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The Advanced Iveco Cursor 10 Heavy Duty Truck Diesel Engine

Giovanni Biaggini,[1) *] Walter Knecht[2)]

[1)]Iveco S.p.A., Lungo Stura Lazio, 49, I-10156 Torino, Italy
[2)]Iveco Motorenforschung AG, Schlossgasse, CH-9320 Arbon, Switzerland

ABSTRACT

Iveco has started production of new advanced diesel engine Cursor 8 in 1998. In 1999 this was followed with the new Cursor 10 engine which reaches a maximum power of 316 kW with a displacement of 10,3 dm^3 and continuous the strategy of developing high BMEP engines which Iveco began more than 10 years ago. This approach shows the benefits of reduced noise, weight and fuel consumption in trucks in comparison to engines having a larger cylinder capacity with the same power. Together with the engine, Iveco introduces an electronic control system with full authority on every operating condition, realising a true drive-by-wire mode of truck operation.

The control of fuelling, boosting, braking and cold starting gives the driver full comfort and guarantees that the engine produces optimum performance under every circumstance. An advanced diagnostic system warns about deviations from acceptable operating conditions or fault occurrences. Advanced technologies have been extensively used in the new engine, like variable geometry turbocharger, high pressure unit injectors mechanically driven by an overhead camshaft, decompression brake, fibre filters and advanced casting technologies. It further features 4 valves per cylinder, wet liners and the gear train is arranged at the rear of the engine. The paper presents, besides the engine design features and performance achievements, the advanced methods employed during the development phase both in Iveco and by suppliers.

Currently the future European emission legislation for EURO 4 Step 1 (year 2005) and EURO 4 Step 2 (2008) are in discussion. Proposed are extreme low particulates standards of 0,02 g/kWh and for EURO 4 Step 2 a nitrogen oxide standard of 2 g/kWh. Therefore, strategies to comply with such emission levels are discussed. The key advantage of the diesel engine with respect to its high efficiency must be maintained. Whereby also the use of advanced exhaust gas aftertreatment has been evaluated and results are presented.

Keywords: Truck diesel engine, unit injector, turbocharger with variable turbine entry geometry, decompression brake, European emission legislation, exhaust gas aftertreatment

1. INTRODUCTION

Iveco is a major diesel engine manufacturer. In 1999 Iveco produced almost 400’000 units, of which one third was used in Iveco vehicles and the rest was sold to customers in different markets (automotive, industrial, agricultural tractors, marine application and gensets).

Iveco is in a phase where its complete engine programme is renewed in order to:

- comply with the increasingly demanding market needs
- offer more competitive products
- give more value to its customers
- meet future emission legislation

The Iveco Cursor 8 and Cursor 10 diesel engines (Cursor originates from the Latin word „currere„ and means „running„) are the first two of a new engine range and the Cursor 8 will be used in the Iveco vehicles of the ‘EuroTech Cursor’ and ‘EuroTrakker Cursor’ range and in buses, while the Cursor 10 engine is to be used in the 'EuroTech Cursor' and the 'EuroStar Cursor' trucks.

While both engines are developed for compliance with EURO 3 emission standards, significant development is still needed to achieve the foreseen European emission standards for the years 2005 and 2008.

2. IVECO CURSOR ENGINES

2.1. ENGINE CONCEPT

After intensive pre-studies the six cylinder in-line engine concept was chosen, **Figure 1**.

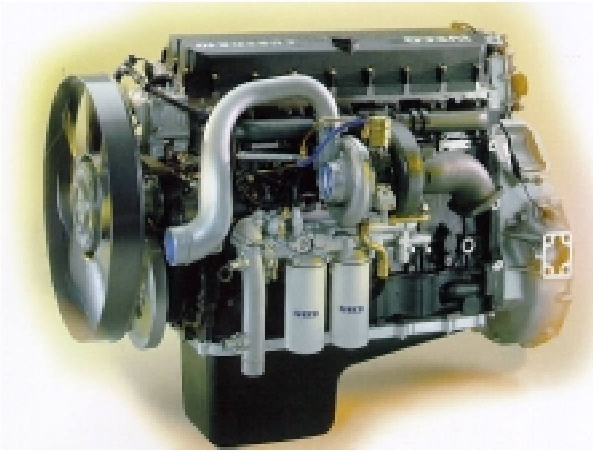

Fig. 1 Cursor 10 engine

This was due to the simpler design, lower number of components, larger crankshaft bearings, more space for the camshaft and higher suitability for turbocharging if compared to a V-engine. Furthermore, vehicle installation is facilitated because of the reduced engine width, no free moments, an optimal firing frequency leading to smaller torque variations and good access to the auxiliaries.

In the development phase of the Cursor 8 and 10 engines it was decided to develop small, high-bmep engines. Diesel engines with high mean effective pressures have been the philosophy of Iveco engines for more than a decade.

For a flexible management of the air/fuel-ratio which is essential to control smoke and the transient response, the concept of a turbocharger with a variable turbine entry area (VGT) was selected in favour to sequential turbocharging or mechanical supercharging, because of its inherent simplicity and higher efficiencies.

