IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 16-21
www.iosrjournals.org

Valvetronic Engine Technology

Shahnawaz Khan[1], Bilal Yar Khan[2], Hashir Khan[3], Aaquib Khan[4]
[1,2,3,4] *Department of Mechanical Engineering, Anjuman College of Engineering & Technology;*

ABSTRACT: *The automobile has been providing individual mobility for more than 100 years. This mobility is made possible first and foremost by combustion engines drawing their power from fossil energy carriers, which, even today, provide the foundation in generating mechanical drive power in the automobile. The primary objectives in developing drive systems are to curb fuel consumption and reduce CO_2 emissions. In an effort to meet this challenge, the automotive industry is developing suitable new engines. The voluntary commitment assumed by the European Automobile Manufacturers Association (ACEA) is to reduce the fleet emission average of all newly introduced cars to 140g of CO_2 per kilometre by 2008.*

Keywords: *combustion engines,CO_2 emission, fossil energy carriers, fleet emission.*

I. INTRODUCTION

The first objective is to minimise emission components such as hydrocarbon, CO_2 and nitrogen oxides (NOx) subject to specific limits. At the same time, manufacturers are seeking to minimise fuel consumption and, accordingly, CO_2 emissions. All of this should be achieved with a maximum standard of comfort and safety on the road. In the homologation of motor vehicles, Europe, Japan and the US apply different driving cycles to determine emissions and fuel consumption. However, it is the individual customer who ultimately decides on his/her particular style of motoring and up to 30% of a car's fuel consumption depends on how it is driven and the style of motoring that is preferred by the driver. Clearly, the development engineer is unable to influence these external parameters – all that he/she can do is change the basic functions and control factors in the car and its drive train. The amount of energy required for driving a vehicle also drops with decreasing driving resistance provided by, for example, a reduction in roll and air resistance. To make more efficient use of the energy in fuel, the actual process of using energy must reach a higher standard of efficiency. Despite modern engine technology, the process of on-going development has not yet come to an end. Looking at the overall concept of a vehicle, the development engineer must therefore optimize the efficiency chain formed by all of the car's individual components. For example, a car with a state of- the-art spark-ignition engine uses only about 20% of the energy consumed to actually generate driving power and mobility in the EU test cycle. This alone demonstrates the remaining potential.

II. VALVETRONIC TECHNOLOGY

2.1. Evolution of Valvetronic

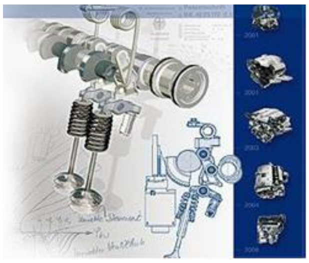
The losses that are capable of being influenced are composed primarily of the following:

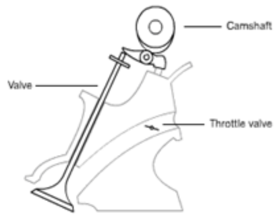
- A combustion process not yet ideal;
- The charge cycle;
- Friction; and
- Thermal losses through the walls.

Optimisation in these areas in driving cycles with low loads and engine speeds provides the greatest improvements in fuel economy. Quite generally, steps taken to reduce the throttle effect have a greater potential for saving fuel than the reduction of friction in the drive train (see *Figure 2.1*). Precisely with this in mind, BMW has developed a fully variable valve drive referred to as Valvetronic, a system offering improvement in fuel consumption comparable in virtually all driving cycles to the latest spark-ignition engines with direct fuel injection (DFI) and lean burn operation. A number of other important items were also included in the list of objectives:

- Achieving dynamic performance, fuel economy, noise management and quality typical of BMW;
- Having a flexible concept capable of fulfilling future
- Creating a benchmark product in terms of its package, weight and cost of ownership;
- Taking a modular approach in order to develop specific engine variants;
- Ensuring a significant potential for on-going development; and
- Providing the foundation for other engine variants, i.e. communality with future engines.

All of this led to the development of a fully variable valve drive system, BMW Valvetronic, helping to significantly reduce fuel consumption while maintaining stoechiometric driving conditions with all the usual advantages.





