Research Regarding the Effects of a Diesel Engine's Control Unit Retrofitting, Focussing on Its Performance and Pollution

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Research regarding the effects of a diesel engine's control unit retrofitting, focussing on its performance and pollution

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Abstract. Due to the stricter and stricter European restrictions on diesel engines, less manufacturers produce vehicles fuelled by diesel and since not anyone affords new vehicles and the out-of-use diesel vehicle waste would be huge. New ways of improving the pollution levels on current registered vehicles must be found. The article presents a novel approach focusing this scope,, starting with the basic actual engine, and developing by retrofitting up to mechanical and software upgrades, aiming to raise the output of mechanical characteristic, and simultaneous reduction of exhaust pollution. In short, the paper is focusing on research regarding the effects of a diesel engine's control unit retrofitting.

1. Scope

The European perspectives are imposing stricter and stricter diesel engine efficiency standard to reduce carbon dioxide, NO_x and other particulate emissions, especially greenhouse gases, according with latest European emission standards [1].

The direction in which the manufacturers are going at is clear; the question is which consideration may occur concerning the lower emission class vehicles already on the road?

Experiments trying to lower the emissions were accomplished; a few examples include retrofitting a cooled exhaust gas recirculation system [2], which is changing the parameters of the compression-ignited engine's control unit [3], by modifying the fuel injection system [4], or by using bio-fuel [5][6]. This research aims to provide a modality of improving both the power output and emissions characteristics of a series produced euro 3 diesel engine.

2. Proposal and results

Before presenting the improvements, understanding what it focuses through the research is essential. In table 1 are presented the engine characteristics [7].

The performance measurements according to the manufacturer are related to a top speed of 180 km/h, with acceleration from 0 to 100 km/h during 12.4 seconds [8].

Table 2 presents the engine's components.

Table 1. Engine characteristics.

Number of cylinders	4
Cylinder's layout	Straight/ in line
Cylinder bore [mm]	79.5
Cylinder stroke [mm]	95.5
Compression ratio	19.5
Number of valves	8
Valve's position	OHC
Engine code	ALH
Fuel type	Diesel
Engine's position	Front, Transversal
Engine's displacement [cm^3]	1,896
Intake	Turbocharged + intercooler
Max power output [kW]	66 @ 3,750 rpm
Max torque output [N·m]	210 @ 2,100 rpm
Transmission layout	Front wheel drive
Gearbox	Manual
Number of gears	5
Fuel tank volume [l]	55

Table 2. Engine components.

Fuel pump	Bosch VP37
Fuel pump's plunger [mm]	10
Injector manufacturer	Bosch
Injector's nozzle size [microns]	0.184
Turbocharger	Garret GT1749V
ECU	Bosch EDC15

Before actually extracting the data, a description of the electronic control unit is presented first. The engine control unit (ECU) controls a number of actuators in internal combustion engines, in order to ensure optimum engine performance. This is achieved by collecting values from a multitude of sensors in the engine compartment, interpreting the data as multidimensional maps, and adjusting the actuators accordingly. The components in the engine compartment, before being ordered by the ECU, are dynamically controlled by mechanical and pneumatic systems. For obtaining the maps, FGTech Galletto 4 and the related program, as described in figure 1, were used.

