DESIGN AND FABRICATION
OF
EXHAUST GAS UTILISATION SYSTEM

A PROJECT REPORT

DONE BY

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In Partial Fulfillment of the requirement in the subject of

(ME 1357) Design And Fabrication project

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APRIL-2008

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The Report of the project work submitted by the above students in partial fulfillment of the award of Bachelor of Engineering degree in Mechanical Engineering of Anna University were evaluated and confirmed to be report of the work done by them.

(INTERNAL EXAMINER) **(EXTERNAL EXAMINER)**

ACKNOWLEDGEMENT

The remarkable pioneering project works ours a Dept to our predecessors to our parents, to our teachers, to the institution.

We express our gratitude and sincere thanks to our management for providing all the facilities needed to complete this project.

We express our sincere thanks to Dr.Sivanandan HOD & Dean, Department of Mechanical Engineering, KCT for morally supporting us in carrying out the project.

We are grateful to Mr.T.Venkatajalapathi Lecturer, Mechanical Engineering Department, and KCT for his guidance in carrying out this project.

We express our thanks to all faculties (teaching and non teaching) of Mechanical Engineering department for their advice and encouragement that helped us in completing this project successfully.

Last but not the least our sincere most thanks are due to our beloved parents without whose guidance and ever persuading efforts this project work would have been a layman's chore.

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INTRODUCTION

The name indicates the project "Exhaust Gas Utilization System". In this project the exhaust gas is analyzed for its temperature and pressure. The two wheeler diesel engine exhaust is well enough to run the turbine and the turbine is coupled with compressor and the air is passed to the engine inlet and thus the efficiency of the engine increases.

Now our project is an extension of turbo charger, the turbine is coupled with single shaft. The alternator is the new component coupled with the same axis of the turbocharger unit, then only the rotation will be continuous without any struck.

The main aim to done this project is to increase the efficiency of the engine by reducing the load by the cost of reduction of slight decrease in turbo charger efficiency.

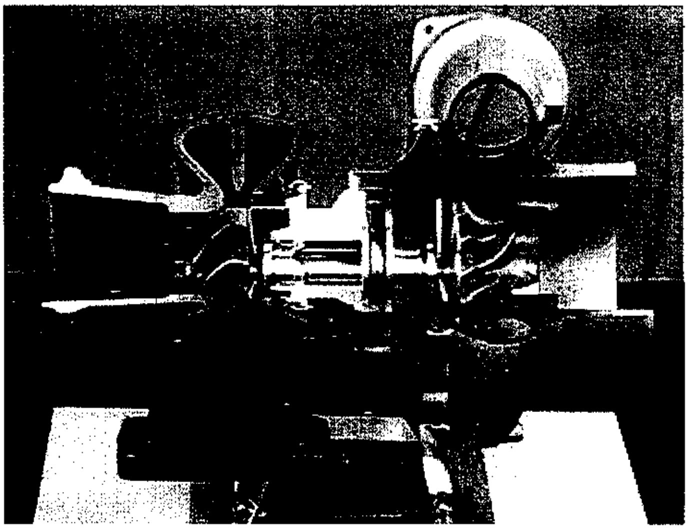
SYNOPSIS

The objective of the project work is to obtain power from the exhaust gases. The exhaust gas utilization system has been designed and fabricated to implement in all four wheeled diesel engines. In this system an alternator is coupled with turbo charger unit. Without affecting the efficiency of the turbo engines this experiment is carried out.

In order to improve the efficiency, the turbo charger unit is made smaller, because of this at ideal speeds itself , the turbine starts rotating and the compressor coupled with turbine also starts rotates and it is well enough to supply the required air to the engine. When the engine speed increases correspondingly the turbine speed increases and the alternator also starts rotating and the power is produced.

By employing this EGUS, the battery capacity can remain same for any external implementation and the load to the engine is reduced and From our calculations, it was found that the system efficiency reduces, but the engine efficiency is increased.

Turbocharger



Air foil bearing-supported turbocharger

A **turbocharger** (short for turbine driven supercharger) is an exhaust gas driven forced induction supercharger used in internal combustion engines. This differentiates it from a normal supercharger (or blower) which uses a prime mover to power the compression device.

Mostly the turbine was manufactured by the material cast-iron and the compressor was manufactured by aluminium.The very high temperature and pressure exhaust gas from the engine directly enters the turbine, so the turbine has to withstand such temperature and pressure, for that cast-iron is well suited material. And the compressor was mainly manufactured by aluminium, because of its major advantages like thermal conductivity, light weight, flexibility etc. The compressor and turbine is coupled by means of the shaft, the shaft is made up of steel, because strength of the steel is more and the coupled shaft is provided with some movement, this movement is provided for even wearness of the shaft.

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Working principle

A turbocharger consists of a turbine and a compressor linked by a shared axle. The turbine inlet receives exhaust gases from the engine exhaust manifold causing the turbine wheel to rotate. This rotation drives the compressor, compressing ambient air and delivering it to the air intake manifold of the engine at higher pressure, resulting in a greater amount of the air and fuel entering the cylinder.

