

# The advantages of the diesel engine engineering essay



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## Introduction

First ever working diesel engine was created in 1897 by German inventor Rudolf Diesel. From this time diesel engine started its way to cars - from trucks to the modern sport cars. This huge step could not have happened, if technology had not evolved so. Diesel powered light-duty vehicles have been available for many decades, but their share of the market has increased rapidly only since about 1980. This was due to direct injection and forced induction, which made diesel engine more flexible and user-friendlier. Light-duty diesel vehicles have become very popular in Europe and their market share has increased from little over 10% in 1980 to 43% in 2003. In some countries in Europe diesel powered cars conquered over 50% of market. In North America, however, diesel powered light-duty vehicles account for less than 0, 5% of the total market. These vehicles enjoyed a brief burst of popularity in the 1974-1984 period, but in 2003 only one manufacturer (VW) offered diesel light-duty vehicles in North America. Today, popularity of diesel powered passenger cars is starting to grow. In 2008 VW introduced their new 2. 0l diesel common-rail injected engine in North America, people started to look differently into diesel cars. These were not slow, dirty, did not feel like " tractor", but fast, clean and economical. In 2010 BMW joined VW introducing car powered by 3. 0l twin-turbocharged diesel engine which met very strict North American exhaust gas emission standards. After introduction of these cars, there is hope for diesel engine cars in North America.

The analysis presented in this section is largely based on engineering analysis and the opinion of diesel engine experts in the automotive industry. <https://assignbuster.com/the-advantages-of-the-diesel-engine-engineering-essay/>

Hence, the results presented here should be treated as preliminary estimated to be confirmed by actual testing.

## **The Benefits of Diesel**

The main advantages of the diesel engine are:

Relative fuel economy and efficiency

Engine durability

More hauling power

Less pollution

The major advantage of the diesel engine over the gasoline engine is its relative fuel economy. Compression ignition engines are more fuel efficient than spark ignited engines. First of all, the diesel cycle requires that fuel ignite spontaneously upon contact with hot compressed air. Secondly, diesel engine uses high compression ratios of 16: 1 to 20: 1, which means that the fuel will be burned more efficiently. Petrol engines cannot use such high compression ratios because the combustion process requires external ignition of a pre-compressed fuel-air mixture; the octane number of the fuel limits the compression ratio to about 10: 1 for the spark ignited engine using petrol, because it can detonate too soon. Second, the power output of the diesel engine is controlled by regulating the amount of fuel per combustion event while the air inducted is unthrottled. In contrast, gasoline engines require the intake air to be throttled to control load, while keeping the air-fuel ratio constant. The throttling of intake air leads to pumping losses that

increase at light loads in a gasoline engine. Such losses are absent in the diesel, and its fuel economy benefit under light conditions over a gasoline engine is quite large.

Diesel engines are very strong. Because a diesel engine must be built heavier to withstand the pressure within the engine, it can be expected to run many hours longer than its gasoline counterparts. Diesel engines have stronger crankshaft, forged connecting-rods to withstand big torque. Diesel engines have a lot of torque at low engine revolutions. This is one of the main characteristic of diesel engine. In contrast, gasoline naturally aspirated engines do not create big amount of torque, but need to rev a bit higher. So the gasoline engines have to be lighter.

The exhaust from a diesel engine is less polluted, than exhaust from gasoline engines. Exhaust contains low levels of toxic elements harmful to people, although diesel gasses are more visible at times. What you see in diesel smoke are heavy particulates, carbon and soot. These can be easily eliminated with catalytic converters, diesel particulate filters (DPF).

