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Determination and Comparison of Parameters between the Conventional Injection System and the Common-Rail Injection System on Diesel Engine

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Abstract: ***This work consists of determining and comparing the parameters between the classic injection system and the Common-rail injection system. To achieve this, we proceeded by studying two injection systems, highlighting the advantage of using each system and their disadvantages, then we presented the parameters determined by the manufacturers, which were for us a starting point for determining the power and torque parameters at given engine speeds, which led us to draw characteristic curves according to the parameters determined and then we were able to make a comparison of the parameters. We showed through the analysis of pollution that the classic injection system was too polluting due to the poor quality of the combustion it offers, because the injection pumps used in this system do not offer the maximum pressure. that has high engine speeds. Subsequently, we also showed through pollution analysis that the Common-rail injection system is less polluting, because it offers good combustion quality thanks to pre-injection, post injection and the fact that the injection pressure is not a function of the engine speed, and that it is the system which offers engines which meet all the requirements in terms of performance and pollution.***

Keywords: injection system, Common-rail, classic, parameters, comparison, pollution, combustion, pressure, engine speed, performance

1. Introduction

In the interest of sustainable development and with the aim of preserving our current means of transport, manufacturers and research laboratories are seeking to improve the engines of our vehicles. Introducing new propulsion systems or new fuels, their goal is to improve efficiency. Thus, from their design, we can impose the desired parameters (torque, power, consumption, etc.). We can thus make automobile mechanical systems competitive.

This is how the Diesel engine underwent a big evolution towards the middle of the years 90 with the appearance of common rail direct injection. For many years, studies have shown that this type of engine produces poor quality combustion. Despite some efforts to reduce its consumption, it remained very polluting.

Indeed, by design, combustion begins the moment the fuel is injected. Unlike the gasoline engine which has precise control of combustion thanks to the spark plug which produces the spark at the desired instant, the diesel engine operates on the principle of self-ignition. Thus, the formation of the air-fuel mixture becomes an essential step in reducing fuel consumption and pollution. This is the reason why many developments aimed to reduce consumption and homogenize the mixture in order to obtain better operation and better performance.

These developments have made it possible to move away from the classic injection system towards the “Common rail” injection system. The classic injection system consisted of having an injection pump which generates the high pressure and sends the fuel directly to the injectors determining the quantity necessary for operation. The injector had two positions, it could be placed either directly in the cylinder (direct injection engine) or in a pre-chamber (indirect injection engine). And the Common-rail injection system consists of having a high pressure injection pump which supplies an injection rail, to which all the injectors are connected which are placed directly in the cylinder.

The study of the parameters of these two injection systems made it possible to highlight this assertion: the determination and comparison of the parameters between the classic injection system and the Common-rail injection system.

Its purpose is:
To carry out a study of the performance according to the two operating modes, that is to say with the classic injection system and the common rail injection system. This study involves the analysis of the following parameters: the effective engine torque and the effective power as well as pollution.

2. Determination and Study of the Parameters of the Conventional and Common Rail Injection System on a Diesel Engine

2.1 Study of the classic injection system on a diesel engine

2.1.1. Presentation

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The classic injection system is an injection system used on a diesel engine, it includes an injection pump which must put the fuel under high pressure and determine the quantity of fuel that the injector must inject into the cylinder. Thus, the fuel is delivered at high pressure by the pump through a hydraulic circuit including a discharge valve, fittings and high pressure lines. The injectors are directly connected to the pump via the high pressure lines. The pump must deliver a precise volume of fuel, at the scheduled time and for a clearly determined duration to the injectors.

2.2. Study of the common rail injection system

2.2.1. Presentation

The common rail injection system, commonly known as "Common-rail", is a system which was invented by the engineer Alexandre TRIPODI of the Fiat/MAGNETI-MARELLI group in collaboration with BOSCH, "The Italian engineer

Alessandro TRIPODI is the inventor of the Common-rail system. The Alfa Romeo 156 is the first car in the world to be equipped with this revolutionary system.

Thus, new requirements in terms of performance, pollution, reduced consumption and driving comfort have led injection equipment manufacturers to seek different solutions. Existing equipment such as the injection pump where the high pressure curves generated no longer correspond to the imposed criteria. The maximum pressure on a conventional injection pump is limited, and is only available at maximum engine speed.