The objective of a turbocharger is the same as a normal supercharger; to improve upon the size-to-output efficiency of an engine by solving one of its cardinal limitations. A naturally aspirated automobile engine uses only the downward stroke of a piston to create an area of low pressure in order to draw air into the cylinder through the inlet valves. Because the pressure in the cylinder cannot go below 0 psi (vacuum), and because of the relatively constant pressure of the atmosphere (about 15 psi), there ultimately will be a limit to the pressure difference across the inlet valves and thus the amount of airflow entering the combustion chamber. This ability to fill the cylinder with air is its volumetric efficiency. Because the turbocharger increases the pressure at the point where air is entering the cylinder, and the amount of air brought into the cylinder is largely a function of time and pressure difference, more air will be forced in as the inlet manifold pressure increases. The additional air makes it possible to add more fuel, increasing the output of the engine. Also, the intake pressure can be controlled by a wastegate, which controls boost by routing some of the exhaust flow away from the exhaust side turbine. This controls shaft speed and regulates boost pressure in the inlet tract.

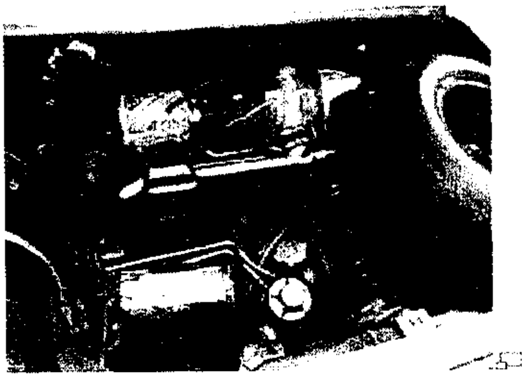
The application of a compressor to increase pressure at the point of cylinder air intake is often referred to as forced induction. Centrifugal superchargers operate in the same fashion as a turbo; however, the energy to spin the compressor is taken from the rotating output energy of the engine's crankshaft as opposed to exhaust gas. Superchargers and turbochargers use output energy from an engine to achieve a net gain, which must be provided from some of the engine's total output. In the case of superchargers, either directly or from a separate smaller engine, perhaps electrically driven from the main engine's generator.

The turbocharger was invented by Swiss engineer Alfred Buchi, who had been working on steam turbines. His patent for the internal combustion turbocharger was applied for in 1905.[1] Diesel ships and locomotives with turbochargers began appearing in the 1920s.

One of the first applications of a turbocharger to a non-Diesel engine came when General Electric engineer Sanford Moss attached a turbo to a V12 *Liberty* aircraft engine. The engine was tested at Pikes Peak in Colorado at 14,000 feet (4,300 m) to demonstrate that it could eliminate the power losses usually experienced in internal combustion engines as a result of altitude.

Turbochargers were first used in production aircraft engines in the 1930s before World War II. The primary purpose behind most aircraft-based applications was to increase the altitude at which the airplane can fly, by compensating for the lower atmospheric pressure present at high altitude. Aircraft such as the Lockheed P-38, Boeing B-17 Flying Fortress and Republic P-47 all used exhaust driven "turbo-superchargers" to increase high altitude engine power. It is important to note that the majority of turbo supercharged aircraft engines used both a gear-driven second stage centrifugal type supercharger and a first stage turbocharger.

The first Turbo-Diesel truck was produced by the "Schweizer Maschinenfabrik Saurer" (Swiss Machine Works Saurer) 1938 [1]. The turbocharger hit the automobile world in 1952 when Fred Agabashian qualified for pole position at the Indianapolis 500 and led for 100 miles (160 km) before tire shards disabled the blower.



The Corvair's innovative turbocharged flat-6 engine; The turbo, located at top right, feeds pressurized air into the engine through the chrome T-tube visible spanning the engine from left to right.

The first production turbocharged automobile engines came from General Motors in 1962. The A-body Oldsmobile Cutlass Jetfire and Chevrolet Corvair Monza Spyder were both fitted with turbochargers. The Oldsmobile is often recognized as the first, since it came out a few months earlier than the Corvair. Its *Turbo Jetfire* was a 215 in^3 (3.5 L) V8, while the Corvair engine was either a 145 in^3 (2.3 L)(1962-63) or a 164 in^3 (2.7 L) (1964-66) flat-6. Both of these engines were abandoned within a few years, and GM's next turbo engine came more than ten years later.

Offenhauser's turbocharged engines returned to Indianapolis in 1966, with victories coming in 1968. The Offy turbo peaked at over 1,000 hp (750 kW) in 1973, while Porsche dominated the Can-Am series with a 1,100 hp (820 kW) 917/30. Turbocharged cars dominated the Le Mans between 1976 and 1988, and then from 2000-2007.

