

University of Wales Trinity Saint David

Wales Institute of Science & Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

**Turbocharging small displacement engines for fuel
efficiency and performance.**

Academic Skills (ACHA4005)

Efren Sabastian

2400744

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1. Introduction

Throughout the years, environmental concerns, consumer expectations and regulatory pressures have forced automotive companies to look towards fuel efficiency for economic vehicles. To address the issues caused, innovative engineering strategies are being turned to by automotive manufacturers, most notably and common turbocharging and reducing the displacement size. Smaller engines will now deliver the power levels of comparable larger displacement engines, therefore balancing fuel consumption and emissions with increased engine performance.

Forcing additional air into the combustion chamber is the role of a turbocharger therefore the engine can increase power output with a smaller fuel cost. In addition to this, paired with a small displacement engine can greatly improve efficiency overall. This shift supports the automotive industry towards sustainable high-performance vehicles.

1.1 Aims

This assignment will aim to analyse the principles and operation of turbocharging in small displacement engines, focusing on how it can enhance engine fuel efficiency and performance. To explore the benefits of turbocharging downsized engines, including improvements in emissions, power and fuel. Finally, to examine Challenges associated with turbocharging downsized engines, problems include low speed pre ignition and thermal management, to investigate potential solutions.

2. Turbocharging Basics

Turbocharging is essentially a method to increase the efficiency and output of an engine by compressing the air intake. It is a forced induction system.

2.1 Turbocharger components

(Herzwan, Azri and Rizalman, 2019) The turbine side, compressor side, and bearing housing are the three primary parts of a turbocharger. The turbine wheel assembly and turbine housing are located on the turbine side. It is common practice to combine the turbine shaft and wheel into one single unit. Usually, a casting process is used to create the turbine wheel from materials that contain a lot of nickel. Cast iron, which can tolerate the high temperatures of the exhaust gases, is typically used to make the turbine housing.

The compressor wheel and the compressor cover are the two components that make up the compressor side. Because it draws in fresh air and accelerates it radially, the compressor wheel is categorised as a radial compressor. While the compressor cover is typically made of aluminium, the majority of compressor wheels are made from different aluminium alloys using casting techniques.

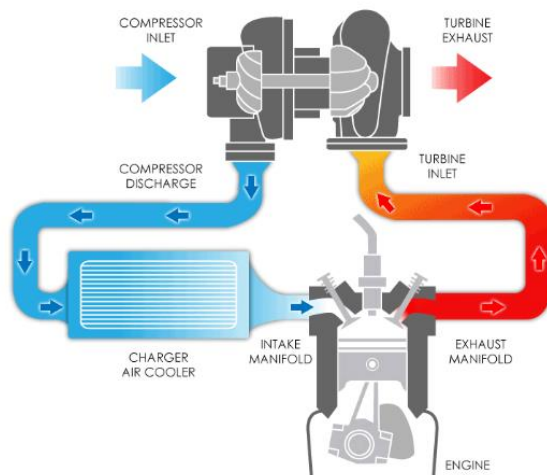


Figure 1 diagram to show how a turbocharger works (Turbo Dynamics, n.d.)

2.2 Turbocharger Operation and Efficiency

(Herzwan, Azri and Rizalman, 2019) Exhaust gases from the engine power two independent impellers positioned on a shaft inside a housing in turbochargers. These gases cause the turbine wheel to spin, which transfers motion to the compressor wheel that is connected. Before the incoming air is sent into the intake manifold, it is compressed by the compressor wheel, which can run at up to 100,000 rpm.

Many turbocharging systems include a wastegate or pressure-relief valve to stop excessive pressure from building up. With most systems operating between 8 and 12 psi, the intake manifold pressure in turbocharged engines typically remains below 15 psi. The compressed air heats up, lowering its density and oxygen content. Combustion efficiency may suffer as a result of this decrease in air density. An intercooler, which functions similarly to a radiator, can be positioned in the airstream to cool the intake air and restore a large portion of the efficiency that was lost as a result of heating.

2.3 Turbo Lag

(Salve et al., 2018) Turbo lag is the amount of time it takes for the exhaust gas to reach the turbine. The gases provide the force to rotate the turbine, which therefore allows more air to be sucked in after each exhaust cycle. Turbo lag is a major disadvantage as it reduces how quickly the engine responds to throttle inputs. When the Turbo does start up a sudden increase in power and torque can be noticed instantly.