3. Calculations of Thermodynamic Parameters of Engines using both Injection Systems

The parameters are determined by the engine manufacturers based on the use of the engine. The parameters determined by the manufacturer are:

- The type of injection system used;
- The number of cylinders the engine has;
- The bore;
- The race;
- The compression rate;
- Engine power;
- The torque of the motor at a given rotation speed;
- Engine displacement;
- Fiscal power

4. Engine using the Conventional Injection System

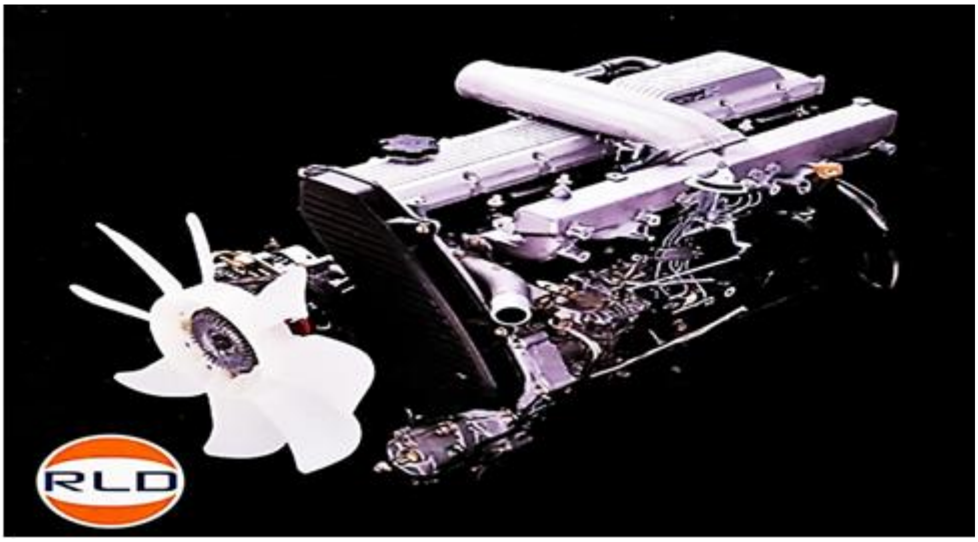

Figure IV: 1 Diesel engine using the classic 1Hz type injection system with cash rocker arm

Diesel engine type: 1HZ
Engine characteristic:

6 cylinders, 4-stroke indirect injection diesel, Denso rotary injection pump, one injector per cylinder (rating: 145 – 155 bars), overhead camshaft with two valves per cylinder, preheating by one spark plug per cylinder.

- Bore × stroke: 94 × 100 mm;
- Displacement: 4,165 $cm3$ => 4.165 l;
- Compression ratio: 22.7 to 1 / 22.4 to 1;
- Maximum power: 96 kW at 3,800 tr/min;
- Maximum torque: 274 Nm at 3,000 tr/min;
- Fiscal power: HZJ73: 17 HP

Engine using Common- Rail Injection System

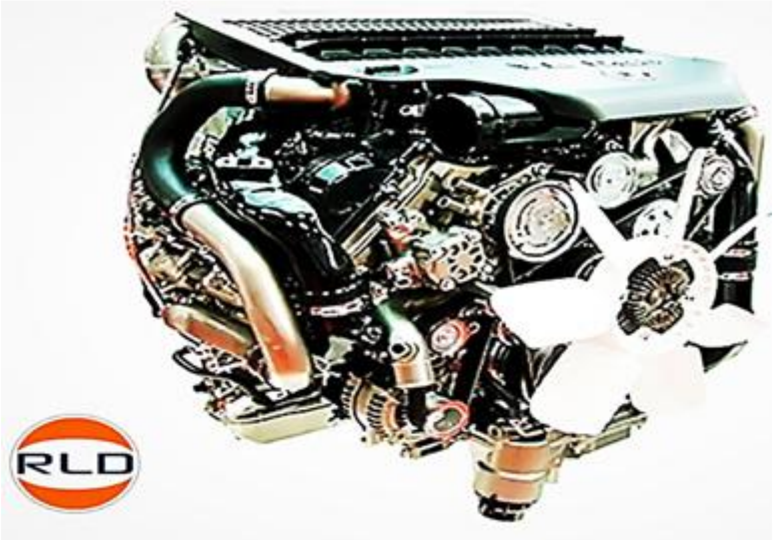

Figure IV. 2: Diesel engine using the Common rail injection system type 1VDFTV (RLD, 2021)
Diesel engine type: 1 VD-FTV

Features

8 V-shaped cylinders, common rail diesel injection, Denso rotary high pressure pump, one injector per cylinder, overhead camshaft with 2 valves per cylinder.

