PJP/2010/FKM (13B) – S704

THE EFFECT OF GEAR RATIO ON TURBO ALTERNATOR TO PRODUCE HIGHER POWER GENERATION IN THE SPARK IGNITION ENGINE

SAFARUDIN GAZALI HERAWAN

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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SAFARUDIN GAZALI HERAWAN

DR. YUSMADY BIN MOHAMED ARIFIN

RESEARCH VOTE NO:

PJP/2010/FKM (13B) – S704

FACULTY OF MECHANICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2011

CENTRE FOR RESEARCH AND INNOVATION MANAGEMENT
PROJECT COMPLETION REPORT

A. PROJECT DETAILS

Project Leader : Safarudin Gazali Herawan

Faculty/Centre : Fakulti Kejuruteraan Mekanikal

Project Title : **Effect of Gear Ratio on Turbo-Alternator to Produce Higher Power Generation in the Spark Ignition Engine**

Project Ref. No.: **PJP/2010/FKM (13B) – S704**

Project Focus Area : **a) Green Technology** b) Emerging Technology c) System Engineering d) Human Technology Interaction

Project Duration : Starts Date **1 April 2010** Final End Date: **31 March 2011**

Budget Approved: RM **14,000.00** Amount Spent : RM **13,998.78**

Project Members : Dr. Yusmady bin Mohamed Arifin (FKM)

B. PROJECT ACHIVEMENT AND PERFORMANCE

OVERALL	0 – 50%	51 – 75%	76 – 100%
Work completion (please state # %)			100%
Financial Utilization (please state # %)			99.99%

RESEARCH OUTPUT

I. PUBLICATION (Recorded at UTeM eRepository)	UTeM Press	Index Scopus/ISI	Others
a. No. of Journal Publication (Please attach the first page of publication)		1	
b. No. of Conference Proceeding (Please attach the first page of publication)			2
c. No. of Other type of publication eg. monograph, books, chapters in book			

II. PROTOTYPE DEVELOPMENT	National	International
a. No. of Intellectual Property Rights		
b. Attended product exhibition & competition		
c. No. of Industrial Collaboration MoU/NDA/MoA)		

III. HUMAN CAPITAL DEVELOPMENT

	Number of Human Capital	On-Going		Graduated	
		Malaysian	Non-M	Malaysian	Non-M
1	PhD Student				
2	Master Student	1			
3	Undergraduate Student (PSM/SRA)	1		2	
	Total	2		2	

IV. ASSETS AND INVENTORY PURCHASED (Cost more than RM 3000 per item)

1. No assets bought more than RM 3000 per item.
2.
3.
4.
5.

DECLARATION OF PROJECT LEADER

I acknowledged UTeM in providing the fund for this research work.

I certify that the information given in this final project report is true to the best of my knowledge.

Project Leader's Signature :

Official stamp :
Name :
Designation :
Date :

ENDORSEMENT BY DEAN or DEPUTY DEAN (RESEARCH), FACULTY/CENTRE
(Please state /comment on the performance of the project)

____

____

Signature & Official Stamp   Date

Revised date : 4Mac2014

Nota:

1. Sila lengkapkan **Lampiran A : Profil Penyelidikan** (maksimum 5 mukasurat sahaja) dan dihantar bersama borang RND010. Penulisan Profil Penyelidikan mesti berasaskan kepada kertas cadangan projek berkaitan yang diluluskan.
2. Hantar dokumen ke CRIM dalam bentuk cetakan hardcopy dan softcopy MS Words.
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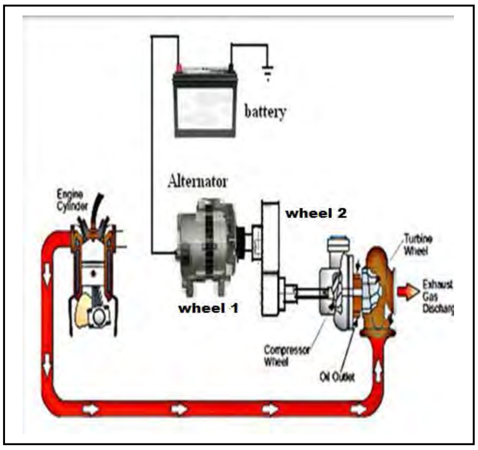
LAMPIRAN A

