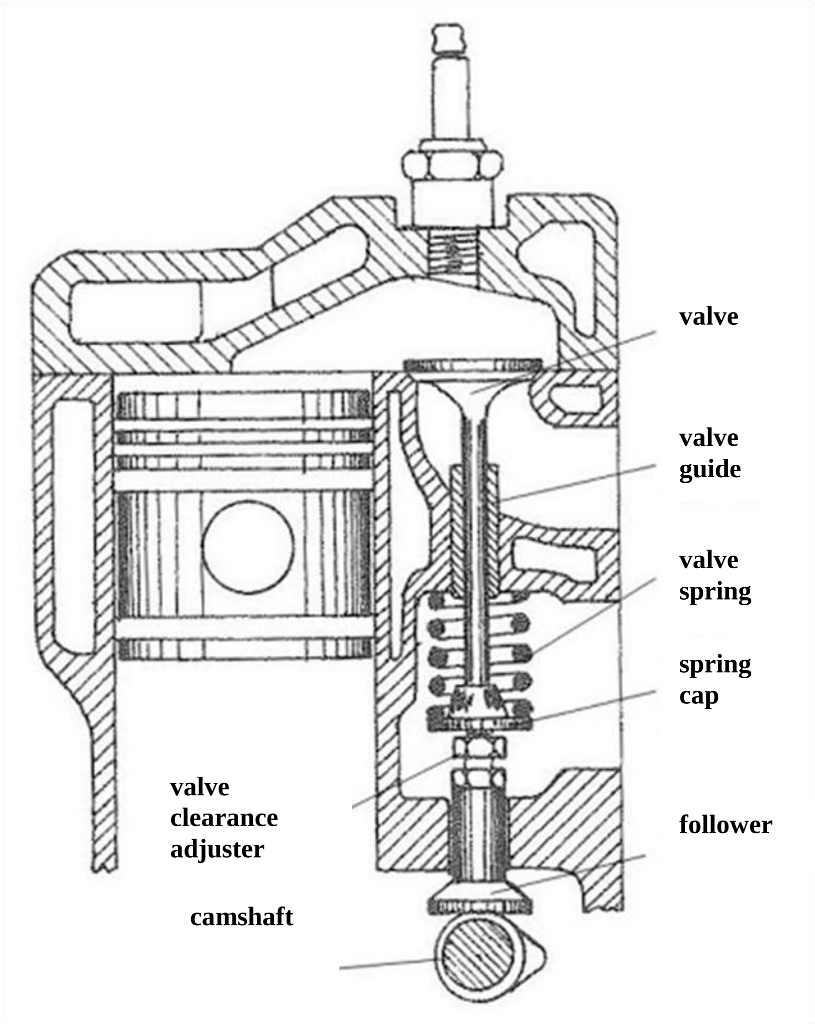


**Basic types of valve mechanism**

**SV** (Side Valves) – the camshaft is located in the engine block, the valves are in the engine block on one side.

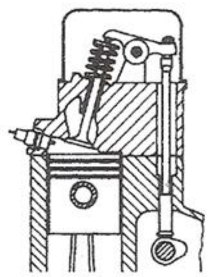


Historically, the first type of valve distribution was the SV type. It was a structurally very simple solution, with a small number of parts. The disadvantage is the complicated approach to the individual parts of the divorce. However, the biggest disadvantage is the complicated shape of the combustion chamber, which allows to achieve a low compression ratio.

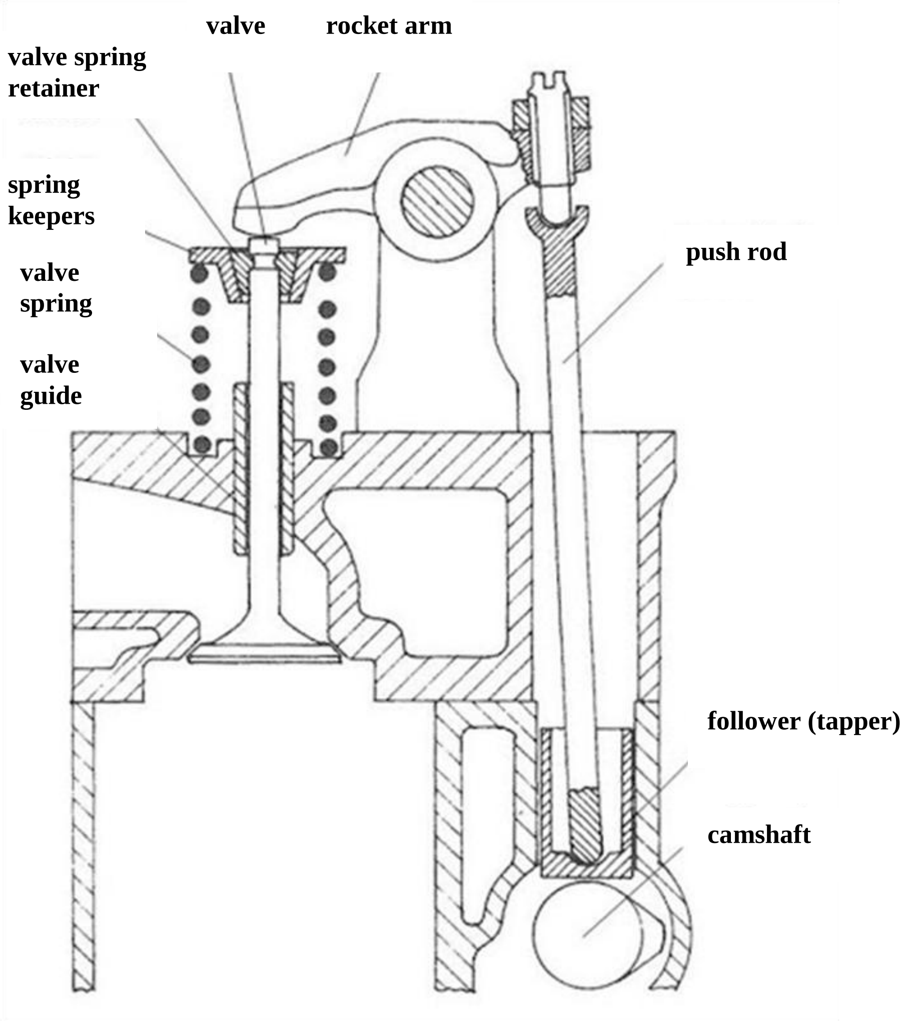


**IOE** (Inter Over Exhout) – the camshaft is located in the engine block, the intake valve is located and operated as in OHV, the exhaust valve as in SV.

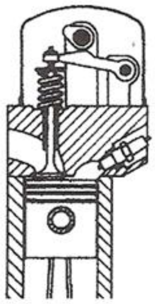
**OHV** (Over Head Valves) – the valves are located in the engine head, the camshaft is located in the engine block.



The complexity of the combustion chamber was eliminated by using valves in the head. However, the timing has several moving parts, which causes large inertial forces that limit the timing. The vertical valves are generally located in the head longitudinally to the axis of the motor. The oblique design of the valves improves the control of the valves.



**OHC** (Over Head Camshaft) – the camshaft is located on the head, the valves are located in the engine head.



The disadvantage of OHV timing is eliminated by placing the camshaft directly in the head. The camshaft can control the valve directly or via rockers. this distribution is more demanding to ensure the transmission of a precise positive connection between the crankshaft and the camshaft. Timing chains, timing belts or directly sprockets are used
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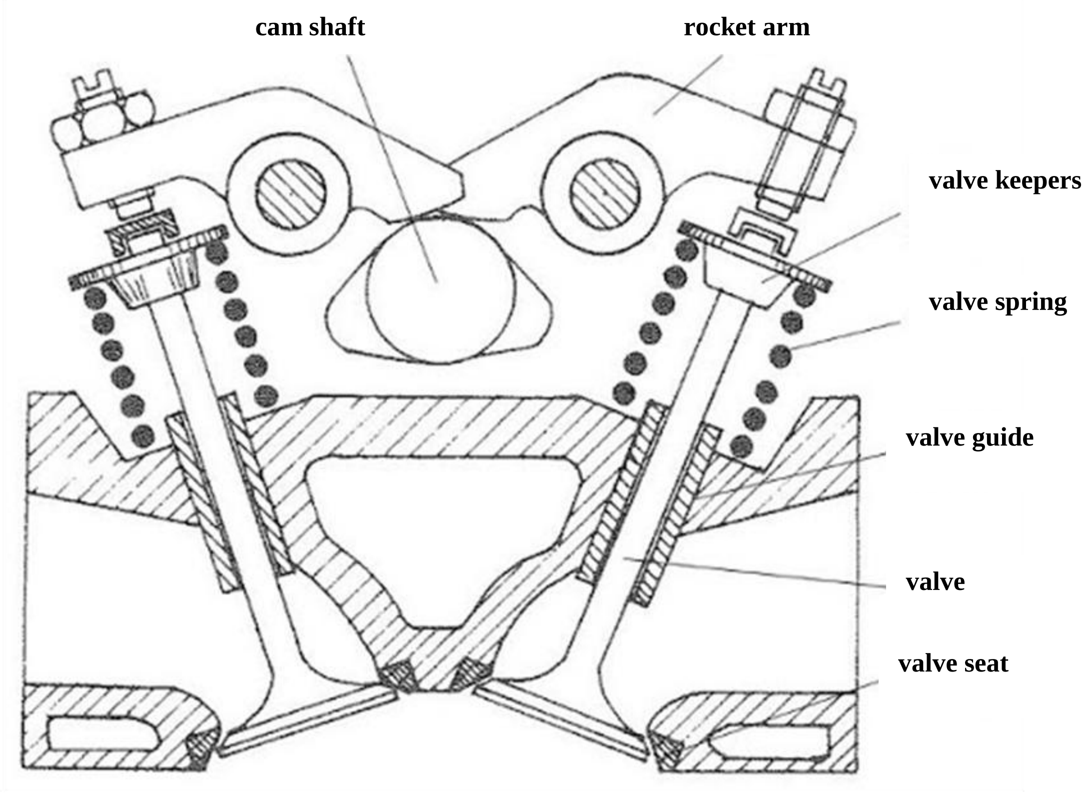
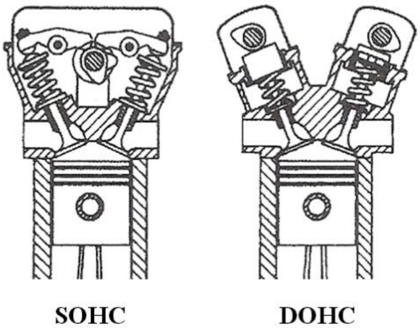
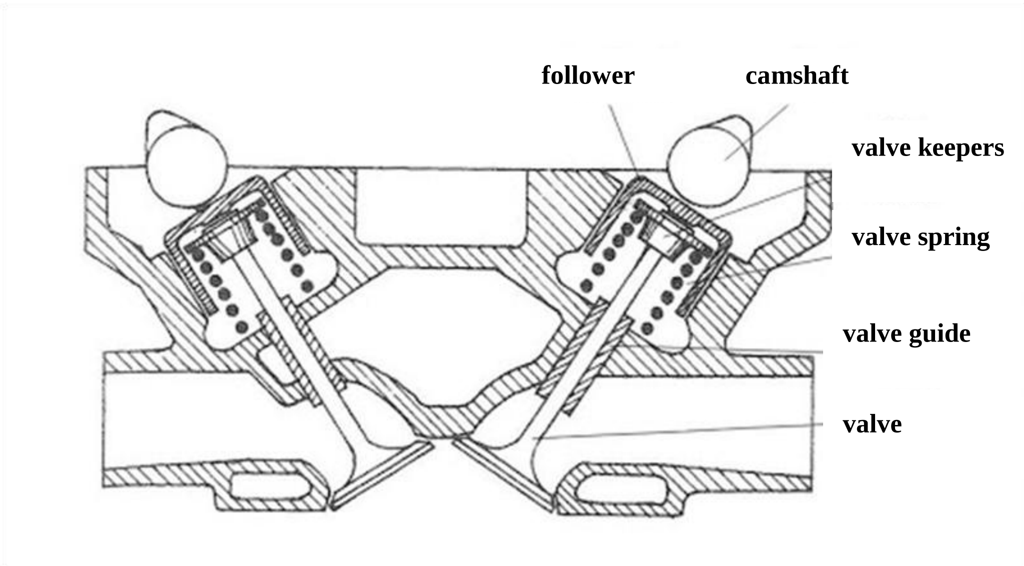



