Der neue Renault V6 dCi diesel Motor

The new Renault V6 dCi diesel engine

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Abstract

Development of Diesel engine market has led to significant CO_2 emission reduction. Customers are demanding for more driving pleasure and comfort.

Renault and Nissan have decided to develop a new Diesel engine family in order to comply with future customer requirements and to prepare more stringent emission regulations. In addition to challenging targets for fuel consumption and emission, engine specifications were focused on performance and NVH in order to reach top class level. The ability to install the engine in vehicle, both in transversal and longitudinal position, was also part of packaging specifications that required very compact engine.

The new V6 dCi engine derives from the 4 cylinders in-line 2.0 dCi launched in 2005. They share components and flexible manufacturing facilities. Nevertheless, the combustion chamber design has been optimized in order to improve the trade-off between emission levels and fuel efficiency.

The design of the air system has been focused on low end torque and leads to maximum power of 175 kW and maximum torque of 550 Nm.

Some major technical innovations such as a larger-proportioned and over-cooled EGR system, the introduction of a "7th injector" localized at the exhaust and the primary catalyst at the turbo-outflow allow the anticipation of the Euro5 emission level standard.

Very low noise levels are the result of a joint optimization of powertrain engine base, injection and tuning strategies.

The "V6 dCi 235" will go in production at end 2008 and will first equip New Laguna Coupé.

1 Introduction

Due to an excellent trade-off between CO2 level, performance and cost, Diesel engines are very popular in Europe. The increasing pressure on fuel consumption makes also necessary to extend Diesel to other markets, while customers expectation is becoming more and more demanding in terms of comfort, driving pleasure, and quality.

In order to be at the top of the competition for the satisfaction of its customers, the Renault Nissan Alliance Board has decided, beg. 2006, to develop a brand new V6 Diesel engine at the top end of its diesel engine range.

The experience and technologies of the now famous Renault Nissan 2.0 dCi engine have been widely used for the V6 dCi development. Best-in-class driving pleasure, best-in-class sound quality, CO2 emission equivalent or better than a gasoline hybrid powertrain, have been the drivers of the V6 dCi development.

The first version, “V6 dCi 235” is being launched in the Renault Laguna coupe, showing Renault excellence in terms of driving pleasure combined with very low CO2 emission.

Other versions are expected on Nissan vehicles in the coming 2009 year, while a US version is scheduled for 2010.

Notes :

“V9X” is the engine family Renault code name for the Renault Nissan V6 dCi

“M9R” is the engine family Renault code name for the Renault Nissan 2.0 dCi engine

“FF” means that the engine is installed in transversal position or East-West.

“FR” means that the engine is installed in longitudinal position or North-South.

“FWD” means Front Wheel Drive

2 Main features of V6 dCi

Fig. 1: *The Renault - Nissan V6 dCi engine*

The characteristics of the first version, “V6 dCi 235” in Laguna Coupé are presented here after (Fig. 2). This version will be coupled with a reinforced version of the Jatco AJO 6 speeds automatic transmission, allowing a maximum torque of 450 N.m for this front wheel drive application.

Engine code	V9X
Cylinder arrangement	V, 6 cylinders
Displacement (cm3)	2993
Bore x stroke (mm)	84 x 90
Bore pitch (mm)	92
Compression ratio	16
max power (kW/rpm)	173 / 3750
Max torque (N.m /rpm)	450 / 1500-3500
Camshaft drive	DOHC, chain + pinion with mechanical lash adjuster
Valve Drive	24v, roller finger follower + hydraulic lash adjuster
Cylinder head / block	Aluminum / CGI
Crankshaft	Micro finished forged steel
Connecting rod	Fractured forged steel
Intake System	VN-Turbo charger + intercooler
Injection system	Common rail 1600 bar + piezo injector
After Treatment system	DOC + DEC + CSF + HC dosing
Emission standard	Euro 5
Balancing shafts	No

Fig. 2: *Characteristics of the V6 dCi 235 for the new Laguna coupe*

3 Engineering goals based on customers' requirement (Fig. 3)

1 : Below average

2 : Average

3 : Above average

4 : Top level

5 : Leader

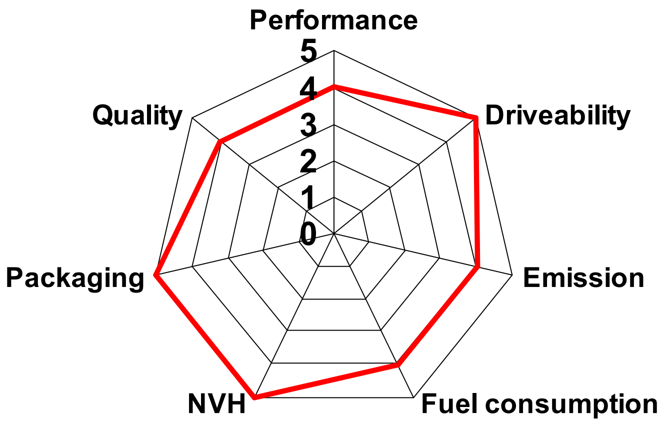

Fig. 3: *V6 dCi targets*

The Renault powertrains all share a common requirement, which is to provide the **enthusiast** feeling of the customer. V6 dCi combines **drivability** and **NVH** as follows:

- Progressive and linear acceleration with extended speed range and without time lag is preferable to a high but brutal acceleration G level.
- No noise nor vibrations at idle and at steady state conditions, while a "V6 sound" feed back during acceleration has to emphasize the power of the engine.

Packaging

The V6 dCi has to be installed in engine bays no larger than for petrol engines, for both transversal (FF) and longitudinal (FR) vehicle architectures. These are the conditions to fulfill for all Renault and Nissan Alliance upper range cars.

Performance

175 kW & 550 N.m. The full torque is dedicated to FR applications, while 450 N.m is well adapted for the FWD Laguna version.

Emission and fuel consumption

Euro 5 level without NOx aftertreatment, is the objective for the first version "V6 dCi 235" being launched on Laguna this year. Thereafter a NOx after treatment will allow reaching more stringent emission standard

Maximum fuel consumption and CO2 are set at 195 g/km for FWD applications.

Quality

The warranty and reliability objectives have been set part by part, based on the best design standard available for each part. The whole engine level is therefore consistent with the quality top 3 objective from Renault 2009 contract.

4 Design and development

4.1 Engine structure and Packaging

Engine performances are of course related to general dimension and architecture choices, but also, and sometimes mainly, to detailed design, optimization and tuning.

The first decision at the project launch, was to carry over the “cylinder module” (Fig. 4) of the 4 cylinder 2.0 dCi engine (code name M9R). The purpose of this “modular design” is to concentrate engineering resources on the same single system, especially for resources consuming functions such as combustion, cooling,… Consequently, finest optimization and better performance are achieved for both engines, M9R and V6 dCi, compared to distinct developments. Furthermore, the top of the art M9R design was the best warranty for V6 dCi performances.

The “cylinder module” dimensions have been determined having in mind both M9R and V6 dCi applications.