TEMPLATE
PROFIL PENYELIDIKAN



THE EFFECT OF GEAR RATIO ON TURBO-ALTERNATOR TO PRODUCE HIGHER POWER GENERATION IN THE SPARK IGNITION ENGINE

Safarudin Gazali Herawan
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Green Technology

ABSTRACT (120 words)

There are only 15 percent of the energy from the fuel from tank gets used to move car down the road or run useful accessories. The rest of the energy is lost to engine, idling, accessories, driveline, aerodynamic drag, rolling resistance and overcoming inertia or braking. Such as in exhaust system, the temperature at the exhaust manifold can reach around 900ºC and this heat will lose to atmosphere. So, the recovery system must be creating to solve this problem. One of the systems is “Turbo System” which uses the energy losses from the exhaust system by convert to electric energy. In this system, the energy that flow to the exhaust will rotate the turbine and the turbine will drive the addition alternator. This alternator functions to produce current by converting from the mechanical energy to electric energy. The current produced can be stored to the battery then use as a future function such as to replace already alternator for reducing engine load. This project was also conducted to investigate the gear ratio on turbo-alternator in the spark ignition engine.

1. INTRODUCTION

Nowadays, most vehicles on the road are powered by internal combustion engine. The most common internal combustion engines for vehicles are fuelled by petrol or diesel. As the heat content of fuel is transformed into useful work, during the combustion process, many different losses take place. The losses can be divided into two general classifications which are thermodynamic and mechanical. The rest of the energy is lost to engine and driveline inefficiencies and idling.

The energy losses in vehicle can be recycling in order to increase the engine efficiency. Turbochargers are the recovery system for this wasted energy by using the waste energy that flow through the exhaust system and had been used again in engine performance. This system uses the flow of wasted energy from exhaust system to rotate the turbine in this system. Related to this project, wasted energy are used to change from mechanical energy to electric energy generate by additional alternator.

Turbo-alternator system only used turbine and the compressor are replaced to rotate the additional alternator through the turbine shaft. Normally in turbocharger, the rotational of the turbine will rotate the shaft that connected to the compressor blade but in this project, the turbine shaft that connected to the compressor before will be drive the alternator’s pulley. So, the turbine functions to move the alternator in producing current. This system is installed to the 4A-GE engine type that use in my research for investigation of gear ratio on turbo-alternator in the spark ignition engine type. The gear ratio is the relationship between the turbine shaft wheel as a driver and alternator wheel as a driven to consider torque and speed for both rotation.

2. RESEARCH METHODOLOGY

This project was conducted by research methodology as follows;

1. Develop turbo system in the exhaust manifold by adapting turbo charger with connecting to alternator via gear ratio.
2. Installing all sensor in the experimental vehicle such as pressure transducer, thermocouple, tachometer, air flow meter, data logger and some accessories.
3. Data collection in running the experimental vehicle.
4. Analysis of the data and conclude the findings.

3. LITERATURE REVIEW

Only about 15 percent of the energy from the fuel you put in your tank gets used to move your car down the road or run useful accessories, such as air conditioning. The rest of the energy is lost to engine and driveline inefficiencies and idling. Figure 1.1 shows the percentages fractions of the energy losses in vehicle.