The OHC distribution also allows for different variations in the number and location of the camshaft and valves. Based on these variations, other types of divorces are created. The location of the camshaft above the valves allows for SOHC and DOHC variations. The placement of the camshaft under the valves allows for a variation of CIH.

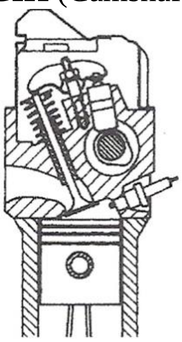
**SOHC** (Single Over Head Camshaft) – the cam is located on the head, the valves are located on both sides in the engine head.

**DOHC** (Double Overhead Camshaft) – the two camshafts are mounted on the head and the valves are in the head.



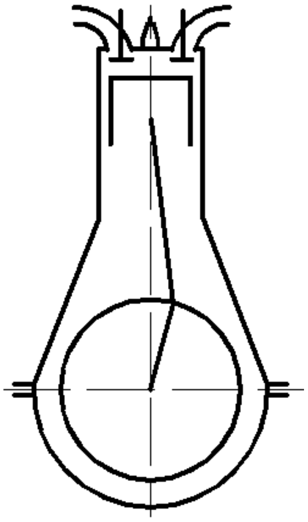

**CIH** (Camshaft In Head) – the camshaft is mounted in the head under the valve rockers.

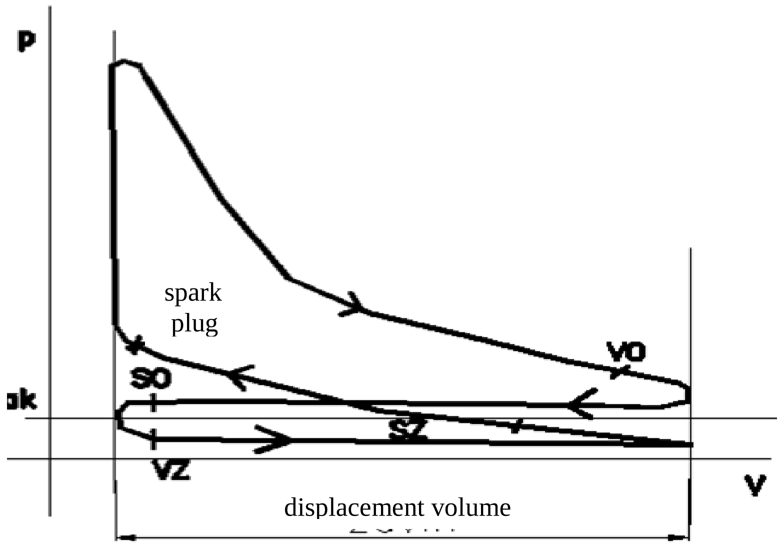


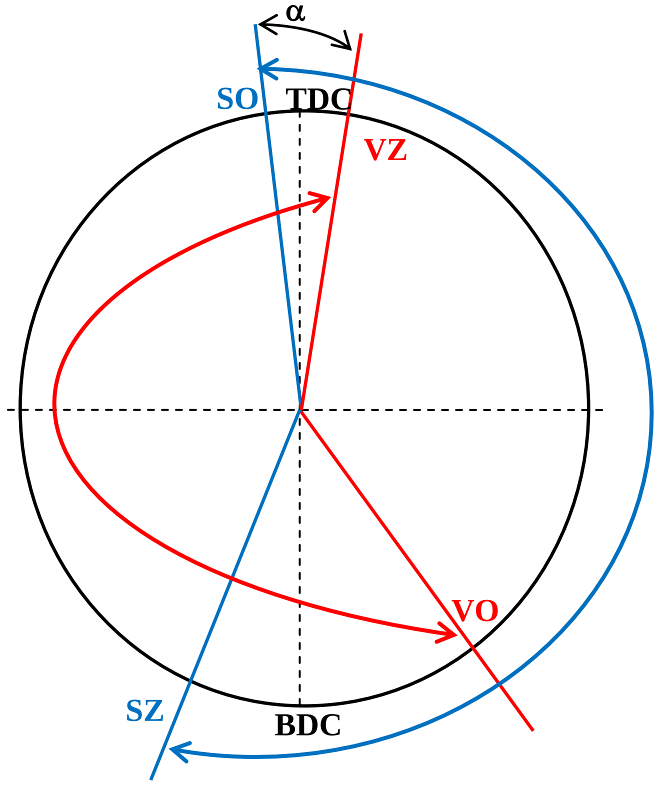
**Valve Timing Chart)**

The timing of the valve train, i.e. the opening and closing of the valves, takes place with respect to the rotation of the crankshaft. To express the mutual position of the crankshaft and the state of opening resp. closing the valves it is suitable to use a circle chart of the timing of the valves fig.

The highest point of the circle corresponds to the top dead center (TDC ) and the lower point of the circle represents the bottom dead center (BDC). The operating cycle of the four-stroke engine is realized during two rotations of the crankshaft, and thus also the circle chart of the timing of the timing represents two rotations of the crankshaft.





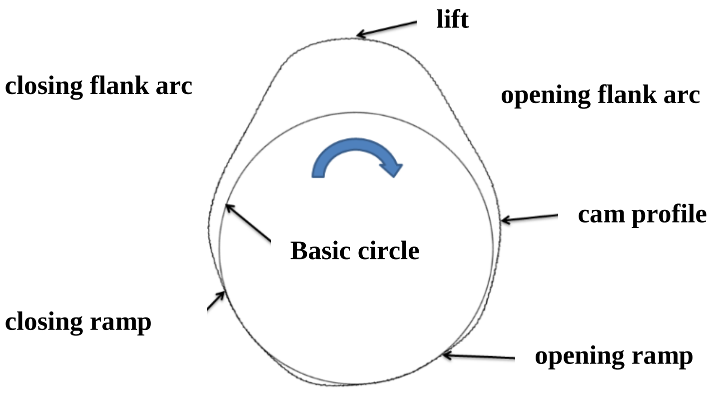
when:

SO- intake valve open
SZ - intake valve close
VO- exhaust valve open
VZ -exhaust valve close
Red arc - exhaust stroke
Blue arc - intake stroke

There is a 1: 2 (slow) gear ratio between the crankshaft and the camshaft, due to the nature of the cylinder contents exchange of the four-stroke engine.
Indicative values of timing of valves are:
SO - (10°-50°) before the top dead center
SZ - (40°-80°) behind the bottom dead center
VO - (40°-80°) before the bottom dead center
VZ - (10°-50°) behind the top dead center
$\alpha$ - angle of valve overlap, thus, a state where both valves are open.