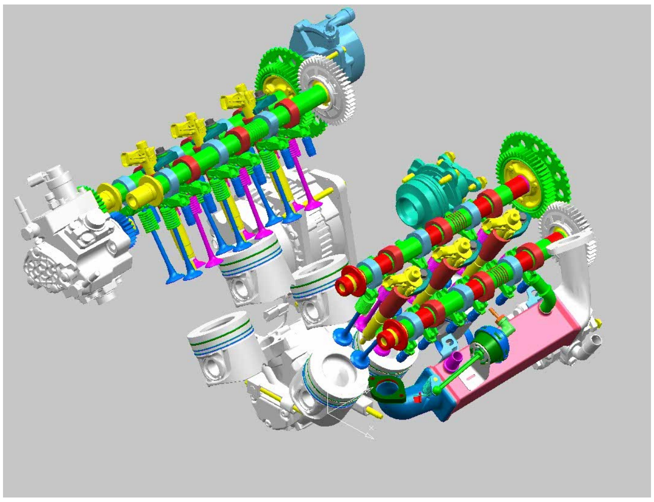

Fig. 4: *Commonality V6 dCi / M9R* (Bore & stroke, bore pitch, piston and combustion chamber, cylinder head module including cooling, intake and exhaust ducts, valve train, injector,…)

The second key decision was the V angle value. Compared to the “standards” 60° or 90°, the chosen value of 65° (Fig. 5) is a very good compromise between the crankshaft balancing, the available room in the center of the engine for oil separation system and intake manifolds, the crankshaft and cylinder block reliability on one side, and engine packaging on the other side.

65° gives a narrow engine, which is a condition to install it in both FF (transversal) and FR (longitudinal) vehicle architecture.

Fig. 5: *Cylinder block with 65° V angle*

The other general characteristics setting has been driven once again by the engine packaging, and also by the general structure stiffness in order to achieve the very ambitious NVH objectives.

- The con-rod length is reduced as much as the piston skirt height allows it. This short length allows to meet easily the pedestrian regulation.
- The skirts of the block follow closely, with a 4 mm clearance, the shape of the rotating parts.
- Accessories, accessories drive and engine mounts are bolted directly on the block, or on the other cases around the block which are casted in aluminum for this purpose.
- High stiffness and resistance materials have been used for the main parts (Fig. 6).

Parts	**Material**
Crankshaft	42 CD4 forged steel
Cylinder block	Compact Graphite Iron (CGI)
Oil pan	Aluminum sand casting
Timing covers	Aluminum sand casting and die casting

Fig. 6 : *Selected material for the main parts*.

The above dimensions (Bore*Stroke 84mm*90mm, bore pitch 92mm, 65° V angle,…) gave probably one of the most difficult low engine side to design, especially crankshaft, con-rod and bearings, but as a results **the V6 dCi is certainly the most compact 6 cylinders diesel engine on the market**, for the benefit of vehicle design (Fig. 7).

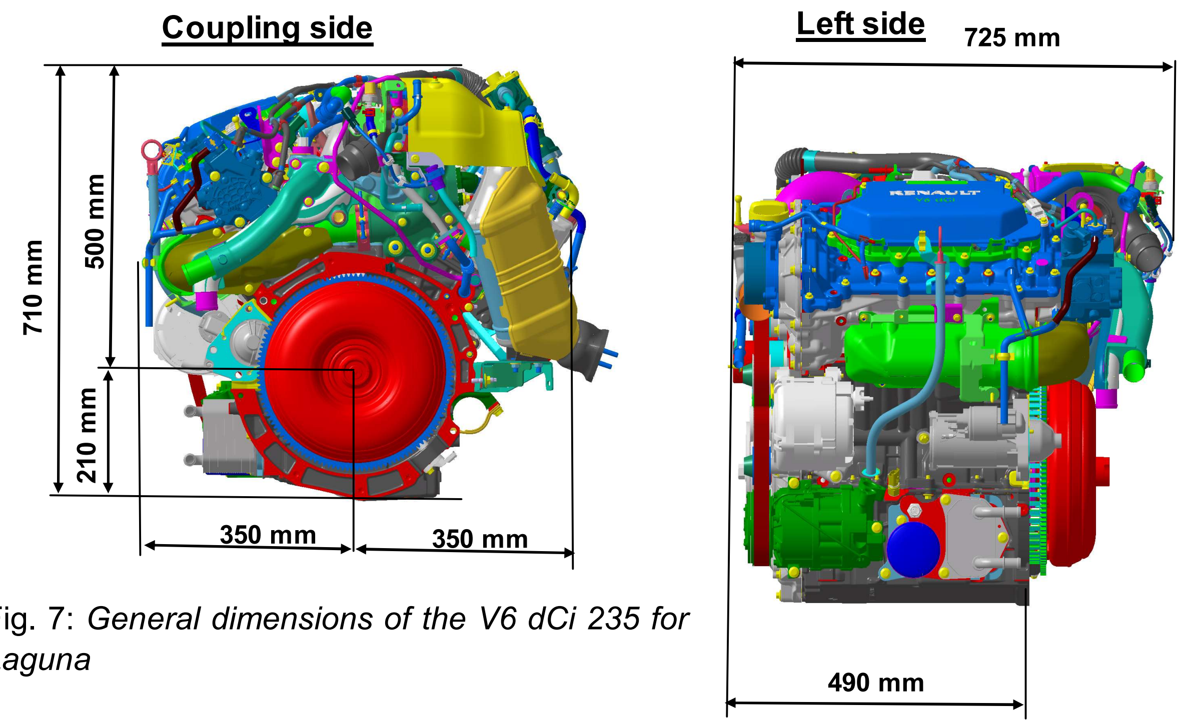

Fig. 7: *General dimensions of the V6 dCi 235 for Laguna*

4.2 Full load performance & Drivability

The first challenge was to find the good trade-off between ambitious full load performance (175 kW & 550 N.m) vs. emission level, especially NOx, since Particulate Matter (PM) and HC/CO are managed respectively by a Catalytic Suit Filter (CSF), where 99% of PM are eliminated, and a Diesel Oxidation Catalyst (DOC).

The technical specification is based on the M9R engine. Obviously, the main step to reach the performance was to increase engine capacity from 4 cylinders 2.0L to 6 cylinders 3.0L.

In addition, the hereafter functions of the Euro 4 version of M9R engine already in production have been improved :

- Combustion chamber, injector and EGR system have been optimized, and will be applied on both V6 dCi and future M9R Euro 5 version. Those evolutions allow to set both PM and NOx below Euro5 regulation as explained in Chapter 4.5.
- A specific single turbocharger has been adapted. In order to increase the energy at the turbine, especially at low RPM, exhaust manifold have been carefully designed and the junction of the two manifolds is integrated in the turbine housing. Based on M9R specific performance, a maximum power close to 190~195 kw was achievable, but a reduced specific air flow was decided in order to increase again the low end specific torque and the transient response, while maximum power was set at 175 kW (Fig. 8.).

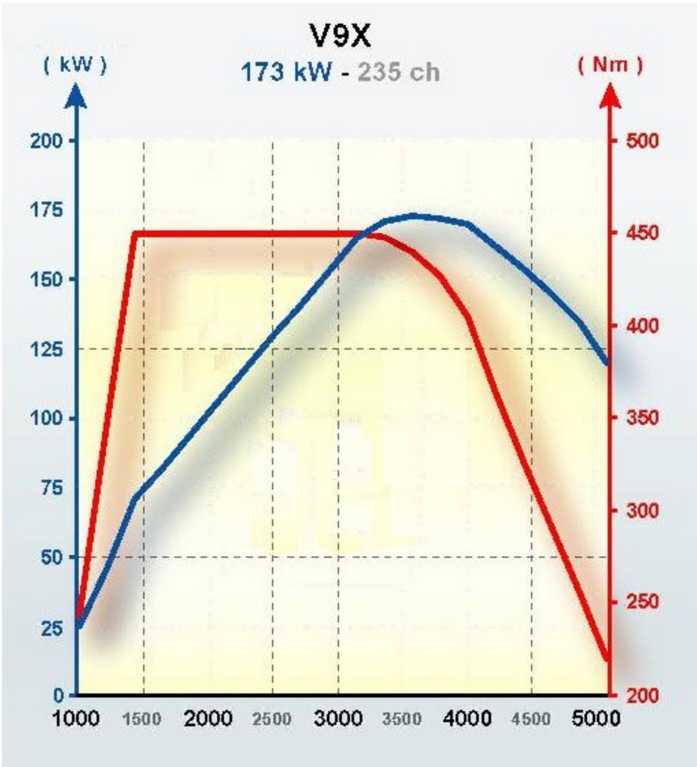

Fig. 8: *Full load performance of the "V6 dCi 235" for Laguna Coupe*

The max power is slightly reduced to 173 kW, due to constraint on exhaust line design of this car

The maximum 450 N.m m torque is available since 1500 rpm and until more than 3500 rpm (Fig.8).