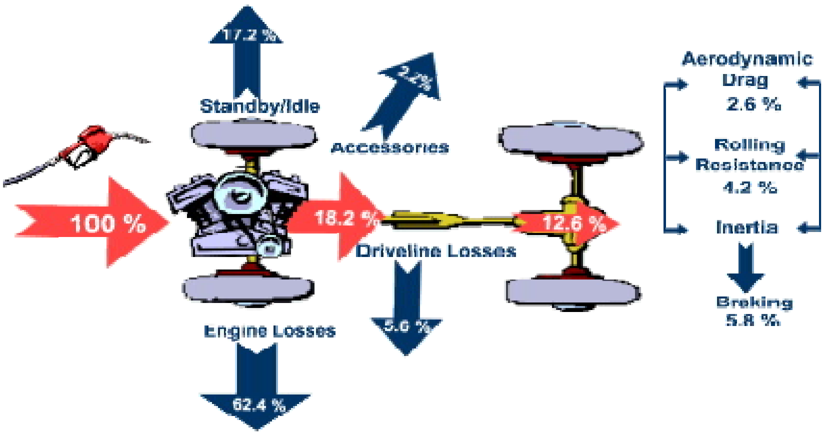

Figure 1.1: Flow of losses energy in vehicles
(Source: www.fueleconomy.gov/feg/atv.shtml)

There are:

- Engine Losses - 62.4 %

In gasoline-powered vehicles, over 62 percent of the fuel's energy is lost in the internal combustion engine (ICE). ICE engines are very inefficient at converting the fuel's chemical energy to mechanical energy, losing energy to engine friction, pumping air into and out of the engine, and wasted heat. In addition, diesels are about 30-35 percent more efficient than gasoline engines, and new advances in diesel technologies and fuels are making these vehicles more attractive.

- Idling Losses - 17.2 %

In city driving, significant energy is lost to idling at stop lights or in traffic. Technologies such as integrated starter/generator systems help reduce these losses by automatically turning the engine off when the vehicle comes to a stop and restarting it instantaneously when the accelerator is pressed.

- Accessories - 2.2 %

Air conditioning, power steering, windshield wipers, and other accessories use energy generated from the engine. Fuel economy improvements of up to 1 percent may be achievable with more efficient alternator systems and power steering pumps.

- Driveline Losses - 5.6 %

Energy is lost in the transmission and other parts of the driveline. Technologies, such as automated manual transmission and continuously variable transmission, are being developed to reduce these losses.

- Aerodynamic Drag - 2.6 %

A vehicle must expend energy to move air out of the way as it goes down the road less energy at lower speeds and progressively more as speed increases. Drag is directly related to the vehicle's shape. Smoother vehicle shapes have already reduced drag significantly, but further reductions of 20-30 percent are possible.

- Rolling Resistance - 4.2 %

Rolling resistance is a measure of the force necessary to move the tire forward and is directly proportional to the weight of the load supported by the tire. A variety of new technologies can be used to reduce rolling resistance, including improved tire tread and shoulder designs and materials used in the tire belt and traction surfaces. For passenger cars, a 5-7 percent reduction in rolling resistance increases fuel efficiency by 1 percent. However, these improvements must be balanced against traction, durability, and noise.

- Overcoming Inertia; Braking Losses - 5.8 %

To move forward, a vehicle's drive train must provide enough energy to overcome the vehicle's inertia, which is directly related to its weight. The less a vehicle weights the less energy it takes to move it. Weight can be reduced by using lightweight materials and lighter-weight technologies (e.g., automated manual transmissions weigh less than conventional automatics).

4. FINDINGS

For natural aspirated engine, the minimum value about 0 psi at 1500 rpm and 17 psi at 6000 rpm. The pressure increase around 1 – 3 psi for each increasing of engine speed. Rising of pressure rapidly; from 1500 – 6000 rpm because temperature flow from the combustion chamber. In higher rpm, piston move quickly and cause the increasing of the temperature. The increasing of temperature will increase the pressure at exhaust manifold.

For the turbine system engine (load), it shown of P1 value is higher than P2 and this is because of the turbine blade. Flow of the gas exhaust blocked by the turbine and at that point it increase the pressure. After the turbine blade, there have no block and the exhaust gas can flow smoothly through the exhaust pipe. So, that is the reason for the different of P1 and P2. P1 has a minimum value 2 psi at 1500 rpm and maximum value about 24 psi at 6000 rpm while P2 has a minimum value 0 psi at 1500 rpm and maximum value 13 psi at 600 rpm. Pattern of the graph rise rapidly from 1500 until 6000 rpm is also related to the combustion of the engine. It has a same reason like natural aspirated engine where in higher rpm the piston move quickly to combust higher combustion. So, it will increase the temperature in combustion chamber.

