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Influence of Fuel Pressure Increment in Diesel Common Rail Engine Using External Tuning Box

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Abstract— The popularity of the diesel engine revolves around its fuel efficiency, reliability, and durability. The performance and emission characteristics of diesel engines depend on various factors like fuel quantity, injection timing, injection pressure, shape of combustion chamber, position and size of injection nozzle hole, fuel spray pattern etc. To modify diesel engine performance in the aftermarket, typical external tuning box is commonly used by only increasing fuel high pressure in which this is similar to trend of Bosch's common rail system. But design of typical external tuning box do not consider other factors such as modification of nozzle spray hole geometry in order to reduce emission and increase engine power. And technical information of typical tuning boxes is typically limited and not published in form technical report. For these reasons, one of commercial external tuning boxes is investigated and installed in Mitsubishi Triton Pickup vehicle with 2.5 Turbo engine (ML Triton Model, 2012). The effect of fuel injection pressure of diesel common rail engine with and without the external tuning box is experimentally investigated in term of fuel consumption and engine power under controlled test conditions on chassis dynamometer. The test conditions cover the steady state of vehicle speed between 20 and 80 kilometers per hour under manual speed control and fixed maximum pedal limit for accelerated state. For fuel consumption, fuel mass during test conditions are measured by fuel weight meter and monitored by On-Board Diagnostics (OBD) device. Furthermore, engine performance with/ without the external tuning box is measured through the OBD device.

Index Terms—**Diesel Engine, Injection Pressure, External Tuning Box, Fuel Efficiency.**

I. INTRODUCTION

Diesel or compression-ignition engine generally takes a heterogeneous charge of previously compressed air and a finely spray of liquid fuel which is injected into the engine cylinder during the end of compression. Then the self ignition properties of the fuel cause combustion to be initiated and spread rapidly within the combustion chamber. After that, the mechanical output power from combustion through piston connection rod and crankshaft is generated. The mixing process of air and fuel is crucial to the efficiency of the diesel engine. Therefore, the variety of combustion system can be fundamentally classified into two groups such as Direction Injection (DI) and Indirect Injection (IDI) systems. In the first one, the fuel is injected directly into a combustion chamber, which is on the top of cylinder. The second one, fuel is injected into a pre-chamber and then rapidly transferred to the main cylinder into main chamber during combustion process. However, these fundamental systems are developed with new production and product technologies such as common rail system, which takes fuel under low-pressure into high-pressure (over 1,000 bar or 15,000 psi) feeding individual injector through distribution pipe (Rail). One reason of such technologies is the improvement of fuel consumption and efficiency of energy conversion in diesel engine. In addition, emission legislation is yearly introduced with tight requirement in order to compensate the increasing number of vehicles, driving behavior and new vehicle concepts with low emission measurement. Therefore, lower emission standards require better engine technologies and exhaust treatment technologies. BOSCH has been developing the fuel injection system for various key characteristics such as mixture formation, maximum pressure injection, rate shape capability and multiple injection stages for future emission legislation [1]. Similarly, DENSO's common rail system for automotive OEM products focuses on improvement of injection characteristics such as maximum pressure injection in order to reduce the concentration of PM in emission, five times multiple injections with a predetermined small fuel quantity and the lightest supply pump for high fuel injection pressure [2].Inevitably, some of external tuning box products are introduced and advertised in

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aftermarket product for common rail diesel engine to increase engine power up to 40% and consume less fuel up to 25% [3,4,5].

However, K. Kannan and M. Udayakumar [6] experimentally studied only the effect of fuel injection pressure between 150 and 250 Bar on direct injection diesel engine. It was found that indicated power was decreased under increment of the injection pressure. But the brake specific fuel consumption was also increased. In addition, Can Cinar et al., [7] reported that the specific fuel consumption deteriorated with increment of injection pressure for a heavy duty direct injection diesel engine. Rosil Abu Baker et al. [8] also report the same phenomena. But Ismet Celıkten [9] experimentally investigated the effect of injection pressure in indirect injection engine. It was found that specific fuel consumption and power were decreased while injection pressure was increased under low engine speed. For these reasons, the objective of this research is to investigate the effect of increase pressure injection using the commercial tuning box in term of fuel consumption for the commercial pickup vehicle with common rail diesel engine. In addition, power and torque of such vehicle with and without the external tuning box are determined through the vehicle OBD II reader.