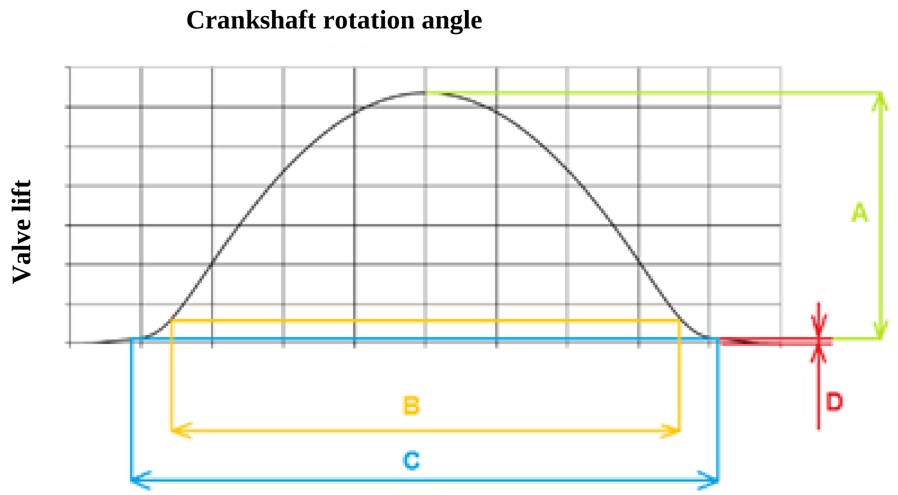
**Developed Timing Diagram - Cam Diagram**

The shape of the cam is adapted so that the engine has the best filling in the range of the most used speeds. The best performance is a prerequisite for the lowest consumption, the highest output, resp. maximum torque. Camshafts are manufactured as cast iron castings, or forgings of Mn-Cr alloy steel. The functional surfaces of the camshafts are cemented, hardened and burnish.
The opening and closing of the valves is ensured by the shape of the camshaft. However, the shape of the cam does not allow the valve to open fully at the moment as defined by the timing circle chart. The camshaft cams can be designed as continuous or discontinuous. The advantage of continuous is that the course of kinematic quantities such as stroke, speed and acceleration has a continuous course. The disadvantage is that it is not possible to use sliding lifts. Discontinuous cams are structurally simpler, they are made as circular arcs, but they have a discontinuous course of kinematic quantities, which has a negative impact on the properties of the distribution as a whole. However, they can use sliding tappets, without significantly affecting the life of the sliding pair.
The basic principle and shape of the cam is shown in FIG.



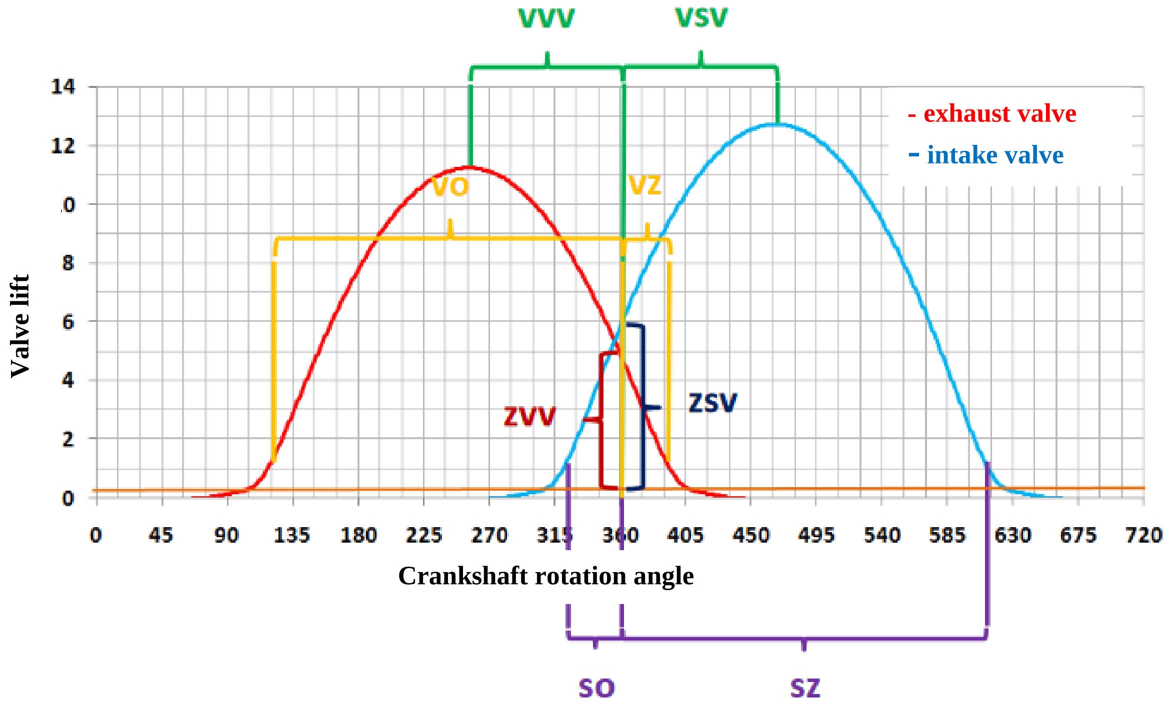
On the base circle, the angle for opening and closing the valve is marked according to the timing diagram. The lift height of the valve is also indicated. The opening flank arc and the closing flank arc of the cam side are adapted to this requirement. To display the basic parameters of the cam and design its shape, it is appropriate to use the cam profile diagram in fig.

When:
A - lift of valve,
B- timing for 1mm lifting,
C - timing in defining valve clearance,
D - valve clearance

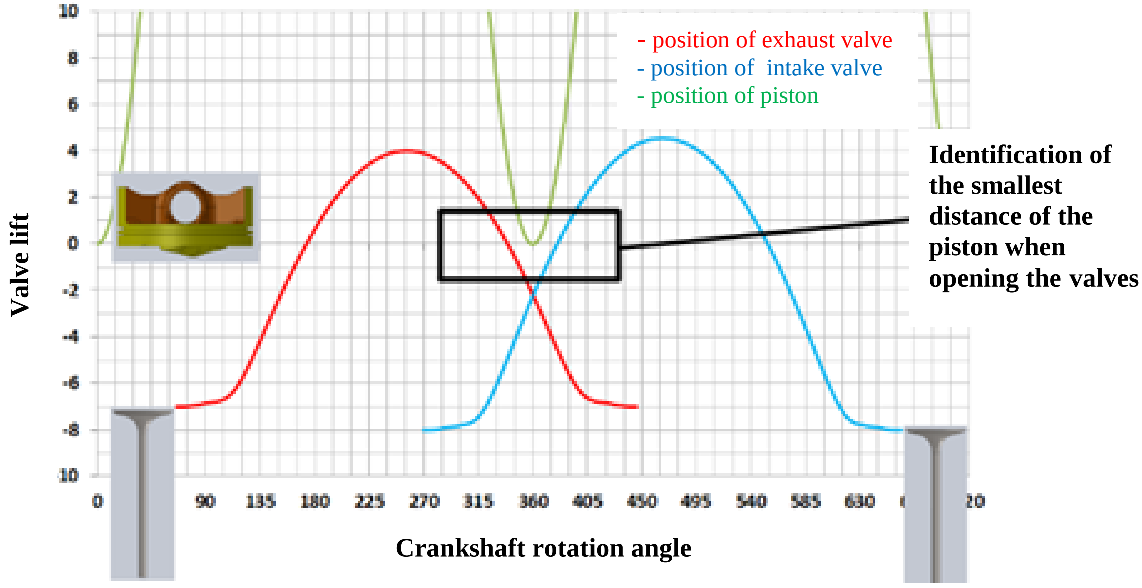



The circle chart of the timing of the distributions can be redrawn into the diagram of the cam profile fig. The valve clearance is plotted in the diagram. The diagram shows the course of valve opening, the size of valve opening and the actual valve overlap.

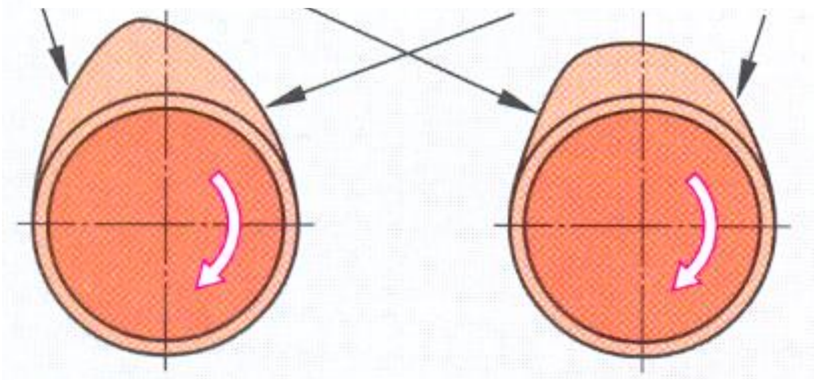
VVV - the top of the exhaust cam
VSV - the top of intake cam
ZVV - exhaust valve lift in TDC
ZSC - intake valve lift in TDC




The mutual position of the valves during the movement of the piston can also be read from the diagram, it is possible to read out any collision that may occur when the valves are opened.




The shape of the cam has a significant effect on the filling of the compression space in a certain speed and operating mode. The pointed cams are more suitable for filling at high speeds. Low lift and Hight lift cams are suitable for low speeds and high engine loads in the low speed range.