- Bore × stroke: 86 × 96mm
- Displacement: 4,461$cm3$ => 4,461l
- Compression ratio: 16.8 to 1
- Power: 162 kW at 3,600 tr/min
- Torque: 466 Nm to 2,500 tr/min

5. Presentation, Analysis, Interpretation and Comparison of Results

5.1 Introduction

In this chapter, we will present, analyze, interpret and compare the different performances developed by the two injection systems, including the effective power and the effective engine torque. We will therefore proceed by determining the performances according to the evolution of the engine speed and then draw curves which will allow us to interpret the results for each system.

5.2 Presentation and Interpretation of Results

5.2.1. Presentation and interpretation of the results of the classic injection system

5.2.1.1. Effective specific power, torque and consumption.

1) Effective power

It is the combination of the effective torque and the rotational frequency of the crankshaft, i.e. the power developed on the piston during expansion. It is supplied by the engine at the end of the crankshaft shaft. It allows corresponding effective work to be carried out, taking into account mechanical losses. It is symbolized by $Peff$ it is expressed in kilowatt [KW] or horsepower [CV].

The effective power of the 1Hz motor considered is:
$\boldsymbol{Peff} = \mathbf{96}\ [\boldsymbol{kW}]$

2) Effective motor torque

This is the mechanical torque available at the crankshaft output, it is used for vehicle propulsion. This torque results from the mechanical torques of the engine (multi-cylinder) or the inertia torque of the crankshaft minus the friction torques of the crankshaft and the drive torques of the auxiliary components (resisting torque). It is symbolized by $Ceff$, it is expressed in Newton meters [Nm].

The effective torque of the 1Hz motor considered is:
$\boldsymbol{Ceff} = \mathbf{274}\ [\boldsymbol{Nm}]$

3) Effective specific consumption

Effective specific consumption is the quantity of fuel consumed by the engine to deliver effective power for a given time. In practice, specific consumption is defined as the fuel consumption in grams to provide 1 [kW] of effective power for one hour. It is symbolized by Cse, expressed in gram per kilowatt [g/kWh]

The effective specific consumption of a diesel engine is 240 to 270 [g/kWh] in economical mode.

5.1.2.2 Characteristic curves

The characteristic curves are curves which represent the different variations in power, motor torque as well as the consumption of a motor, as a function of the rotation speed.

1) Power curve

This curve and the graphic representation of the effective power as a function of the rotation speed and therefore the rpm. It is given by the following formula:
Pe=Peffmax×N/Nn×[0.6+1.4×N/Nn-(N/Nn)^2]
With :
$Peffmax = 96\ [kW]$
$Nn = 3800[tr/min]$
. Ce=9554 X P_eff/N III.2

6. Presentation and interpretation of the results of the Common-rail injection system

6.1 Effective specific power, torque and consumption.

1) Effective power

It is the combination of the effective torque and the rotational frequency of the crankshaft, i.e. the power developed on the piston during expansion. It is supplied by the engine at the end of the crankshaft shaft. It allows corresponding effective work to be carried out, taking into account mechanical losses. It is symbolized by $Peff$ it is expressed in kilowatt [KW] or horsepower [CV].

The effective power of the 1Hz brand diesel engine considered is:

$\boldsymbol{Peff} = \mathbf{162}\ [\boldsymbol{kW}]$

2) Effective motor torque

This is the mechanical torque available at the crankshaft output, it is used for vehicle propulsion. This torque results from the engine mechanical torques (multi-cylinder) or inertia torque of the crankshaft minus the friction torque of the crankshaft and

driving the auxiliary organs (resisting torque). It is symbolized by $Ceff$, it is expressed in Newton meters [Nm].

The effective torque of the 1VD-FTV brand diesel engine considered is:

$\boldsymbol{Ceff} = \mathbf{466}\ [\boldsymbol{Nm}]$

3) Effective specific consumption

Effective specific consumption is the quantity of fuel consumed by the engine to deliver effective power for a given time. In practice, specific consumption is defined as the fuel consumption in

gram to provide 1 $[kW]$ of effective power for one hour. It is symbolized by Cse,

It is given by the following relation:

Cse=3600/(ηeff×Pci)

The table below gives us the values of the effective powers as a function of the rotation speed.