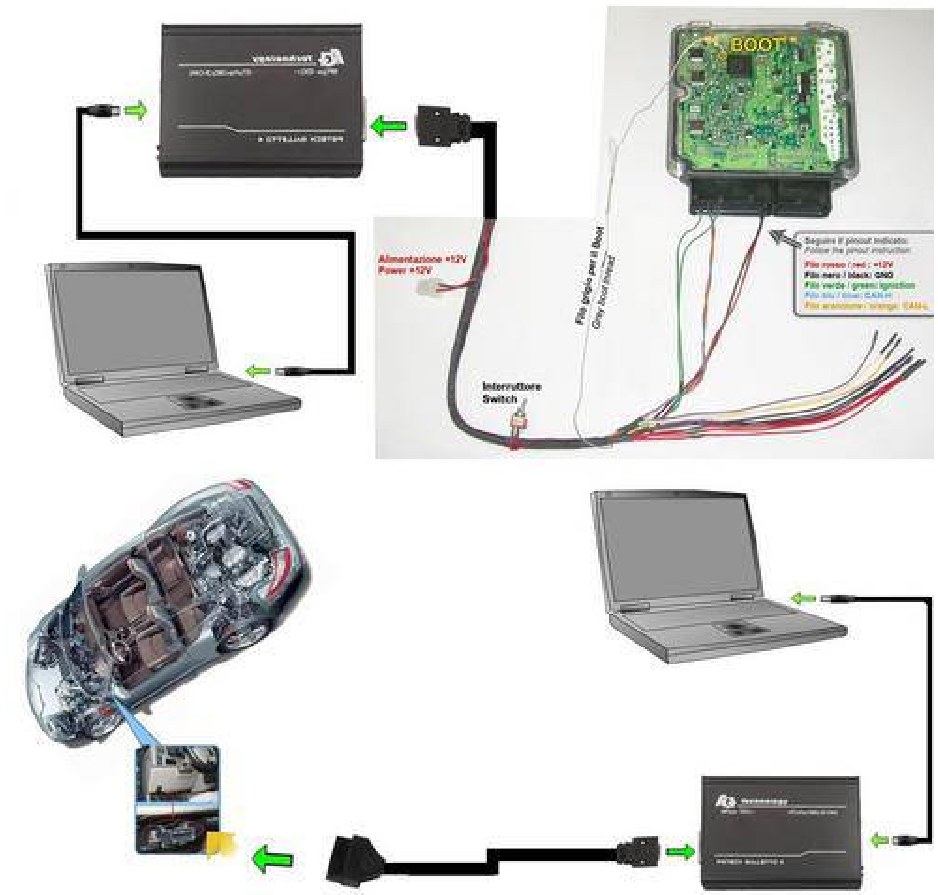

Figure 1. FGTech Galletto with possible uses.

The on-board diagnostics (OBD) cable is inserted in the OBD socket in the passenger compartment of the vehicle, as shown in the bottom of figure 1. The software that is delivered with the device is accessed and thus the ignition is turned on. In the software, it chooses the vehicle type, for which it intends to read or write the file with the maps, following of course by saving or writing of the generated data on the engine control unit.

2.1. Solution proposed for the engine upgrading retrofit

After obtaining the data from the ECU, engine upgrades are performed.

2.1.1. Flywheel, pressure plate and clutch

From the factory, the car is equipped with a double-mass flywheel. The reason for choosing to use it for a retrofit is linked to the idea of reducing the vibrations transmitted by a single-mass flywheel. The problem encountered is connected to its limit when it comes to high values of engine torque, which led to accelerated wear. It was replaced with a single mass flywheel, characterised by a reduced mass, its weight being about 6 kg. The benefits of such a flywheel are: (i) increased acceleration, more efficient engine brake, and (ii) a lower fuel consumption at constant speeds.

Together with the conversion of the flywheel, it proposes also that the clutch must be replaced, as well. It was opted for an organic disc with Kevlar inserts and a hardened pressure plate, for a better control in urban traffic. The advance of the flywheel comes in accelerations, where less fuel is used. This has a high impact in urban traffic and when launching the vehicle at the traffic lights.

2.1.2. Injection system

For higher performance, components of the injection system have been improved, such as:

i) Enlarged injector nozzles: 0.270 micrometres with 5 holes, instead of 0.180 micrometres with holes.

ii) Enlarged injection pump plunger to 12 mm, from 10 mm.

These two proposals allow that the fuel might be injected at higher pressure and the maximum quantity of fuel injected/stroke was, in consequence, also increased [9,10].

2.1.3. Turbocharger and air intake system

One also opted for a larger variable geometry turbocharger, Garrett GT1749VB (presented in figure 2), with a maximum output of 200 kPa, in acceleration bursts. It notes that the exhaust gallery is delivered with the turbine housing, being cast together.