To meet the targets of fuel consumption, gaseous and particulate emissions, different injection systems were evaluated: unit injector, unit pump and common rail. The Fiat Group has been involved in the basic development of a viable common rail system from a very early stage. However, a common rail solution was judged to be unsuitable for this engine, because an injection pressure of 1600 bar would not be available in time for the start of production of the Cursor engines. The unit pump was considered unsatisfactory due to the presence of external high-pressure lines and the external noise sources.

While the principle of air handling by a VGT influences only marginally the architecture of the engine, the choice of the injection system has far greater consequences: individual unit injectors for each cylinder required a very stiff drive that led to the design of an overhead camshaft and a cylinder head in one piece.

A stroke/bore-ratio of approximately 1,1 was adopted during the early design stage in order to reach the best compromise between the enlarged usable speed range and small mean piston speeds without negatively affecting the friction losses in the crank mechanism.

For these high-performance engines, an enhanced engine brake was required with a system combining the concept of a decompression brake and turbocharging by a VGT to increase the amount of dissipated work. This choice reinforced the need of a rigid structure of the valve drive as already mentioned for the unit injectors.

To meet the low noise target of 95 dB(A), two major design concepts were applied. These being a bedplate design, where the main bearing caps are an integral part of the lower block structure and a rear gear train, where the crankshaft oscillations are small.

Starting from the stiff structure of an engine with a two-piece cylinder block and a camshaft drive without pushrods and tappets, a good basis for a high durability was reached.

Advanced technologies were used in most engine components to extend life and maintenance intervals. It is the first time that so many new technologies, most of which developed originally to meet emissions constraints, have been packed together and harmonised to give the maximum value to the customer of an industrial vehicle.

The main characteristics of the Cursor 8 and Cursor 10 engines are given in Table I.

2.2. DESIGN FEATURES

The main design features of the Cursor 10 engine are identical to the Cursor 8 engine and are described in [1].

The Cursor engines have been designed for a maximum peak cylinder pressure of 180 bar.

Engine block: The block structure consists of two parts, **Figure 2**. The lower bedplate houses the bearing caps and is fixed to the upper block by two series of bolts. The equally spaced six cylinder head bolts lead to an even gasket pressure distribution and, hence, reduced bore distortion, a critical feature for low oil consumption and blow-by targets. The block is made of stabilised cast-iron and the cylinder spacing is 138 mm. Wet liners, evenly cooled and made of special cast-iron, containing Mo and V with low surface roughness, are used. Three O-rings are fixed in the lower section of the liner.

Cylinder head: A one piece cylinder head for all six cylinders is used and is made of cast-iron with 1,5% Ni-content, **Figure 3**. The fuel passages, the camshaft, rocker supports and the intake manifold are all integrated in the cylinder head. A multi-layer cylinder head gasket is employed for high reliability gas and water sealing.

Crankshaft: A forged crankshaft with induction-hardened main and con-rod journals made of micro-alloy

		Cursor 8	Cursor 10
Bore	mm	115	125
Stroke	mm	125	140
Stroke/Bore Ratio	-	1,087	1,12
Cylinder Capacity	dm^3	7,79	10,308
Valve Number/Cylinder	-	4	4
Compression Ratio	-	17	17
Injection System	-	Bosch/DTC PDE 30	Bosch/DTC PDE 31
Turbocharger	-	Holset HX40V	Holset HDX55V
Charge Air Cooling	-	Air/Air	Air/Air
Performance	kW	180, 200, 228, 259	287,316
Nominal Speed	min^{-1}	1700-2400	1600-2100
Max. Torque	Nm	950, 1115, 1280	1700, 1900
Speed	min^{-1}	1000-2000	1000-1600
Engine Weight	kg	680	914
Weight to Power Ratio	kg/kW	2,62	2,89
Specific output	kW/dm^3	33,24	30,66

Table I - Characteristics of Iveco Cursor engines

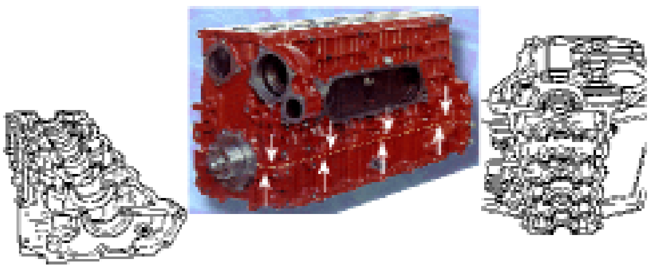

Fig. 2 Engine block of Cursor 8

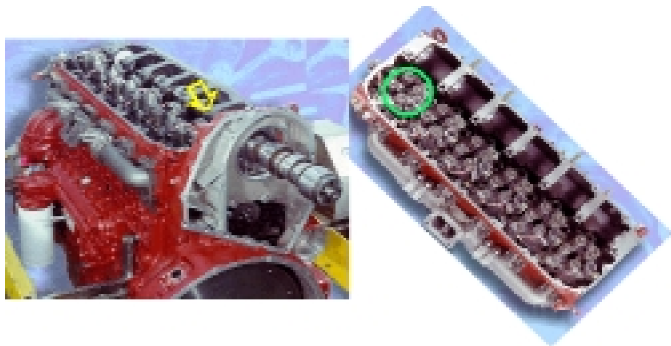

Fig. 3 Cylinder head

steel is used. Integral counterweights were adopted. A viscous damper has been employed.