BMW led the resurgence of the automobile turbo with the 1973 2002 Turbo, with Porsche following with the 911 Turbo, introduced at the 1974 Paris Motor Show. Buick was the first GM division to bring back the turbo, in the 1978 Buick Regal, followed by the Mercedes-Benz 300D, Saab 99 in 1978. Japanese manufacturers and Ford followed suit, with Mitsubishi Lancer in 1978, Ford Mustang in 1979, Audi Quattro in 1980, Toyota Supra in 1980, Nissan 280ZX in 1982 and Mazda RX-7 in 1987.

The world's first production turbodiesel automobile was also introduced in 1978 by Peugeot with the launch of the Peugeot 604 turbodiesel. Today, nearly all automotive diesels are turbocharged.

Alfa Romeo introduced the first mass-produced Italian turbocharged car, the Alfetta GTV 2000 Turbo delta in 1979. Pontiac also introduced a turbo in 1980 and Volvo Cars followed in 1981. Maserati in 1980 was the first to introduce twin or bi-turbo Maserati Biturbo. Renault however gave another step and installed a turbocharger to the smallest and lightest car they had, the R5, making it the first Supermini automobile with a turbocharger in year 1980. This gave the car about 160 bhp (120 kW) in street form and up to 300+ in race setup, which was extraordinary output for a 1400 cc motor. The R5's powerful motor was complemented by an incredible lightweight chassis, and as a consequence it was possible for an R5 to nip at the heels of the quick Italian sports car Ferrari 308.

In Formula One, in the so called "Turbo Era" of 1977 until 1989, engines with a capacity of 1500 cc could achieve anywhere from 1000 to 1500 hp (746 to 1119 kW) (Renault, Honda, BMW, Ferrari). Renault was the first manufacturer to apply turbo technology in the F1 field, in 1977. The project's high cost was compensated for by its performance, and led to other engine manufacturers following suit. The Turbo-charged engines took over the F1 field and ended the Ford Cosworth DFV era in the mid 1980s. However, the FIA decided that turbos were making the sport too dangerous and expensive, and from 1987 onwards, the maximum boost pressure was reduced before the technology was banned completely for 1989.

In Rallying, turbocharged engines of up to 2000 cc have long been the preferred motive power for the Group A/NWorld Rally Car (top level) competitors, due to the exceptional power-to-weight ratios (and enormous torque) attainable. This combines with the use of vehicles with relatively small bodyshells for manoeuvreability and handling. As turbo outputs rose to similar levels as the F1 category (see above), the FIA, rather than banning the technology, enforced a restricted turbo inlet diameter (currently 34 mm), effectively "starving" the turbo of compressible air and making high boost pressures unfeasible.

The success of small, turbocharged, four-wheel-drive vehicles in rally competition began with Audi Quattro in the 1980 Paris-Dakar Rally. In 1981 Audi entered the FIA championship with 4 podium finishes that year, and a manufacturers title in 1982 (2nd and 3rd for driver championship). The advantages of turbochargers combined with all wheel drive were clear, and led to the production of many other similar rally cars including the; Peugeot 205 T16, the Renault 5 Turbo, the Lancia Delta S4 and the Mazda 323GTX, has led to exceptional road cars in the modern era such as the Lancia Delta Integrale, Toyota Celica GT-Four, Subaru Impreza WRX and the Mitsubishi Lancer Evolution.

In the late 1970s, Ford and GM looked to the turbocharger to gain power, without sacrificing fuel consumption, during not only the emissions crunch of the federal government but also a gas shortage. GM released turbo versions of the Pontiac Firebird, Buick Regal, and Chevy Monte Carlo. Ford responded with a turbocharged Mustang in the form of the 2.3L from the Pinto. The engine design was dated, but it worked well. The bullet-proof 2.3L Turbo was used in early carbureted trim as well as fuel injected and intercooled versions in the Mustang SVO and the Thunderbird Turbo Coupe until 1988. GM also liked the idea enough to evolve the 3.8L V6 used in early turbo Buicks into late '80s muscle in the form of the Buick Grand National and it's pinnacle (and final) form, the GNX.

Although late to use turbo charging, Chrysler Corporation, after some joint development with Maserati (Chrysler TC), turned to turbochargers in 1984 and quickly churned out more turbocharged engines than any other manufacturer, using turbocharged, fuel-injected 2.2 and 2.5 litre four-cylinder engines in minivans, sedans, convertibles, and coupes. Their 2.2 litre turbocharged engines ranged from 142 hp (106 kW) to 225 hp (168 kW), a substantial gain over the normally aspirated ratings of 86 to 93 horsepower (69 kW); the 2.5 litre engines had about 150 horsepower (110 kW) and had no intercooler. They also pioneered variable geometry turbo charging,(an industry first) with the introduction of the Dodge based 1989 Shelby CSX, a system that completely eliminated "turbo lag". Though the company stopped using turbochargers in 1993, they returned to turbocharged engines in 2002 with their 2.4 litre engines, boosting output by 70 horsepower.[2]

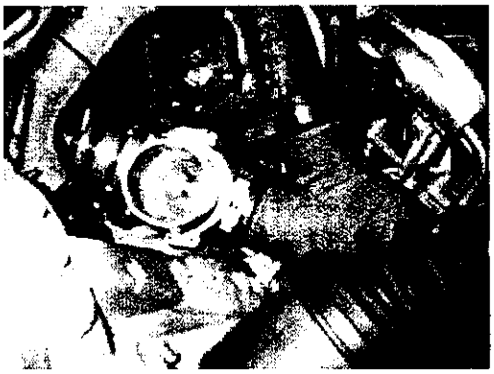
Design details

Components

On the left, the brass oil drains connection. On the right are the braided oil supply line and water coolant line connections.