## **Diesel engine disadvantages**

The main disadvantages of diesel engine are:

Diesel engine is more expensive

More complex design

Noise and vibration

Harder to start at cold temperatures

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The basic disadvantage of diesel engine is that it is expensive. It is expensive to manufacture and maintain the diesel engine. It is expensive due to ecological problems because diesel cars have to use catalytic converters, diesel particulate filters to meet various international agreements. The price of diesel engine comes from use of tougher materials, because the engine has to withstand the high pressure within the engine. Also diesel engines are more complex. Injection system has a lot of elements, if it uses forced induction; it makes the engine more complex too. Also these things make the price tag bigger.

Another negative side of diesel engines are, that they have much higher internal mechanical friction because of the need to seal the cylinder against high pressures. The high compression ratio and combustion process also lead to higher engine weight relative to a similar displacement gasoline engine, as well as reduced specific output and increased noise and vibration.

Noise and vibration till the latest times could not be separated from the words “ Diesel engine”. Attempts to neutralize them are in wrapping up the engine compartment by acoustic insulation, balancing the engine moments and calibrating the control units.

There are some problems with diesel fuel too. There are mainly two types of diesel fuel – summer and winter. They differ in the temperature of solidification. When the fuel freezes the fuel pump is unable to flush it and you cannot start the car. You can overcome this problem by warming up the fuel piping (also fuel tank for trucks). Unlikely the diesel fuel, the petrol is

non-freezing. Nowadays starting at cold temperatures is simpler, because of use of glow plugs.

Glow plugs warm the combustion chamber, so that the atomized fuel would ignite better at cold temperatures. Also new technologies, like electronically controlled injection, help to lower the noise and vibrations.

## **Improving the diesel engine**

### **New age diesel technologies**

The latest designs of light-duty diesel engines marketed in Europe provide significant improvements in virtually all of the characteristics of interest.

Most of the development in diesel engines is centered in Europe. First direct injected and turbocharged engine was released by VW group, first common-rail injected diesel engine was released by Fiat concern.

Until 1991, most diesel powered passenger cars and light trucks were all of the indirect injection type (IDI), where fuel is sprayed into a prechamber, partially mixed and combusted with air before mixing and further combustion takes place in main combustion chamber. The prechamber design results in smoother combustion with less noise and lower NO<sub>x</sub> emissions. However, heat transfer from the prechamber and pressure losses from the partially combusted gases as they flow through the small passages connecting the prechamber to the main combustion chamber result in reduced efficiency. In fact, the peak efficiency of an IDI diesel is comparable to or only slightly better than that of a modern spark ignition engine.

Picture 1. Indirect injection.

## **Direct Injection**

Direct injection (DI) systems avoid the heat and flow losses from the prechamber by injecting the fuel directly into the combustion chamber. The fuel injection system must be quite sophisticated, as it must be capable of injecting very little fuel during the ignition delay period, while providing highly atomized fuel and intensive mixing during the diffusion burning phase of combustion. Advancements in fuel injection technology and diesel combustion chamber design led to introduction of passenger car DI diesels by Volkswagen in their Audi and VW model lines in the early 1990s and by most other European manufacturers thereafter. Advanced fuel injection systems have been classified as key to the future of diesel in both light-duty and heavy-duty vehicles. These systems will be instrumental in developing new engines that will comply with future emission regulations. Modern fuel injection systems are one of the main reasons the diesel vehicle market has grown so rapidly in Europe with two predominant types: high-pressure, electronically-controlled unit injectors and the common rail system.

Picture 2. Direct injection.

In 1986 Fiat released a first passenger car in the world to have direct injection diesel engine. In 1997 Fiat concern released first diesel car in the world with common – rail injection. Introduction of common-rail injection into diesel world made a real revolution. It changed everything: technology lowered emissions, noise, vibrations and because of higher injection pressure fuel was able to burn better, thus increasing power.

The way in which fuel is injected into the cylinders of diesel vehicles determines their torque, fuel consumption, emissions and noise level. Two factors are the key: the fuel pressure as it enters the cylinder, and the shape and number of the injections.