Camshaft: An overhead steel camshaft, which is carburised and quenched to a depth of more than 2 mm, is used. The camshaft is rotating in seven bearings with three cams per cylinder (intake, exhaust, fuel injection).

Piston: Hypereutectoid light metal alloy pistons with cooling galleries are equipped with three rings.

Con-rods: These are forged and made of micro-alloyed steel.

Timing gears: These are, due to the reduced torsional vibrations from the crankshaft, arranged on the flywheel side of the rear main bearing and only 5 gears are needed to drive the camshaft. A special surface finishing technique is used for the gears, that are carburized and quenched.

Cooling system: A centrifugal pump is integrated into the engine block and driven by a Poly-V-belt. A sliding thermostat is used and the operating temperature is between 85 and 95 °C. The coolant flow in block and cylinder head was optimised by CFD computation with Star CD. All water pipes are integrated into the engine structure in order to avoid gaskets and potential leakages.

Lubricating system: Lubricating oil is supplied from a crankshaft driven oil pump. A control valve governs the oil pressure in the main gallery and a safety valve in the pump limits the maximum oil pressure to 10 bar. During the warm-up phase the oil flow circumvents the cooler with a thermostat valve and a bypass.

The lube oil filtration and oil-contaminated particles were extensively investigated. A composite micro-fibre multistrate filter with a high micro-pore density, a high pressure fatigue membrane resistance, as well as a high dirt accumulation capacity, has been chosen.

Blow-by recirculation: The closed crankcase ventilation system is shown schematically in **Figure 4.** A coalescent filter is used which permits the gas to pass, but it condenses the oil content. The filter has been developed

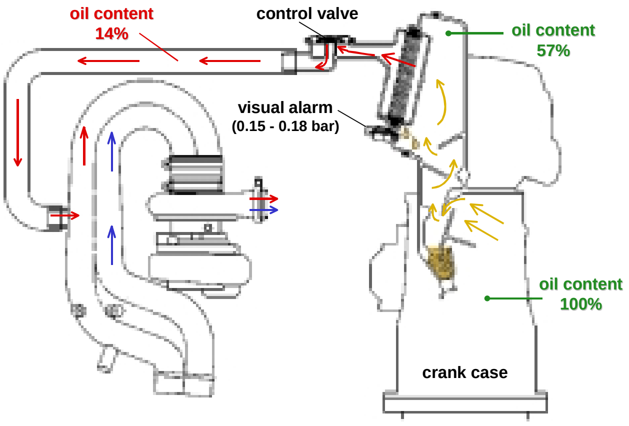

Fig. 4 Blow-by recirculation

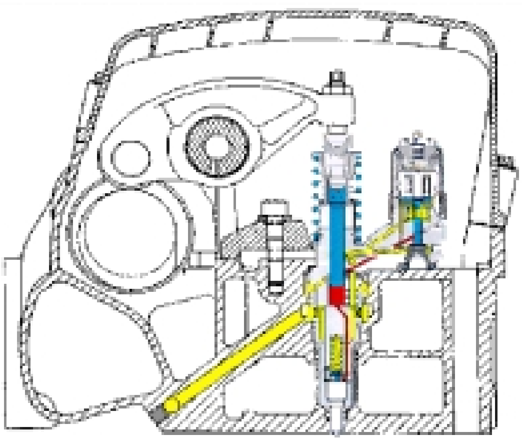

Fig. 5 Arrangement of unit injector in the cylinder head

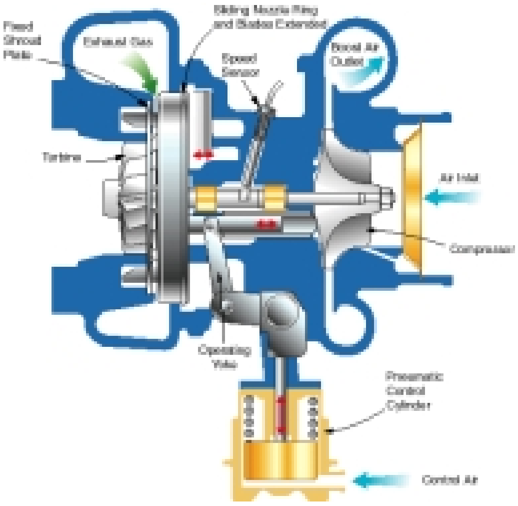

Fig. 6 Turbocharger with variable turbine entry geometry

to allow the majority of soot particles present to return with the oil droplets to the oil sump. This necessitates a filter replacement every 160'000 km.

Fuel injection system: As mentioned, electronically controlled BOSCH PDE 30 unit injectors were chosen. They operate up to 1600 bar maximum injection pressure and are mechanically actuated by the overhead camshaft, **Figure 5**.

Turbocharger: A variable geometry turbocharger built on the principle of a sliding nozzle ring with shaped vanes which is positioned with a pneumatic actuator. The turbocharger is water cooled in order to ensure a bearing life equal to the engine life. **Figure 6**.