Table I.1: Comparison of the effective powers of the two engines

$[tr/\,min]$ Rotation speed	$[tr/\,min]$ Effective motor power 1Hz 1Hz $[kW]$	$[kW]$ Effective power of 1VD-FTV motor $[kW]$
500	10	16
1 000	23	40
1 500	38	67
2 000	54	95
2 200	60	107
2 500	69	122
3 000	86	144
3 500	92	160
3 600	93	162
3 800	96	-

The graph below represents the nuance of the variation of two couples

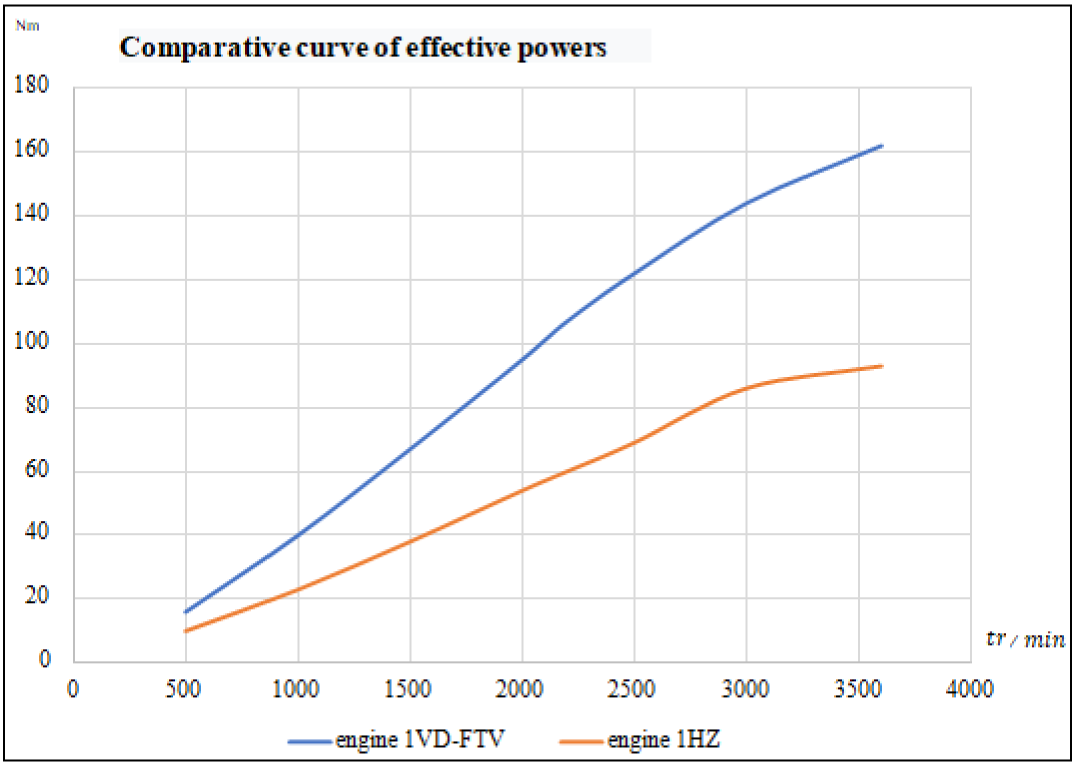

Figure I. 2: Comparative curve of effective power as a function of engine speed of the 1HZ engine and 1VD-FTV engine

Considering what this graph presents to us, we can therefore declare, by saying that the 1VD-FTV engine which represents the performance of the common rail injection system is more efficient than the 1Hz engine which represents the performance of the injection system classic, because it presents a curve which is much higher than that of the 1Hz motor at low and high engine speeds.

As a result, the common rail injection system allows a rapid increase in power and, thanks to its different injection performances, provides good power at low engine speeds.

