PERPUSTAKAAN UMP
0000076101

ANALYSIS ON THE BEHAVIOUR OF THE TRANSIENT RESPONSE IN TURBOCHARGER DIESEL ENGINE BY USING SIMULATION

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Proposal submitted in fulfillment of the requirements
for the awards of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

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JUNE 2012

ABSTRACT

The turbocharger is a centrifugal compressor powered by a turbine that is driven by an engine's exhaust gases. The engine performance in a turbocharged depends on engine speed, turbocharger speed, air fuel ratio, air flow rate, boost pressure, fuel pump rack position, exhaust temperature, initial applied load, combustion efficiency and so on. The objective of this project is to study the engine performance under transient response in a turbocharged diesel engine. The effect of the transient response on turbocharger diesel engine by simulation using Fortran language. The estimated accuracy of the simulation instrumentation is ±5%. The variable control are the initial applied load from 2, 4, 6, and 8 bar, the engine speed from 500, 1000, 1500 and 2000 rpm and the dynamometer delay time from 500, 1000, 1500 and 2000 ms. The result by a simulation shown in Chapter 4 from Figure 4.1 until 4.10. So for the conclusion this programmed can be use to get predict the engine performance in a turbocharger diesel engine.

ABSTRAK

Pengecas turbo adalah kuasa pemampat gempur yang diputarkan oleh turbin dimana ia didorong oleh gas ekzos enjin. Prestasi enjin dalam pengecas turbo bergantung kepada kelajuan enjin, kelajuan pengecas turbo, nisbah bahan api udara, kadar aliran udara, tekanan rangsangan, kedudukan rak pam bahan api, suhu ekzos, beban permulaan diletak, kecekapan pembakaran dan sebagainya. Objektif projek ini adalah untuk mengkaji prestasi enjin di bawah transient response dalam enjin diesel turbo. Kesan transient response pada enjin diesel turbocharger dikaji melalui simulasi menggunakan Fortran. Ketepatan anggaran simulasi adalah diantara ± 5%. Kawalan pembolehubah adalah beban awal yang diletak dari 2, 4, 6, dan 8 bar, kelajuan enjin dari 500, 1000, 1500 dan 2000 rpm dan masa kelewatan dinamometer dari 500, 1000, 1500 dan 2000 ms. Keputusan simulasi ditunjukkan dalam Bab 4 dari Rajah 4.1 hingga 4,10. Kesimpulan simulasi ini dapat digunakan untuk menganggar prestasi enjin dalam enjin diesel.

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LIST OF SYMBOLS

A_{ev}	:	Exhaust valve area
A_{iv}	:	Exhaust inlet valve
A_v	:	Valve area
α	:	Crank angle
$\dot{\alpha}$	:	Rate of angular acceleration [rad/s^2]
α_f	:	Crank angle during the firing interval [deg]
α_{ov}	:	Crank angle during the valve overlap period [deg]
C_P	:	Specific heat at constant pressure [kJ/kg/K]
ε_t	:	Air fuel ratio
$F_E\,Cd_e$	:	The effective area of the exhaust valve
$F_i\,Cd_i$	:	The effective area of the air valve
ΔH_E	:	Change of enthalpy across the engine [kJ/kg]
I	:	Moment inertia [kg m^2]
I_E	:	Engine moment of inertia [kgf.m.s^2]
I_d	:	Load moment of inertia [kgf.m.s2]
L	:	Net torque on a shaft [Nm]
L_b	:	Engine output torque [MEP]
$L\alpha$	:	Applied load torque [MEP]
L_{bf}	:	Bearing friction torque [kgf m]
m	:	Mass
m_f	:	Mass of fuel injected into each cylinder [kg]

m_{sc}	:	Scavenge mass flow [kg]
$\dot{m}_{sc}$	:	Mass flow rate through the engine [kg/s]
$\dot{m}_T$	:	Mass flow rate through the turbine [kg/s]
N	:	Engine actual speed [rpm]
n_c	:	Number of cylinder
N_T	:	Turbocharger speed [rpm]
η_c	:	Compressor efficiency
η_d	:	Diagram factor
η_{sc}	:	Scavenge efficiency
η_{Ta}	:	Apparent turbine efficiency
η_{TA}	:	Relative turbine apparent efficiency
η_{th}	:	Thermal efficiency of diesel engine
η_v	:	Volumetric efficiency
P	:	Pressure [bar]
$\bar{P}_i$	:	Indicated mean effective pressure [bar]
P_{ov}	:	Exhaust manifold pressure during the valve overlap period [bar]
q	:	Fuel pump rack position [mm]
$\dot{Q}_{loss}$	:	Cooling heat loss [kJ/s]
R	:	Gas constant [kcal/kg/K]
r	:	Compression ratio
t	:	Time [sec]
T	:	Temperature rise [K]
ΔT_E	:	Dynamic temperature rise [K]