Decompression brake: The design consists of an eccentric bush that changes the position of the rocker arm axis relative to the one of the camshaft. There are two positions: one for firing and the other for brake mode. In the second position, the rocker arm feels an additional lift on the base cam circle which causes a small opening of the exhaust valve at TDC **Figure 7**. The bush is moved by a hydraulic piston, fed by lube oil when an electric valve is switched on. The Iveco engine brake, in combination with the VGT, substantially increases brake power and is also active in the cruise control mode.

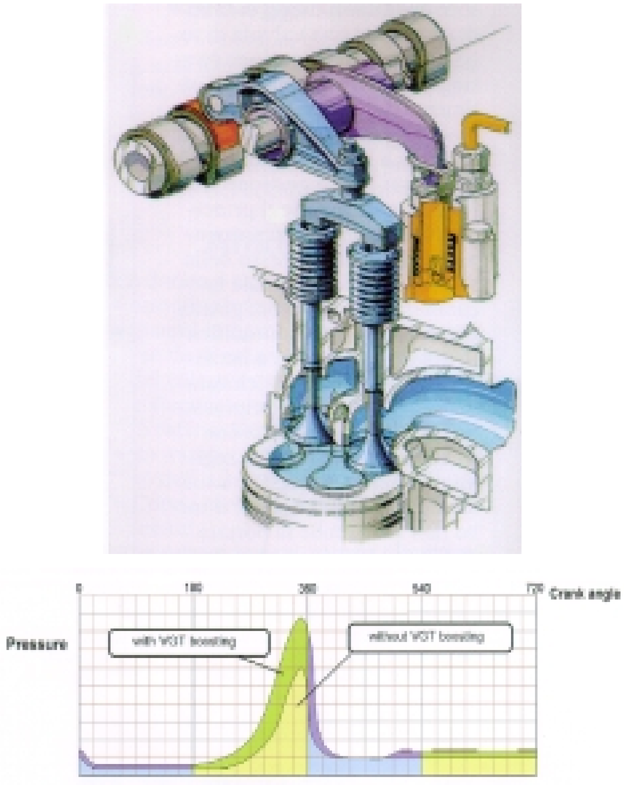

Fig. 7 Function of Iveco decompression brake

Besides the fuel quantity and injection start control as a function of the cooling water temperature, the turbocharger contributes to a fast cold start in that the turbine entry area is kept to the minimum opening position during the start-up and warm-up phase.

The new advanced Iveco Cursor engines exhibit a very low specific engine weight and a high power per unit cylinder capacity, **Figure 8**.

The engine performance and the fuel consumption of the Iveco Cursor 10 are given in **Figure 9**.

2.3. ENGINE DEVELOPMENT

Combustion system: The 4 valve cylinder head permitted a central and vertical arrangement of the injector and this is a favourable boundary condition for the mixture formation and combustion processes.

The actual mixture formation for this engine is not so much dependent on the port-induced air motion, but mainly on the fuel jet energy. Investigations showed that 'low swirl' systems favour open combustion chambers which, however, often lead to substantial problems with regard to lube oil ageing.

The required large fuel spray angles necessary at late injection timings (for the reduction of nitrogen oxides emissions)

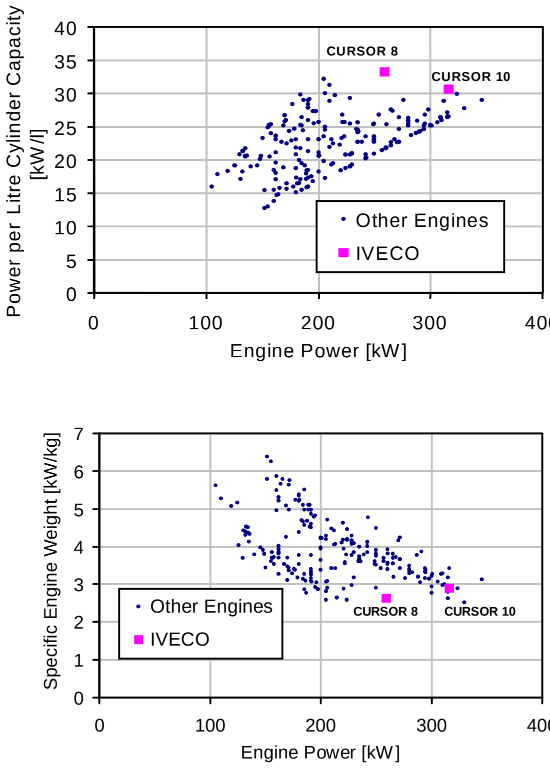

Fig. 8 Power per litre cylinder capacity of Iveco Cursor 8 and Cursor 10 engines (top) and engine weight per kW (bottom) relative to other European diesel engines

leads to an increased fuel and soot content in the oil. Therefore, Iveco developed a combustion system with a re-entrant combustion bowl and carefully matched spray angles such that as little fuel as possible, even in reverse squish condition, could reach the liner walls.

The injection cams were optimised for a constant rate of injection and the combustion development aimed at a low premixed heat release rate in order to keep the temperature level of the combustion gases to a minimum for low NOx-formation. At the same time, care was taken to achieve an increased rate of diffusion burning in order to avoid a delayed end of combustion. An important element of the combustion optimisation was the flexible control of the boost pressure in the whole operating range.