II. EXPERIMENTAL SETUP AND PROCEDURE

One of commercial external tuning boxes named "Speed kit" was investigated and installed in Misubishi Triton Pickup vehicle with 2.5 Turbo engine (ML Triton Model, 2012) according to "Speed kit" manual installation [3]. To investigate fuel consumption and vehicle performance, the OBD II reader named "OBD-Link" and OBD software named "ScanXL Professional" were used [10,11]. In addition, the digital weight measurement device is used to measure the actual fuel mass consumption of vehicle, together with external fuel tank as shown in Figure 1 and 2.

Fig 1 External Fuel Tank

Fig 1 Digital Weight Measurement Devices

In order to investigate effect of fuel injection pressure of diesel common rail engine with and without the external tuning box on the vehicle fuel consumption, the chassis dynamometer is used as shown in Figure 3.Furthermore, the voltage connector at the end of rail pressure sensor in the common rail is measured in order to monitor the voltage difference before and after using the external tuning box. In test procedure, there are three testing schemes as follows.

a) The tested vehicle is driven for one minute at each constant speed of 20, 30, 40, 50, 60, 70 and 80 kilometer per hour under the 3rd gear position on the chassis dynamometer with and without the external tuning box.

b) In acceleration state, the stopper is used to control 20% of foot pedal stroke for safety reason. The tested vehicle is accelerated from 20 kilometer per hour under the 3rd gear to 20% of foot pedal stroke with and without the external tuning box.

c) The tested vehicle is speeded in the 3rd and 4th gear positions in order to measure the power of vehicle with and without the external tuning box respectively. Such vehicle performances are measured using OBD reader and software.

Fig 3 Chassis Dynamometer

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Fig 3 Chassis Dynamometer

III. RESULT AND DISCUSSION

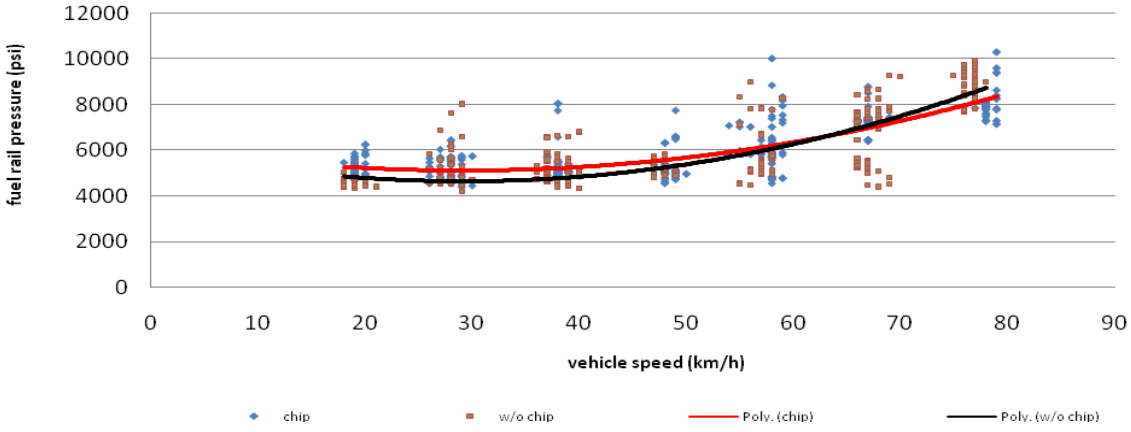

Fig 4 Fuel Rail Pressure versus Vehicle Speed Based On Calculation with Data from OBD II