The turbine shaft for ratio 2 can be rotated well with the maximum speed which is 16000 rpm at the 5500 rpm of engine speed. The turbine shaft will turn faster when the engine running at the maximum speed which the experiment just cover at 5500 rpm of engine speed.

5. CONCLUSION

By referring to the analysis that has been done, the turbine system operated well and successfully achieved the required objective and scope. The performance of vehicle based on the gear ratio has been investigated and it can run properly. Experiment to investigate the gear ratio in “turbo-alternator system” has been done successfully. The alternator can generated up to 14 volts at maximum engine speed. Based on calculation for ratio 1 it has more torque and high speed compare to ratio 3, it happen when high torque was produced by driver the speed also high at driven. For ratio 3, torque value is smaller than others ratio same as the speed it is smaller than other. Following the theory the more diameter wheel the more speed but due the experiment the torque is smaller so it can’t rotate the alternator wheel that require more torque so the speed at driver automatically become small in value. Based on ratio 2, it must increase the driver speed to get more torque compare to ratio 1. Hence, ratio 1 is suitable for this experiment to get higher torque at turbine shaft wheel and higher speed at alternator wheel.

ACHIEVEMENT

i) Name of articles/ manuscripts/ books published

Herawan, Safarudin Gazali, Abdul Hakim , Rohhaian, Putra, Azma and Ahmad Faris , Ismail (2014) *PREDICTION OF WASTE HEAT ENERGY RECOVERY PERFORMANCE IN A NATURALLY*

ASPIRATED ENGINE USING ARTIFICIAL NEURAL NETWORK. In: ISRN Mechanical Engineering, Volume 2014, Article ID 240942, 6 pages.

ii) Title of Paper presentations (international/ local)

1. Herawan, Safarudin Gazali, Abdul Hakim , Rohhaian and Ahmad Faris , Ismail (2012) *WASTE HEAT RECOVERY FROM THE EXHAUST OF NATURAL ASPIRATED ENGINE.* In: The 3rd International Conference on Engineering and ICT (ICEI 2012), 4 - 5 APRIL 2012, MELAKA.
2. Rohhaian, Abdul Hakim, Herawan, Safarudin Gazali and Ayob, Md Razali (2012) *EXPERIMENTALLY INVESTIGATION THE PERFORMANCE OF TURBO-GENERATOR IN GASOLINE VEHICLE.* In: The 3rd International Conference on Engineering and ICT (ICEI 2012), 4 - 5 April 2012, Melaka, Malaysia.

iii) MALAYSIA.Human Capital Development
1 master student, and 3 PSM student.

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ABSTRACT

(*Keywords*: *Heat recovery, Turbo system; alternator*)

In vehicles system, there are many type of energy flow from fuel as a chemical energy to the exhaust system as a thermal energy. Without realize, there have a lots of wasted energy been occurs when the engine starts running. In fact, there are only 15 percent of the energy from the fuel from tank gets used to move car down the road or run useful accessories. The rest of the energy is lost to engine, idling, accessories, driveline, aerodynamic drag, rolling resistance and overcoming inertia or braking. Such as in exhaust system, the temperature at the exhaust manifold can reach around 900ºC and this heat will lose to atmosphere. So, the recovery system must be creating to solve this problem. One of the systems is "Turbo System" which uses the energy losses from the exhaust system by convert to electric energy. In this system, the energy that flow to the exhaust will rotate the turbine and the turbine will drive the addition alternator. This alternator functions to produce current by converting from the mechanical energy to electric energy. The current produced can be stored to the battery then use as a future function such as to replace already alternator for reducing engine load. This project was also conducted to investigate the gear ratio on turbo-alternator in the spark ignition engine.

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The authors are grateful to Professor Madya Dr. Ir. Abdul Talib bin Din, Deputy Dean of Research and Post Graduate Study, Faculty of Mechanical Engineering, also Staffs of the Faculty of Mechanical Engineering, and University-Industry Centre, UTeM, for their assistance and co-operation in carrying out the research in one way or another.