Indeed the primary capacity of the engine exceed 550 N.m, the maximum torque of this first application is limited at 450 N.m which is the capacity of the AJO compact 6 speed automatic transmission. 450 N.m is well adapted to this FWD vehicle as explained in the next lines. The low end torque is reached, of course, without any risk of turbo charger pumping.

At high engine speed, the power decrease feeling is also moved forward, higher than 4500 rpm, and the V6 dCi has the same enjoyable high speed behavior as the M9R engine: 5000 rpm could be reached easily.

One of the key issues of the development was to achieve the best performance in take-off conditions as a key contributor to enthusiast feeling and driving pleasure.

V6 dCi 235 performance on Laguna is compared to competitors in Fig. 9a & 9b :

- A significant gap has been made compared to Renault previous AT applications.
- A top acceleration level is reach at 0.8 s, which means “no time lag”. It was especially important to reach this 0.45 G value at 0.8 s as far as the Laguna FWD architecture does not allow higher G level, even at 2 s when the turbo reach its full speed and efficiency.
- A fine tuning and software optimizations where made in order to avoid a 2 steps acceleration and to improve the subjective feeling (Fig. 9b).

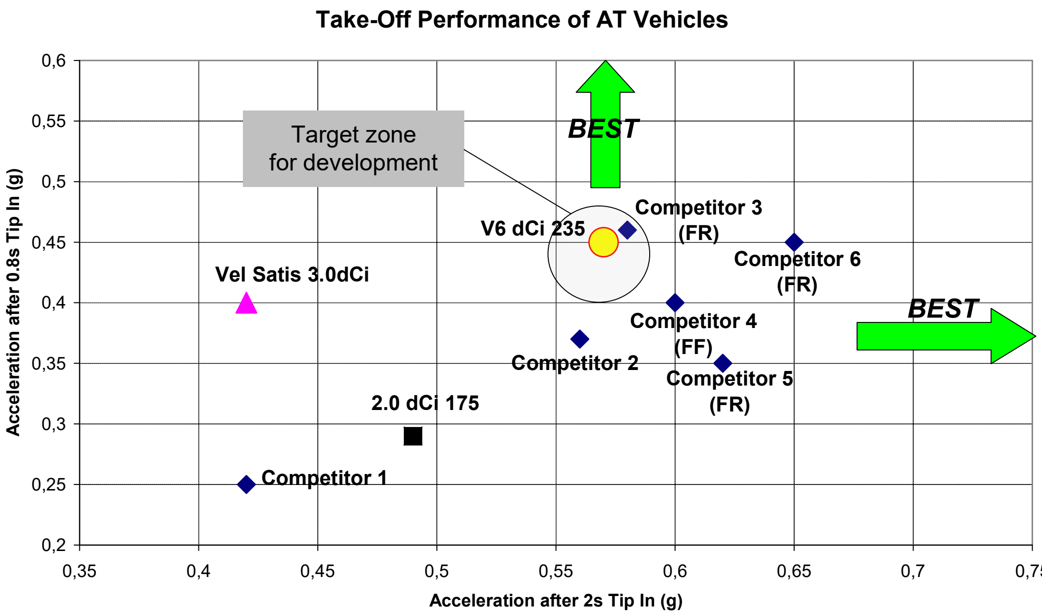

Fig. 9a:
Take off performances of AT versions

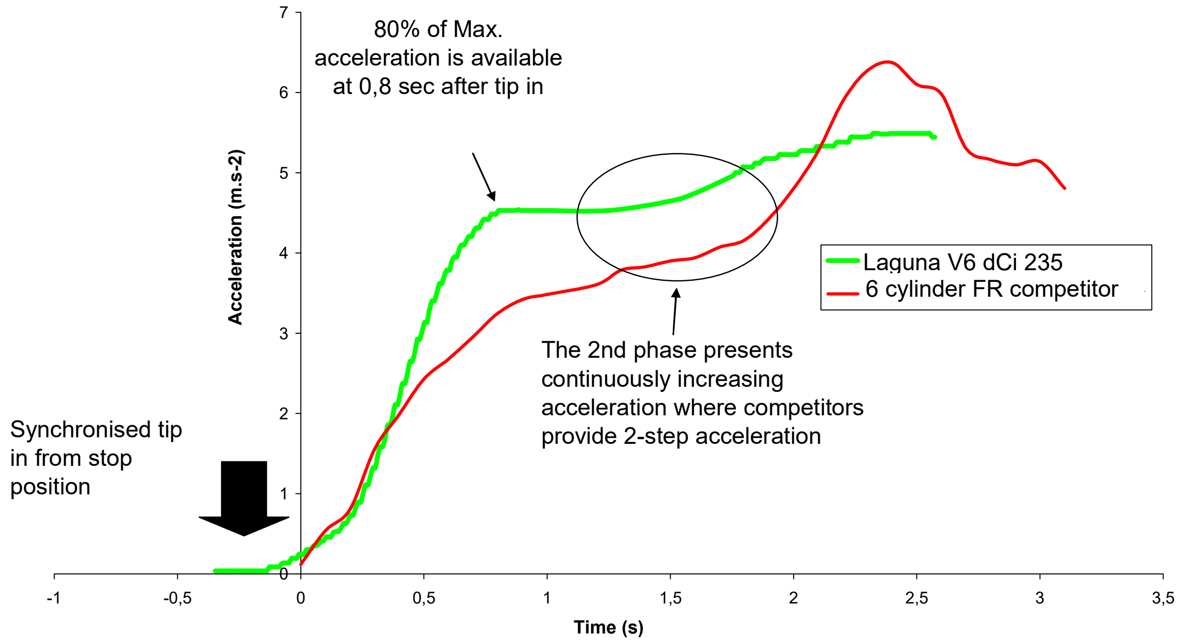

Fig. 9b: *Take off performances of AT versions*

4.3 Fuel consumption and CO2

A great part of the engine development has been focused on CO2 emissions. Some elements of the optimization are the following:

- Idle speed is one of the lowest of Diesel engines. To reach the 650 rpm value, engine acyclism and vibrations damping in the vehicle have been optimized.
- Overcooled EGR system (chap. 4.5.2) coupled to a fine-tuning of injection, air and turbo management permitted to reach high engine efficiency while keeping NOx emissions under control.
- Penalty due to CSF Regeneration has been significantly reduced. Thanks to HC dosing (chap. 4.5.3), full regeneration is quicker than for a standard architecture. This involves shorter over consuming phases.
- AT gear shift map has been calibrated to select the best operating mode of the engine, as explain is the below chart (Fig. 10). Idle neutral strategy and lockup management also aim at reduced CO2 emission.