ΔT_F	:	Final steady-state temperature rise [K]
ΔT_I	:	Initial steady-state temperature rise [K]
X	:	Ratio of specific heat
λ	:	Scavenge ratio

LIST OF ABBREVIATIONS

1	Upstream of compressor
2	Downstream of compressor
3	Downstream of inlet manifold
4	Upstream of exhaust manifold
5	Upstream of turbine
6	Downstream of turbine
a	Air
c	Compressor
d	Dynamometer
D	Diffusion
DBMEP	bmep developed by engine-load bmep; essentially the error between nominal and actual load
E	Engine
f	Fuel
inj	At fuel injection state
P	Premixed
T	Turbine

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed about the overall project background such as problem statement, objectives and scopes of the project. All the information is important to start this project. This project is focused the effect of the transient response on a turbocharger diesel engine by simulation. The introduction of internal combustion engine, turbocharger and diesel engines are described below.

1.1.1 Internal Combustion Engine

An engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. Engines normally convert thermal energy into mechanical work and, therefore, there are called heat engines. When fuel burns in the presence of atmospheric air, a tremendous amount of heat energy is released. The products of combustion attain a very high temperature. A heat engine converts the released heat energy into useful work with the help of a working fluid.

The usual aim of internal combustion engine is to achieve a high work output with a high efficiency. The two main types of internal combustion engine are spark ignition (SI) engines and compression ignition (CI) engines. In this final year project will be study about CI engine.

1.1.2 Turbocharger

The turbocharger is a centrifugal compressor powered by a turbine that is driven by an engine's exhaust gas. Its benefit lies with the compressor increasing the mass of air entering the engine, thereby resulting in greater performance. A diesel engine is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel, which is injected into the combustion chamber. Diesel engines are manufactured in two stroke and four stroke versions. In order to improve diesel engine performance, variable geometry turbine turbochargers can be used.

The concept of turbocharged, supplying pressure air to an engine and dates back to the beginning of the century. The mass flow rate of air increase while the air pressure at inlet to the engine. There can be a corresponding increase in the fuel flow rate. This leads to an increase in power output, and usually an improvement in efficiency since mechanical losses in the engine are not solely dependent on power output. The principle of turbocharger shown in Figure 1.1.