A common rail injection system separates these two functions (generating pressure and injecting) by first storing fuel under high pressure in a central accumulator rail and then delivering it to the individual electronically-controlled injection valves (injectors). This ensures that incredibly high injection pressures (in some cases over 25, 000 pounds per square inch) are available at all times. High fuel pressure produces a fine mist of fuel that burns better and cleaner in the combustion chamber. Not only that, but for each combustion cycle, the common rail allows up to five injections per cycle. The driver benefits as lower fuel consumption (improved mileage), better engine performance and less noise compared with older diesels.

Picture 3. Common-rail injection.

## **Forced induction**

Turbochargers are an integral part of the advanced clean diesel system. They increase the efficiency and performance of a diesel engine and extract more power out of a given engine compared to a non-turbocharged engine.

The turbocharger consists of a set of two connected fans (or turbines) that recycle the energy from wasted exhaust gases. In gasoline engines, it takes 9, 000 gallons of air to burn 1 gallon of fuel. For diesels, it takes 20, 000 gallons. Satisfying this appetite for air is the turbocharger's job. The turbo, along with common rail fuel injection and direct injection, gives the diesel its <https://assignbuster.com/the-advantages-of-the-diesel-engine-engineering-essay/>



phenomenal efficiency by extracting more power from the same size engine. The power output of any engine is determined in large part by how much air and fuel can be packed into its cylinders: the more air and fuel, the greater the power. All internal combustion engines are basically air pumps. Fuel is combined with air, then it is ignited, and, in turn, this powers the engine. Air is pulled into the engine when the piston moves down in the cylinder and creates a vacuum. In other words, the weight of the atmosphere “ pushes” air into the cylinder. As air and fuel must combine in very precise ratios, and fuel is pumped into cylinders at high pressures, the limiting factor for power output is how much air the engine can get. Enter the turbocharger. In addition to the air provided by the weight of the earth’s atmosphere (at sea level, this pressure is 14. 7 pounds per square-inch), turbochargers blow additional air (between 5-20 lbs. per square inch in additional atmospheric pressure) into the cylinder, thereby increasing power and improving efficiency. Drivers experience this firsthand when they drive through the mountains or high elevations. Fewer atmospheres equal less power. Turbochargers, in effect, create their own atmosphere.

Turbochargers contribute to the advanced clean diesel system of lower emissions by increasing the efficiency of the combustion process and burning fuel more efficiently (especially under highly variable operating conditions). For this reason, virtually all heavy-duty trucks use turbo diesels. Turbo charging is the precondition for downsizing too: reducing the piston displacement volume while retaining the same engine performance. This will result in engines with lower fuel consumption and correspondingly reduced CO2 output.

Picture 4. Turbocharging.

## **Start/Stop systems**

The operating principle of the start/stop system is as simple as it is efficient: when the vehicle comes to a stop, the engine is automatically switched off. To drive off again, all you need to do is to activate the clutch or, in the case of vehicles with automatic transmission, take your foot off the brake pedal to restart the engine.

The relatively low extra cost for acquiring such a system is more than outweighed by its enormous savings potential: in the ECE15 measuring cycle, the urban section of the New European Driving Cycle (NEDC), reductions in fuel consumption and emissions of around 8% were measured. This cycle comprises a trip of 7 km with 12 stops of 15 seconds each. In actual urban traffic, stopping times can be considerably longer and savings – both in terms of fuel consumption and CO<sub>2</sub> output – can be as much as 15%.

Picture 5. Start/Stop system.

## **Answers to the diesel engine problems**

### **Low Ambient Temperatures**

As noted, short trips in combination with low ambient temperatures is one of the main causes of gasoline vehicle shortfall. Diesel engine require much less enrichment during cold start, and the typical level of excess fuel consumption at a 0°C cold start is only about 35 to 40% of excess fuel used in a gasoline engine. As a result of this reduced enrichment, many of the “

fast warm-up” technologies and electrically driven water pumps have only a minor effect on actual in-use diesel fuel economy.