Turbocharging system: Two concepts of variable geometry turbochargers were investigated:

- swing vane design
- sliding nozzle ring configuration

The sliding nozzle ring design was finally chosen in preference to the swing vane design for the following reasons:

- simplicity and robustness of the actuation system, lower friction and hysteresis of the mechanism
- good efficiency equivalent to that of the swing vane concept due to the optimisation of the nozzle blade shape.

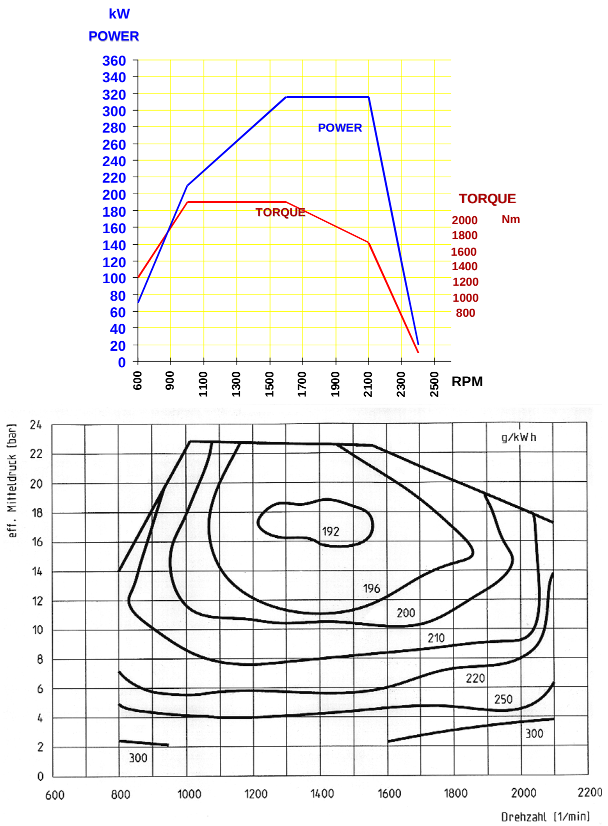

Fig. 9 Engine performance and fuel consumption map of Cursor 10

The variable geometry turbocharger of the Cursor engines has been developed jointly by Iveco and Holset as a part of a totally integrated fuel and air handling system.

Using a turbocharger with a variable turbine entry area results in a system that manages the available exhaust gas flow to meet air flow demand over a wide power and speed range.

Exhaust gases are directed onto the turbine wheel through a gap between a fixed shroud plate, the blade assembly and a sliding nozzle ring. The position of the sliding nozzle is controlled by a mechanical yoke and external pneumatic cylinder.

The nozzle ring and blades are retracted, allowing exhaust gas to act on a small turbine area. This enables the available gas flow rate to give more energy to the turbine, thus increasing the compressor speed and boost pressure without the usual 'turbo lag'.

When less turbine power is needed, the nozzle ring and blades are extended allowing the exhaust gas to act on a large turbine entry area, the optimum conditions for high-speed fuel economy at low boost pressures.

In order to achieve the greatest benefits of integrating such an innovative component into the engine, significant resources were assigned to develop:

- an advanced control system
- special materials used in the operating mechanism which are resistant to stress and wear at high temperatures
- compressor with 'wide' maps to achieve a pressure ratio close to 3:1 and good efficiency over the whole operating range of the engine, **Figure 10**

As a result of extensive development, the following advantages of a VGT were fully utilised:

- optimum boost pressure in each operating point (load/engine speed) with regard to fuel consumption without compromising emissions
- high boost pressure and, hence, low smoke values, even at high torque in the lower speed range of the engine
- the combination of the characteristics of a small turbine (high boost pressure at low engine speeds) with those of a large turbine (high flow rate at high engine speed for turbocharger speed control). This has enabled an engine to be developed with a high torque output over a wide range of load and engine speeds, with very good fuel economy
- altitude compensation
- very good transient behaviour due to a fast boost pressure build-up
- enhanced engine brake.

Engine Management: Advanced diesel engines are equipped with an electronically controlled fuel injection system permitting the control of fuel quantity and injection timing in steady state, during accelerations and during a cold start. A VGT offers with a change of the turbine entry area a control of the boost pressure and, hence, of the air/fuel-ratio and this results in optimal fuel consumption and emissions. After investigating different control strategies, Iveco adopted additionally on the Cursor engines the direct turbocharger speed measurement and this signal is used to perform a turbocharger speed governor in all conditions, specially during the braking phase. In fact the engine controller drives directly the engine brake and the turbocharger is used to increase the braking power, provided that the maximum turbocharger speed is not exceeded.

