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Research paper

Theoretical study to determine the proper injection system for upgrading fuel system of diesel engine om357 to common rail system

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Abstract

In this research, we tried to investigate all the fuel injection systems of diesel engines in order to select the most suitable fuel injection system for the OM357 diesel engine to achieve the highest efficiency, maximize output torque and reduce emissions and even reduce fuel consumption. The prevailing strategy for this study was to investigate the effect of injection pressure changes, injection timing and multi-stage injection. By comparing the engines equipped with common rail injection system, the proposed injector for engine OM357 is solenoid, due to the cost of this type of injector, MAP and controller (ECU). It is clear that this will not be possible only with the optimization of the injection system, and so other systems that influence engine performance such as the engine's respiratory system and combustion chamber shape, etc. should also be optimized.

Keywords: *Diesel Engine; Common Rail; NO_X; Soot.*

1. Introduction

Today's world is moving at an unbelievably fast pace to produce science-and-environment-friendly technologies. The production of clean fuels for the replacement of fossil fuels, the use of new energies and the production of clean cars are among the most important ways to help solve environmental problems.

According to Euro 1, NO_x formation for diesel vehicles is up to 8 g per kwh, and for PM, 0.36 g per kwh (<85 kW). In the recent law, Euro 6, which was adopted in 2014, the maximum permissble standard for NO_x emission was reduced to 0.46 g / kWh and PM was reduced to 0.01 g / kWh [1]. In order to meet the standards of pollution, diesel and auto manufacturers are heavily invested in new technologies that can help reduce diesel pollution [2].

Busch Co. introduced the common rail system for the first time in 1997. In common rail technology, compare with the conventional systems, there are differences that provide multi-stage injection in the work cycles. At this technology, the primary injection is to slow down the engine, the main injection to create the ideal power, the secondary injection to reduce emissions. The fuel reaches the injectors by short compression tubes and then spills from the injection apertures to the combustion chamber [3]. The main application of the common rail system is in piezoelectric injectors, they have a better control over the amount of injection than the solenoid and unit injectors do. [4].

The first Denso Rails system is the HP0 model that was launched. This model uses the HP0 pump and is installed on large trucks and buses. The HP2 model uses the HP2 pump and is mounted on riding cars. The HP3 model, which is smaller and lighter than the previous model, provides higher pressure and the HP4 model based on the HP3 model, the only difference being that it uses the HP4 pump [5].

Delphi is developing a second-generation system to help manufacturers to meet greenhouse gas emission standards for Euro 5, Euro 6 and beyond. Important features of diesel engines are quick action injector and a common rail, an engine controller module with a suitable program, a powerful fuel pump unit with an input valve [6].

2. Solutions for emission reduction of diesel engine

There are many ways to reduce the amount of NO_x and PM produced by combustion of a diesel engine. In some cases, Exhaust gas recirculation (EGR) is used to reduce NO_X, but increase PM and smoke and reduce motor durability. Another way to reduce emissions from the diesel engine is to use devices that separate the pollutants after combustion in the combustion chamber. These devices include Diesel Particulate Filter (DPF) and Selective Reduction Catalyst (SCR).

Multi-stage injection has been proposed in several ways to reduce diesel exhaust emissions. This reduction in pollution includes a decrease in the amount of PM, but NO_X levels do not change much. Also, by adjusting injection schedules using either pre-injection or pilot injection; as well as the effect of a combination of injection and high pressure injecting, NOx is reduced by up to 35% and soot by 60 to 80%; without changing the fuel consumption. On the other hand, the effect of the stagnation time (the time between the end of injection and the beginning of the next injection) varies between each injection. When the stagnation time is reduced, the fuel used in the second injection is at a point near the

TDC, which results in lower fuel consumption, but engine noise and smoke production increase with decreasing stagnation. This is due to the characteristics of combustion at a lower temperature.

Durnholz et al. examined the effect of the injecting of the pilot on the engine noise, engine efficiency, pollution, and found through a microphone that the compression noise of the combustion chamber was reduced to 10 dB by pilot injection. When the engine operates in its optimal state, the NO_X level is reduced to 30% and HC level decreases by up to 50% without any change in black smoke [7]. Choi and Ritz [9] investigated the multi-stage injection effect on emission of engine combustion at low and high loads. In a high load, as in the low load, multi-stage injection, compared to single stage injection, has the desired effect on the amount of combustion Soot.