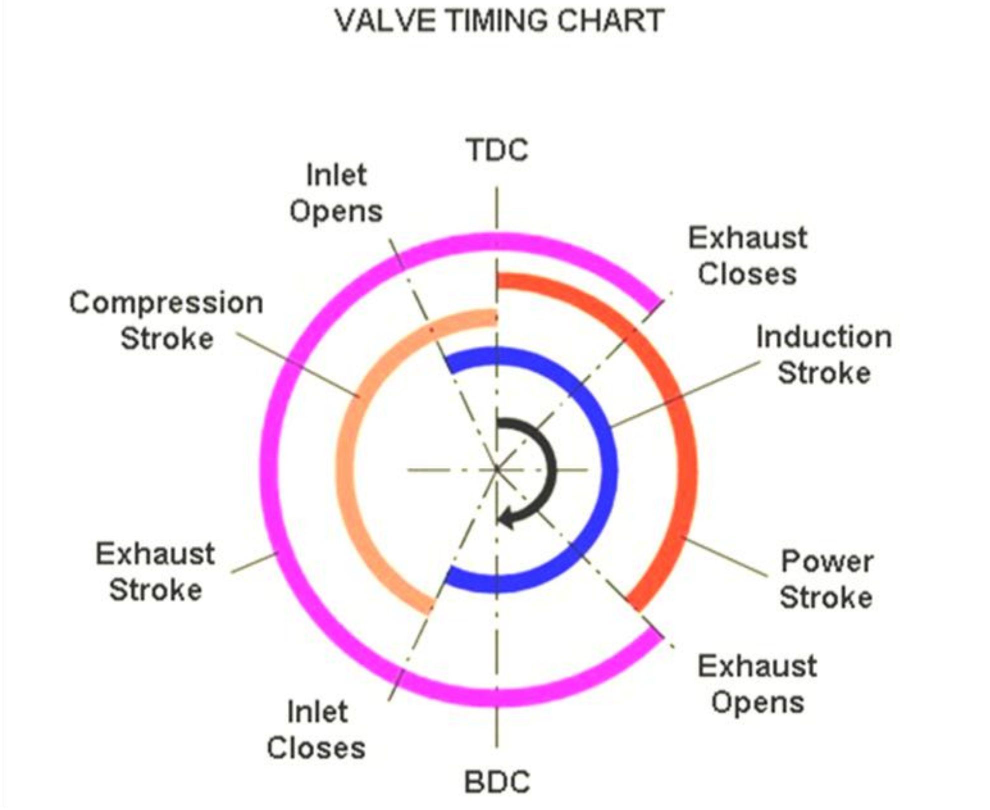



**Valves mechanism with variable timing**

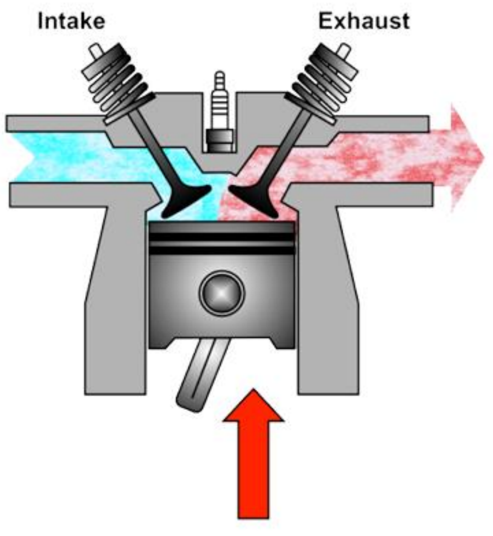
The opening and closing of the valves does not correspond to the position of the top and bottom dead center, because the exchange of the working filling is a dynamic proces. The effort is to get the largest possible amount of working filling into the cylinder, but then only a short moment of time is available. The effort is therefore to effectively adjust this moment in time to the operating range of the engine. In principle, it is expected that the kinetic energy of the gases and the wave effects of the flowing medium will be used for better filling of the cylinder.

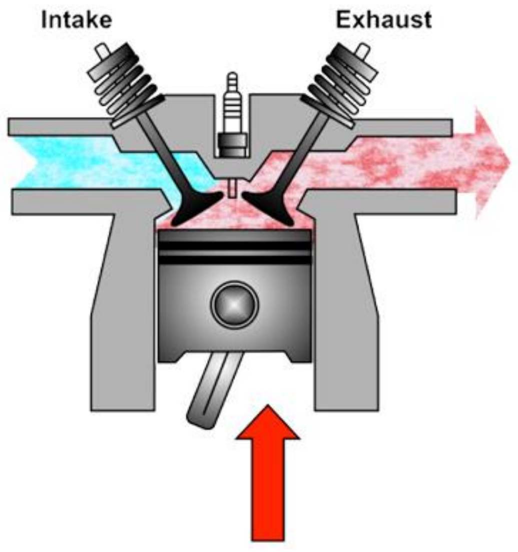
1. Inertia effect: moving the piston from TDC to BDC creates a mixture column in the cylinder that has significant kinetic energy. This energy can be used for more efective filling by closing the intake valve at the appropriate moment, when due to the inertia of the flowing mixture, the space above the piston is more perfectly filled. The same is true for the exhaust pipe.

2. Wave effect: By moving the piston to BDC, a vacuum is created above the piston, the wave of which spreads with the speed of the air in the intake pipe. The wave that propagates through the intake pipe is reflected at its mouth and, based on the theory of wave propagation, propagates back as an pressure wave. The goal is to use the pressure wave for additional filling of the cylinder.
However, both effects are effective only in a certain speed and load regime, since the length of the intake and exhaust pipes is constant and the valve timing is fixed defined. In order to be able to use these two effects in a wider range of revolutions, it is necessary to ensure the variability of these parameters.




With a fixed camshaft, engineers have to balance between idle quality and performance on one side and power and low emission and fuel economy on the other. As a result, none of these goals are achieved completely. Variable valve timing allows the engine to obtain a smooth idle while achieving the rest of the goals. Modern VVT systems combined with technologies like electronic throttle control and direct fuel injection allow smaller engines to produce high horsepower and torque at lower RPM.



For increased performance, the exhaust cam is retarded a small amount to promote engine breathing. Higher engine speeds mean shorter valve open times and higher air velocity. The increased velocity pushes more exhaust out of the cylinder. The retarded exhaust valve timing increases Volumetric Efficiency. The exhaust valve is still open when the intake opens. Outgoing exhaust pulse creates a low-pressure zone behind the valve, which increases the pressure differential between the intake port and the combustion chamber. The result is better cylinder filling. Remember, this can't be done at idle due to low air speeds.

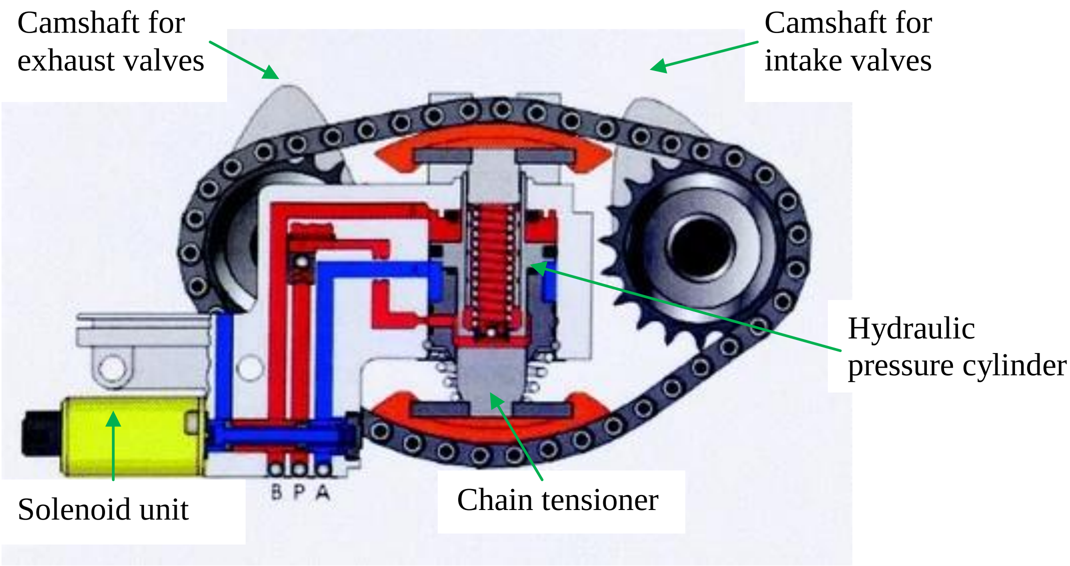
**Basic types of variable timing of valves mechanism:**
**1. Variable timing of intake valves -** gradual change in valve opening time.
**2. Variable control of camshafts.**
**3. Fully variable valve distributions** - changing the timing and the size of the valve lift.

**1. Variable intake valve timing with gradual change of valve opening time.**

The rotation of the camshaft of the intake valves changes - in relation to the camshaft of the exhaust valves, type of distribution DOHC. This will change the opening and closing angle of the intake valve. The opening time (opening angles), expressed in degrees in the circular diagram, does not change. Regulation is usually two-stage: Intake valve (InV) opened earlier or InV opened later. The main criterion is engine speed, secondary criteria are temperature and engine load.

Three modes are usually programmed, namely:
1. from idling speed to 2000 $min^{-1}$, the mode is set - InV opens "later". The valve overlap is reduced and the return of exhaust gases to the intake is very small. The combustion process and torque will improve, idling speed can be reduced.
2. In the area of medium and higher speeds, i.e. from 2000 to 5000$min^{-1}$, the camshaft of the intake valves rotates, e.g. by 20° crankshaft angle to the "earlier" position. The intake valves close after BDC and the pistons, which move up, do not return any mixture to the intake. Due to the low velocity of the intake mixture, a part of the exhaust gases also enters the intake in the area of valve overlap. These are then sucked into the cylinder together with the fresh mixture and the so-called internal exhaust gas recirculation. This reduces the temperature during combustion and thus the production of nitrogen oxide - $NO_x$. This is particularly advantageous for diesel engines and spark-ignition engines with direct fuel injection.
3. At high revolutions, above 5000$min^{-1}$, the camshaft of the intake valves turns in the "later" direction. The intake valves close far beyond the BDC. Due to the high flow velocity in the slide at high engine speeds, air or mixture flows into the cylinder even as the piston moves upward on the compression stroke. This leads to increased pressure in the cylinder, which has an impact on increasing torque and power.

**Systéms VarioCam for timing of intake valve**




A- Basic setting (mode later)
B - Tuning setting (mode early)
P - Pressure oil

Fig. Variabile chain tensioner of timing chain - VarioCam

The Effect of timing intake valves with system VarioCam is drawing in following fig.