Compressor impeller side with the cover removed

Turbine side housing removed.



A wastegate installed next to the turbocharger.

The turbocharger has four main components. The turbine and impeller/compressor wheels are each contained within their own folded conical housing on opposite sides of the third component, the center housing/hub rotating assembly (CHRA).

The housings fitted around the compressor impeller and turbine collect and direct the gas flow through the wheels as they spin. The size and shape can dictate some performance characteristics of the overall turbocharger. The area of the cone to radius from center hub is expressed as a ratio (AR, A/R, or A:R). Often the same basic turbocharger assembly will be available from the manufacturer with multiple AR choices for the turbine housing and sometimes the compressor cover as well. This allows the designer of the engine system to tailor the compromises between performance, response, and efficiency to application or preference. Both housings resemble snail shells, and thus turbochargers are sometimes referred to in slang as *snails*.

Split-Inlet Exhaust Housings known as "Twin Scroll" permit the exhaust pulses to be grouped (or separated) by cylinder all the way to the turbine. The reason for doing this in keeping the individual package of energy, an exhaust pulse, intact and undisturbed by other pulses, all the way to the turbine. This in turn can give the turbine a better kick to get it moving. This is specifically useful in four-cylinder engines. Because a four-cylinder only sees one pulse every 180 degrees of crank rotation, it needs all the energy it can get from each pulse. Keeping them separate and undisturbed will therefore pay back some dividends. 5* (Information from "Maximum Boost" by Corky Bell).

The turbine and impeller wheel sizes also dictate the amount of air or exhaust that can be flowed through the system, and the relative efficiency at which they operate. Generally, the larger the turbine wheel and compressor wheel, the larger the flow capacity. Measurements and shapes can vary, as well as curvature and number of blades on the wheels.

The center hub rotating assembly houses the shaft which connects the compressor impeller and turbine. It also must contain a bearing system to suspend the shaft, allowing it to rotate at very high speed with minimal friction. For instance, in automotive applications the CHRA typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized engine oil. The CHRA may also be considered "water cooled" by having an entry and exit point for engine coolant to be cycled. Water cooled models allow engine coolant to be used to keep the lubricating oil cooler, avoiding possible oil coking from the extreme heat found in the turbine.

Boost

Boost refers to the increase in manifold pressure that is generated by the turbocharger in the intake path or specifically intake manifold that exceeds normal atmospheric pressure. This is also the level of boost as shown on a pressure gauge, usually in bar, psi or possibly kPa This is representative of the extra air pressure that is achieved over what would be achieved without the forced induction. Manifold pressure should not be confused with the volume of air that a turbo can flow.

Boost pressure is limited to keep the entire engine system, including the turbo, inside its thermal and mechanical design operating range by controlling the wastegate which shunts the exhaust gases away from the exhaust side turbine.

The maximum possible boost depends on the fuel's octane rating and the inherent tendency of any particular engine towards preignition. With appropriate calibration and efficient charge cooling, relatively high boost pressures can safely be attained Ethanol, methanol, liquefied petroleum gas (LPG) and diesel fuels allow higher boost than gasoline, because of these fuels' combustion characteristics.

Many diesel engine turbochargers do not have a wastegate, because the amount of exhaust energy is controlled directly by the amount of fuel injected into the engine and slight variations in boost pressure do not make a difference for the engine

Wastegate

By spinning at a relatively high speed the compressor turbine draws in a large volume of air and forces it into the engine. As the turbocharger's output flow volume exceeds the engine's volumetric flow, air pressure in the intake system begins to build, often called boost. The speed at which the assembly spins is proportional to the pressure of the compressed air and total mass of air flow being moved. Since a turbo can spin to RPMs far beyond what is needed, or of what it is safely capable of, the speed must be controlled. A wastegate is the most common mechanical speed control system, and is often further augmented by an electronic boost controller. The main function of a wastegate is to allow some of the exhaust to bypass the turbine when the set intake pressure is achieved. Most passenger cars have wastegates that are integral to the turbocharger.

Anti-Surge/Dump/Blow off Valves

Turbo charged engines operating at wide open throttle and high rpm require a large volume of air to flow between the turbo and the inlet of the engine. When the throttle is closed compressed air will flow to the throttle valve without an exit (*i.e.* the air has nowhere to go).