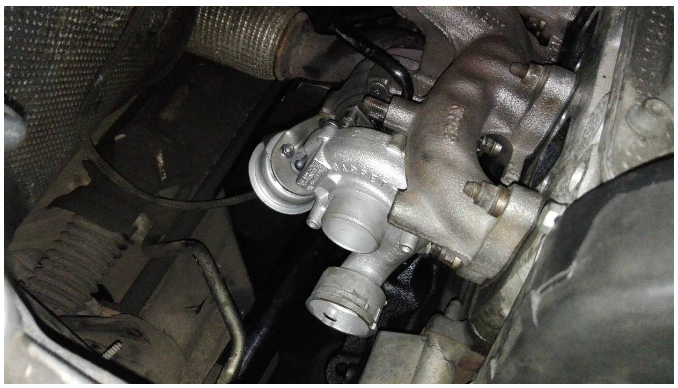

Figure 2. Garrett GT1749VB mounted on the engine.

Starting from the turbocharger's compressor to the intake manifold, the intercooler's standard rubber tubes were replaced with an aluminum pipe route with a diameter of 70 mm. The side mounted factory intercooler was replaced with a front mounted one, and the intake manifold was replaced with a larger, more efficient one presented in figure 3.

Figure 3. Intake manifold proposed for the retrofit.

For the comparison tests, temperature values were measure using VCDS diagnose interface. Measurement results presented a very large difference in temperature values. Comparing to the initial intercooler, at an ambient temperature of 28°C, at constant speed, with the upgraded system, an increase by 2 - 4°C, for an ambient temperature of 29-30°C, during an acceleration regime, is recorded, while with the factory setup it reached temperatures over 50°C.

2.2. Measurements and interpretation

In order to modify the maps as efficiently as much as possible, the dynamometer stand MAHA LPS 3000 presented in figure 4, was used [11].

Figure 4. MAHA LPS 3000.

On the dynamometer, measurements were performed, from where data was obtained regarding the maximum power and torque developed. Measurements consisted in power runs, from where the graph from figure 5 was obtained as well as in constant speed running mode, 2000, 2500, 3000, 3500 revolutions/minute in 4th gear.

In figure 5, generated by MAHA LPS 3000 dynamometer, are presented the measurements results, after software optimizations and mechanical upgrades.

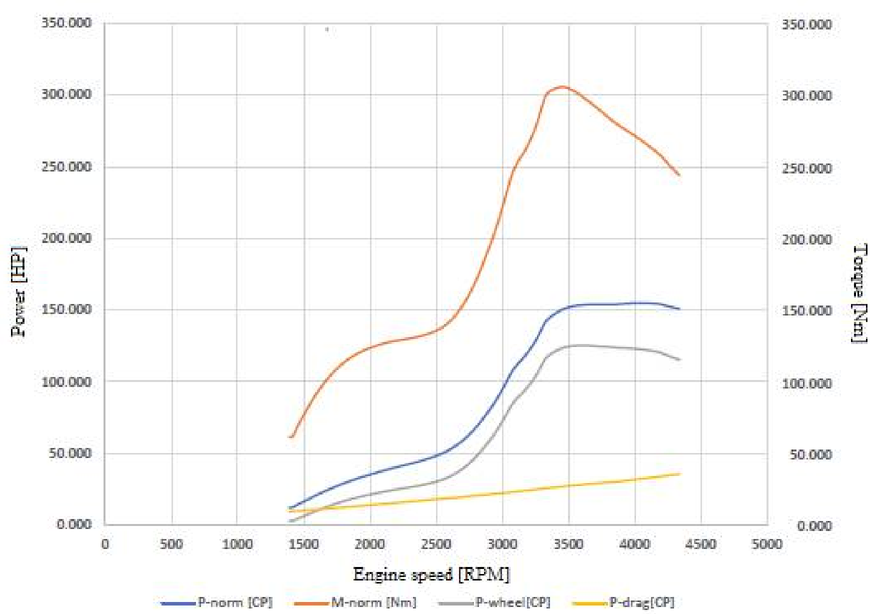

Figure 5. Measurement results, after software and hardware upgrades.

The axis and coloured lines from figure 5 are to be interpreted as it follows: engine speed [rpm] is represented on the X axis, measured power in horsepower (hp) unit of measurement, torque and drag are represented on the Y axis, engine's power output is represented by the blue curve, engine torque is represented by the orange curve, engine's power at the wheels is represented by the grey curve, force of drag [hp] is represented by the yellow curve. The values obtained are converted into international unit of measurement from the common units in table 3.