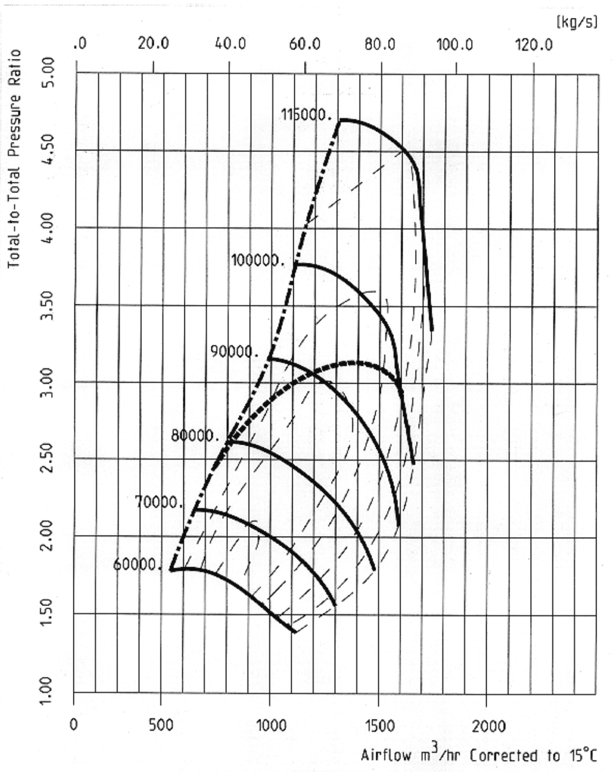

Fig. 10 Compressor map with Cursor 10

Therefore, compliance with the following criteria must be ensured in all operating points:

- in normal engine operation the optimal air mass flow rate should be adjusted by a boost pressure control under consideration of the ambient pressure
- in altitude operation excessive boost pressures must be avoided in order not to exceed the permissible turbocharger speed. Therefore, instead of a boost pressure control, a turbocharger speed control is automatically applied
- the dynamic behaviour required intelligent anticipative control
- in engine brake operation a modulation of the VGT control permits a controlled vehicle speed
- the maximum acceptable exhaust back pressure should not be exceeded
- the maximum permissible cylinder pressure must be respected
- the maximum turbocharger speed can not be exceeded
- the turbocharger must be operated in stable conditions (excessive pressure before turbine may lead to a reduced boost pressure).

Furthermore, the following aspects - essential for the VGT-control had to be accounted for:

- the system is not linear
- turbocharger tolerances have to be accepted and anticipated
- high demands on the control quality (turbocharger speed change up to 100’000 rpm/sec)
- limp home capability in cases of erroneous operation (example: sensors, actuators)

Particular care has been directed to the environmental performance of the engine:

- enhanced cold start aid system control, combined with the optimum fuel delivery and timing control, allows to prevent white smoke and to heat up the engine in the fastest way
- the enhanced boost control during transient operations allows to prevent typical black smoke emissions, without affecting the acceleration characteristics required by the driver
- fuel delivery and timing actuated cylinder-per-cylinder and cycle-per-cycle allow to control the engine in such a way to guarantee the compliance with the engine fuel map in all conditions and for life

Driveability requirements have also been taken into account, in order to comply with the customer demands as well as with the legislation demands:

- two vehicle speed limiting thresholds (the first one according to the legislation, the second one selectable for special purposes)
- cruise control
- isochronous engine speed governor to facilitate PTO operations
- communication with the immobiliser ECU, in order to prevent non-authorised engine start
- communication with enhanced braking systems and electronic gear box controller
- communication with the on-board information system
- communication with the Iveco Service Tester

Diagnostics: During the normal operation the engine controller protects the engine against over-speed, over-heating and exceeding the maximum torque. The engine control system allows a continuous monitoring in order:

- to identify and to insulate failed areas and to actuate limp home strategies (to prevent failure propagation), possibly without mission interruption
- to store the failure and the related ambient conditions
- to make evident the failure status to the driver
- to allow an efficient repair action

As a monitor, the system is continuously checking, when the engine is running:

- the electrical integrity of all sensors (pressure, temperature, etc.) and actuators (valves for injectors, engine brake, VGT, etc.)
- plausibility of critical sensors (engine speed, accelerator position)
- plausibility of controlled system response (e.g, between target boost pressure and actual boost pressure).

In case of detected failure or errors, the control system:

- whenever possible, uses replacement functions (for example, in case of water temperature sensor failure the fuel temperature sensor is used instead)
- if necessary, reduces engine power (for example, 'naturally aspirated' map if the VGT control is out of operation)
- informs the driver of existing faults (dash board indication)
- records in a permanent memory the fault and other relevant information which may be helpful for fault repair and the mechanic can identify this by reading the failure memory

The electronic system allows also to perform an engine diagnosis, much more efficient than with a mechanical injection equipment.

Using an external diagnostic unit (like Iveco MODUS) the following tests can be performed either for checking ability of the engine to perform correctly or for troubleshooting:

- actuator tests (VGT, engine brake, lamps, air pre-heater)
- engine friction check (free acceleration from idle)
- single cylinder power test (as above, de-activating one cylinder each time)
- engine brake (deceleration test with and without activation of engine brake)
- turbocharging system test (boost pressure reached at a given engine speed in a given VGT position)
- compression test (speed fluctuation during cranking)

Even though none of the tests are actually assessing full engine power, however, all systems contributing to power generation are verified. If all tests are fulfilled, the full engine performance can be guaranteed.

On Board Diagnostics (OBD): OBD is in Europe required for HD diesel vehicles as from Euro 4 Step 1 enforcement date.

OBD should reliably detect and report failures of emission related powertrain components throughout the vehicle life, including also additional devices, like exhaust gas aftertreatment systems.

The engine control system has to be improved properly in order to comply with the OBD requirements, and this means additional HW (new ECU and additional sensors) and SW.