NEDC phase	Gear (flat road)	Converter state
15 km/h	2nd	Hydraulic
32 km/h	3rd	Hydraulic
35 km/h	4th	Sliding
50 km/h	4th to 5th	Sliding
70 -120km/h	6th	Locked since 90 km/h

Fig. 10: *Example of AT management on NEDC cycle*

This optimized tuning allows Laguna with V6 dCi 235 to reach 192 g/km in 1700 kg inertia class. This is a very good ranking in the benchmark (Fig. 11), especially considering that this first version of the engine supports an hydraulic power steering and does not includes the stop & start technology.

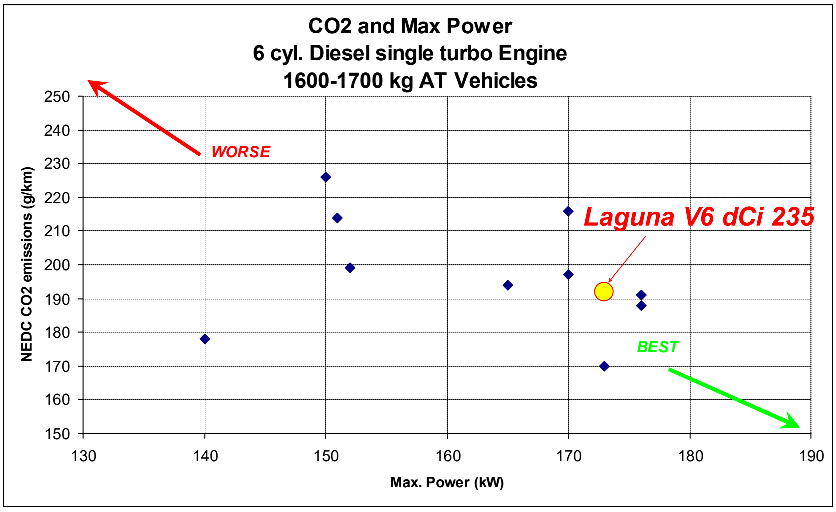

Fig. 11: *CO2 benchmark*

4.4 NVH

In order to manage the high constraint on the engine structure due to the high specific torque and power, and considering the Euro 5 impact on the tuning balance , emission versus combustion noise, it was decided in the early stage of the project :

- To implement key characteristics of a very stiff engine structure : large and stiff coupling face between converter housing and engine, CGI cylinder block with semi-deep skirts, auxiliaries direct bolting on the crankcase, on the oil pan and on the lower timing cover, integrated engine bracket in upper timing covers, structural oil pan, stiff torque converter housing, axial driveline bearing on gearbox side. The goal of this very stiff structure is to reduce engine vibrations at the mounting points on the chassis (structure borne path), and to reduce the engine noise radiation (airborne path).
- To launch intensive work during the preliminary design phase, using finite elements calculations (Fig. 12), both for excitation sources and structure calculations in order to fully optimize this structure.

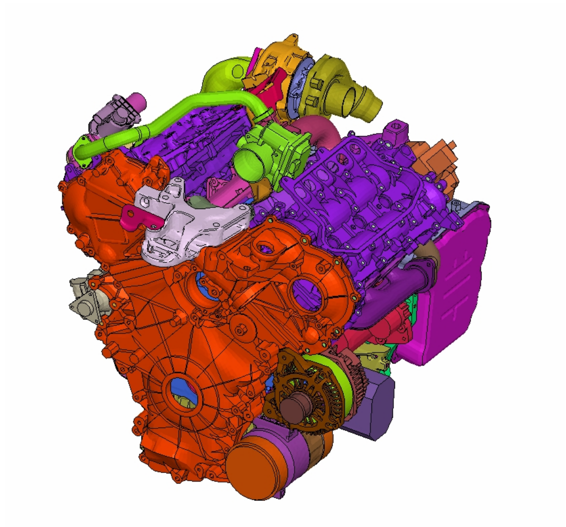

Fig. 12: *Finite Elements powertrain model*

A specific strategy has been implemented to arrange the most energetic eigenmodes (P/T bending & torsion, engine bracket modes, driveline torsion) and the 3rd engine order between themselves (Fig. 13). The goal was to separate them, and so to avoid bad resonances in the engine speed range between driveline vibrations, engine bracket and structure response.

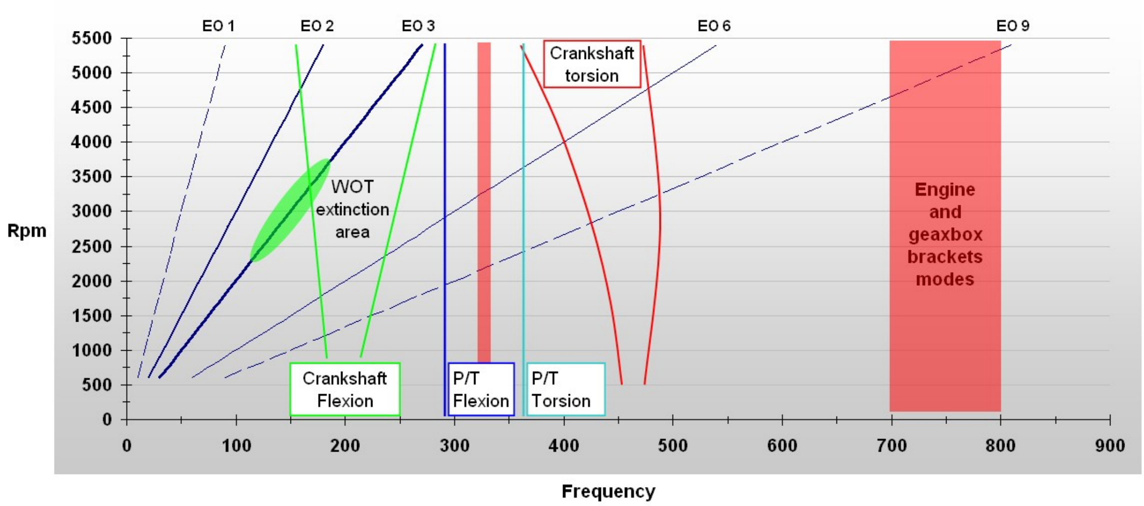

Fig. 13: *V9X Campbell diagram*

The initial information about NVH performance of the structure was early obtained. The main structural problems where identified and critical engine components were NVH optimized even before the first prototype was built. This ensured that only refinement was required in a further prototype phase.

Mid-frequencies 250 Hz octave band vibration (engine rumble)

A "mixed" structure model of each component of the power train, directly produced from CAD mocks-up was built (Fig 14). The calculation process uses the forced response of the entire power train unit, taking into account different dynamic interaction forces between the power unit and the internal moving parts (crankshaft, piston...).