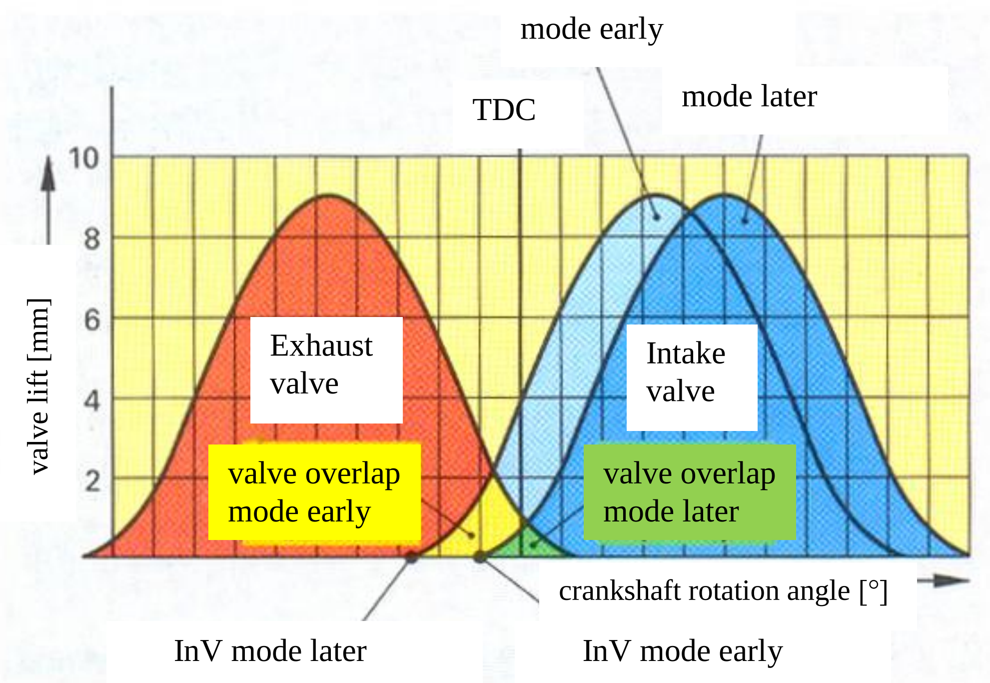



Fig. Graph of Variable timing of intake valves

## 2. Variable control of camshafts

Variable control of camshafts are usually characteristic like continuously variable valve timing, and are design like the single or dual systems. The single system control only one camshaft - intake camshaft. The dual systems control both camshafts.
Basic princip for controled of camshaft can be design on mechanical (Vanos), hydraulical fundaments (CVVT), or combine.

Vanos system:The camshaft rotates smoothly against the timing wheel. This is ensured by a mechanical adjustment unit with a toothed clutch with axial teeth. The hydraulic piston of the adjustment unit is connected to the sliding part of the tooth clutch. The hydraulic piston is controlled by oil pressure from the lubrication system. The change of rotation is smooth. The angle of rotation of the camshafts (InV up to 60° of crankshaft rotation, for the ExV system up to 40° - Double Vanos).

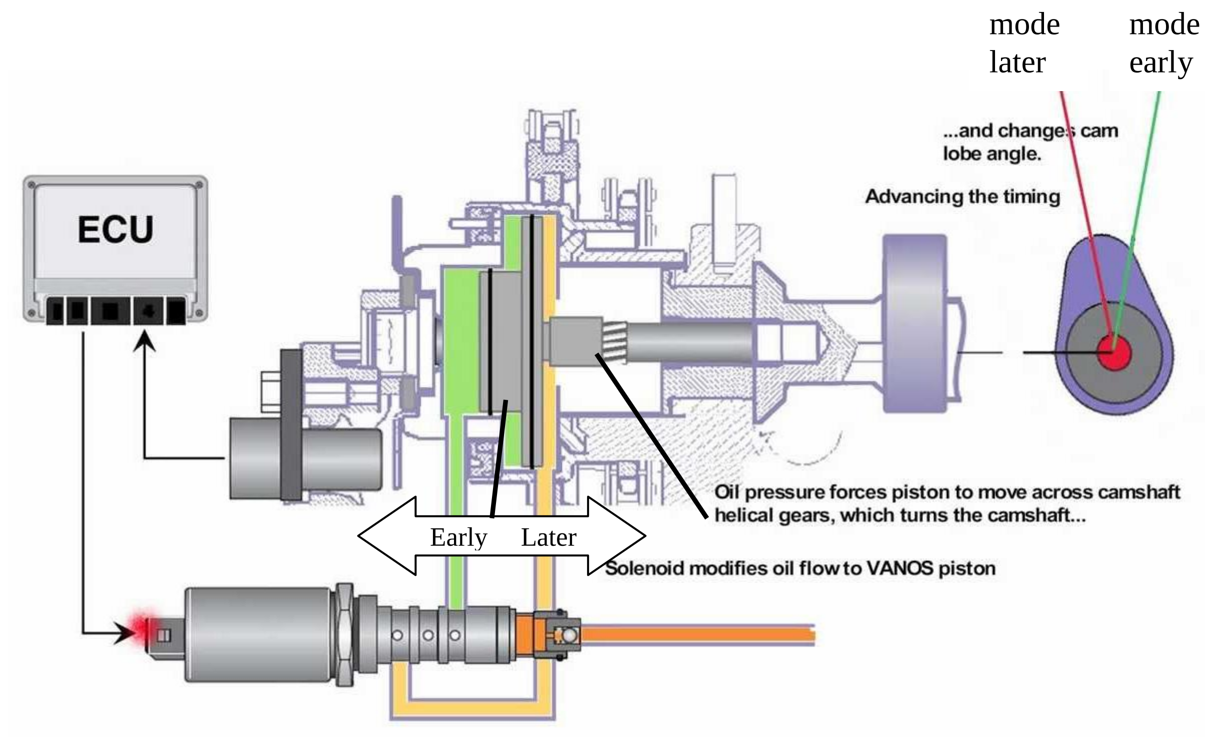



Fig. Mechanical system of timing camshaft with helical gears controlled by hydraulic piston – Vanos.

CVVT system: In the following fig. is a system of continuously adjusting the rotation of the camshaft using a rotary hydraulic motor. It is used for both types of camshafts. The outer part of the hydraulic motor (1) is driven by a chain or timing belt. The mutual position of parts of of the motor (2) is controlled by pressurized oil. The advantage of this hydraulic system (e.g. CVVT) compared to gear systems is a relatively simple and inexpensive design.

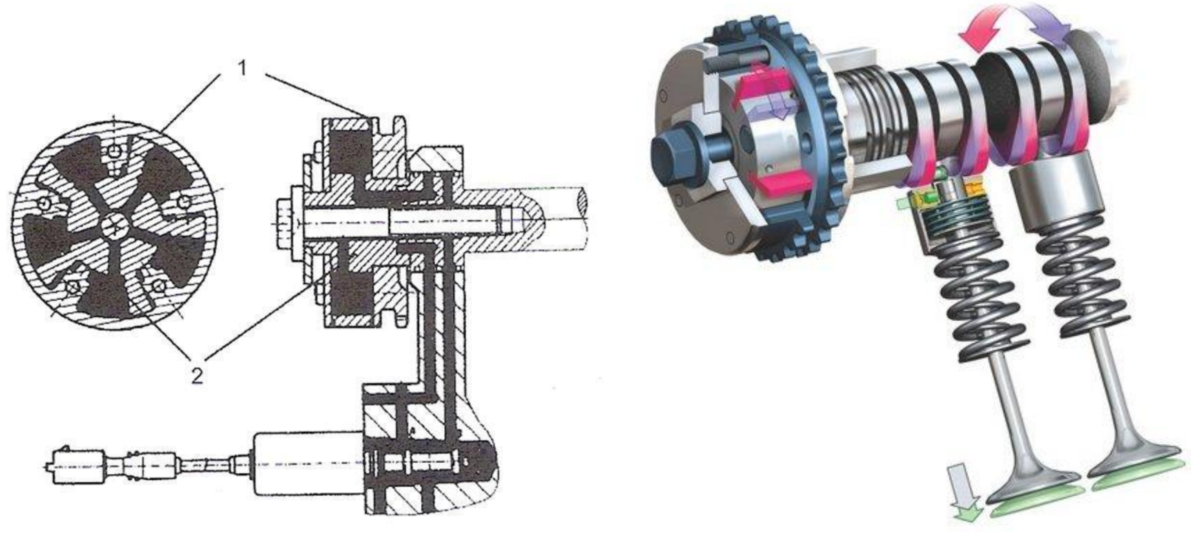
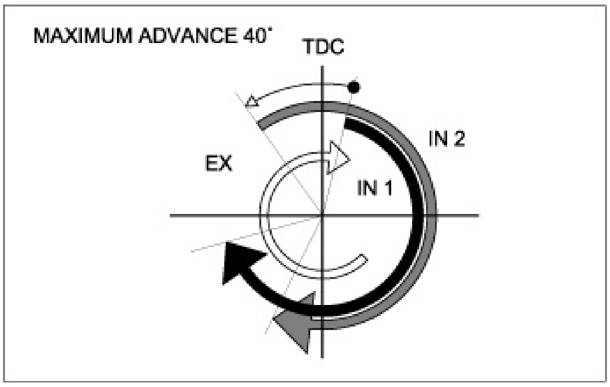