The effect of increasing the injection pressure on the process of emission changes has been investigated by some researchers. Morgan et al. examined the effect of injection pressure on the amount of soot (Fig. 1). It is worth noting that by excessive pressure injection system, because of the increased length of the injection, the possibility of a fuel crash goes up with a piston crown or cylinder walls, resulting in increased HC and soot; although the design of the combustion chamber and the respiratory system plays an important role. Today, high-pressure common rail injection systems give you the flexibility to control timing and amount of fuel injection, which greatly impacts engine noise and exhaust emissions, regardless of fuel consumption and efficiency.

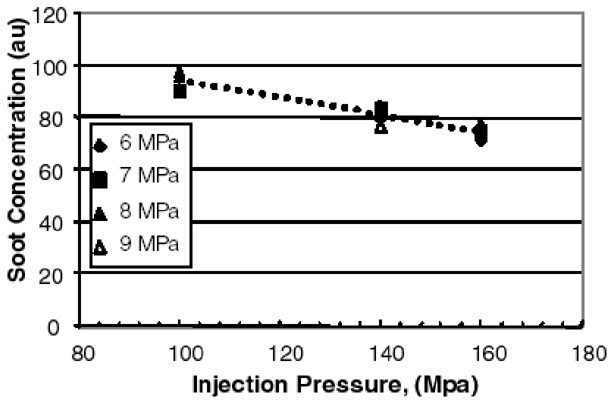

Fig. 1: Soot Changes versus Pressure Variations of Injection.

Figure 2 illustrates the benefits of using a multi-stage injection system. One or two pilot injections at low pressures reduce engine noise and NO_X. Also, the form of boot expansion can help reduce NO_X. Therefore, dual injection with high pressure reduces the amount of soot [11].

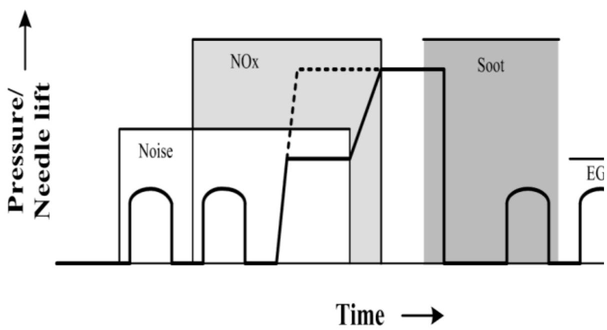

Fig. 2: Advantages of Using A Multi-Stage Injection System.

In spite of the reduction in other pollutants, the production of Soot will increase by multi-stage injection. The reason is that by injecting fuel in the second cycle in a region that burns out during the first cycle, there is a fuel rich combustion zone. It is clear that the greater the amount of fuel spill in the second cycle, the soot content will increase. In addition, the higher the injecting angle, the production soot will increase [12]. In Fig. 3, the effect of the injection pattern on the amount of exhaust emissions in a single cylinder engine was investigated at 1400 rpm. In rectangular injection, it is possible that the amount of fuel and injection time is equal to the shape of the boot, but the production of soot and NO_X increases. At full load and using a common rail system, boot dispersion shows the best results in terms of pollution reduction [13].

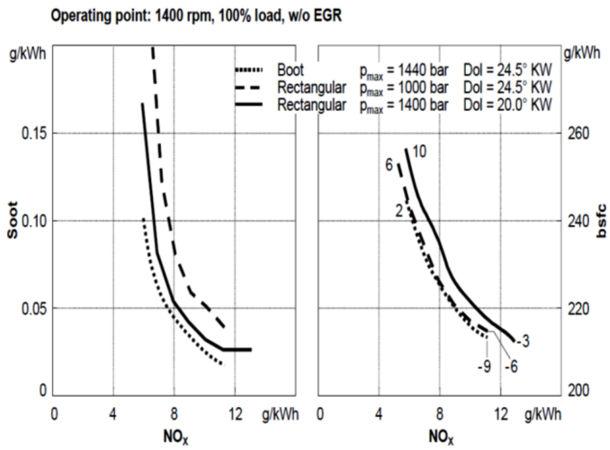

Fig. 3: Effect of Injection Pattern on Exhaust Outlet Pollutants.

3. Current state of injection system of engine OM357

The OM357 engine specification is shown in Table 1. Other I information about the type of pump and type of injector and the fuel injection system were obtained with the assistance of the Idem CO. in Tabriz. The injector is of a row type, nozzle is a PES-type made by Bosch, injection system is a direct-injection equipped with turbocharged.