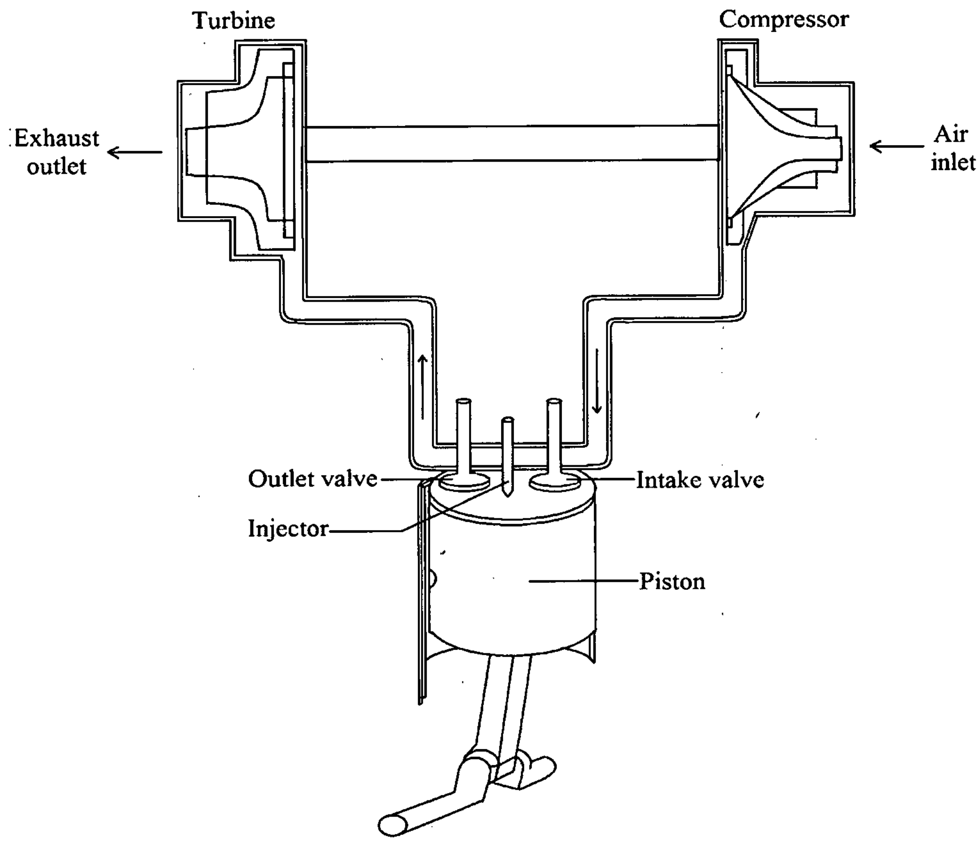

Figure 1.1: Principles of turbocharger

1.1.3 Diesel Engine

Diesels are workhorse engines. That is why it used to power heavy-duty trucks, buses, tractors and trains, not to mention large ships, bulldozers, cranes, and other construction equipment. In the past, diesels fitted the stereotype of muscle-bound behemoths. There were dirty and sluggish, smelly and loud. That image does not apply to today's diesel engines, however, and tomorrow's diesels will show even greater improvements. They will be even more fuel efficient, more flexible in the fuels they can use, and also much cleaner in emission.

A diesel is an internal combustion engine that converts chemical energy in fuel to mechanical energy that moves the pistons up and down inside enclosed spaces called cylinders. The pistons are connected to the engine's crankshaft, which changes their linear motion into the rotary motion needed to propel the vehicle's wheel.

1.2 PROBLEM STATEMENT

The engine performance depends on many factors. There is engine speed, turbocharger speed, air fuel ratio, air flow rate, boost pressure, fuel pump rack position, exhaust temperature, initial applied load, combustion efficiency and so on. All these factors affect the engine performance. The poor performance in an engine can be solved with the turbocharger. In this thesis, the investigation of turbocharger in diesel engine performance to solve the poor performance in engine cause by turbo lag during the transient response.

1.3 PROJECT OBJECTIVES

The main objectives this work is to study the effect of transient response turbocharged diesel engine by a simulation respect to engine speed, turbocharger speed, boost pressure, air flow, air-fuel ratio, exhaust temperature, rack position, initial applied load, DBMEP and combustion efficiency.

1.4 THESIS ORGANIZATION

This thesis was included from chapter 1 to chapter 5. The chapter 1 is about the introduction of this final year project followed by chapter 2 is the literature review about performance turbocharged in diesel engines. In the chapter 3 is about the methodology that the method uses and the progress of the project. In chapter 4, it is about the result and discussion. Since the last chapter is about the conclusion about this thesis. This thesis is about the effect of the transient response of turbocharger engine by simulation. In order to achieve the objective none above successfully, this work in guide by a several scope as shown in Figure 1.1.

The flow chart of the project shows for the overall steps that are taken in completing the project. The project starts with determining and understand the title of the project. The next step is problem statement. Then determine the project scope and objectives.

The project is continued by searching the literature and gathering all the information needed for this project. The source of information includes the information from supervisors, books, journals and others. The data that are analyzed to gain more understand about the project.

The next step is making the coding in Fortran software to get the result. All the equation necessary put in this software and then the programming will run smoothly. After making the coding and the result already get, the analysis will continued. The analysis about this result will compare with others author simulation result. The next step is making the discussion and the conclusion. Finally the project ends with the complete result