May Allah reward and bless all of them. Finally the authors are expressing our sincere gratitude to Allah once again who made the research to complete.

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1.0 INTRODUCTION

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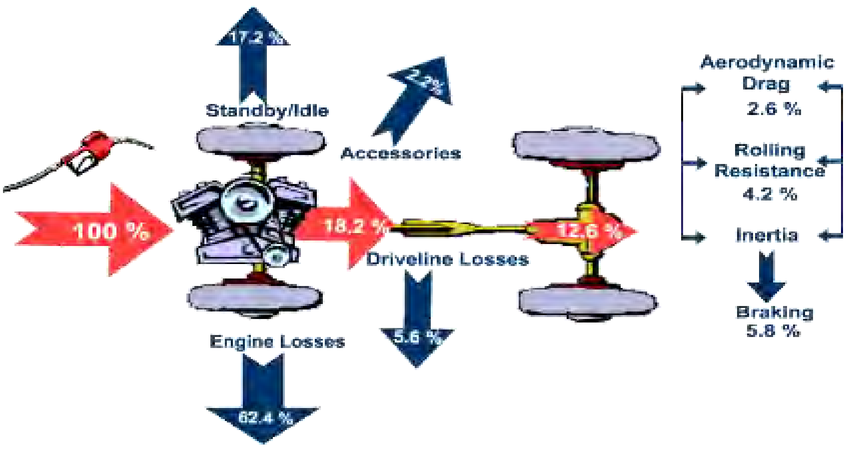

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1.2 Internal Combustion Engine

The internal combustion engine (ICE) is a heat engine that converts chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft. Chemical energy of the fuel is the first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine and the high-pressure gas then expends against the mechanical mechanisms of the engine. This expansion converted by the mechanical linkage of the engine to a rotating crankshaft, which is output of the engine. The crankshaft, in turn, is connected to a transmission or power train to transmit the propulsion of a vehicle.

There are so many different engine manufacturers, past, present and future, that produces and have produced engine which differ in size, geometry, style and operating characteristics, that no absolute limit can be stated for any range of engine characteristics such as size, number of cylinders and stroke in a cycle. Internal combustion engine, the type of ignition can be classified into two types and they are:-

1. Spark Ignition (SI)

   An SI engine starts the combustion process in each cycle by use a spark plug. The spark plug functions to give a high-voltage electrical discharge between two electrodes which ignites the air-fuel mixture in the combustion chamber.
2. Compression Ignition (CI)

   The combustion process in a CI engine starts when air-fuel mixture self-ignition due to high temperature in the combustion chamber caused by high compression.

For the SI ignition engine, they have two type of engine cycle and they are four-stroke cycle and two-stroke cycle. These basic cycles are fairly standard for all engines, with only slight variations found in individual designs. Below, the mechanism about four-stroke and two-stroke cycle can be determined.

1.2.1 Four-stroke SI engine cycle

Figure 1.2 shows a four stroke-stroke SI engine cycle which at the first stroke, the piston travels from top dead centre (TDC) to bottom dead centre (BDC) with the intake valve open and exhaust valve close. This creates an increasing volume in the combustion chamber. The resulting pressure differential through the intake system from atmosphere pressure on the outside to the vacuum on the inside causes air to be pushed into the cylinder. As the air passed through the intake system, fuel is added to it in the desired amount by means of fuel injector or a carburetor.

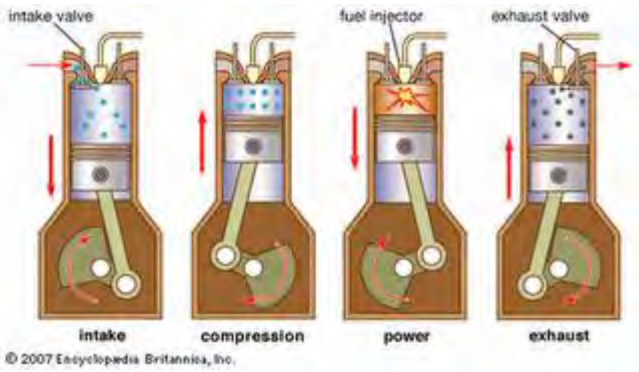

Figure 1.2: Four-stroke SI engine cycle
(www.britannica.com)