2.2. What Is Valvetronic?

The Valvetronic engine is the world's first engine without a throttle butterfly. Valvetronic allows the engine to run without a throttle butterfly, the cylinder charge being determined under part load as a function of the valve-opening period. The intake and outlet camshafts are driven by variable cam adjustment, BMW's Vanes technology. A further advantage of this concept is that it allows worldwide use of the proven three-way catalyst for emissions management, thus meeting even the strictest emissions standards in the US. Innovative technology was essential in order to reach the demanding objectives and functional requirements desired. However, at the same time, this concept demanded the utmost of the electronic control and management systems in the engine.

2.3. Concept

Taking nature as the role model: human beings also apply the Valvetronic principle A comparison with the human being clearly explains how Valvetronic works: Whenever we are required to make a great effort, we human beings breathe in a deep and long process of ventilation. Whenever we need less air, we do not throttle the supply of air by, say, closing our nose or our mouth, but simply breathe in a shorter, flatter process of ventilation. In a conventional combustion engine the throttle butterfly is basically comparable to a human being keeping his nose or mouth at least partially closed.

With its large valve lift (= deep, long ventilation) and short valve lift (= flat, short process of ventilation), Valvetronic, on the other hand, is able to breathe in the same way as nature – always in line with current requirements, without any kind of throttling effect and therefore with maximum efficiency.

2.4. Valvetronic Technology

Accordingly, the Valvetronic engine no longer requires a throttle butterfly, which has quite literally restricted the free ventilation of the internal combustion engine ever since its invention. Now Valvetronic replaces this conventional function by infinitely variable intake valve lift, offering a quantum leap in technology quite comparable to the changeover from the carburettor to fuel injection. Its most important feature is that it is able to save at least 10 per cent fuel throughout the entire operating range relevant to the customer, with a corresponding reduction in exhaust emissions, regardless of fuel quality. And a further important point is that the efficient operation of Valvetronic does not require any unusual types and grades of oil possibly difficult to obtain. As a result of these particular features the 85 kW/115bhp BMW 316ti compact with its top speed of 210 km/h or 125 mph consumes a mere 6.9 litters of premium fuel on 100 kilometres in the European test cycle, equivalent to 40.9 mpg Imp. This is a significant 0.7 liters less than the former 77 kW/105 bhp compact and well over a liter less than all competitors in this class.

The Valvetronic system is based consistently on BMW's proven double-VANOS (VANOS = variable adjustment of the camshafts), with infinite camshaft adjustment to meet specific requirements. The additional, variable valve lift adjusts the effective cam action and, accordingly, the opening cross-section of the valves. This is done by a lever positioned between the camshaft and the intake valves, its distance from the camshaft being adjusted infinitely by an additional eccentric shaft operated by an electric motor. Depending on the position of the Valvetronic control system, the lever converts the cam contour into a larger or smaller valve lift, whatever may be required.

III. WORKING OF VALVETRONIC ENGINE

3.1. Working of Ordinary Engine

In engines without valvetronic technology fuel injection systems monitor the volume of air passing through the throttle butterfly and determine the corresponding amount of fuel required by the engine. The larger the throttle butterfly opening, the more air enters the combustion chamber. At light throttle, the throttle butterfly partially or even nearly closes. The pistons are still running, taking air from the partially closed intake manifold. The intake manifold between the throttle and the combustion chamber has a partial vacuum, resisting the sucking and pumping action of the pistons, wasting energy. Automotive engineers refer to this phenomenon as "pumping loss". The slower the engine runs, the more the throttle butterfly closes, and the more energy is lost.

3.2. Working Of Valvetronic Engine

Compared with conventional twin-cam engines with finger followers, Valvetronic employs an additional eccentric shaft, an electric motor and several intermediate rocker arms, which in turn activates the opening and closing of valves. If the rocker arms push deeper, the intake valves will have a higher lift, and vice-versa. Thus, Valvetronic has the ability to get deep, long ventilation (large valve lift) and flat, short ventilation (short valve lift), depending on the demands placed on the engine.