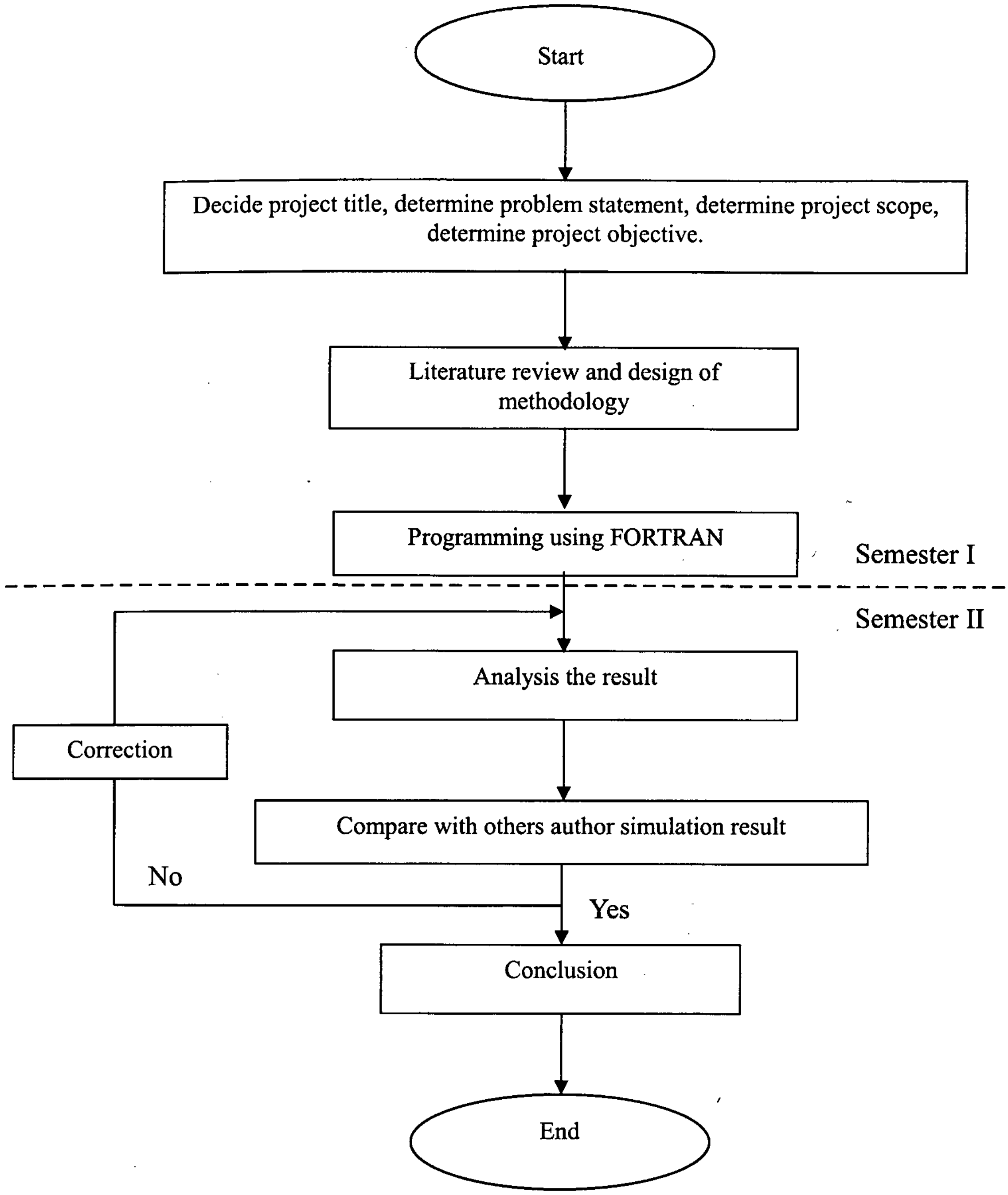

Figure 1.2: Project flow chart

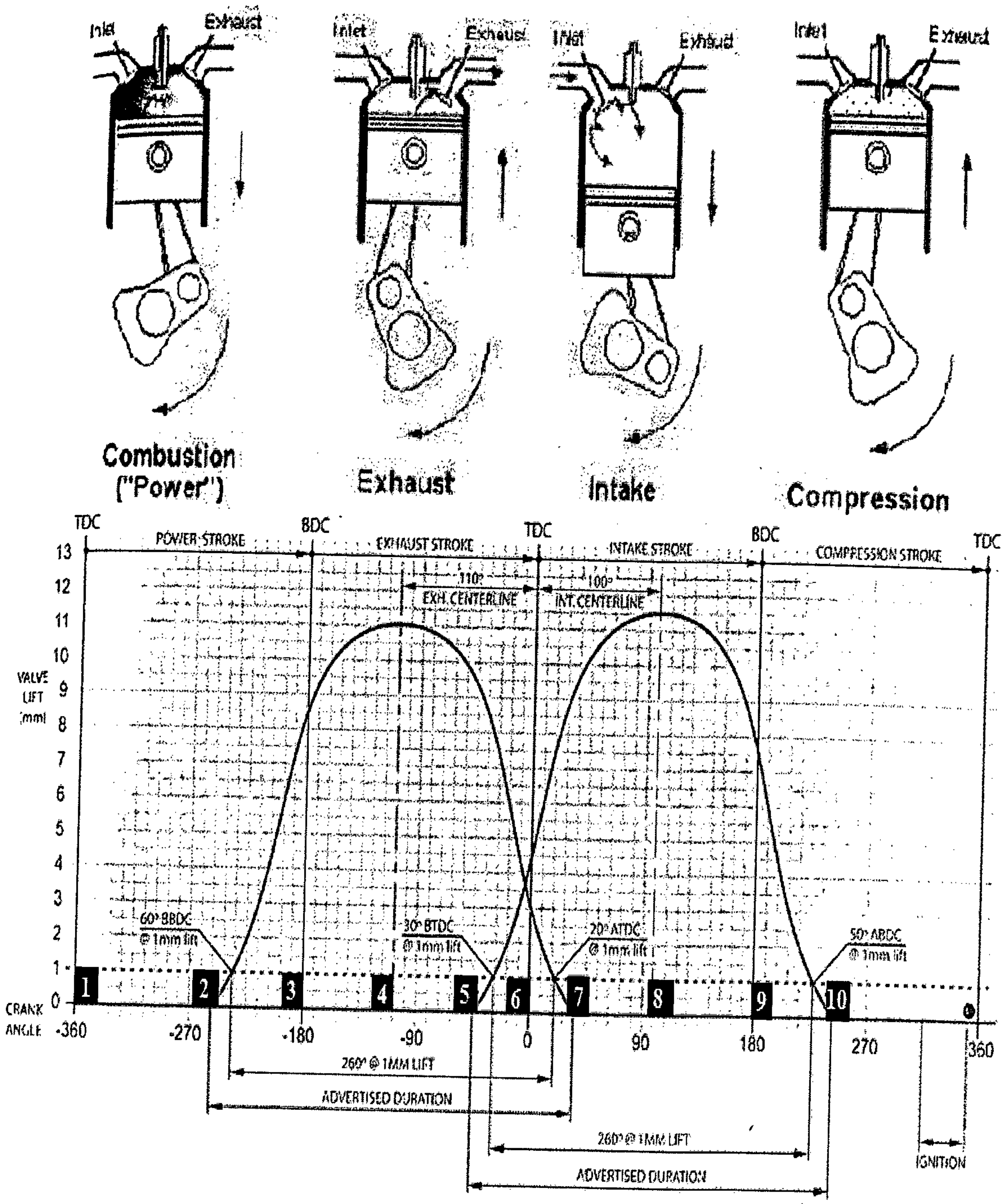

Figure 2.1: The inside a four-stroke engine.

Source: http://www.skunk2.com

At point 1 in the figure, the piston is at the top of the bore or Top Dead Centre (TDC) and both valves are closed. Ignition occurred about 20°-40° before. The piston is being pushed down by the combustion pressure.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter described about the information which related to the project such as Internal Combustion Engine, Characteristic of Diesel Engine with Turbocharged and also the software that used during completed my thesis, Fortran Software to get the result.

2.2 CHARACTERISTIC OF DIESEL ENGINE

Diesel engines are broadly used in medium and heavy duty applications because of their lower fuel consumption, higher brake thermal efficiency and lower emissions. According to Holt, D.J. 2004, stated that the diesel engine is a four-stroke, compression ignition engine in which the fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber. The generate high temperatures which are sufficient for the diesel fuel to spontaneously ignite when it is injected into the cylinder. The diesel engine thus uses heat to release the chemical energy contained within the diesel fuel and convert it into mechanical force. The four stroke cycle diagram as shown in Figure 2.1.

At point 2, by 90° after top dead center (ATDC) the cylinder pressure is already starting to decrease and the exhaust valve can begin to open safely before the piston reaches its lowest point or Bottom Dead Centre (BDC). The combustion cylinder pressure pushes the burnt fuel mixture/exhaust gases out the exhaust port.