For the second stroke, when the piston reaches the BDC, the intake valve closes and the piston travels back to the TDC with all valve closed. This compresses the air-fuel mixture, raising both the pressure and the temperature in the cylinder. Near the end of the compression stroke, the spark plug is fired and combustion initiate. Combustion of the air-fuel mixture occurs very short but finite length of time with the piston near TDC. It also changes the composition of the gas mixture to that of exhaust products and increases the temperature in the cylinder to a very high peak value.

The third stroke known as expansion stroke happen with all valve closes and the high pressure created by combustion process pushed the piston away from TDC. This is the stroke which produces the work output of the engine cycle. Late in the expansion stroke, the exhaust valve is opened and exhaust blow-down occurs. Pressure and temperature in the cylinder still high relative to the surrounding at this point, and a pressure differential is created through the exhaust system which is open to atmospheric pressure.

Last stroke known as exhaust stroke by time the piston reaches BDC and exhaust blow-down is complete but the cylinder is still full of exhaust gases at approximately atmospheric pressure. With the exhaust valve remaining open, the piston now travels from BDC to TDC in the exhaust stroke. This pushes most of the remaining exhaust gases out of the cylinder into the exhaust system at about atmospheric pressure, leaving only that trapped in the clearance volume when the piston reaches TDC. Near the end of the exhaust stroke, the intake valve starts to open and so that it is fully open by TDC when the new intake stroke starts the next cycle.

1.3 Turbocharger and Supercharger mechanism

Turbocharger and Supercharger mechanism are the same system, which is to increase the air volume into the combustion chamber.

1.3.1 Supercharger Mechanism

Superchargers as in Figure 1.3 are mechanically driven directly from the engine crankshaft and the speed of engine will running the compressor with the same speed. It can be powered mechanically by a belt, gear, shaft, or chain connected to the engine's crankshaft. The power to drive the compressor is a parasitic load on the engine output, and this is the major disadvantages compared to the turbocharger system. This is because, if the power output of the engine low, it cannot run the compressor with the optimum speed.

A major advantage of the supercharger is very quick response to throttle changes. Being mechanically linked to the crankshaft, any engine speed change is immediately transferred to the compressor. Nowadays, people have modified this system to be more efficient by running the compressor by using the turbine known as turbocharger system. So, the compressor did not add any load to engine.

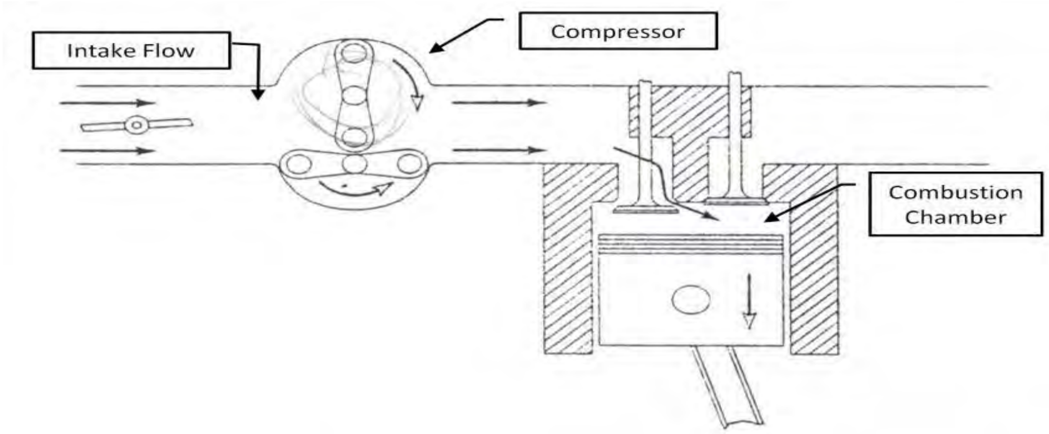

Figure 1.3: Supercharger used to increase inlet air pressure to engine
(Source: Willard W. Pulkrabek, 2004)