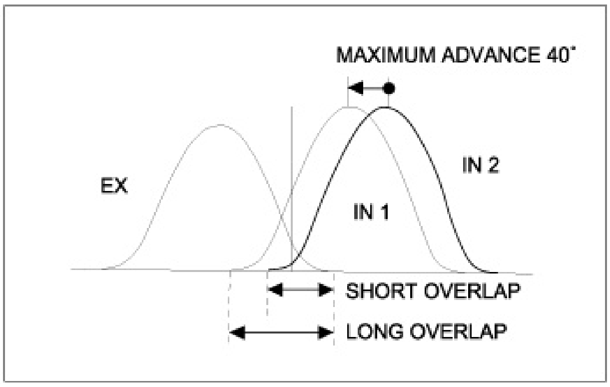

Fig. CVVT - Continuously variable valve timing hydraulic system

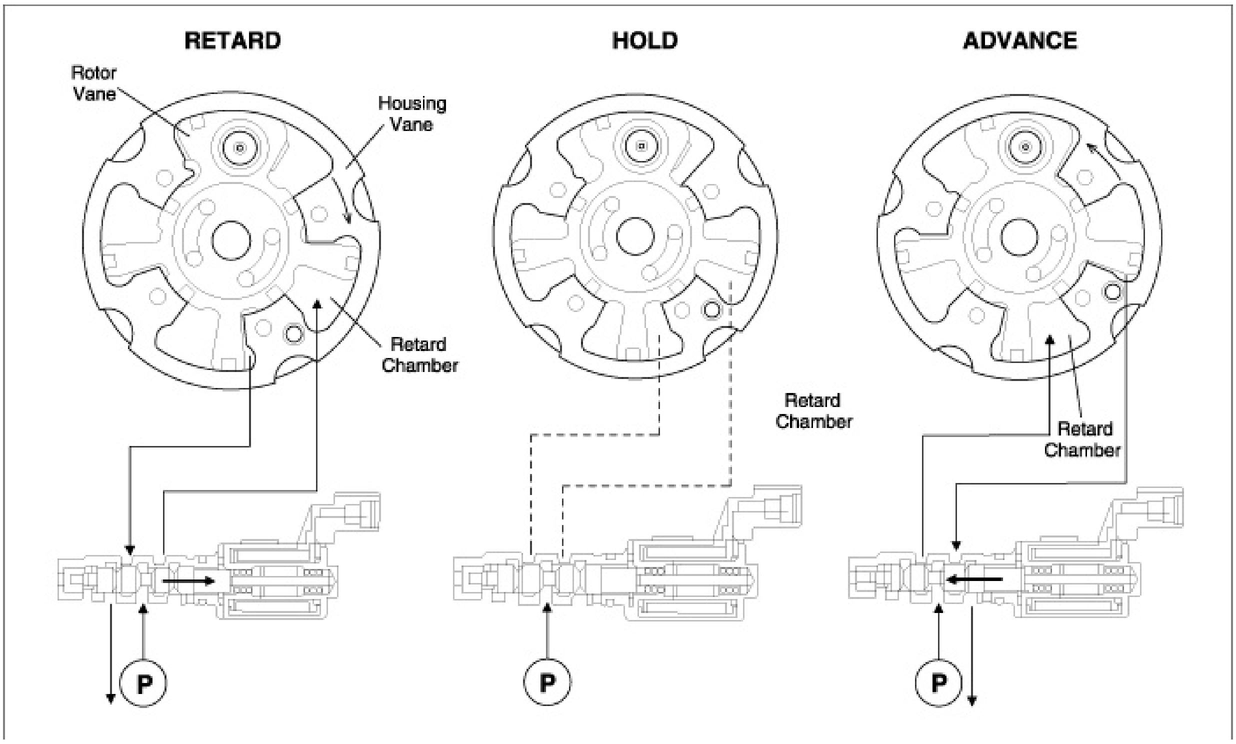
Continuous Variable Valve Timing (CVVT) system advances or retards the valve timing of the intake and exhaust valve in accordance with the ECM control signal which is calculated by the engine speed and load.
By controlling CVVT, the valve overlap or underlap occurs, which makes better fuel economy, reduces exhaust gases (NOx, HC) and improves engine performance by reducing pumping loss, giving internal EGR effect, improving combustion stability and volumetric efficiency, and increasing expansion work.

This system consists of
– the CVVT Oil Control Valve (OCV) which supplies the engine oil to the cam phaser or takes out the engine oil from the cam phaser in accordance with the ECM PWM (Pulse Width Modulation) control signal,
– the CVVT Oil Temperature Sensor (OTS) which measures the engine oil temperature,
– Cam Phaser : Changes the cam phase by using the hydraulic force of the engine oil.
The engine oil which is supplied from the CVVT oil control valve changes the cam phase in the direction (Intake Advance/Exhaust Retard) or opposite direction (Intake Retard/Exhaust Advance) of the engine rotation by rotating the rotor connected with the camshaft inside the cam phaser.

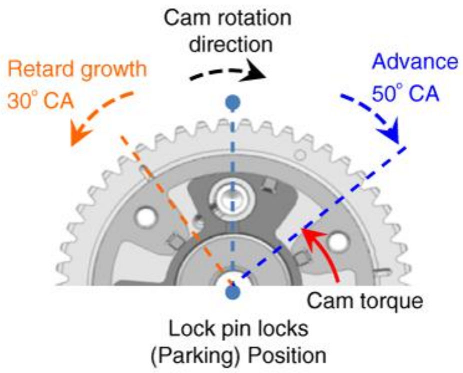
The CVVT system can be design like single, for control only one camshaft. The effect of the CVVT on intake operating range, and range of increases and retarded of camshaft is up to 40° compared to the default state. see fig.

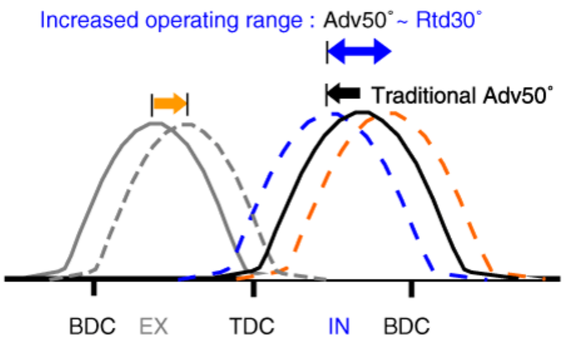


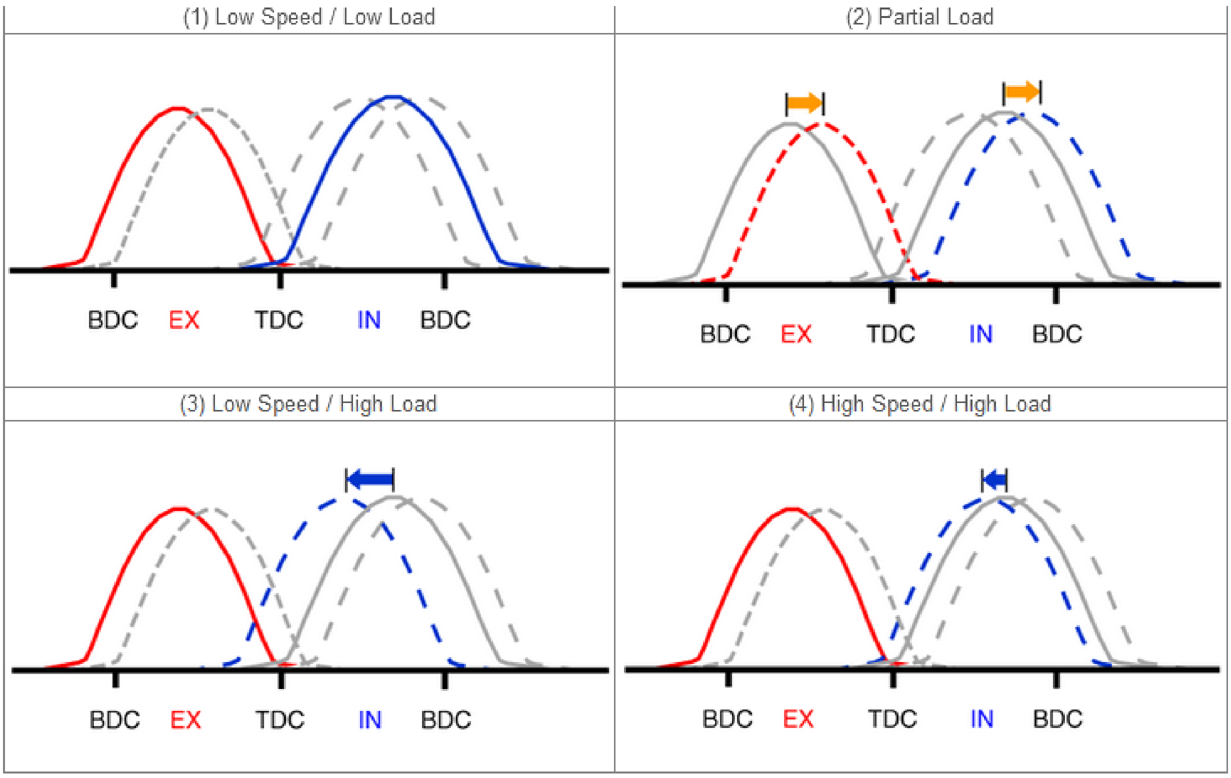



Dual CVVT systems control both camshaft. The princip and effect on the operating range of camshafts see follow fig.




| Driving Condition | Exhaust Valve | | Intake Valve | |
|---|---|---|---|---|
| | Valve Timing | Effect | Valve Timing | Effect |
| (1) Low Speed /Low Load | Completely Advance | * Valve Under-lap<br>* Improvement of combustion stability | Completely Retard | * Valve Under-lap<br>* Improvement of combustion stability |
| (2) Partial Load | Retard | * Increase of expansion work<br>* Reduction of pumping loss<br>* Reduction of HC | Retard | * Reduction of pumping loss |
| (3) Low Speed /High Load | Retard | * Increase of expansion work | Advance | * Prevention of intake back flow (Improvement of volumetric efficiency) |
| (4) High Speed /High Load | Advance | * Reduction of pumping loss | Retard | * Improvement of volumetric efficiency |

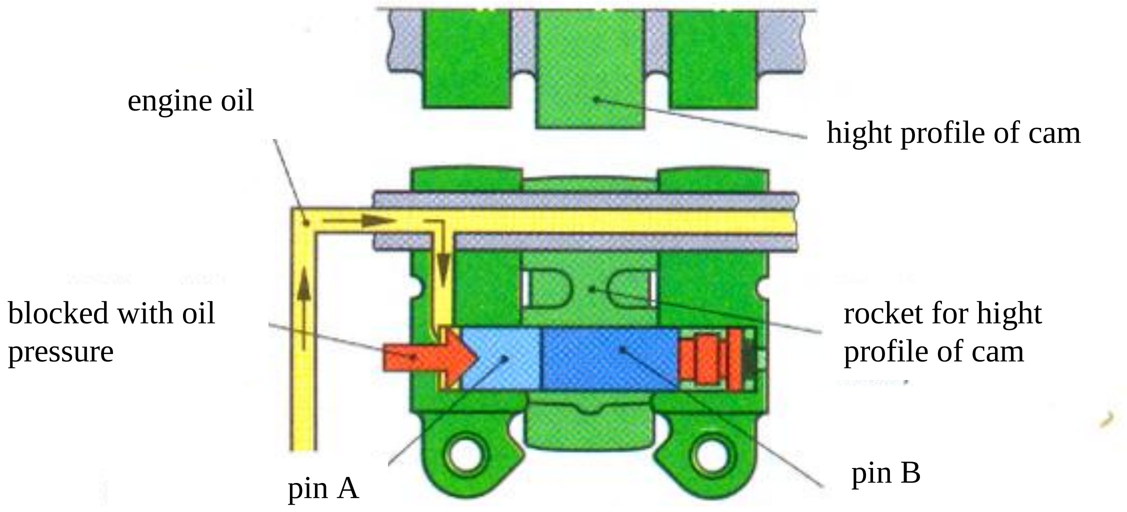
### 3. Fully variable valve distributions

- changing the timing and the size of the valve lift.