Another diesel problem at low temperatures is ignition. Unlike gasoline engines in which spark plugs ignite a premixed air-fuel mixture in the combustion chamber, diesel engines work according to the so-called self-ignition process. With this process, intake air is compressed and close to top dead center diesel fuel is injected into the combustion chamber. The injected fuel mixes with the compressed air, evaporates and ignites almost simultaneously because the intake air heats up during compression and diesel fuel has a relatively low ignition temperature. No external ignition device like a spark plug is needed. However, with a cold diesel engine, the compression temperature might not be high enough to ensure proper ignition of the injected diesel fuel, causing inconvenience to the driver and increased exhaust emissions. The glow plug - an electrical heating device - helps to solve this problem.

A glow plug typically comprises a heating coil in a metal tube closed at one end and filled with electrically insulating ceramic powder. The closed end of the metal tube with the heating coil protrudes through a hole in the cylinder head into the combustion chamber. When the glow plug is electrically energized, its heated portion reaches a surface temperature of more than 1000°C within a few seconds. The air-fuel spray generated by the injection ignites close to the glow plug and initiates combustion.

Advanced glow control modules like BERU’s Instant Start System (ISS) can be integrated into the engine management system to provide gasoline-like turn-

key starting performance and additional glow functions for highly sophisticated emission reduction strategies.

Driven by ever stricter emission standards, it will become essential to obtain a better understanding of combustion processes inside the cylinder. Glow plugs offer mechanical access to the combustion chamber. Engineering efforts have been expended to utilize the glow plug for advanced sensor functions. Federal-Mogul and Siemens VDO Automotive have announced that they will jointly develop a combustion sensor that is integrated into the glow plug. BERU has developed an advanced piezo-resistive Pressure Sensor Glow Plug (PSG). This combines an electromechanical glow plug with sophisticated sensor functions and electronics. Both sensor concepts aim to monitor combustion pressure directly in the cylinder.

## **Emissions**

The biggest problem of diesel engine is solid particles, carbon and soot. In order to minimize the amount of unburned fuel, modern diesels use high-pressure fuel injection for better fuel atomization and turbochargers to more aggressively mix and force the air-fuel mixture into the combustion chamber. The result is a reduction in the formation of particulates, although some particulate matter is still produced. Barring significant developments in diesel combustion technology, if the mandate is to reduce particulate matter, particulate filters are a proven technology for PM reduction on both light-duty and heavy-duty diesels. Particulate filter technology has been around for years. It has been proven over and over to be able to reduce PM by 95 percent or more. However, the key to the successful application of

particulate filters on diesel engines was the ability to reliably regenerate the <https://assignbuster.com/the-advantages-of-the-diesel-engine-engineering-essay/>

filter, or in other words, burn the PM that the particulate filter “traps” or collects.

To understand how a filter regenerates, one must understand how soot or PM burns. Traditionally, combustion of soot is done in an oxygen atmosphere (air). In air, soot will burn at about 450° to 500° Centigrade (840° to 930° F). However, this is not a typical operating temperature for diesel engine exhaust. As a result, in order to burn soot in air, an active system, one that increase the temperature of the exhaust using some external heat source, is required. But if an active system is not carefully controlled, it can often experience an “uncontrolled burn” where the temperature increases to 600° C (1112° F) or more. This will damage the filter element and also pose some potential risk to the vehicle.

An alternate method of burning soot was identified and patented by Johnson Matthey in the 1980's. Johnson Matthey discovered that soot will burn at about 250° C (482° F) in the presence of nitrogen dioxide (NO<sub>2</sub>). Typical diesel engine exhaust contains about 5 - 10 percent NO<sub>2</sub>, so if this discovery were to have practical application, Johnson Matthey needed to develop a technology that would increase the amount of NO<sub>2</sub> in the exhaust enough to allow for this low temperature combustion to occur. The technology that Johnson Matthey developed was the CRT particulate filter.