Table 1: Specifications of the OM357 Engine

Technical Specifications		Unit
Type	355.93	
Number of cylinders	6	
Maximum power	225@2200	Kw@rpm
Maximum Torque	1140@1400	N.m@rpm
Compression Ratio	16.82:1	
Cylinder bore	128	mm
Stroke	150	mm
volume	11.98	Lit
Weight to Power ratio	4	Kg/KW
Minimum fuel consumption	208.7	Gr/Kw-hr
Total engine weight	900	Kg
Aspiration	Turbo	
Application	Bus-Truck	
Standard	Euro2	

4. Results and discussion

In this study, the strategy was to investigate the effect of injection pressure changes, injection timing, injection shape and multi-stage injection. The general trend of the effect of the injection pressure on the amount of engine emission has the same trend for the various conditions of the diesel engines; that is, by increasing the relative pressure and optimizing the fuel system pressure and taking into account the shape of the combustion chamber, it will reduce the emissions of the exhaust, especially the soot. Therefore, this process is fully consistent with the OM357 engine's common rail system, and the results can be used to predict the impact of the injection pressure on the OM357 engine's common rail system. The reason for using high pressure injection is to improve engine performance by reducing engine emissions and increasing engine performance. Increasing the injection pressure generally increases the temperature efficiency and improves fuel consumption and reduces CO, HC and soot, but NO_X increases [14]. The nozzle used in the OM357 engine has 7 holes, and the spraying angle is 153 and 157, which is roughly the same as the results of [11]. In the 7-hole injection system, the amount of wetting of the cylinder wall was higher than that of the 12-hole system, which increased exhaust emissions (Fig4).

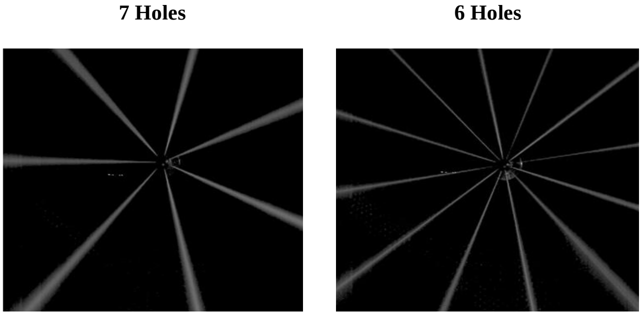

Fig. 4: Distribution of Fuel in Nozzles with Different Number of Holes.

To determine the effect of the injection angle, two different angles were investigated by Nemati et al. [13]. They found that the increase in combustion chamber pressure at 60 ° C was greater than the increase in combustion chamber pressure at 156 ° (Fig5). In some common engines, a 156-degree fuel injecting angle is used with a 30-40 degree BTDC timing, which results in incomplete fuel combustion.

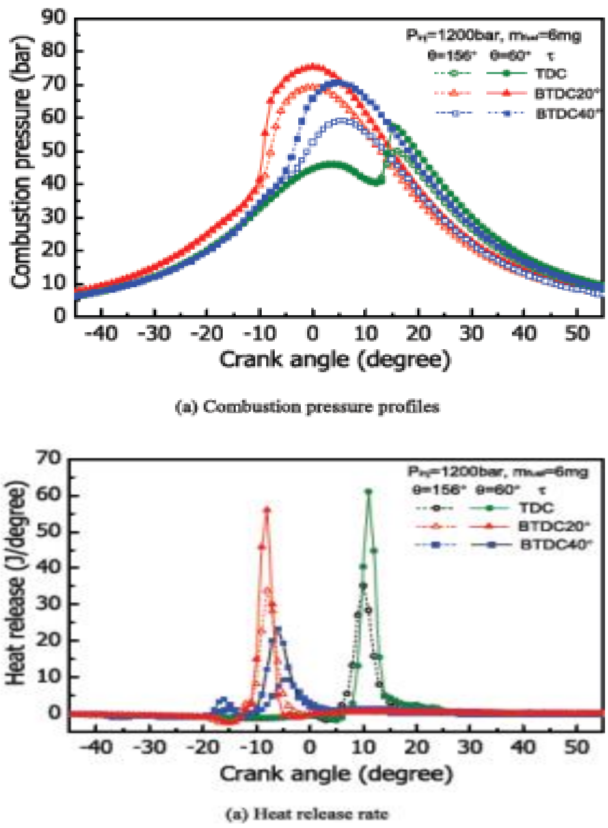

Fig. 5: Changes in Combustion Chamber Pressure Relative to Change in Fuel Injection Angle.

Spraying hole is one of the most important geometric features of the nozzle. Spray characteristics are determined by the micro-geometric properties of nozzle stops. The nozzle parameters (diameter, length, input edge, geometry, form, and micro level) are related to reaching the optimal flow profile that generates emissions to a standard level. By improving the nozzle geometry, the fuel injection system has been modified to match the design of the combustion chamber to improve the combustion system and exhaust emissions from the engine. Hole geometry has an effect on the amount of soot and NO_X and engine sound. The HC pollutant is reduced by reducing the volume of Sac. As the Sac increases from 2 mm to 6 mm, the amount of NO_X is reduced to 6% and the fuel consumption increases slightly due to the approaching spray to the piston bowl.