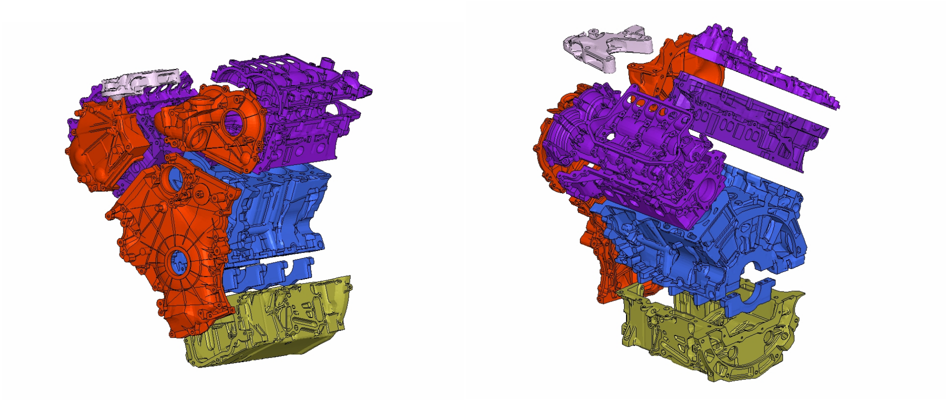

Fig. 14: *FE model for 250 Hz optimization*

The first representative prototypes where used for testing (transfer functions, experimental modal analysis), allowing the readjustment of each modeled component or sub-assembly. After this operation, good correlations between FE model and measure are obtained. Vibrations on engine mount brackets are estimated with a precision between [0-5dB] on the 0-1000 Hz frequency range (Fig 15).

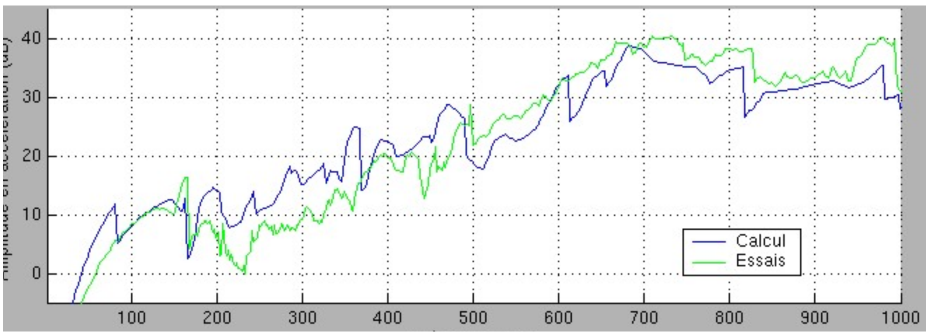

Fig. 15: *Calculation and test results comparison*

Due to the large and stiff coupling face and to the optimized converter housing, powertrain first bending mode frequency and torsion frequency reach 270 Hz and 390 Hz which avoid excitation of these modes by the 3rd engine order.

The global result in the mid-frequency 250 Hz octave band is lowered by 6 dB compared to the previous bought out V6 diesel engine, leading to a close to gasoline engines vibration level (Fig. 16).

Mid-frequencies 500 Hz octave band (engine presence)

In Laguna, the engine mounting is located in the area between the cylinder heads. In order to reach a high stiffness despite this unfavourable configuration, engine bracket has been bolted directly on the structural upper timing covers without intermediary part. Engine bracket first mode reaches the targeted value of 700 Hz. Furthermore, engine bracket, timing covers and water pump casing and coupling face design reduce the V-engines specific “bank flap” mode contribution.

To avoid high vertical displacements of upper torque rod, this one has been bolted directly in the stiff area of engine bracket. This solution eliminates a dedicated upper torque rod bracket.

The final result in the mid-frequency 500 Hz octave band is lowered by 4 dB compared to the previous V6 diesel engine, close again to gasoline engines level (Fig. 16).

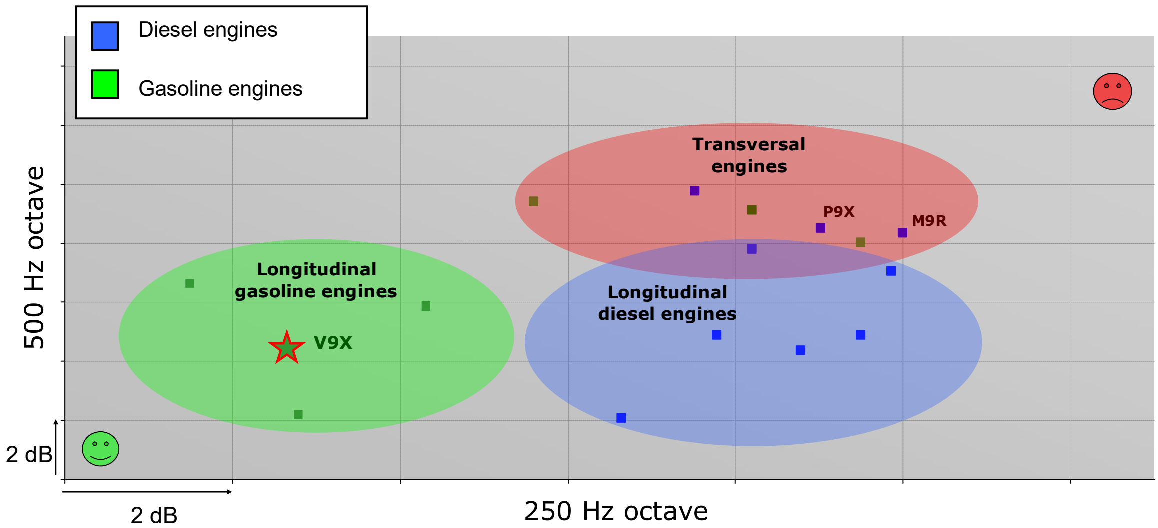

Fig. 16: *V6 dCi 250 Hz and 500 Hz average vibrations at engine brackets*

This impressive low vibration result was obtained thanks to the models and computations explained in the above pages, making possible to design and redesign as many times it was requested until the appropriate configuration for each main part was found. As an example, the area of the engine bracket has been redesigned more than 10 times in order to increase the first mode frequency up to 700 Hz, before launching a prototype.

High-frequency noise

FEM calculations have been used to lower the sound radiation of the aluminum parts (timing covers, cylinder heads covers, oil pan). Turbocharger has received an absorber at compressor exhaust to reduce whistle and wind noise. Combustion noise has been closely tuned to reduce as much as possible the structure internal excitation. Unusual noises due to camshafts twin pinions are managed with mechanical lash adjusters, same as M9R engine. High pressure fuel pipes have been designed in accordance with fuel pressure to avoid coupling between hydraulic and structural resonances which could result in fuel pipes noises. Heat shields shape and material have been designed to reduce HF noises amplification. Finally, two acoustic-proof shields have been bolted on each cylinder head cover to reduce piezo-electric injector specific high-frequency noise.

Combustion noise

Calibration team has taken into account very early the combustion noise in the mapping development. To reach the ambitious targeted combustion noise and transient clatter noise levels, split pre-injection has been extensively used. Thus combustion parameters (advance, injection pressure, injected quantities) have been precisely tuned and show very progressive evolutions.

This low combustion noise tuning optimization has been possible because of the low emission capability of the technical definition (combustion chamber, EGR,…) as explained in chap. 4.5.

Consequently combustion noise is very low and smooth.

4.5 Emission and after treatment system

A low emission capacity for the engine basis was requested, in order :

- To reach Euro 5 (Fig. 17) without NOx after treatment for the first application as explained in chap. 3.
- To manage at the same time combustion noise reduction

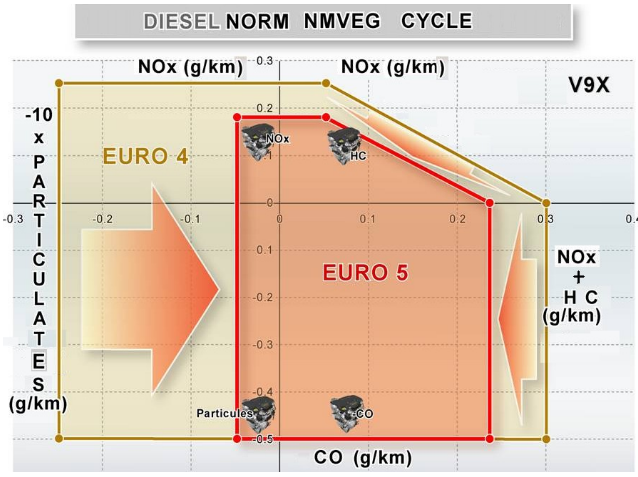

Fig. 17*: Euro 5 / Euro 4*

4.5.1 Piston bowl and injector definition

The design of the bowl shape was optimized on a single cylinder engine. The starting point was the already performing combustion chamber of the M9R engine. The objective was to improve the emissions at part load and the air/fuel ratio at full load.