**Particulate Traps**The CRT particulate filter is a passive filter using only the heat in the exhaust to combust the soot. It is a dual brick system containing a highly loaded platinum (Pt) catalyst upstream of a filter element. The Pt catalyst serves two functions: first to convert a portion of the nitrous oxide

(NO) in the exhaust to NO<sub>2</sub>, which allows the soot to be burned at this much lower temperature; and secondly to burn or reduce both carbon monoxide (CO) and hydrocarbons (HC) by over 90 percent. However, this same Pt catalyst will make significant sulfate if used with 500 ppm S fuel. So a requirement for the use of the CRT filter is ultra low sulfur diesel fuel (ULSD) containing no more than 50 ppm Sulfur. And for very low PM levels and reliable operation, 15 ppm S fuel is required.

The requirements for the CRT filter technology to reliably operate are simple.

They are:

1. Use of ULSD
2. An exhaust temperature of 250° C for 40 percent of the operating cycle
3. A NO<sub>x</sub>/PM ratio of 20 or more for the proper amount of NO<sub>2</sub> for combustion

When these conditions are met, the CRT filter will operate reliably and will reduce PM, CO and HC by more than 90 percent for many years and hundreds of thousands of miles. In fact there are over 70, 000 CRT filters in operation on HDD vehicles around the world. Some of these filter systems have over 1, 000, 000 miles of reliable service reducing diesel emissions every day.

And technology is not standing still. The next generation CRT filter, recently commercialized and trademarked the CCRT filter, combines a Pt pre-catalyst with a Pt coated filter and is included within the scope of the CRT patent. The

CCRT filter requires a reduced exhaust temperature of 220° C (428° F) for <https://assignbuster.com/the-advantages-of-the-diesel-engine-engineering-essay/>

proper operation. Field testing has demonstrated that the CCRT regenerates more quickly than the CRT filter and it still reduces PM, CO and HC by 90 percent or more.

Other passive filter technologies include the catalyzed soot filter (CSF) with a Pt catalyst on the filter element itself as well as a Pt additive in combination with a bare or lightly catalyzed filter. Both have their proponents and both have their place in the market.

Another type exhaust gas cleaning solution is Selective Catalytic Reduction (SCR) System. Selective Catalytic Reduction is a technology that injects urea - a liquid-reductant agent - through a catalyst into the exhaust stream of a diesel engine. The urea sets off a chemical reaction that converts nitrogen oxides into nitrogen and water, which is then expelled through the vehicle tailpipe. While urea is the primary operating fluid presently used in SCR systems, alternatives to the urea agent are currently being explored. One option involves the use of diesel fuel to transform NO<sub>x</sub> into harmless gases.

SCR technology is one of the most cost-effective and fuel-efficient technologies available to help reduce emissions. SCR can reduce NO<sub>x</sub> emissions up to 90 percent while simultaneously reducing HC and CO emissions by 50-90 percent, and PM emissions by 30-50 percent. SCR systems can also be combined with a diesel particulate filter to achieve even greater emission reductions for PM. SCR technology may play a key role in achieving emissions reductions that allow light-duty diesel vehicles to meet the new, lower EPA emissions regulations to be phased in through 2009 and potentially expand the diesel vehicle sales market to all 50 states.

Picture 6. Selective Catalytic Reduction system.

## **New Engine Performance**

All manufacturers have introduced a range of new diesel engines featuring common-rail technology. Even VW group left the unit injector technology for the common-rail, because common-rail enables better controlling and higher pressure of fuel to keep the engines under strict emission rules.

Specifications for a small selection of gasoline and equivalent diesel engine powered vehicles are shown in the table below, for six-cylinder and four-cylinder diesels. The fuel economy benefit of the DI diesel over an “ equal performance” gasoline engine is closely dependent in the engine model and axle ratios employed for the gasoline versus the diesel car. The older IDI diesel typically showed much smaller benefit on high speed cycles, whereas the newer DI diesels show only a modest reduction in benefits on the higher speed cycle relative to the very low speed.