At point 3, the piston then changes direction after it reaches BDC and begins to help push out the remaining exhaust gases. It is important for the valve to open early enough so the exhaust valve is nearly wide open when the exhaust stroke begins. This reduces the resistance, known as pumping losses, caused by the piston trying to push against the exhaust pressure. Opening the valve earlier will give the engine more time to blow down the exhaust pressure. The process

At point 4, the exhaust valve is at its maximum opening or peak lift. This is the exhaust centerline position, or rather how many degrees peak lift occurs before top dead center (BTDC). It is important that the peak exhaust lift occurs when the piston is near its maximum velocity on the exhaust stroke to reduce pumping losses.

At point 5, before the exhaust stroke is complete and the piston reaches TDC, the intake valve begins to open as the exhaust valve continues to close. The exhaust gases travelling out the exhaust port create a suction that helps to draw in the intake charge. This phenomenon is commonly referred to as "scavenging". When to open the valve is critical because it will determine how much the valve is open when the piston is at maximum velocity on the intake stroke; thus increasing volumetric efficiency (VE).

At point 6, as the piston reaches TDC, both the intake and the exhaust valves are open. The period of time between point 5 and 7 is commonly referred to as the overlap period. On low rpm engines the overlap period lasts around 20°-30°. On high rpm race engines overlap may be as long a 50° - 100°. This much overlap causes the engine to run rough, and the intake charge to go right out the exhaust ports at low speeds.

At point 7, as the piston is moving downward, the exhaust valve closes shut. The later the valve is closed may help with high rpm performance, but will result in poor low rpm operation and emissions.

At point 8, the intake valve reaches its maximum opening or peak lift. This is the intake centerline position, or rather how many degrees peak lift occurs after top dead center (ATDC). It is important for the centerline to be near the peak piston velocity on the intake stroke in order to optimize cylinder filling.

At point 9, the piston reaches BDC and begins to travel upward. Notice that the intake valve is still open. Even though the piston is pushing upwards, the inertia generated by the speed and mass of the air/fuel causes the mixture to continue to rush in and fill the cylinder. This phenomenon is called a "supercharging" effect and is the reason why some naturally aspirated engines can even fill the cylinder up to 130% of its volume.

At point 10, the intake valve closes shut before the piston reaches maximum velocity on the compression stroke. When the intake valve is closed ultimately determines the optimum operating rpm range and also the dynamic compression ratio of the engine. Closing the valve early results in better low rpm operation, but limits power output and rpm. Early valve closing also results in higher cylinder pressures and increased pumping losses during the compression stroke.

At point 11, before the piston reaches TDC the spark plug ignites the compressed charge. The higher the rpm, the earlier the ignition must begin. More efficient engines do not require as much timing advance. After the piston reaches TDC, the combustion pressure pushes down on the piston beginning the power stroke once again. Back to point 1.

2.3 TURBOCHARGED

The turbocharger is an increasingly popular method of reducing the harmful emissions of an internal combustion engine. A turbocharger utilizes energy from exhaust gases and uses it to pressurize the air at the inlet to the cylinders. This allows for the density of air in the cylinder to be greater than the density of ambient air. This allows more power to be produced for a given size of an engine. (Oliver, S., Rao, H.V. and Fieldhouse, J.D. 2007)

From James, D.H. 1981, a turbocharger consists of two chambers connected by center housing. The two chambers contain a turbine wheel and a compressor wheel connected by a shaft which passes through the center housing.

To take full advantage of the exhaust heat which provides the rotating force, a turbocharger must be positioned as close as possible to the exhaust manifold. This allows the hot exhaust to pass directly into the unit with a minimum of heat loss. As the exhaust gas enters the turbocharger, it rotates the turbine blades. The turbine wheel and compressor wheel are on the same shaft so that they turn at the same speed. Rotation of the compressor wheel draws air in through a central inlet and centrifugal force pumps it through an outlet at the edge of the housing. Pair of bearings in the center housing supports the turbine and the compressor wheel shaft, and are lubricated by engine oil.

Both the turbine and compressor wheel must operate with extremely close clearances to minimize possible leakage around their blades. Any leakage around the turbine blades causes a dissipation of the heat energy required for compressor rotation. Leakage around the compressor blades prevents the turbocharger from developing its full boost pressure.

When the engine is started and runs at low speed, both exhaust heat and pressure are low and the turbine runs at a low speed (approximately 1000 rpm). Because the compressor does not turn fast enough to develop boost pressure, air simply passes through it and the engine works like any naturally aspirated engine. As an engine runs faster or load increases, both exhaust heat and flow increases, causing the turbine and the compressor wheels to rotate faster. Since there is no brake and very little rotating resistance on the turbocharger shaft, the turbine and compressor wheels accelerate as the exhaust heat energy increase. When an engine is running at full power, the typical turbocharger rotates at speeds between 100 000 and 150 000 rpm.