The following parameters of the M9R engine are kept:

- Compression ratio
- Reduced valve pockets depth to avoid bad quality combustion in the squish area
- Cone shape that plays a major role in the distribution of fuel within the combustion chamber

Nozzle choice turned to the now available minisac 7-holes technical definition (instead of the micro-sac 6-holes of M9R). The dead volume under the needle has been significantly reduced compared to existing minisac nozzle, which cancels the HC penalty of this 7-holes nozzle. The bowl diameter has been widened (Fig. 18) and the spray angle adapted consequently to take best advantage of this new nozzle technology. The 450cc hydraulic flow, Ks hole and piezo injectors are carried over from M9R.

This combustion chamber will be also applied on next generation of M9R, thanks to the modular dimensions of both engines.

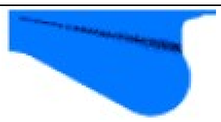	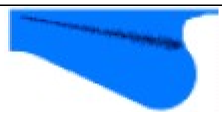
M9R dCi bowl shape	V6 dCi 235 bowl shape

Fig. 18: V*6 dCi and M9R bowl shapes*

4.5.2 EGR system

To achieve most effective engine-based reduction of Nox, the best solution is to maintain the highest possible exhaust gas recirculation, at the lowest possible gas mixture temperature in the intake manifold.

V6 dCi 235 EGR system includes (Fig. 19):

- An electric controlled EGR valve, which offers benefits in term of controllability precision. The valve is water cooled to ensure a high reliability.
- An EGR cooler by water, 212 mm length, with an integrated exhaust gas bypass. This bypass is used just after starting the engine, not to cool the EGR gaz, when oxidation catalyst has not reached light-off temperature in order to reduce CO/HC level.
- Pressure losses reduction, using high section components, which increase the EGR amount.

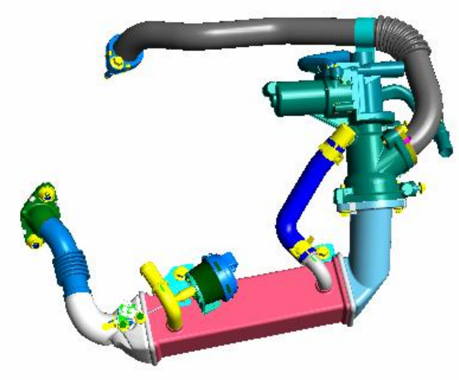

Fig 19*: EGR system*

A low temperature water circuit for the EGR cooler has been developed to further reduce the EGR gas temperature.

Specifics pump and radiator are combined with the existing engine cooling circuit (Fig. 20) and offer advantages in all the three operating phases:

(1) Just after engine starting, EGR cooling circuit is independent from engine cooling circuit. So EGR is over cooled by both radiators, main one and the additional EGR one, with the help of the extra EGR electric water pump (Fig 21.).

(2) When engine water reaches 90°C, EGR is mainly cooled by water going through the EGR radiator. So that the water temperature in the EGR cooler is reduce by more than 20°C, compared to a classic system (Fig. 21).

(3) In very warm external conditions, over 30°C, the engine needs no EGR. EGR radiator is used to give an extra engine global cooling capacity, permitting to fulfill very easily maximum water temperature requirements for engine reliability.

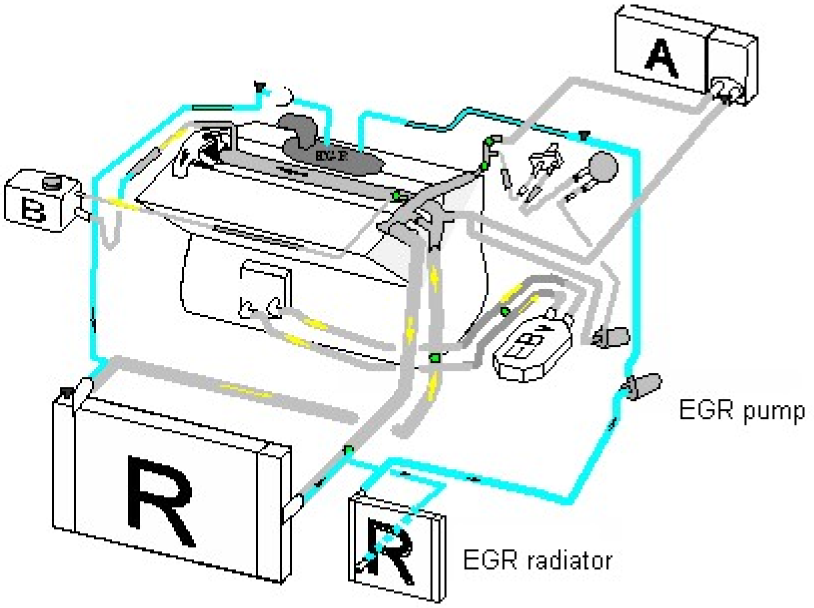

Fig. 20*: EGR cooler specific water circuit (blue color)*

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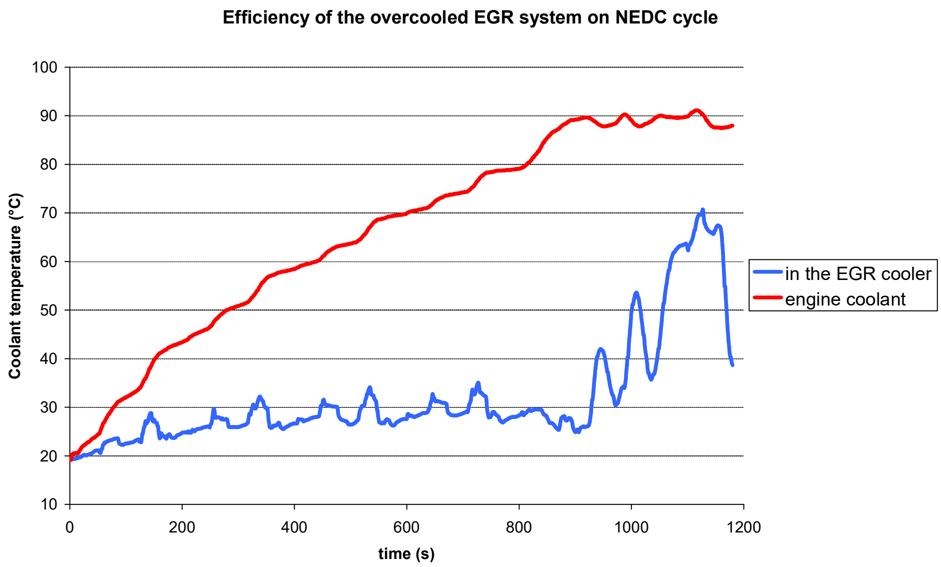

Fig. 21 :*EGR Water cooling circuit performance*

This specific water cooling system increase EGR cooling capacity by 20% on the NEDC cycle compared to a classic system.