This causes a surge which can raise the pressure of the air to a level which can be destructive to the engine *e.g.* damage may occur to the throttle plate, induction pipes may burst. The surge will also decompress back across the turbo as this is the only path that the air can take. This sudden flow of air will often cause turbulence and a subsequent whistling noise as the air passes past the compressor wheel.

The reverse flow back across the turbo acts on the compressor wheel and causes the turbine shaft to reduce in speed quicker than it would naturally. When the throttle is opened again, the turbo will have to make up for lost momentum and will take longer to achieve the required speed, as turbo speed is proportional to boost/volume flow. (This is known as Turbo Lag) In order to prevent this from happening, a valve is fitted between the turbo and inlet which vents off the excess air pressure. These are known as an anti-surge, bypass, blow-off or dump valve. They are normally operated by engine vacuum.

The primary use of this valve is to prevent damage to the engine by a surge of compressed air and to maintain the turbo spinning at a high speed. The air is usually recycled back into the turbo inlet but can also be vented to the atmosphere. Recycling back into the turbo causes the venting sound to be reduced and can actually help keep the turbo spooled while changing gears. The benefits of venting to the atmosphere are simply the ease of installation (because there is no need to run an extra hose to plumb the charge back into the system) and that it makes a sound considered desirable by some. There are no/little performance benefits for venting to the atmosphere, but because a Dump Valve is present the Turbo will slow down naturally rather than forcefully and will shorten the time needed to "spool-up" to counteract any turbo lag.

Fuel efficiency

Since a turbocharger increases the specific horsepower output of an engine, the engine will also produce increased amounts of waste heat. This can sometimes be a problem when fitting a turbocharger to a car that was not designed to cope with high heat loads. However, the higher compression ratios attained generally contribute to greater fuel efficiency.

It is another form of cooling that has the largest impact on fuel efficiency: charge cooling. Even with the benefits of intercooling, the total compression in the combustion chamber is greater than that in a naturally-aspirated engine. To avoid knock while still extracting maximum power from the engine, it is common practice to introduce extra fuel into the charge for the sole purpose of cooling. While this seems counterintuitive, this fuel is not burned. Instead, it absorbs and carries away heat when it changes phase from liquid mist to gas vapor. Also, because it is more dense than the other inert substance in the combustion chamber, nitrogen, it has a higher specific heat and more heat capacitance. It "holds" this heat until it is released in the exhaust stream, preventing destructive knock. This thermodynamic property allows manufacturers to achieve good power output with common pump fuel at the expense of fuel economy and emissions. The stoichiometric Air-to-Fuel ratio (A/F) for combustion of gasoline is 14.7:1. A common A/F in a turbocharged engine while under full design boost is approximately 12:1. Richer mixtures are sometimes run when the design of the system has flaws in it such as a catalytic converter which has limited endurance of high exhaust temperatures or the engine has a compression ratio that is too high for efficient operation with the fuel given.

Lastly, the efficiency of the turbocharger itself can have an impact on fuel efficiency. Using a small turbocharger will give quick response and low lag at low to mid RPMs, but can choke the engine on the exhaust side and generate huge amounts of pumping-related heat on the intake side as RPMs rise. A large turbocharger will be very efficient at high RPMs, but is not a realistic application for a street driven automobile. Variable vane and ball bearing technologies can make a turbo more efficient across a wider operating range, however, other problems have prevented this technology from appearing in more road cars (see Variable geometry turbocharger). Currently, the Porsche 911 (997) Turbo is the only gasoline car in production with this kind of turbocharger, although in Europe turbos of this type are rapidly becoming standard-fitment on turbodiesel cars, vans and other commercial vehicles, because they can greatly enhance the diesel engine's characteristic low-speed torque. One way to take advantage of the different operating regimes of the two types of supercharger is sequential turbo charging, which uses a small turbocharger at low RPMs and a larger one at high RPMs.

The engine management systems of most modern vehicles can control boost and fuel delivery according to charge temperature, fuel quality, and altitude, among other factors. Some systems are more sophisticated and aim to deliver fuel even more precisely based on combustion quality. For example, the Trionic-7 system from Saab Automobile provides immediate feedback on the combustion while it is occurring by using the spark plug to measure the cylinder pressure via the ionization voltage over the spark plug gap.

The new 2.0L TFSI turbo engine from Volkswagen/Audi incorporates lean burn and direct injection technology to conserve fuel under low load conditions. It is a very complex system that involves many moving parts and sensors in order to manage airflow characteristics inside the chamber itself, allowing it to use a stratified charge with excellent atomization. The direct injection also has a tremendous charge cooling effect enabling engines to use higher compression ratios and boost pressures than a typical port-injection turbo engine.

Automotive design details

The ideal gas law states that when all other variables are held constant, if pressure is increased in a system so will temperature. Here exists one of the negative consequences of turbo charging, the increase in the temperature of air entering the engine due to compression.