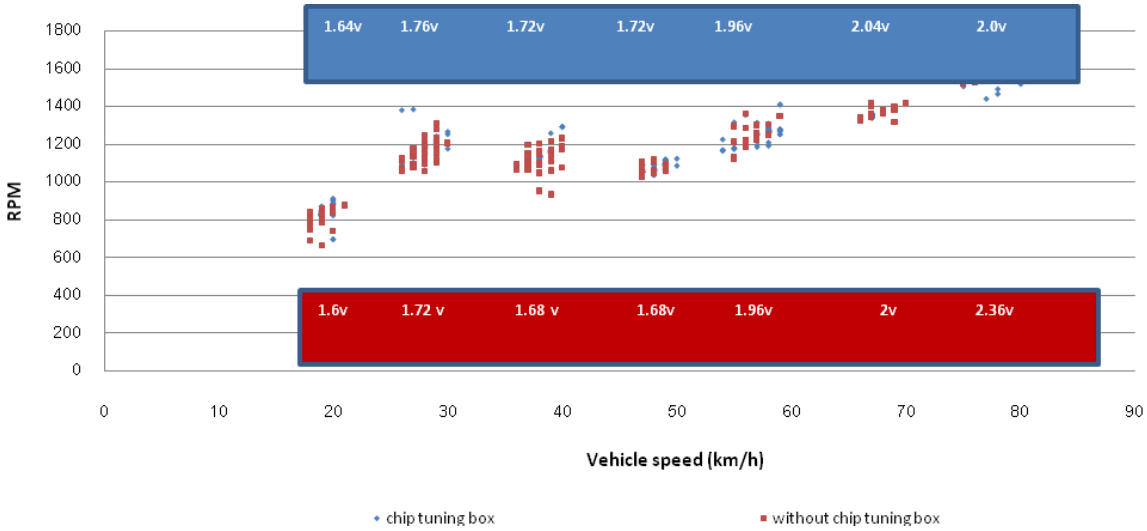

Fig 5 RPM Versus Vehicle Speed and Voltage Measurement at the Pressure Sensor in Common Rail System

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Table 1 Comparison of the Fuel Consumption between Car with and Without Chip Tuning Box

TYPE	TOOLS	Used fuel at specific velocities for one minute						
		20 km/h	30km/h	40km/h	50km/h	60km/h	70km/h	80km/h
A car with chip tuning box	Weight measurement	0.02587 (litre) 12.88 (km/l)	0.03175 (litre) 15.74 (km/l)	0.02822 (litre) 23.62 (km/l)	0.03576 (litre) 23.303 (km/l)	0.03998 (litre) 25.01 (km/l)	0.04233 (litre) 27.56 (km/l)	0.03998 (litre) 33.35 (km/l)
A car w/o chip tuning box	Weight measurement	0.01646 (litre) 20.25 (km/l)	0.02234 (litre) 22.38 (km/l)	0.02352 (litre) 28.34 (km/l)	0.02234 (litre) 37.30 (km/l)	0.03645 (litre) 27.43 (km/l)	0.03998 (litre) 29.18 (km/l)	0.05644 (litre) 23.623 (km/l)