Table 3. Engine characteristics.

Characteristics	Value
Power – engine [kW]	113.9
Power – wheel [kW]	90.1
Power – drag [kW]	23.7
Engine speed [rpm]	4050
Vehicle speed [km/h]	144.7
Torque – engine [N·m]	305.6
Engine speed [rpm]	3,455
Vehicle speed [km/h]	123.3

Concerning the gas measurements, it indicates that they were performed at different engine speeds: 2,000, 2,500, 3,000, 3,500 rpm, covering for 60 seconds, each set of research.

Table 4 presents the engine and vehicles characteristics for each of the measurements.

Table 4. Measurement input data.

Characteristics, in specific units	2,000 rpm	2,500 rpm	3,000 rpm	3,500 rpm
Injection quantity [mg/stroke]	14	15	18.6	19.6
Acceleration pedal position [%]	39	40.8	47.8	49.4
Vehicle speed [km/h]	72	86	104	123
Fuel consumption [l/h]	4	5.4	8.1	10.2
Coolant temperature [°C]	91.8	92.7	90.9	99.9
Fuel temperature [°C]	57.6	58.5	57.6	67.7
Intake air temperature [°C]	49	54	57.6	72
Boost – specified [kPa]	117.3	122.4	136.6	146.8
Boost – actual [kPa]	117.3	122.4	137.7	146.8

The gas analyser results are presented in table 5, in association with the results indicated in table 4.

Table 5. Gaz analyser output data.

Characteristics, in specific units	2,000 rpm	2,500 rpm	3,000 rpm	3,500 rpm
CO [% vol.]	0.02	0.022	0.012	0.01
CO_2 [% vol.]	4.3	5.3	6	8.9
HC [ppm vol.]	6	6	**7**	8
O_2 [% vol.]	14.5	13.3	11.7	9.2
Air excess ratio	3.353	2.752	2.206	1.724
NO_x [ppm vol.]	163	156	226	379
CO_{corr} [%vol]	0.07	0.06	0.03	0.02

Reporting to the input data extracted in table 4, the engine load from 2,000 rpm to 3,500 rpm of constant engine speed is not high, due to the fact that the difference in throttle usage is 10.4% and the maximum value reached is under 50% of its total possible usage (100%). Due to the lighter flywheel, the inertia is lower and so the necessary quantity of fuel necessary in higher speeds is also higher, that can be observed by the increase in injected fuel quantity/stroke. This can be also tracked by looking at the boost pressure, rising significantly at high engine speed. The initial mechanical stress on the engine's internal components is also reduces due to the lightened flywheel, therefore the overall lifespan predicted by the manufacturer does not suffer negative effects. The output recorded by the gas analyzer proves that at lower engine speeds of 2,000 rpm, the excess air ratio is 94.4% higher than at 3,500 rpm. NO_x is at its lowest value at an engine speed of 2,500 rpm and since in urban traffic it does not daily exceed that value, proves that the updates on the engine are beneficial to the case. The way the power is delivered thru the engine's speed, it does not impact its reliability and in daily drive situations there are no real necessities of exploiting the engine at full potential. The limit in terms of forces to be applied on engine's mechanical components are known, therefore only the ones necessary of an upgrade have been replaced [12][13][14][15]. The results are important for older vehicles, as by the proposed retrofitting, it is possible to benefit of important reductions in terms of pollution exhaust levels, as well with simultaneous fuel reduction.

3. Conclusion

One demonstrated that an engine that develops 66 kW, according to initial factory specifications, has reached over 110 kW, by benefitting of changes concerning both the engine control unit and mechanical ones. All results are essential and reached, without exceeding the values imposed by the law in terms of emissions' limits, for a vehicle having the right to drive on public roads. Overall, the way the car behaves is notable improved, in both acceleration and braking terms. The average fuel consumption also decreased, meaning that the pollution is reduced. By reducing the levels of emissions and changing the pollution class of a vehicle one can also reduce the waste and number of vehicles needed to be replaced.

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