3.4.2. Comparisons of effective torques

The table below gives us the effective motor values of the two motors

Table I. 3: Comparisons of effective motor torques

Rotation Speed [tr/ min]	[tr/ min] Effective motor torque 1 Hz [*Nm*]	[*Nm*] Effective motor torque 1VD- FTV [*Nm*]
500	191	308
1 000	220	382
1 500	242	428
2 000	258	454
2 200	260	464
2 500	264	466
3 000	458	458
3 500	251	437

The graph below gives us the nuance between the evolution of the two effective engine torque curves

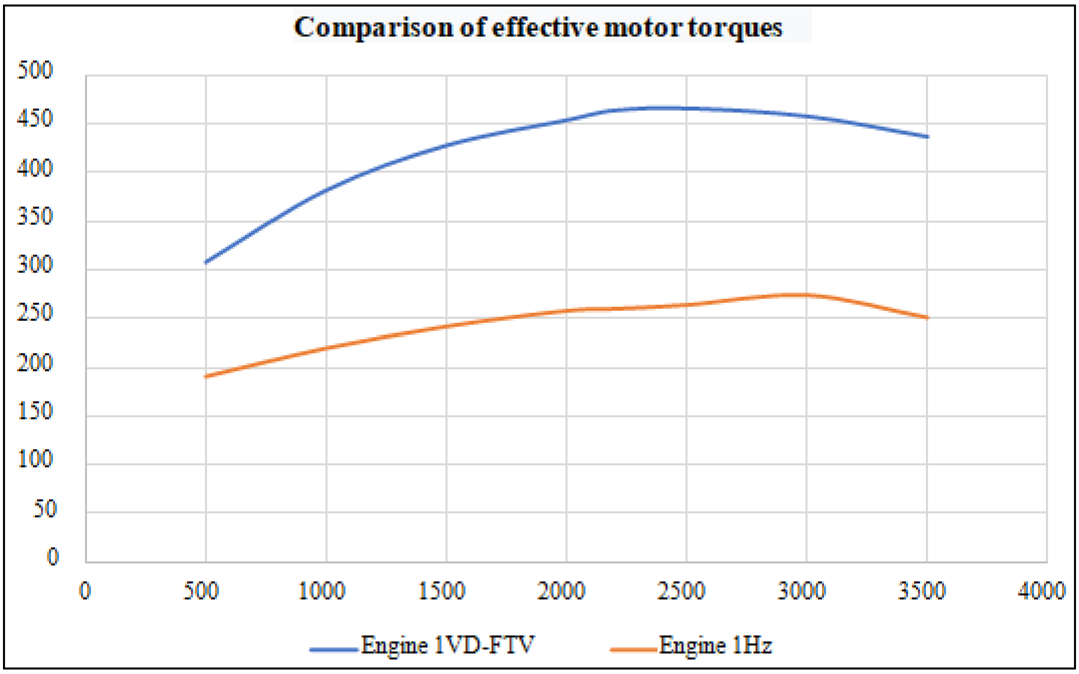

Figure I. 4: Comparative curve of engine torque as a function of engine speed of the 1HZ engine and the 1VD-FTV engine

Considering what the graph above shows us, we say that the engine 1VD-FTV which represents the performance of the common rail injection system, presents a better effective engine torque than that of the 1 Hz engine which represents the performance of the common rail injection system.

As a result, the common rail injection system presents us with more torquey engines than the traditional injection system. The torque generated by the common rail injection system is greater and allows a rapid increase in engine power.

7. General Conclusion

This work concerns the determination and comparison of the parameters between the classic injection system and the Common-rail injection system on a diesel engine. The aim pursued by this work was to demonstrate by the study and determination of the parameters developed by the two injection systems, which was more efficient than the other, and by the analysis of the different results found, decide which one is suitable. better meet performance and pollution requirements.

Therefore, we studied the classic injection system, it is a system which has injection pumps, which are responsible for generating the high injection pressure and determining the quantity of diesel that the injector should spray into the combustion chamber. We have demonstrated through pollution analysis that this injection system produces poor quality combustion due to low injection pressures. In fact, the injection pressure on this system is a function of the engine rotation speed and this leads to a lack of homogeneity of the mixture and poor combustion. Then, we studied the Common-rail injection system, it is a system which has a high pressure pump and an injection rail common to all the injectors, this system allows, thanks to high pressure injection, have good quality combustion, and this allows a rapid increase in power and torque by offering less polluting engines. It is a system that meets new requirements in terms of performance, pollution, reduced consumption, and driving comfort.

Thus, we can say that the system that is best suited for our vehicles is the Common-rail injection system, because it is the system that meets the requirements in terms of performance and pollution.

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