An engine deceleration from full power to idle requires only a second two because of its internal friction, pumping resistant, and drive train load. The turbocharger however, has no such load on its shaft, and is already turning many times faster than the engine at top speed. As a result, it can take as much as a minute or more after the engine has returned to idle speed before the turbocharger also returned to idle. If the engine is decelerated to idle and then shut off immediately, engine lubrication stops flowing to the center housing bearings while the turbocharger is still spinning at thousands of RPM. The oil in the center housing is then subjected to extreme heat and can gradually "coke" or oxidize. The coked oil can clog passages and will reduce the life of the turbocharger.

The high rotating speeds and extremely close clearances of the turbine and compressor wheels in their housings require equally critical bearing clearances. The bearings must keep radial clearances of 0.003 to 0.006 inches (0.08 to 0.15mm). The axial clearance (end play) must be maintained at 0.001 to 0.003 inches (0.025 to 0.08mm). If properly maintained, the turbocharger also is a trouble-free device.

Late-model turbochargers all have liquid-cooled center bearings to prevent heat damage. In a liquid-cooled turbocharger, engine coolant is circulated through passages cast in the center housing to draw off the excess heat. This allows the bearings to run cooler and minimize the probability of oil coking when the engine is shut down.

A turbocharger turbine looks much like a typical centrifugal pump used for supercharging. Hot exhaust gases flow from the combustion chamber to the turbine wheel. The gases are heated and expanded as they leave the engine. It is not the speed of the force of the exhaust gases that forces the turbine wheel to turn, as is commonly thought, but the expansion of hot gases against the turbine wheel's blades. The power performance with turbocharger and without turbocharger are shown in Figure 2.2.

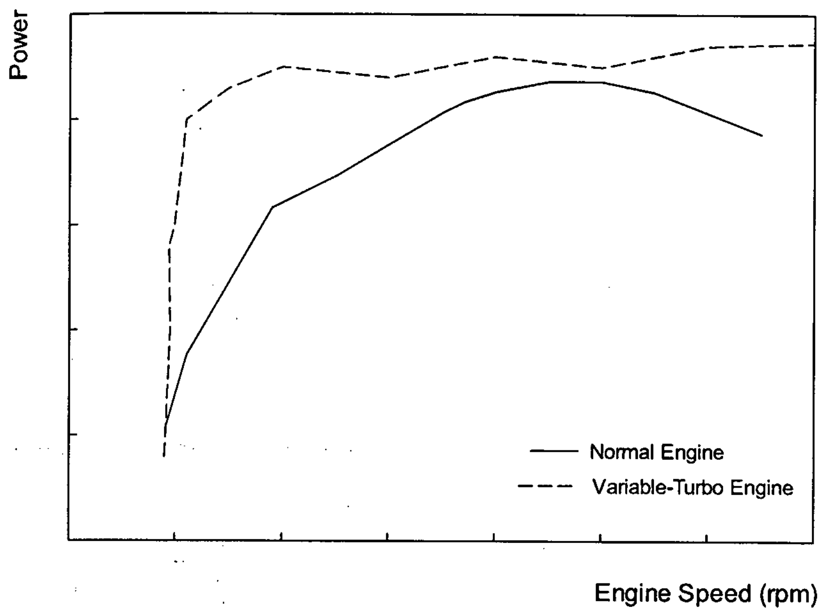

Figure 2.2: Hypothetical power curves for an engine with and without a variable turbo.

Source: http://large.stanford.edu

2.3.1 Advantages Of Turbocharged

There are several advantages in the turbocharged diesel engines over naturally aspirated engines. These advantages are considerably important from performance, energy utilization, pollution and economic points of view. Consequently, more engines are being turbocharged. The principle advantages of turbocharged are as follows:

(i) Turbocharged increase the power output of the engine. Consequently, there is an increase in power/watt and power/volume ratios which are very important for automotive applications.

(ii) Exhaust energy which would have been wasted is utilized. This improves efficiency and leads to reduced fuel consumption.

(iii) The engine cost/output ratio is reduced.

(iv) The performance of the engine at high altitudes, as the reduction in air density is reduced, is improved.