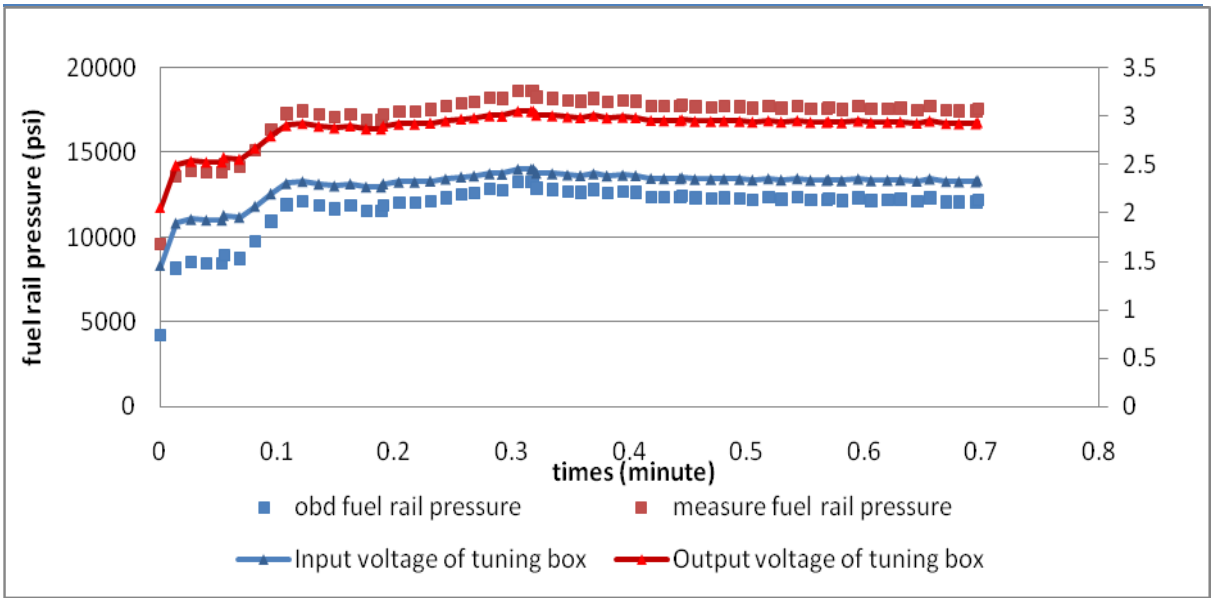

Fig 6 Fuel Rail Pressure and Voltage versus Time (A Car with Chip Tuning Box) in Acceleration State

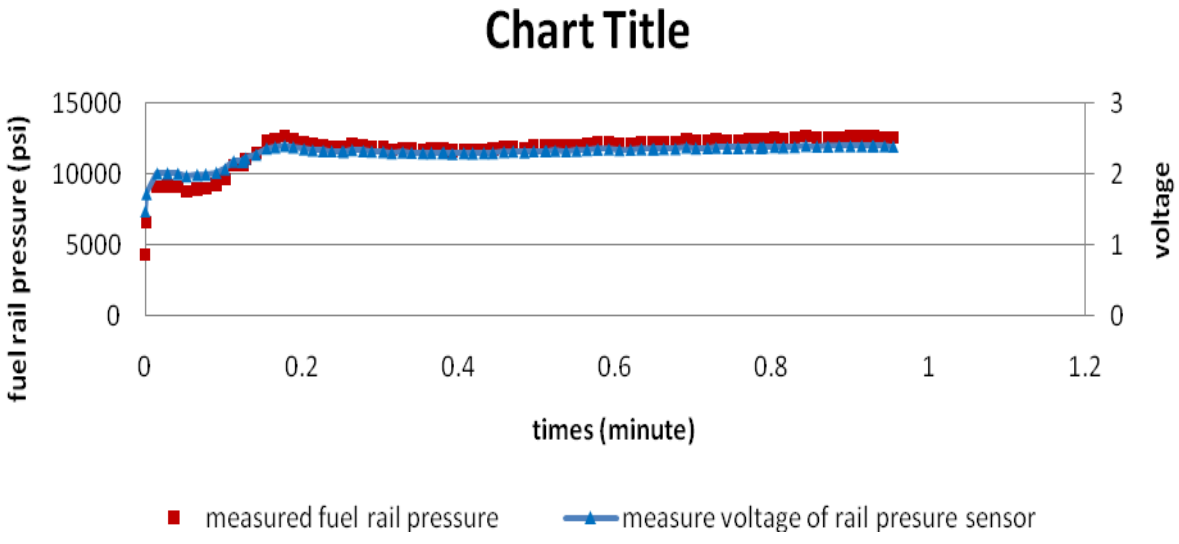

Fig 7 Fuel Rail Pressure and Voltage versus Time (A Car without Chip Tuning Box)