4.5.3 After treatment system

The after treatment system combines in the exhaust line (Fig. 22)

- A Platinum-Palladium metallic Diesel Oxidation Catalyst (DOC). The metallic design offers lower pressure loss and smaller packaging compared to ceramics.
- A HC dosing system (the “7th fuel injector”, Fig 23).
- A Diesel Exothermic Catalyst (DEC 2) + a Catalytic Soot Filter (CSF) in the same canning. The DEC2 converts the additional HC from the “7th injector” into thermal energy for the CSF regeneration. This Silicon Carbide CSF is designed to force exhaust gases to pass through a low porosity substrate wall filtering 99% of particulate matters (Fig. 24). The 3.7L CSF is the same as the M9R engine.

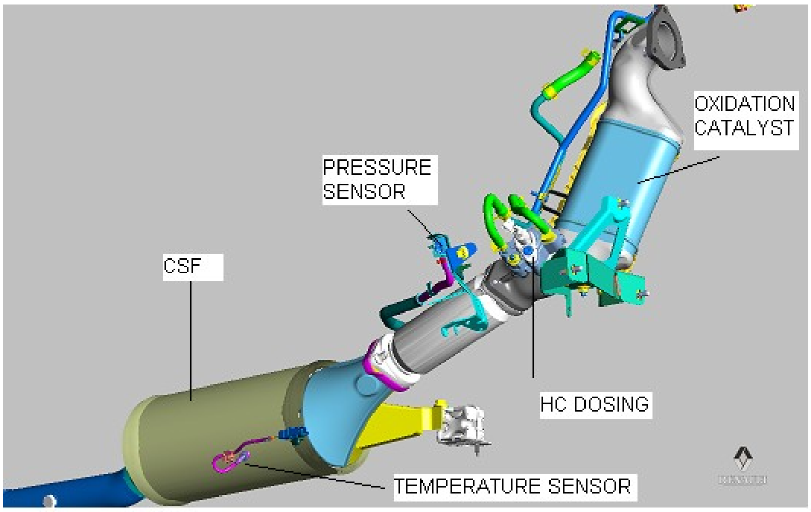

Fig 22 : *Exhaust line: DOC , HC Dosing, DEC2 and CSF in the same box, and temperature & pressure sensors.*

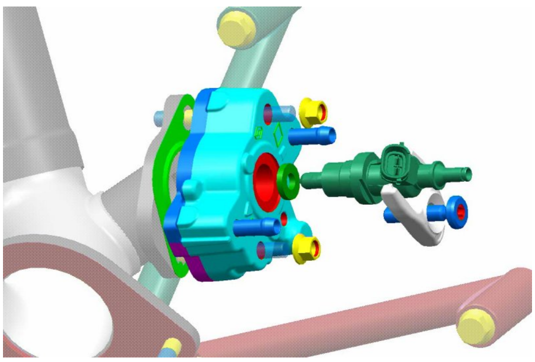

Fig. 23 *: The “7th injector” at the DOC outlet*

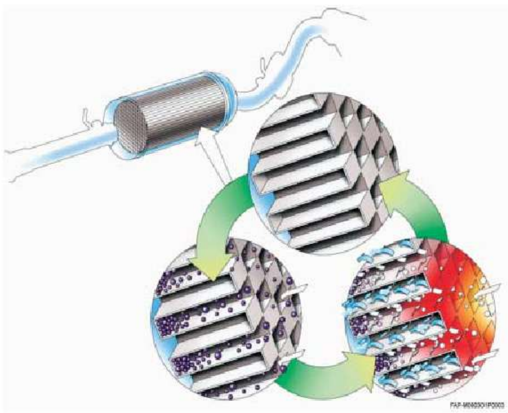

Fig. 24 *: CSF working process*

CSF regeneration is mainly performed according to an active regeneration based on late post injection and HC dosing. The CSF control system includes several means for regeneration efficiency, mainly fine regulation of exhaust temperatures. In such condition, CO oxidation is also performed.

The HC dosing allows getting the requested temperature for regeneration with limited impact on the engine oil dilution and turbine temperature, since the use of post injection is limited. The other advantage of this feature is to be able to regenerate the CSF even on low load engine points like idle. Therefore, regenerations reach high efficiency on all possible customer profiles. This gap of efficiency compared to M9R engine without HC dosing is illustrated on the Fig. 25:

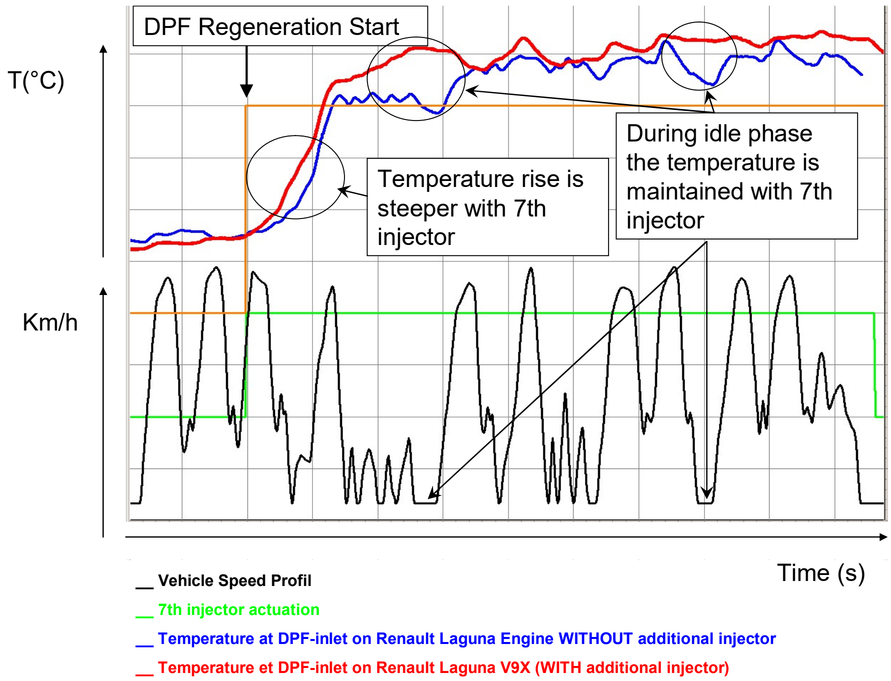

Fig 25 : *Regeneration with HC dosing*

The software was upgraded with a new Oil Control System (OCS) including

- An accurate model estimating the oil dilution
- A specific CSF-supervisor, able to cover all possible customer profiles, especially the most critical ones. Actually, severe customer profiles as “city” and “door to door” get as high regeneration efficiency as standard customers.

With the described HC dosing system architecture and these software functions up to 30 Kkm oil drain Interval is achieved for most of the customers.

Adapted CSF volume and appropriate engine lubricant (so called low-SAPS lubricant) lead to an additive-free and maintenance-free CSF system.

4.6 Quality and reliability

To insure the quality top 3 level of the V6 dCi engine, design to quality process has been used (Fig. 26). The quality situation in the field of the carry-over parts, and of the most similar parts in case of new parts has been checked part by part. Each time a default was found, quality improvements have been implemented and validated.

Amongst the 330 parts references of the V6 dCi, 25% are common with the M9R engine. The V6 dCi quality is expected at the same level due to the use of common parts and due to the same method of development than M9R whose results have proved efficiency: less than 0,5 % of customer complain in the first year of warranty.

During the development, more than 12000 hours of durability test on engine test bench have been run. At the same time, more than 1.250.000 km were driven on vehicle equipped with V6 dCi. Each single problem faced has been analysed and solved.