Cylinder heads with Valvetronic use an extra set of rocker arms, called intermediate arms (lift scaler), positioned between the valve stem and the camshaft. These intermediate arms are able to pivot on a central point, by means of an extra, electro analytic actuated camshaft. This movement alone, without any movement of the intake camshaft, can open or close the intake valves. The Valvetronic system is based on BMW's established double VANOS system, which stainlessly varies the timing of both the inlet and exhaust cams. However, the Valvetronic system adds variable valve lift to the inlet cam, achieved by the use of a lever positioned between the camshaft and the inlet valves.

Valvetronic varies the timing and the lift of the intake valves. The Valvetronic system has a conventional intake cam, but it also uses a secondary eccentric shaft with a series of levers and roller followers, activated by a stepper motor. Based on signals formerly taken mechanically from the accelerator pedal, the stepper motor changes the phase of the eccentric cam, modifying the action of the intake valves. An additional eccentric shaft alters the lever's distance from the camshaft, with the eccentric's position determined by a worm drive from an electric motor. The position of the lever converts the cam action into a smaller or larger valve lift, as requested by the engine management system. Intake vale lift can be altered from a minimum of 0.25mm(!) to a maximum of 9.7mm, with the electric motor adjusting the eccentric shaft in 0.3 seconds. Because the intake valves now have the ability to move from fully closed to fully open positions, and everywhere in between, the primary means of engine load control is transferred from the throttle plate to the intake valve train. By eliminating the throttle plate's "bottleneck" in the intake track, pumping losses are reduced, fuel economy and responsiveness are improved.

3.3. OPERATING PARAMETERS

Valve lift is variable between 0 and 9.7 mm.
Adjustment of the worm gear from one extreme to the other takes 300 milliseconds.
Combined with double-vanes valve timing technology, the camshaft angle relative to the crankshaft can be adjusted by up to 60°.
The intermediate arm is finished to a tolerance of 0.008 mm.
The cams controlling the eccentric shaft are machined to tolerances of a few hundredths of a millimetre.

IV. ENGINE DESIGN ASPECTS

4.1. Basic engine design completely revised

Not only the cylinder head with BMW’s new Valvetronic technology, but also the complete four-cylinder power unit featured in the BMW 316ti is an all-new development from the ground up. The new cross-flow cooling concept with its open deck crankcase reduces coolant flow resistance and therefore allows use of a smaller water pump with just 60 per cent of the usual power uptake. Made of aluminium, the engine block ends exactly on the centerline of the crankshaft bearings. A ladder frame between the crankcase and the oil sump connects the lower halves of the bearing bridges to form one complete unit also accommodating the balance shaft housing and the two-stage oil pump. This makes the entire drive unit very stiff and robust, minimizing any vibration of other vehicle components the driver would otherwise feel on the steering wheel, gearshift lever and pedals, and also perceive as a kind of consistent humming noise. All ancillaries are bolted directly to the crankcase without the rather elaborate supports and attachments otherwise required – again an important contribution to running smoothness with vibrations reduced to a minimum.

4.2. Throttle plate is not removed

It is important to note however, that the throttle plate is not removed, but rather defaults to a fully open position once the engine is running. The throttle will partially close when the engine is first started, to create the initial vacuum needed for certain engine functions, such as emissions control. Once the engine reaches operating speed, a vacuum pump run off the passenger side exhaust camshaft (on the N62 V8 only) provides a vacuum source, much as a diesel engine would, and the throttle plate once again goes to the fully open position. The throttle plate also doubles as an emergency backup, should the Valvetronic system fail. In this case, the engine would enter a "limp home" program, and engine speed would once again be controlled by the throttle plate.

V. ADVANTAGES AND BENEFITS

5.1. Fuel economy increased

Valvetronic offers the customer direct, immediate benefits, with fuel consumption and exhaust emissions decreasing, but dynamic performance and the spontaneous response of the engine improving accordingly.