1.3.2 Turbocharger Mechanism

The turbocharger as in Figure 1.4 is bolted to the exhaust manifold of the engine. The exhaust from the cylinders spins the turbine, which works like a gas turbine engine. The turbine is connected by a shaft to the compressor, which is located between the air filter and the intake manifold. The compressor pressurizes the air going into the pistons. The exhaust from the cylinders passes through the turbine blades, causing the turbine to spin. The more exhaust that goes through the blades, the faster they spin.

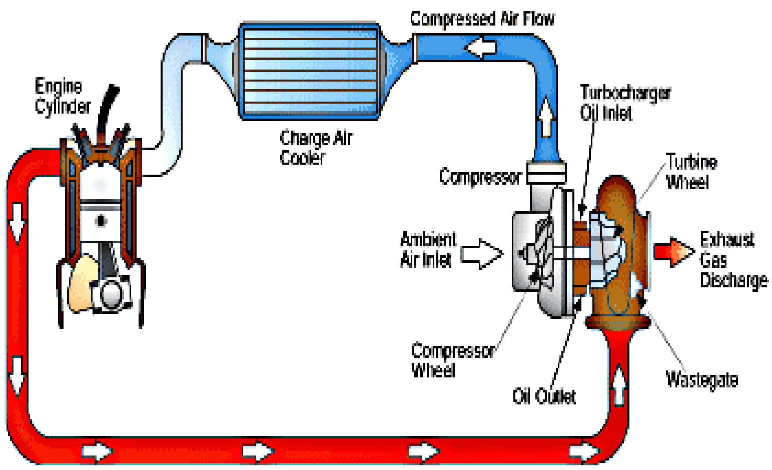

Figure 1.4: Compressor used to increase air pressure to engine
(Source: www.google.com)

On the other end of the shaft that the turbine is attached to, the compressor pumps air into the cylinders as in Figure 1.5. The compressor is a type of centrifugal pump; it draws air in at the center of its blades and flings it outward as it spins. In order to handle speeds of up to 150,000 rpm, the turbine shaft has to be supported very carefully. Most bearings would explode at speeds like this, so most turbochargers use a fluid bearing. This type of bearing supports the shaft on a thin layer of oil that is constantly pumped around the shaft. This serves two purposes: It cools the shaft and some of the other turbocharger parts, and it allows the shaft to spin without much friction. There are many tradeoffs involved in designing a turbocharger for an engine.

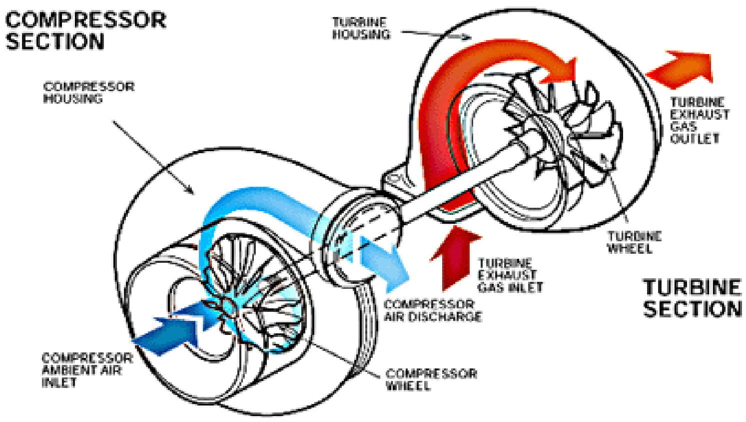

Figure 1.5: Compressor and turbine section
(Source: www.google.com)

However, a turbocharger differs in that the compressor is powered by a turbine driven by the exhaust gases. From Figure 1.6, we can see the different performance of the engine with and without turbocharger for 1982 Datsun 280ZX engine according power and torque graph versus revolution per minutes. From the graph, it shows that the performance of the turbocharger engine is better than the natural aspirated (without turbocharger).