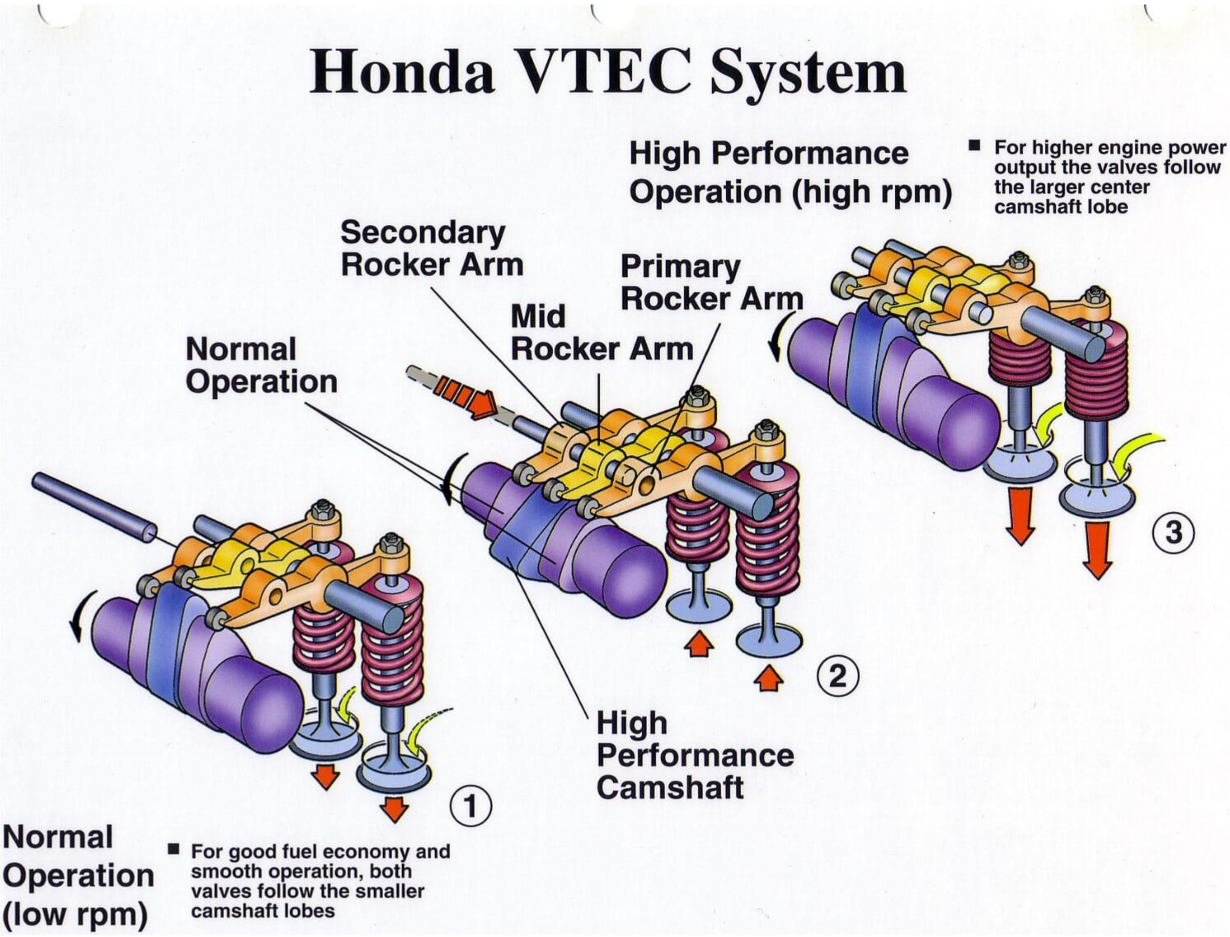
Currently, there are several systems of fully variable valve timing. The first company with this technique was Honda in 1989 with series-produced VTEC engines. It was preceded by 5 years of research and application in F1 engines.

With the VTEC system, three rockers are used on the camshaft side. Each rocker arm is controlled by a different cam profile. In the mode of lower and medium speeds, both the intake and exhaust valves are controlled by means of secondary rockers arms. The interesting thing is that each valve has a different lift due to different cam profiles. e.g. intake 5 and 8 mm and exhaust 4.5 and 7.5 mm. This condition will cause intense swirling of the filling and exhaust medium, which has a direct effect on the perfection of combustion. It also allows you to burn a lean mixture. Sliding pins (A, B) are inserted in the rockers. At the moment when the control unit gives an instruction to switch, an electromagnetic valve causes a sudden increase in the pressure of the lubricating oil in the shaft of the rockers, the oil pressure moves the pins (A, B) and they mechanically connect the rockers into one functional unit. This will make only the middle and largest cam with a sharp InV profile e.g. to 10.4 mm and for ExV to 9.4 mm.

When the speed decreases and the control unit gives an instruction to decrease, the return spring returns the pins (A, B) to the basic extreme position. The rockers are disconnected and the valves are controlled by smaller cams. These changes last 0.02sec.




**Obr.** VTEC system - hight revolutions regime



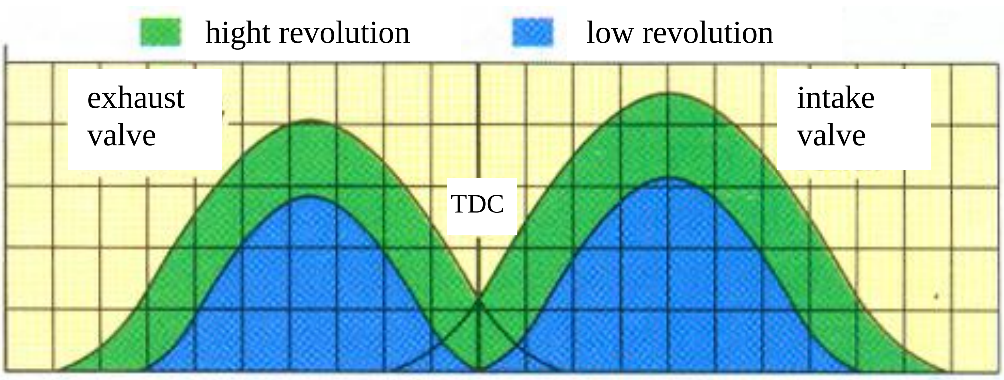




Fig. Effect of VTEC system on lift valves

Valvetronic system

In the next fig. the Valvetronic variable valve timing is shown and explained. The adjustment from the maximum lift of the intake valves of 9.9 mm to 0.18 mm takes 0.3s. The Double Vamos system ensures the rotation of the camshafts. Variable valve lift made it possible to remove the throttle (acceleration) valve from the intake manifold. It contributed to the reduction of aerodynamic losses in the pipeline.

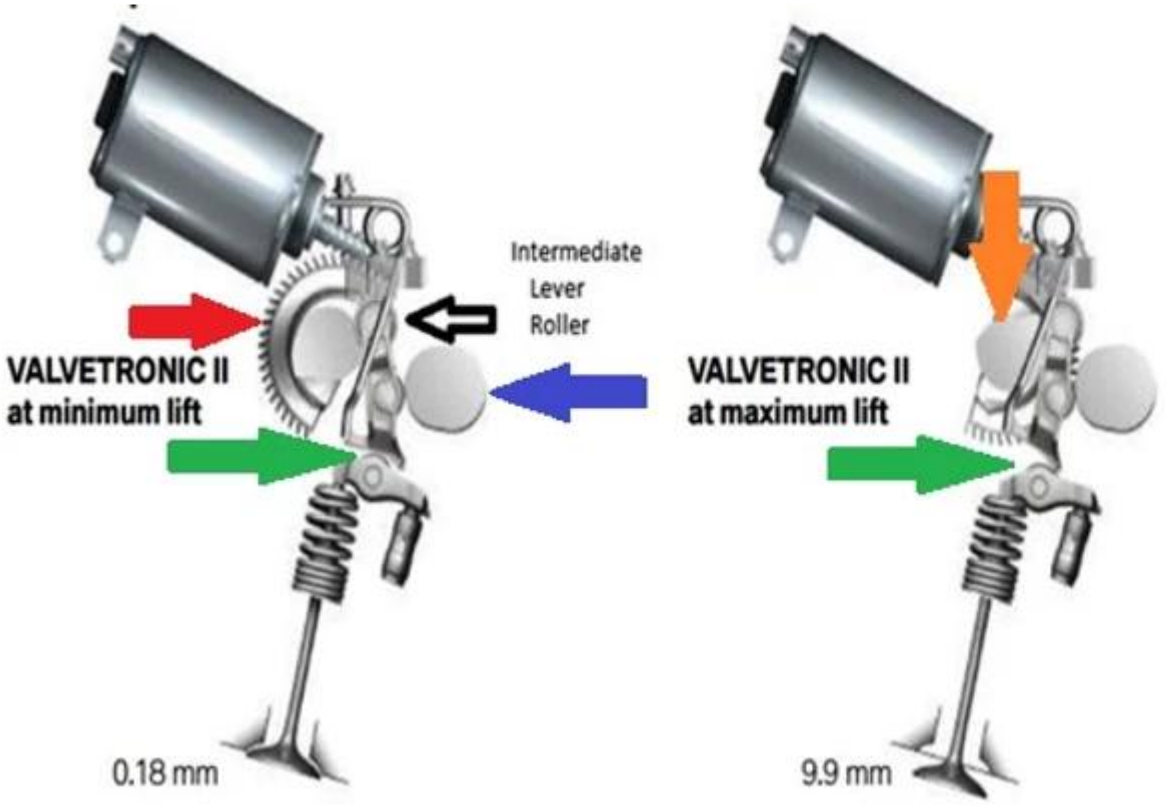



Fig. Variable lifting system of intake valves – Valvetronic

What Valvetronic does though is it eliminates the throttle body altogether. Valvetronic in conjunction with VANOS can determine how much the intake valve opens, how long it opens and where in the intake stroke it opens. This allows it to control the amount of air entering the engine directly at the intake valve in order to decrease pumping losses and allow for a very responsive throttle. In layman's terms, Valvetronic turns the intake valves into the throttle bodies - meaning there is no partial vacuum and the engine can respond instantaneously.