Engine brake: A high brake performance reaching the engine rated power is desired in commercial vehicles, as this is a decisive factor to achieve high transport performance. The Iveco engine brake is a decompression brake, matched with VGT charging, where pressure in the cylinder is released by a small opening of the exhaust valve shortly before TDC.

As a matter of fact, combining decompression brake and flexible turbocharging, a considerable increase in brake power could be achieved, **Figure 11**.

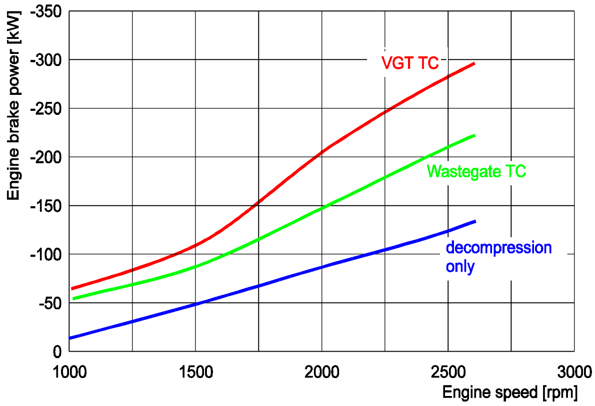

Fig. 11 Engine brake power with decompression brake only, with wastegate turbocharger and with VTG-turbocharger

The possibility to control the amount of energy transformed in the turbine by the variation of the entry cross section area gives the driver the brake power he expects and requires. A vehicle velocity (cruise) control is also available in engine brake operation.

Contrary to a flap valve, the VGT creates in braking conditions a continuous air flow similarly to that in fired conditions. As a consequence of this, the usually critical injector nozzle temperature is significantly reduced so that even at maximum power a continuous use is possible. At the same time the heat rejected to the cooling water is reduced and, hence, vehicles with retarders permit an increase of the continuous total brake power with the same cooling system capacity.

Noise: The engine noise was set to 95 dB(A) at one meter distance for driver comfort. At this level of sound, emission of the engine becomes a secondary noise source when the total vehicle noise is considered, allowing the elimination of heavy noise shieldings that make engine servicing difficult.

The design approach followed 3 major guidelines:

- engine structure with a symmetrical block closed by the bedplate
- acoustic insulation of some components, like cylinder head cover and oil sump
- local treatment of individual components and sources like alternator, damper and inlet manifold.

Mechanical development: Due to the high level of innovation in the Cursor engines, it was imperative, that a thorough and systematic approach in the development process was applied in order to achieve a life target of 1'000'000 km for the Cursor 10.

The Cursor engines were first tested in the usual stringent Iveco durability tests on engine test beds, followed by a field test program with 22 vehicles at customers to confirm the test bed reliability. Field tests were conducted with engines and vehicles, initially in prototype state, up to fully representative engines of the series production. Several engines have been stripped down and inspections and measurements indicated a very good result with respect to wear of key components.

3. FUTURE EMISSION STANDARDS

In the European Union (EU) very severe emission standards for truck diesel engines are planned to be introduced. At the same time the test procedure is changed and for EURO 3 the European Steady Cycle (ESC) and a European Load Response Test (ELR) and particularly with EURO 4 the European Transient Test (ETC) is to be introduced. The latter is a more dynamic test than the US Transient Test.

The planned emission standards are summarised in Table II. In this context two aspects are of importance:

a. the particulates standards of 0,02 g/kWh are so low that they can be measured with the prescribed gravimetric procedure only with a high degree of inaccuracy, and
b. so far insufficient fuel characteristics are planned to be available. In fact only the sulphur content has been proposed to be 50 ppm. The latter is for some exhaust gas aftertreatment techniques not sufficient and should be lowered. For EURO 4 Step 1 a fuel with a maximum sulphur level of 10 ppm is urgently requested.

4. STRATEGIES TO COMPLY WITH FUTURE EMISSION REQUIREMENTS

The Cursor 10 has been developed to achieve emission standards beyond EURO 3 and excellent vehicle performances and fuel economy. But to comply with the EURO 4 Step 1 and Step 2 emission standards, a further development is required and various approaches are investigated:

- in-cylinder measures, and
- exhaust gas aftertreatment

In a choice of approach, the effect on fuel consumption and life cycle cost are of great importance. Basically the following routes are feasible:

In-cylinder measures:

- Improved conventional combustion systems which may permit to reduce the demands on exhaust gas aftertreatment. Thereby very high injection pressures (< 2000 bar), injection rate shaping, pilot- and multiple-injection, pressure modulated injection, etc. are evaluated.
- cooled exhaust gas recirculation (EGR) employing relative high recirculation rates even at high bmep’s
- turbocompounding with EGR
- the use of water/diesel fuel emulsions or direct injection of water
- completely different diesel combustion systems such as homogeneous charge diesel combustion