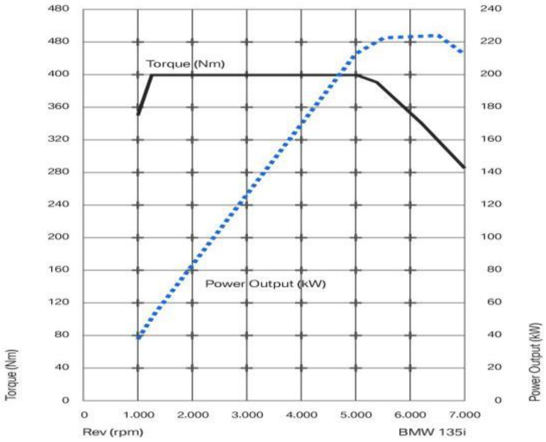


FIGURE NO 4

Added to this there is the even higher standard of running smoothness, since the valves move only slightly in a precisely controlled process. The improvement in fuel economy ensured by this concept of throttle-free engine load management is approximately 10 per cent in the EU cycle and at least 10 per cent under the typical driving conditions encountered by a customer. The basic rule is that fuel economy versus other concepts increases with the driver running the vehicle at lower loads and engine speeds. The consumption figures the motorist is able to achieve in this way are comparable to the fuel economy only a diesel engine was able to offer just a few years ago. At the same time the new four-cylinder is even more dynamic than its predecessor, the 316ti now accelerating well over a second faster to 100 km/h, achieving this important mark from a standstill in 10.9 seconds.

The standing-start kilometre, in turn, comes after 31.6 seconds, 1.8 seconds faster than before, and the top speed of the 316ti is now 201 km/h or 125 mph, 11 km/h faster than the top speed of the former model. Another advantage is the unusually spontaneous response of the 316ti to the gas pedal. This is attributable to the simple fact that load control, to use the technical term for "giving gas", now takes place "right there where the action is", that is directly in the combustion chamber. This eliminates the usual time lag between the process of "giving gas" and the actual acceleration of the car, which used to be inevitable due to the need to fill the intake manifold between the throttle butterfly and the combustion chamber. In this respect, Valvetronic even outperforms the most advanced concepts using individual throttle butterflies, thus offering an unprecedented combination of spontaneous engine response and ultra-fine dosage of power and performance under low loads.

5.2. Perfectly suited for all fuel grades

Another significant advantage of Valvetronic highly beneficial to the customer is that a Valvetronic engine offers at least the same fuel economy as the most advanced direct injection petrol engines without the same compromises in terms of emissions. Accordingly, the 316ti is able to do without the elaborate and so far hardly reliable emission management technologies still required today on a direct injection petrol engine. And it does not require sulphur-free fuel like a direct-injection petrol engine, achieving its superior fuel economy with proven l =1 technology, which allows the Valvetronic engine to run on all commercially available grades of regular petrol. In other words, the customer enjoys all the consumption-related advantages of Valvetronic also when driving in countries without a nationwide supply of sulphur-free fuel.

The consumption figures for the 316ti nevertheless relate to the use of premium fuel with an octane rating of 95 RON. Together with its 63-liter (13.9 Imp gal) fuel tank, the 316ti offers a much longer range than its predecessor, with extra-urban fuel consumption in the European EU test cycle of just 5.3 liters for 100 kilometers (53.3 Imp gals). This means that the driver would only have to refuel after a very significant 1,188 kilometers or 737 miles.

5.3. Other Advantages

Anti-knock control for running on all fuel grades between 87 and 99 octane.
Maintenance-free ignition system with individual coils.
Maintenance-free valve drive with hydraulic valve play compensation.
A Service Interval Indicator to keep the cost of service to a minimum
A two-mass flywheel for maximum running smoothness
Valve drive with roller bearings throughout in the interest of minimum friction and fuel consumption.
Advanced catalysts near the engine in special manifold design for minimum emissions.
In Valvetronic engines coolant flows across the head, resulting in a temperature reduction of 60%.
The water pump size is cut in half, reducing power consumption by 60%.
The power steering fluid is warmed quickly, reducing the power used by the hydraulic pump.
Mounting the water and power pump on the same shaft and a heat exchanger between coolant and engine oil reduces oil temperature by 30%. BMW has successfully completed this quantum leap in technology, even in the light of a demanding product development process. An important task in this process is to reduce the product development period to just 30 months.

5.4. Disadvantages

Facing such a high standard of software and hardware complexity, a manufacturer obviously also runs a greater risk of making mistakes. It is essential to acquire a sufficient stock of data under all kinds of operating conditions in order to understand how such a new system behaves. However, such data cannot be provided by the usual sequential test runs. All-round, general use of the latest direct-injection technology, in turn, faces some significant drawbacks such as costs, the need to make the combustion process very robust and the potentials in exhaust emissions treatment.