A turbo spins very fast; most peak between 80,000 and 200,000 RPM (using low inertia turbos, 150,000-250,000 RPM) depending on size, weight of the rotating parts, boost pressure developed and compressor design. Such high rotation speeds would cause problems for standard ball bearings leading to failure so most turbo-chargers use fluid bearings. These feature a flowing layer of oil that suspends and cools the moving parts. The oil is usually taken from the engine-oil circuit. Some turbochargers use incredibly precise ball bearings that offer less friction than a fluid bearing but these are also suspended in fluid-dampened cavities. Lower friction means the turbo shaft can be made of lighter materials, reducing so-called *turbo lag* or *boost lag*. Some car makers use water cooled turbochargers for added bearing life. This can also account for why many tuners upgrade their standard journal bearing turbos (such as a T25) which use a 270 degree thrust bearing and a brass journal bearing which only has 3 oil passages, to a 360 degree bearing which has a beefier thrust bearing and washer having 6 oil passages to enable better flow, response and cooling efficiency. Turbochargers with foil bearings are in development which eliminates the need for bearing cooling or oil delivery systems, thereby eliminating the most common cause of failure, while also significantly reducing turbo lag.

To manage the *upper-deck* air pressure, the turbocharger's exhaust gas flow is regulated with a wastegate that bypasses excess exhaust gas entering the turbocharger's turbine. This regulates the rotational speed of the turbine and the output of the compressor. The wastegate is opened and closed by the compressed air from turbo (the upper-deck pressure) and can be raised by using a solenoid to regulate the pressure fed to the wastegate membrane. This solenoid can be controlled by Automatic Performance Control, the engine's electronic control unit or an after market boost control computer. Another method of raising the boost pressure is through the use of check and bleed valves to keep the pressure at the membrane lower than the pressure within the system.

Some turbochargers, called **Variable-Geometry** or **Variable-Nozzle** turbos, use a set of vanes in the exhaust housing to maintain a constant gas velocity across the turbine, the same kind of control as used on power plant turbines. Other designations for this type of turbo include **Variable Area Turbine Nozzle**, **Variable Turbine Geometry**, and **Variable Vane Turbine**. Such turbochargers have minimal lag like a small conventional turbocharger and can achieve full boost as low as 1,500 engine

Rpm, yet remain efficient as a large conventional turbocharger at higher engine speeds; they are also used in diesel engines.[3] In many setups these turbos do not use a wastegate the vanes are controlled by a membrane identical to the one on a wastegate but the mechanism is different.

The first production car to use a variable-nozzle turbos was the limited-production 1989 Shelby CSX-VNT equipped with a 2.2L engine. The Shelby CSX-VNT uses a Garrett turbo designated **VNT-25**, a variable-geometry version of Garrett's T-25. This type of turbine is called a **Variable Nozzle Turbine (VNT)**. A number of other Chrysler Corporation vehicles used this turbocharger in 1990, including the Dodge Daytona and Dodge Shadow. These engines produced 174 horsepower (130 kW) and 225 foot-pounds force (305 N·m) of torque, the same horsepower as the standard intercooled 2.2 liter engines but with 25 more pound-feet of torque and greatly reduced turbo lag.

The 2006 Porsche 911 Turbo has a twin turbocharged 3.6-litre flat six, and the turbos used are BorgWarner's Variable Geometry Turbos (VGTs). This is the third time the technology has been implemented on a production petrol car, after the 1989-90 Chrysler Corporation vehicles and the 1992 Peugeot 405 T16.

Motorcycles

Using turbochargers to gain performance without a large gain in weight was very appealing to the Japanese factories in the 1980s. The first example of a turbocharged bike is the 1978 Kawasaki Z1R TC. It used a Rayjay ATP turbo kit to build 5 lb (2.3 kg) of boost, bringing power up from ~90 hp to ~105 hp. However, it was only marginally faster than the standard model (11 lb and 145 hp (108 kW) with a modified wastegate). A US Kawasaki importer came up with the idea of modifying the Z1-R with a turbo charging kit as a solution to the Z1-R being a low selling bike. In 1982 Honda released the CX500T featuring a carefully developed turbo (as oppose to the Z1-R's bolt on approach). The development of the CX500T was riddled with problems; due to being a V-twin engine the intake periods in the engine rotation are staggered leading to periods of high intake and long periods of no intake at all. Designing around these problems drove the price of the bike up, and the performance still was not as good as the cheaper CX900, making turbo charging motorcycles from factory an educational experience; as of 2007 no factories offer turbocharged motorcycles (although the Suzuki B-King prototype featured a supercharged Hayabusa engine).