Table 1. Higher class automobile comparison.

Model

BMW 3-series Coupe

Jaguar XF

335d

335i

3. 0 TDV6



3, 0 V6

Weight (kg)

1570

1525

1820

1679

HP

286

306

240

238

Torque(Nm)

80 Nm

407 Nm

500 Nm

293 Nm

Acceleration(0-100)

5, 9 s

5, 5 s

7. 1 s

8, 3 s

Mixed cycle(l/100km)

6, 6

8, 4

6, 8

10, 5

CO2 (g/km)

174

196

179

249

In the table above, there is a comparison of luxury performance cars with equivalent diesel and gasoline engines. BMW 3-series Coupe shows that nowadays you can combine diesel and sportiness. BMW with its 3. 0l inline-6 diesel engine creates 286hp and 580Nm, which can push the car to the

100km/h point in just under 6 seconds. Equivalent engine to this diesel is 3.0l inline-6 twin-turbocharged gasoline engine, which makes 306hp and 407Nm.

On the other side we have Jaguar XF with two 3.0l V6 diesel and gasoline engines. Because Jaguar's 3.0l V6 gasoline engine is naturally aspirated, it does not come up with the performance and economy, that 3.0l V6 turbocharged diesel engine gives. Furthermore diesel created 70 g/km less of CO<sub>2</sub>.

Table 2. Compact class automobile comparison.

Model

VW Golf

Renault Clio

1.6 TDI

1.2 TSI

1.5 dCi

1.2 I

Weight (kg)

1314

1233

1165

1090

HP

105

105

68

75

Torque(Nm)

250 Nm

175 Nm

160 Nm

105 Nm

Acceleration(0-100)

11, 3 s

10, 6 s

—

—

Mixed cycle(l/100km)

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4, 5

5, 7

4, 6

5, 9

CO2 (g/km)

119

134

123

139

In another table I am giving the comparison of some popular compact family hatchbacks. VW Golf has both diesel and gasoline engines turbocharged and direct injected. So they both show good results on the economy and performance sides. On the other side I am showing you Renault Clio. Renault Clio uses a bit outdated engines. As VW introduced their 1.6 TDI and 1.2 TDI in the fall of 2010, Renault engines are used since 2005. You can see from the table, that very similar engines are showing very different numbers. 1.6 TDI is showing over 60% more of horsepower and torque than 1.5l Renault diesel. Economy is not on the Renault side too. VW Golf is a bit bigger than Renault Clio, but it manages to get better mileage and better performance due to more powerful engine. I can say, that technology done a good job to making cars more powerful and economical at the same time. All naturally-

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aspirated gasoline engines are no match for the modern diesel engines, because they show neither performance, nor economy. Only turbocharged gasoline engines can keep up diesel as we see from BMW and VW examples.

## **Conslusions**

When doing this work I made these conclusions:

Diesel powered cars have its own specific advantages and disadvantages over petrol powered cars like relative fuel economy and efficiency, engine durability, more lugging power. The disadvantages are complex design, the expensiveness, because of complex design, noise and vibrations.

All disadvantages can be easily removed using latest technologies like direct injection, glow plugs, forced injection, catalytic converters and diesel particulate filters (DPF).

The direct injection is the main in improving diesel technology, because it allows for fuel to burn efficiently, thus improving mileage, emissions, noise, vibrations and mainly increasing power.

In last twenty years diesel technology stepped huge steps to make diesel powered cars more powerful, more fuel efficient. Comparing last decade and latest diesel powered cars I can say, that turbocharged and direct injected diesel cars have overstepped petrol powered cars. Only turbocharged and direct injected petrol cars can show similar performance and good fuel economy of diesel powered cars.