VI. EXPERIMENTAL RESULTS

First Working Model

The first BMW model to enter the market in 2001 with a large production spark-ignition engine featuring fully variable Valvetronic and Vanos valve control was the 316ti Compact. In turn, the first representative of this newly developed family of engines was a four-cylinder four-valve spark-ignition power unit displacing 1.8 litres, developing maximum torque of 175 Newton meters (Nm) and maximum output of 85kW (see *Figure 4*). BMW's new Valvetronic four-cylinder power units come with 1.8-litre and 2.0-litre capacities.

Some Experimental results

Despite the reduction in engine size by 100 cubic centimeters, compared with the former generation of power units, torque is up from 165Nm to 175Nm, with output increasing from 77kW to 85kW. With displacement of the 2.0-litre engine being increased by 5%, torque was up by no less than 11% from 180Nm to 200Nm, engine output increasing from 87kW to 105kW, resulting in specific torque of 100Nm/litre and specific output of 52.5kW/litre. The driver senses this enhanced performance through the more powerful torque curve, the car's dynamic behaviour on the road clearly proving the advantages of this extra torque. More
than 90% of the engine's torque comesat just 2,000 revolutions per minute (rpm), with torque peaking at 3,750rpm. Engine output, in turn, remains consistently at its near-maximum
throughout a wide speed range. The 4.4-litre power unit develops a maximum output of 245kW with a fuel consumption of only 10.9 litres/100km (or 25.9 miles per gallon) and already complies with the EU4 standard, which does not become obligatory until 2005.

The oil service intervals, in turn, have been extended up to 40,000km or 25,000 miles. One of the most important objectives from the start was to reduce fuel consumption. These engines offer a particular enhancement of fuel economy above all at low loads. When idling, fuel consumption is down by approximately 25% and the overall improvement in the European fuel consumption test cycle in 12%. The customer will also experience this improved economy and fuel efficiency in everyday motoring on the road. Using the power of the engine in full, on the other hand, the driver does not have greater fuel efficiency than with a conventional power unit. The reason for this is that, under these conditions, the engine runs like a throttle butterfly power unit with its butterfly fully open. Under normal driving conditions, however, throttle-free load management significantly reduces fuel consumption in practice.

VII. CONCLUSION

In summary, these innovative developments provide a combination of product features thus far inconceivable with a spark-ignition engine. The introduction of the world's first intake manifold providing infinite variation in manifold length serves to improve the torque level, which is already very good to begin with. A particular highlight of engines with Valvetronic load management is the significantly improved fuel/air mixture guaranteeing minimum fuel consumption, maximum spontaneity and optimum refinement. DFI with a stoechiometric air/fuel ratio provides the highest level of specific output as well as a combustion process helping to fulfil all exhaust emissions standards worldwide. All-round, general use of the latest direct-injection technology, in turn, faces some significant drawbacks such as costs, the need to make the combustion process very robust and the potentials in exhaust emissions treatment. Valvetronic combines a significant improvement of fuel consumption with excellent engine response and control, allowing optimum valve timing under all running conditions. The result is smooth and free operation of the engine under part load with very little throttle effect. Optimised fuel/air mixture management ensures significant advantages in fuel efficiency compared with a conventional four-cylinder engine, reaching the same standard as today's lean-burn concepts. Since such an engine with Valvetronic does not require an NOx removal catalyst, it can be used worldwide with all types and grades of fuel.

REFERENCES

[1]. www.bmwworld.com/technology/valvetronic
[2]. www.bmwworld.com/engines/valvetronic
[3]. www.Wikipedia.org/wiki/valvetronic
[4]. R Flierl, R Hofmann, C Landerl, T Melcher… - MTZMotortechnische, 2001 - Springer
[5]. DIS Missy, DIJ Thams, IM Bollig, R Tatschl… - MTZMotortechnische, 2002 – Springer
[6]. IH Unger, IC Schwarz, J Schneider, IKF Koch – MTZ worldwide, 2008 - Springer