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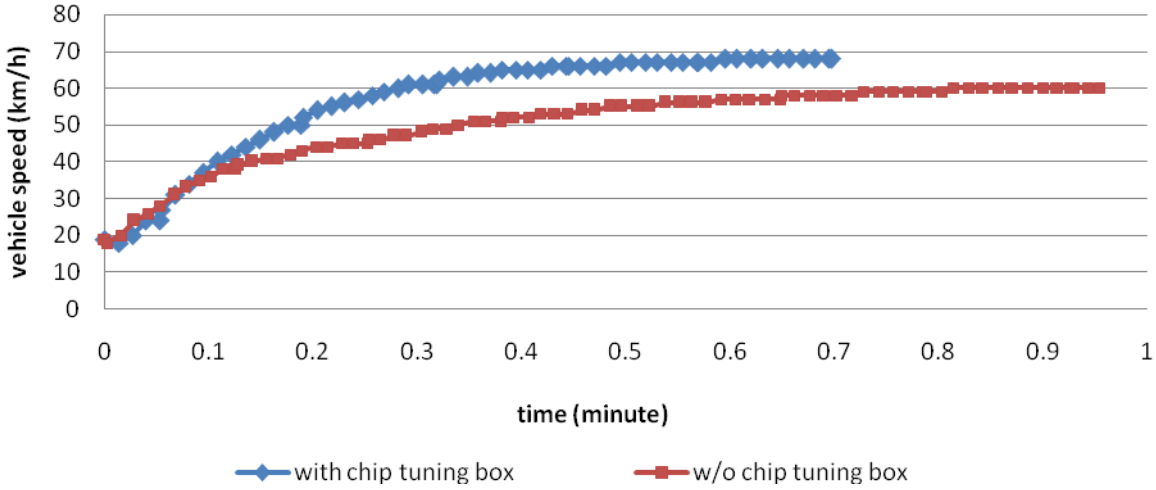

Fig 8 Vehicle Speed versus Time (Comparison between a Car with and Without Chip Tuning Box)