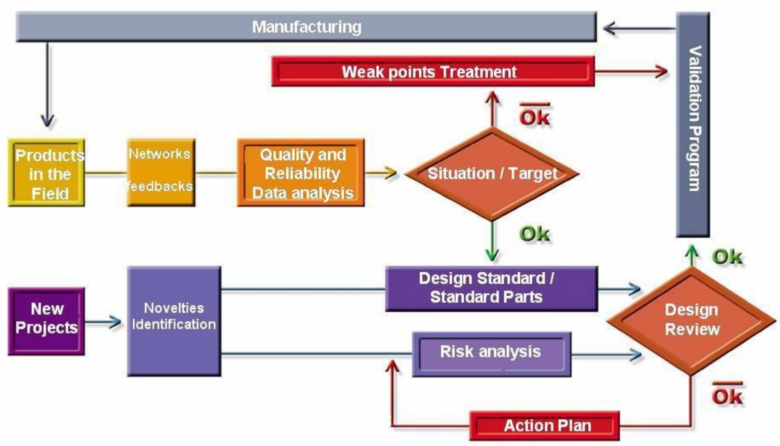

Fig. 26: *Design-to-Quality process*

Design to quality

Since the preliminary phase of design, the process consists in the evaluation of each engine part and control management system, according to the three categories:

1- New parts and systems (novelty part or system)

2- Carry over of parts or systems with a good production quality level

3- Carry over of parts or systems with a production quality level to be improved

The exhaustive working plan is implemented in 3 steps based on previous evaluation:

- Step 1 is to apply the appropriate Quality tools (PHA, P-FTA, FMEA)* for each novelty part or system, to set the influence of each root cause and to validate them. The follow-up of main novelty part (or system) development was jointly made with Nissan engineering.
- Steps 2 and 3 lead to check respectively the implementation of design policies for all parts or systems, then to check the application of all countermeasures applied in production related to parts or systems of above third category.

(*)

PHA: Preliminary Hazard Analysis

P-FTA: Perfect Fault Tree Analysis

FMEA: Failure Mode Effect Analysis

4.7 Environment

The V6 dCi engine is design to meet current and future environment regulations

- no Cr6
- no lead.

The development of lead-free main journal bearings and con-rod bearings is one of the first successful developments on high loaded V6 diesel engine. Specific projected pressure on con-rod bearings can reach 95 MPa and oil temperature can go over 150°C without failure. To reach this good result, specific works were led on materials, con-rod deformation, quality of oil feeding, micro-geometry quality of bearings, cleanliness and assembly.

Considering the maintenance, no part is to be changed before 180.000 km (except oil and filters)

5 Machining and Assembly plant

The chosen assembly plant is at Cleon, in France, 100 km west of Paris. It is the main assembly plant for Renault engines and is already producing the M9R engine.

4 facilities are used for V9X:
- A new dedicated assembly line
- Hot test benches on which every engine is checked
- Camshaft and cylinder heads machining flexible lines

Other parts are bought out, including crankshaft, connecting rods and cylinder-block machining, which are outsourced to expert suppliers.

Camshaft and cylinder head are very close to M9R, thanks to modular design. So only minor modifications were to be made on flexible lines, which are already producing M9R parts, resulting in low investment and engineering resources.

Hot tests benches were already installed at Cleon, and only adaptation was to be made (Fig. 26). 100% of V9X engine are tested before to be delivered to vehicle plants.
During the 10 minutes cycle, the engine is heated up and about ¼ of the maximum load is applied. More than 200 parameters are checked: pressures, temperatures, electric currents and voltages, flows, sensors and actuators functioning, sealings, NVH, Control Unit signals, …in order to contribute to the zero defect quality level when the engine is delivered out of Cleon.
Furthermore, the above parameters are registered for every engine. This will help, in case a defect occurs at vehicle plant or in the field, to increase the efficiency of this test procedure.

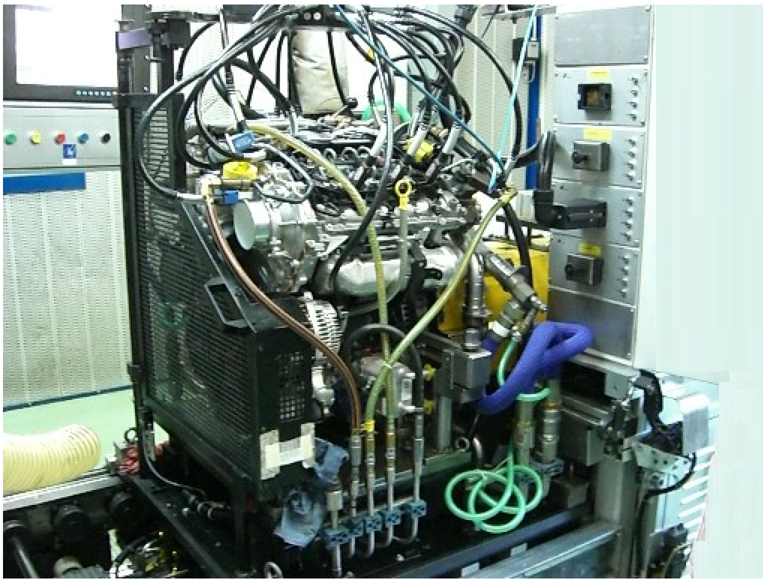

Fig. 26: *Hot test bench*

The assembly line engineering has taken from the beginning the constraints to be flexible to the engine definition and to the vehicle plant diversity

- FF or FR, …
- With or without accessories, …

Several operations are manually made, in order to ensure this flexibility.
This also allows lowering the investment, which has been one of the guideline for each decision, after the quality.
Complex assembly operations, such as cylinder head tightening, glue deposit, control by camera, … are automatics, while the manual operations quality are ensured by ad-hoc poka-yoke and control systems.
A careful identification of all the possible troubles during the assembly process was made (more than 2000 where identified) in order to define and implement these poka-yoke and control systems.
This failure analysis was extended to incoming quality of bought out parts. All possible defects especially those going through the assembly line then through the hot bench tests, have been analyzed, and countermeasures have been implemented to eradicate them event, or to warranty that engine could not been delivered in such a case.

Fig. 27: *V9X Assembly line in Cleon plant*

6 Conclusion

The V6 dCi is the first V6 engine developed by Renault for the Renault Nissan alliance.

The carry-over of the *2.0 dCi* engine “cylinder module” and of the associated technologies have allowed concentrating the engineering work on the V6 engine structure and on improvements of the key functions for diesel performance, which improvements will be shared with the *2.0 dCi* engine future versions, thanks to the “modular design”.

The same “frugal engineering” was applied to build up the production lines, in order to further lower the entry cost of this brand new V6 engine.

Concentrated on the customer requirements, the engineering efficiency has been maximized. As a result:

- The V6 dCi engine basis is certainly one of the lowest vibration level, and the most compact one of the 6 cylinders diesel engine on the market.
- Measurements show that the “enthusiast feeling” and “driving pleasure” leader position targeted for the new *Laguna Coupe V6 dCi 235* is achieved.

A high potential for low emission and low fuel consumption is the best insurance for success of the on-going V6 dCi development for Nissan SUV and luxury cars and for the “diesel-challenging” US market.

The development of the engine basis and its first application *V6 dCi 235* on Laguna has been demanding, sometimes really challenging, but always very rich and providing great satisfaction for all the V6 dCi team members who are really proud to contribute and to show the “Excellence Mécanique” of Renault powertrain.