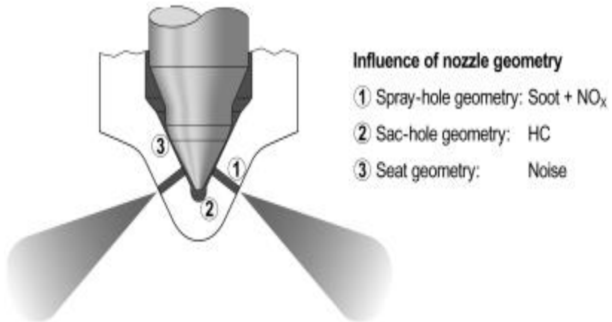

Fig. 6: The Relationship between the Form of Spraying and the Type of Exhaust Emission.

To investigate the effect of pilot injection, the results of Schailer et al. [15] can be used to predict the behavior of the OM357 engine against pilot injection. By doubling the initial injection, the amount of NO_X will be significantly reduced. But there is a problem with the amount of soot. Figure 7 shows that applying a pilot injection can greatly increase the amount of NO_X. The reason for this phenomenon is that the pilot injection causes the temperature to rise and NO_X increases.

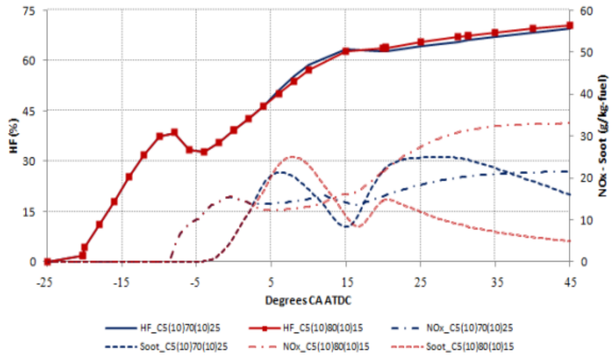

Fig. 7: The Effect of the Rate of Injection on Emission.

The injection timing results of a 4-cylinder engine with direct injection and common rail system are shown in Figure 8. The cylinder capacity and the fuel volume were 1600 cc and 425 cc respectively, the compression ratio was 14 and the number of hole per nozzle was [7]. The start of injection in the combustion chamber is noticeably effective on the combustion delay. The injection timing strategy varies in each engine according to speed and load. Larger delay increases the premixed phase and increases the temperature inside the cylinder which subsequently increases the NO_X. In addition, when the temperature and pressure inside the cylinder is relatively low, the fuel evaporation rate decreases, resulting in more cylinder walls, lower power levels and pollution of soot.

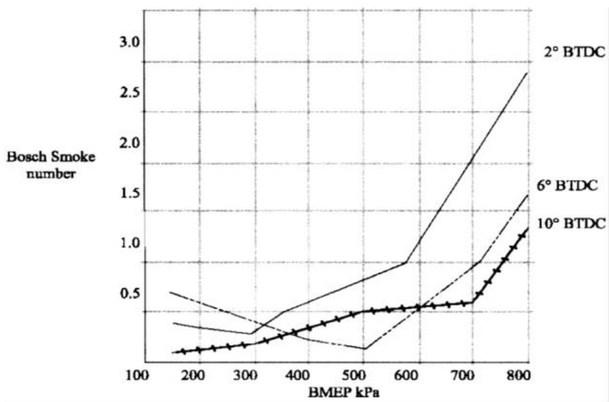

Fig. 8: Effect of Injection Timing.

In the end, with regard to the type of fuel, it should be noted that new fuels are usable to reduce pollutants, but it is important to note that the overall process of checking the parameters shows that all of the parameters mentioned, regardless of the type of fuel, can also be used to reach Euro 5. In fact, there is no other expectation other than this, for the country's industry.

5. Conclusion

Characteristics of the engines similar to the OM357 engine are compared in Table 2 to summarize and select the most suitable injection system.