		EURO 3		EURO 4 Step 1		EURO 4 Step 2	
		ESC[1)]	ETC	ESC[1)]	ETC	ESC[1)]	ETC
NOx	g/kWh	5,0	5,0	3,5	3,5	2,0	2,0
HC	g/kWh	0,66	-	0,46	-	0,46	-
CO	g/kWh	2,1	5,45	1,5	4,0	1,5	4,0
PM[3)]	g/kWh	0,1/0,13[2)]	0,16/0,21[2)]	0,02	0,03	0,02	0,03
NMHC	g/kWh		0,78		0,55		0,55
CH_4 [4)]	g/kWh		1,6		1,1		1,1
Dyn. Smoke	m^{-1}	0,8	-	0,5	-	0,5	-

1) includes load response test ELR
2) for engine having a swept volume of less than 0,75 dm^3 per cylinder and a rated speed of more than 3000min^{-1}
3) for diesel engines only
4) for gas engines only

Table II: European emission standards for diesel engines of heavy duty vehicles

	Temperature-Range (°C)	NOx (%)	CO (%)	HC (%)	PM (%)	BSFC (%)
Oxidation catalyst	180 - 300	0	>70	>70	30	1-2
Active 'lean NOx' catalyst	180 - 300	10 - 20	>70	>70	>25	2-4
Selective Catalytic Reduction (SCR)	180 - 550	70 - 80	+20 - +40	>90	10-30	1-2
Adsorber catalyst	180 - 500	50 - 80	>70	>70	>25	5-8
Non-thermal plasma	180 - 300	40 - 60	>70	>70	>25	4-6
Catalytic soot filter	220 - 500	0	>70	>90	>90	1-3
CRT-particulate filter	250 - 500	0	>70	>90	>90	1-3

Table III - Characteristics of exhaust gas aftertreatment systems

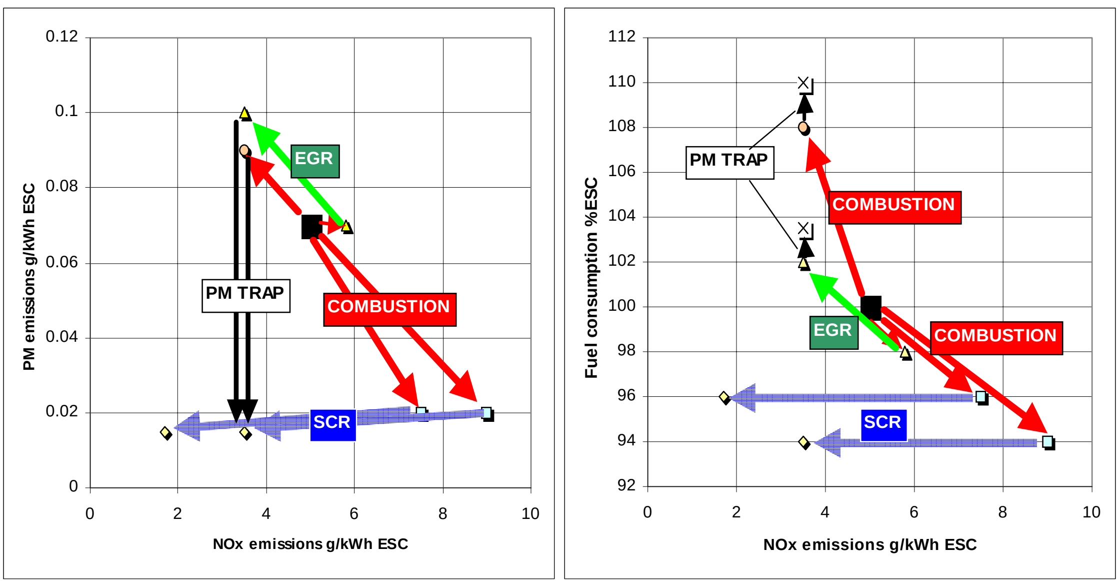

Fig. 12 Strategies to comply with European emission standards

Exhaust gas aftertreatment:

- particulate traps such as the continuously regenerating trap (CRT) or catalysed soot filters possibly by using an additive to reduce the regeneration temperature
- Selective catalytic reduction (SCR) using urea/water-solution as a reducing agent [2]
- Adsorber catalyst with a special hydrocarbon admission system in order to create periodically a rich mixture at the catalyst entry.

In a number of places work in developing aftertreatment systems using a non-thermal plasma are in progress, [3].

The main characteristics of these exhaust gas aftertreatment systems are given in Table III.

The strategies with regard to NOx , PM and fuel consumption are given in **Figure 12**.

Exhaust gas aftertreatment is generally not very much liked because:

- the required volume of the systems and the weight
- the relatively high cost
- the possible need of an infrastructure for an additional reducing agent

On the other hand, technically complicated in-cylinder measures necessitate considerable maintenance costs and high demands of the maintenance personnel.

Therefore, since two aftertreatment devices (SCR and PM-trap) are an expensive solution, the real alternative for EURO 4, step 1 is EGR and PM trap while for EURO 4, Step 2 an SCR-system seems at present non-avoidable.

A PM-trap can realistically be avoided by improved combustion.

As mentioned earlier, the final choice of measures depends on the effect on life cycle cost of the vehicle. This has been investigated for several technologies, vehicles and missions.

5. CONCLUSIONS

In this paper the new IVECO Cursor 10 diesel engine, its design and characteristics were presented. Furthermore, approaches to comply with the very stringent European emission legislation for the years 2005 and 2008 were outlined and discussed.

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