Properties and applications

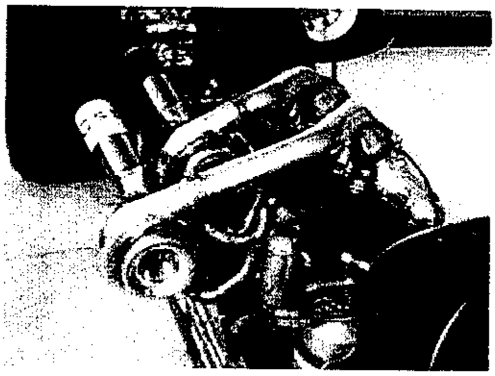
Reliability

Turbochargers can be damaged by dirty or ineffective oil, and most manufacturers recommend more frequent oil changes for turbocharged engines; many owners and some companies recommend using synthetic oils, which tend to flow more readily when cold and do not break down as quickly as conventional oils. Because the turbocharger will get hot when running, many recommend letting the engine idle for one to three minutes before shutting off the engine if the turbocharger was used shortly before stopping (most manufacturers specify a 10-second period of idling before switching off to ensure the turbocharger is running at its idle speed to prevent damage to the bearings when the oil supply is cut off). This lets the turbo rotating assembly cool from the lower exhaust gas temperatures, and ensures that oil is supplied to the turbocharger while the turbine housing and exhaust manifold are still very hot; otherwise coking of the lubricating oil trapped in the unit may occur when the heat soaks into the bearings, causing rapid bearing wear and failure when the car is restarted. Even small particles of burnt oil will accumulate and lead to choking the oil supply and failure. This problem is less pronounced in diesel engines, due to the lower exhaust temperatures and generally slower engine speeds.

A turbo timer can keep an engine running for a pre-specified period of time, to automatically provide this cool-down period. Oil coking is also eliminated by foil bearings. A more complex and problematic protective barrier against oil coking is the use of water-cooled bearing cartridges. The water boils in the cartridge when the engine is shut off and forms a natural recirculation to drain away the heat. It is still not a good idea to shut the engine off while the turbo and manifold are still glowing.

In custom applications utilizing tubular headers rather than cast iron manifolds, the need for a cool down period is reduced because the lighter headers store much less heat than heavy cast iron manifolds.

Lag



A pair of turbochargers mounted to an Inline 6 engine (2JZ-GTE from an MkIV Toyota Supra) in a dragster.

A lag is sometimes felt by the driver of a turbocharged vehicle as a delay between pushing on the accelerator pedal and feeling the turbo *kick-in*. This is symptomatic of the time taken for the exhaust system driving the turbine to come to high pressure and for the turbine rotor to overcome its rotational inertia and reach the speed necessary to supply boost pressure. The directly-driven compressor in a supercharger does not suffer this problem. (Centrifugal superchargers do not build boost at low RPMs like a positive displacement supercharger will). Conversely on light loads or at low RPM a turbocharger supplies less boost and the engine is less efficient than a supercharged engine.

Lag can be reduced by lowering the rotational inertia of the turbine, for example by using lighter parts to allow the spool-up to happen more quickly. Ceramic turbines are a big help in this direction. Unfortunately, their relative fragility limits the maximum boost they can supply. Another way to reduce lag is to change the aspect ratio of the turbine by reducing the diameter and increasing the gas-flow path-length. Increasing the upper-deck air pressure and improving the wastegate response helps but there are cost increases and reliability disadvantages that car manufacturers are not happy about. Lag is also reduced by using a foil bearing rather than a conventional oil bearing. This reduces friction and contributes to faster acceleration of the turbo's rotating assembly. Variable-nozzle turbochargers (discussed above) eliminate lag.

Another common method of equalizing turbo lag is to have the turbine wheel "clipped", or to reduce the surface area of the turbine wheel's rotating blades. By clipping a minute portion off the tip of each blade of the turbine wheel, less restriction is imposed upon the escaping exhaust gases. This imparts less impedance onto the flow of exhaust gases at low RPM, allowing the vehicle to retain more of its low-end torque, but also pushes the effective boost RPM to a slightly higher level. The amount of turbine wheel clipping is highly application-specific. Turbine clipping is measured and specified in degrees.

Other setups, most notably in V-type engines, utilize two identically-sized but smaller turbos, each fed by a separate set of exhaust streams from the engine. The two smaller turbos produce the same (or more) aggregate amount of boost as a larger single turbo, but since they are smaller they reach their optimal RPM, and thus optimal boost delivery, faster. Such an arrangement of turbos is typically referred to as a parallel twin-turbo system.

Some car makers combat lag by using two small turbos (such as Nissan, Toyota, Subaru, Maserati, Mazda, and Audi). A typical arrangement for this is to have one turbo active across the entire rev range of the engine and one coming on-line at higher RPM. Early designs would have one turbocharger active up to a certain RPM, after which both turbochargers are active. Below this RPM, both exhaust and air inlet of the secondary turbo are closed. Being individually smaller they do not suffer from excessive lag and having the second turbo operating at a higher RPM range allows it to get to full rotational speed before it is required. Such combinations are referred to as a sequential twin-turbo. Sequential twin-turbos are usually much more complicated than a single or parallel twin-turbo systems because they require what amounts to three sets of pipes-intake and wastegate pipes for the two turbochargers as well as valves to control the direction of the exhaust gases. An example of this is the current BMW E60 5-Series 535d. Another well-known example is the 1993-2002 Mazda RX-7. Many new diesel engines use this technology to not only eliminate lag but also to reduce fuel consumption and produce cleaner emissions.