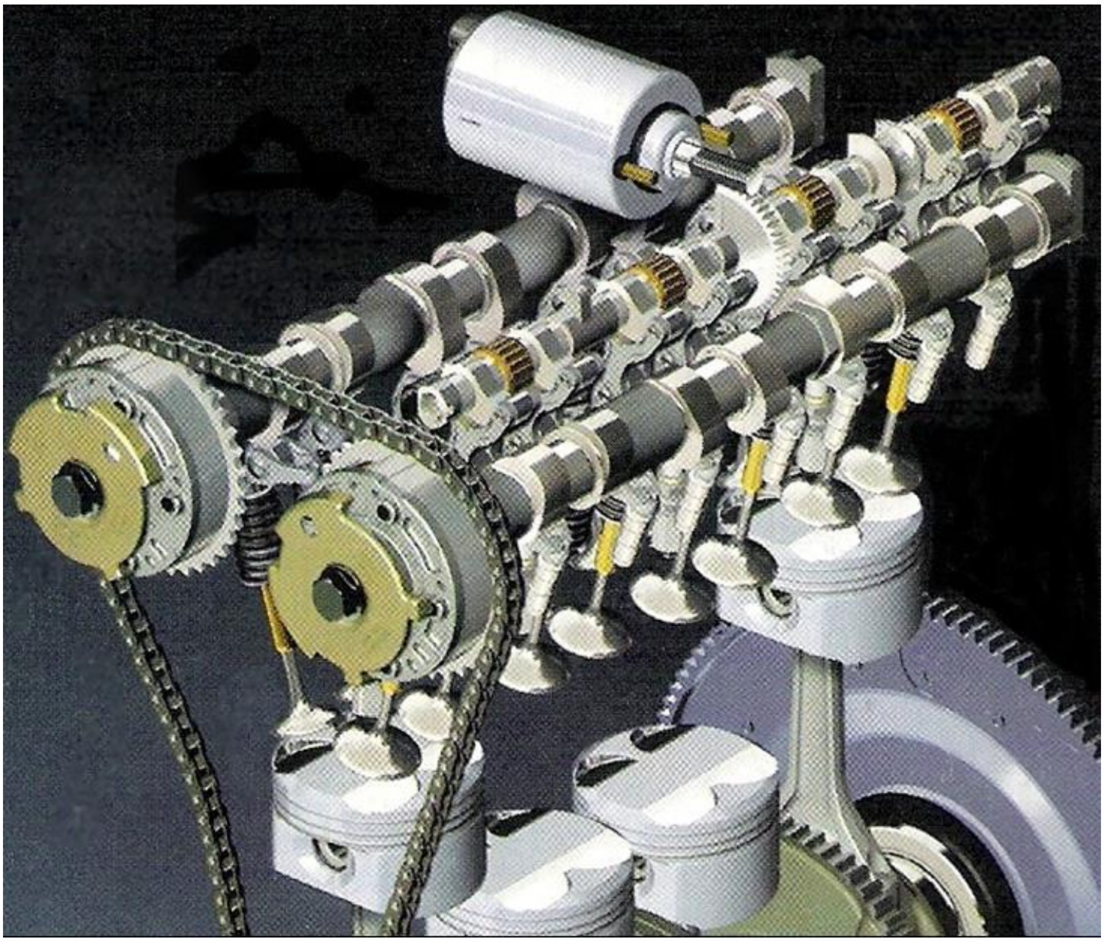
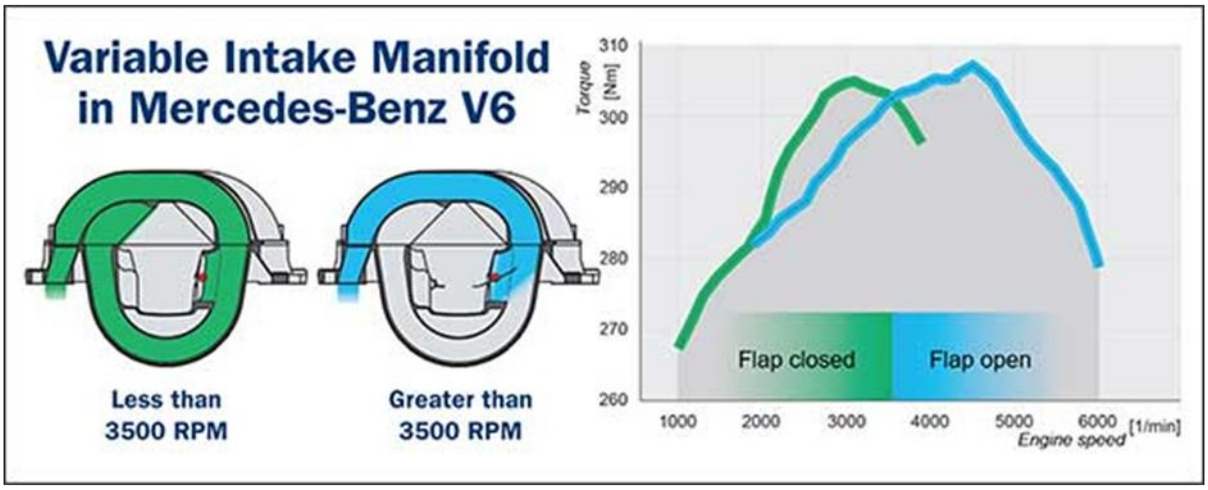
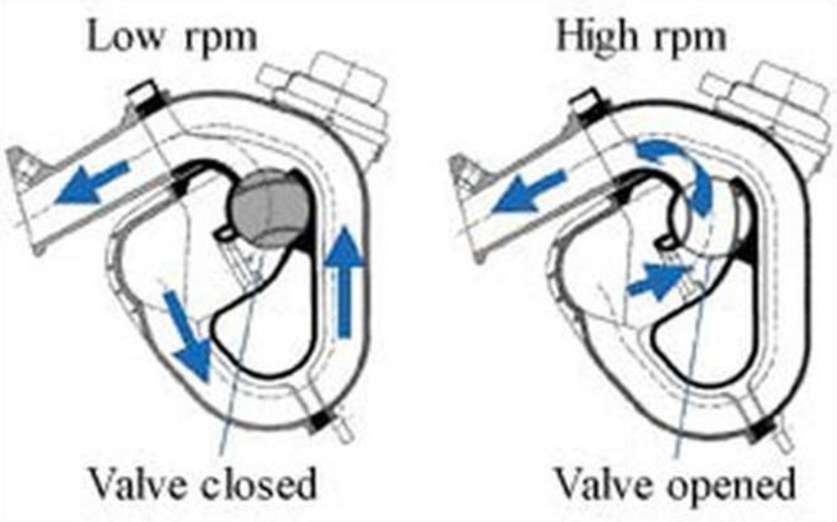


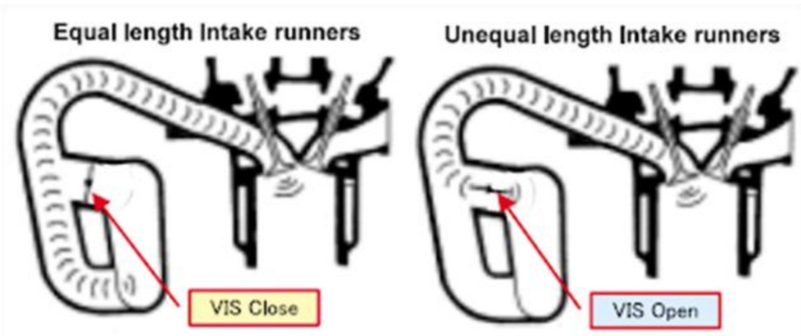
Fig. Combination of Valvetronic and Double Vanos systems – BMW

**Variable lenght of intake manifold**






Between 3250 and 5000rpm the VIS valve is closed to maximise torque and produce a nice sound from equal length intake runners. Above 5000rpm to redline the valve opens creating shorter unequal runner lengths and altering the induction noise to become a more throaty rumble. In the UK the inlet manifold has extra swirl-control valves to reduce exhaust emissions at low revs and improve driveability from cold. Mazda says inlet restriction has been reduced by 57 percent and exhaust restriction is down by 40 percent.




Odkazy na videa variabilných rozvodov:
http://cs.autolexicon.net/articles/valvematic/
http://www.youtube.com/watch?v=YQahUtR6XPc
http://www.youtube.com/watch?v=H-ZhbnJ3ZTI
http://www.youtube.com/watch?v=ukJ7Az1FtF8
http://www.youtube.com/watch?v=hEfOxKmCstg
http://www.youtube.com/watch?v=vFvRwdKgGNU
http://www.youtube.com/watch?v=OtRlQrAc5IY
http://www.youtube.com/watch?v=eqcezELKa5o
http://www.youtube.com/watch?v=hW_1CBoLUCQ

http://autoasist.vachta.cz/index.php?right=slovnik&lan=cs&sid