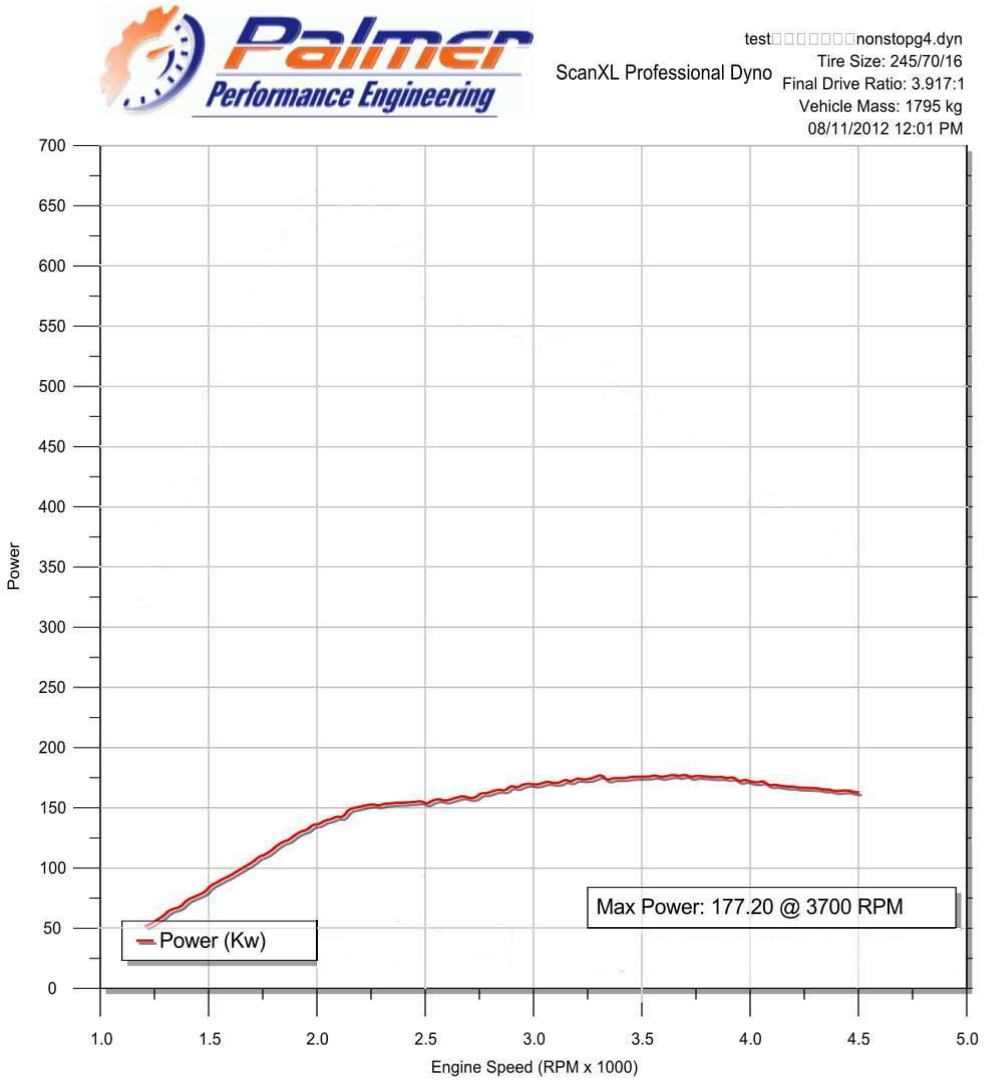

Fig 9 Power versus RPM (A Car with Chip Tuning Box)

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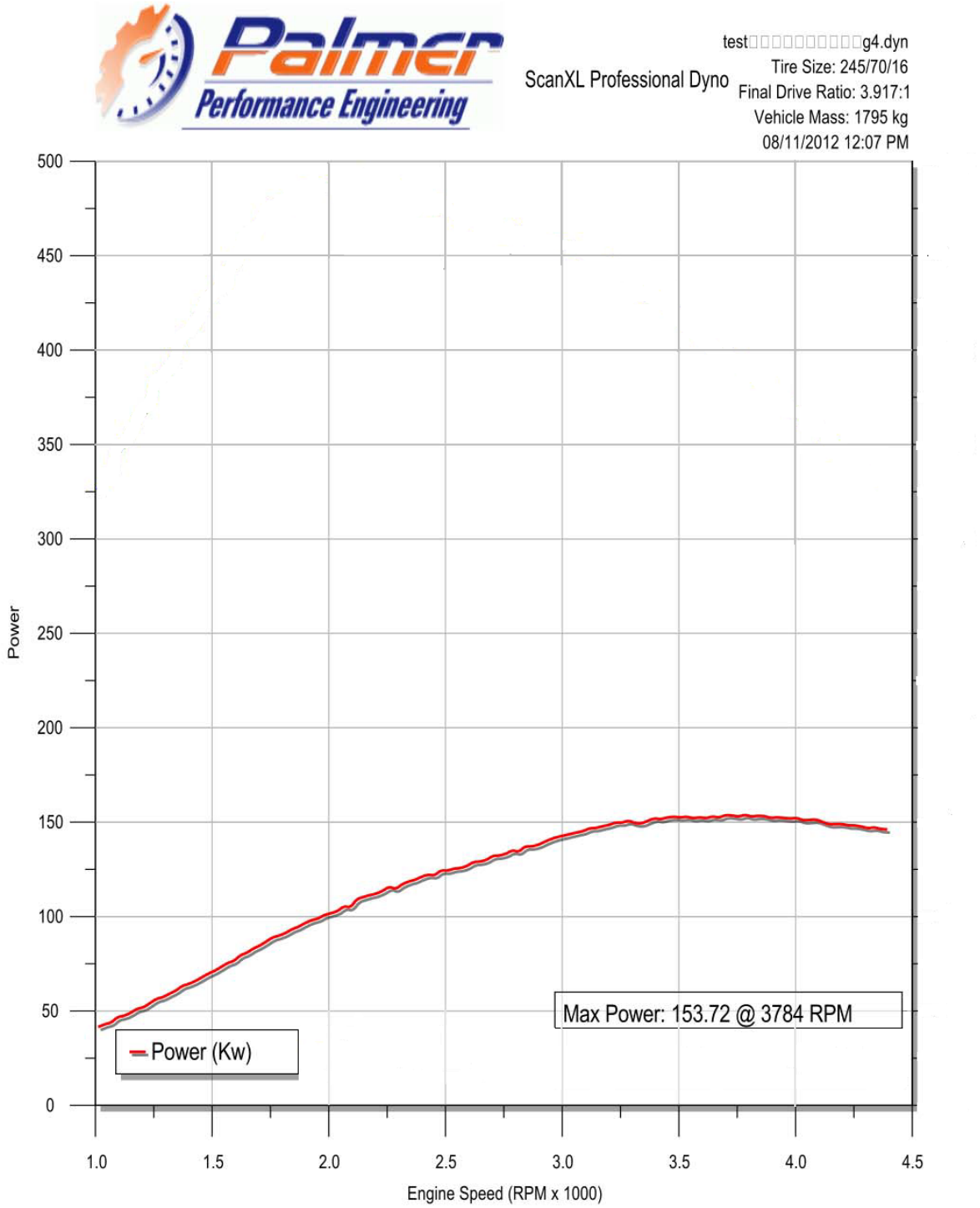