Table 2: Specifications of Engines (with Common Rail- Solenoids Injector) Similar to the OM357

Fuel	R	T (Nm)	S (mm)	D (mm)	P (kw)	V (L)	Co.	Model
65.3 l/hr	16/3	1246	147	125	261	10/8	Cummins	QSM11
211 g/kw.hr	17	1540	142	128	245	10/96	Doosan (Daewoo)	DV11
213 g/kw.hr	16/5	1432	150	131	313	12/1	Volvo	D12
188 g/kw.hr	17	2300	166	126	353	12/4	Man	D2676
208.7 g/kw.hr	16/82	1140	150	128	225	11/98	Benz (Idem)	OM357

Although similar engines such as the DC12 Scania and the C12 Caterpillar are currently on the market and is being installed on different vehicles, but due to the difference in its injection system with engine OM357, it was not examined and analyzed. The injection system on the two engines was an electric injector unit.
By comparing the engines in Table 2 and the efficiency and performance of these engines, also considering the capabilities and potential of the common rail system, the proposed type of injection system is solenoid injectors due to the cost of this type of injector, MAP and also controller (ECU) required for this engine is proportional to the injector. Since the amount of fuel spraying per cycle of the cylinder and the mode of operation of the injector per pulse are importance due to the amount of exhaust emissions, therefore selection of a solenoid injector has a special sensitivity.
Considering the number of OM357 engine cylinders as well as its output power, Busch's CRIN 3-18BL injector needle and also the common rail of the HFRN-18PLV model, according to the technical information of the engine (OM357) and the following information is suggested (Fig. 9).

Fig. 9: Proposed Injector for the Engine OM357.

- Maximum system pressure: 1800 Bar
- Operating voltage: 12 V to 24 V
- Pollution level: Euro 4 and above
- Spraying number per cycle: maximum 4 sprays

Finally, it should be recalled that all the issues raised in this study are subject to the modification and optimization of all systems associated with the combustion system of this engine, such as the combustion chamber shape, the type of respiration system, and the related items affecting the combustion and performance of the OM357 engine. Obviously, optimizing and changing the injection system, it's not possible to reach an emission level of Euro 5. just a change in the spray system, not only does not improve the performance of the engine and reduce the emissions from the combustion, but also the probability of slowing down the efficiency and increasing fuel consumption and emissions. Therefore, optimization and changes to all factors affecting the performance of a diesel engine should also be considered as important factors in design.

References

[1] European environment agency. ble:http://www.eea.europa.eu/data-and-maps/, Cited on 28/05/2014.

[2] D. Swift and W. Foster, Air Pollutants and the Respiratory Tract. Marcel Dekker، (1999).

[3] Roger Busch Advanced Diesel Common Rail Injection System for Future Emission Legislation, 10th Diesel Emission Reduction Conference 10th Diesel, August 29 - September 2, Coronado, California. Emission Reduction Co. 2004**n.** http://boschservicetehran.com/Fa/ProductView.aspx.

[4] DENSO,"Annual report 2011", tech. rep., DENSO Corporation Japan, 2011.

[5] G. Dober, N. Guerrassi and K. Karimi. Mixture preparation and combustion analysis, SIA diesel powertrain international conference, Roune. (2012).

[6] M. Durnholz, H. Endres, P. Frisse. Pre-injection a measure to optimize the emission behavior of DI-diesel engine. SAE paper. (1994).

[7] T. Tow, D. Pierpont, R. Reitz. Reducing particulate and NOx emissions by using multiple injections in a heavy duty DI diesel engine. SAE paper. (1994).

[8] C. Choi and R. Reitz. An experimental study on the effects of oxygenated fuel blends and multiple injection strategies on DI diesel engine emissions. Fuel. (1999) https://doi.org/10.1016/S0016-2361(99)00058-7.

[9] R.E. Morgan, M.R Gold, O. and Laguitton, Characterisation of the Soot Formation Processes in a High Pressure Combusting Diesel Fuel Spray, (2003).

[10] B. Mahr. Future and potential of diesel injection system. Conference on thermo and fluid-dynamic process in diesel engines .(2002).

[11] M. Arai and K. Amagai, Experimental study on a diesel spray of multi stage injection. Internatioal symposium COMODIA 94. (1994).

[12] A. Nemati, Sh. Khalilarya, S. Jafarmadar, H. Khatamzade and V. Fathi. Effect of injection characteristics on emission and combustion of an engine. International Journal of Automotive Engineering. (2011).

[13] A. Agarwal, A. Dhar, D. Shrivastava, R. Maurya, and A. Singh. Effect of fuel injection pressure on diesel particulate size and number distribution in a CRDI single cylinder research engine", Fuel, vol. 107. (2013) https://doi.org/10.1016/j.fuel.2013.01.077.

[14] P. Shayler, T.D. Brooks, G. Pugh, and R. Gambrill, The in uence of pilot and split-main injection parameters on diesel emissions and fuel consumption, SAE Paper 2005-01-0375, (2005).