3. Advantages of Turbocharged Downsized Engines

3.1 Fuel Efficiency of Turbocharged Downsized Engines

(ICCT international council of clean transportation, 2016) Turbocharging downsized engines can bring many benefits, one of the main reasons being fuel efficiency. Downsized turbocharged engines at lower loads and everyday driving consume much less fuel than higher displacement engines, since smaller engines displace less air they would consume less fuel, when paired with a turbocharger which can provide power on demand instead of running at high capacity. Studies have shown that fuel efficiency is greatest in city and motorway driving. A great example is (Ford, n.d.) Fords EcoBoost engines, which have proven their fuel efficiency. Ford and many other manufacturers make use of direct injection which is a precise pressurised amount of fuel injected into the combustion chamber, for Fords engines this means only a bare amount of fuel is needed. (Ford, 2012) The 1.0 EcoBoost that ford uses in the Ford focus have combined mpg figures of around 55 to 58mpg proving that turbocharging smaller displacement engines can bring an increase to fuel efficiency.

3.2 Increased Power and Decreased Emissions

(Ford, n.d.) Ford has equipped every EcoBoost engine with a turbocharger that can create enough power to far exceed its engine size. Fords 1.0 EcoBoost can provide figures up to 140bhp. This is similar to that of their older cars which use bigger displacement sizes and are considerably less fuel efficient. Turbos can create a wide spread of torque making sure these engines can perform.

Using less fuel leads to a serious decrease in CO₂ emissions, according to ford for their 1.0 EcoBoost produces emissions as low as 99g/km. This can help automotive manufactures stick to laws on emissions without sacrificing engine performance.

4. Challenges and Solutions.

4.1 Low Speed Pre-Ignition

(Deva et al., 2022) abnormal combustion events that occur in downsized turbocharged engines are known as low speed pre ignition (LSPI). This event is particularly common in situations like rapid acceleration at low revolutions. LSPI occurs due to high pressure and temperature conditions in the combustion chamber, the air fuel mixture can pre ignite. This can lead to a serious form of knocking called “super knock” which results in serious engine damage, damaged pistons, bent connecting rods and broken piston rings, particularly when the engine is operating close to knock condition due to high compressions ratios or boost pressure. (Namar et al., 2021) Causes of LSPI can be from several factors, contaminants such as deposits on chamber walls from combustion, lubricant oil can act as a fuel additive which can influence LSPI and ignition timing. Automotive Manufactures have approached several strategies to mitigate against LSPI such as, split injection and miller cycles which can enhance knock resistance.

4.2 Thermal Management

(Mueller et al., 2011) Turbocharged Downsized engines must handle higher thermal loads because of increased boost pressure. This heat can reduce lifespan of components such as cylinder liners, pistons, and bearings. Heat is mainly generated through combustions and friction of moving parts, so manufacturers have put in place some measures to make sure the engines work as efficiently as possible. Thermal management systems can help reduce engine warm up time and increase fuel efficiency, systems like heat exchangers and a controlled coolant pump. Some Specific thermal management measures such as heat storage, can decrease particulate emissions providing an environmental benefit.

5. Conclusion

In conclusion, turbocharged downsized engines have become strategies in the automotive world because they achieve improved fuel efficiency, reduced emissions and increased performance. Turbocharging forces additional air into the combustion chamber, turbochargers allow smaller less powerful engines to generate the power of larger engines while consuming less fuel overall. The benefits of turbocharging downsized engines are evident, particularly in fuel efficiency, as seen in Fords EcoBoost Engines, which combine low fuel consumption and higher engine performance. CO₂ emissions can be significantly reduced due to turbocharging, aligning with global efforts to meet environmental regulations.

However, challenges still remain, low speed pre ignition and thermal management being the biggest problems. These issues, if not addressed, could impact engine longevity and performance severely. Solutions such as split injection and improved thermal management systems are being investigated to mitigate these risks.

Overall turbocharging downsized engines represents a promising solution for automotive manufacturers to balance demands of better fuel efficiency, increased performance and lower emissions in modern vehicles.

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