Fig 10 Power versus RPM (A Car without Chip Tuning Box)

In the first scheme (a), results from Figure 4 and figure 5 show that the fuel rail pressure of the car with chop tuning box is slightly higher than the car without chip tuning box at lower speed,20,30,40 to70 km/h and gradually lower at 80 km/h. The car with chip tuning box is also consumed fuel more than the car without chip tuning box at lower speed 20, 30 ,40 to70 km/h and less at 80 km/h as shown in Table 1. From the results, diesel engine development is not only rely on the fuel rail pressure adjustment but also depends on combustion shape, nozzle geometry, injection timing, etc concurrently to get the flexibility of diesel combustion engine [12] In the second

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scheme (b), the result shows that there are distinct for fuel rail pressure in acceleration state. Figure 6 shows the fuel rail pressure and voltage versus time of the car with chip tuning box, the pressure of the fuel rail was adjusted up along the acceleration state around 6000 psi or 1.5volt. Figure 7 shows the fuel rail pressure and voltage versus time of a car without chip tuning box. Figure 8 shows Vehicle speed versus time for the car with and without chip tuning box. The high speed of a car with chip tuning box is 67 km/h@ 0.49375minute. The High speed of a car without chip tuning box is 60 km/h@ 0.8138minute. From the results, the fuel rail pressure not over the 4th generation of common rail diesel with the highest pressure level of 2.500 bar or 36259.435974 psi [13]

In the third scheme (c), the result shows the different of engine power of a car with and without chip tuning box. Figure 9 and Figure 10 show the max power versus RPM at the 4th gear on dynamometer software, the maximum power of a car with chip tuning box is 177.20 Kw @ 3700 RPM, and the maximum power of the car without chip tuning box is 153.72 Kw@3784RPM.

IV. CONCLUSION

In the first scheme (a), the fuel rail pressure obtained with the car with chip tuning box in the first scheme was slightly higher than that obtained with a car without chip tuning box. While the car with chip tuning box increase the fuel rail pressure, not just only its fuel consumption is not better than a car without chip tuning box but also consumed more, except at the high speed 80 km/h. In the second scheme (b), acceleration state, the fuel rail pressure obtained from the car with chip tuning box is obviously detected much higher than the car without chip tuning box. While the fuel rail pressure increase, the acceleration of the car with chip tuning box is also better than a car without chip tuning box. The maximum power obtain from a car with chip tuning box is177.20 Kw @ 3700 RPM@4th gear greater than a car without chip tuning box around 13.72 % . The overall analysis has shown that the chip tuning box, which only fuel rail adjustment, is got a better power performance but not enough for the fuel consumption. Because it should have another composition: combustion chamber shape, nozzle geometry and injection timing in order to get through the high performance and efficiency.

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