Lag is not to be confused with the boost threshold; however, many information still make this basic mistake. The boost threshold of a turbo system describes the minimum engine RPM at which there is sufficient exhaust flow to the turbo to allow it to generate significant amounts of boost newer turbocharger and engine developments have caused boost thresholds to steadily decline to where day-to-day use feels perfectly natural. Putting your foot down at 1200 engine RPM and having no boost until 2000 engine RPM is an example of boost threshold and not *lag*. If lag was experienced in this situation, the RPM would either not start to rise for a short period of time after the throttle was increased, or increase slowly for a few seconds and then suddenly build up at a greater rate as the turbo become effective. However, the term lag is used erroneously for boost threshold by many manufacturers themselves.

Electrical boosting ("E-boosting") is a new technology under development; it uses a high speed electrical motor to drive the turbocharger to speed before exhaust gases are available, *e.g.* from a stop-light. The electric motor is about an inch long.[4]

Race cars often utilize an Anti-Lag System to completely eliminate lag at the cost of reduced turbocharger life.

On modern diesel engines, this problem is virtually eliminated by utilizing a variable geometry turbocharger.

Boost Threshold

Turbochargers start producing boost only above a certain rpm (depending on the size of the turbo) because they are powered by the movement exhaust gases; without an appropriate exhaust gas velocity, they logically cannot force air into the engine. The point at which the airflow in the exhaust is strong enough to force air into the engine is known as the boost threshold rpm. Engineers have, in some cases, been able to reduce the boost threshold rpm to idle speed to allow for instant response.

Both Lag and Threshold characteristics can be acquired through the use of a compressor map using a compressor map and a mathematical equation. Performance shops have the maps on hand and/or can walk you through the process of mapping a turbo for your particular vehicle and the type of racing you wish to do.

Automotive Applications

Turbo charging is very common on diesel engines in conventional automobiles, in trucks, locomotives, for marine and heavy machinery applications. In fact, for current automotive applications, non-turbocharged diesel engines are becoming increasingly rare. Diesels are particularly suitable for turbo charging for several reasons:

- Naturally-aspirated diesels will develop less power than a gasoline engine of the same size, and will weigh significantly more because diesel engines require heavier, stronger components. This gives such engines a poor power-to-weight ratio; turbo charging can dramatically improve this P:W ratio, with large power gains for a very small increase in weight.
- Diesel engines require more robust construction because they already run at very high compression ratio and at high temperatures so they generally require little additional reinforcement to be able to cope with the addition of the turbocharger. Gasoline engines often require extensive modification for turbocharging.
- Diesel engines have a narrower band of engine speeds at which they operate, thus making the operating characteristics of the turbocharger over that "rev range" less of a compromise than on a gasoline-powered engine.
- Diesel engines blow nothing but air into the cylinders during cylinder charging, squirting fuel into the cylinder only after the intake valve has closed and compression has begun. Gasoline/petrol engines differ from this in that both fuel and air are introduced during the intake cycle and both are compressed during the compression cycle. The higher intake charge temperatures of forced-induction engines reduces the amount of compression that is possible with a gasoline/petrol engine, whereas diesel engines are far less sensitive to this.

Today, turbo charging is most commonly used on two types of engines Gasoline engines in high-performance automobiles and diesel engines in transportation and other industrial equipment. Small cars in particular benefit from this technology, as there is often little room to fit a larger-output (and physically larger) engine. Saab is a leader in production car turbochargers, starting with the 1978 Saab 99; all current Saab models are turbocharged with the exception of the 9-7X. The Porsche 944 utilized a turbo unit in the 944 Turbo (Porsche internal model number 951), to great advantage, bringing its 0-100 km/h (0-60 mph) times very close to its contemporary non-turbo "big brother", the Porsche 928.

In the 1980s, when turbocharged production cars became common, they gained a reputation for being difficult to handle. The tuned engines fitted to the cars, and the often primitive turbocharger technology meant that power delivery was unpredictable and the engine often suddenly delivered a huge boost in power at certain speeds. Some drivers said this made cars such as the BMW 2002 and the Porsche 911 exciting to drive, requiring high levels of skill. Others said the cars were difficult and often dangerous. As turbocharger technology improved, it became possible to produce turbocharged engines with a smoother, more predictable but just as effective power delivery.

Chrysler Corporation was an innovator of turbocharger use in the 1980s. Many of their production vehicles, for example the Chrysler LeBaron, Dodge Daytona, Dodge Shadow/Plymouth Sundance twins, and the Dodge Spirit/Plymouth Acclaim twins were available with turbochargers, and they proved very popular with the public. They are still considered competitive vehicles today, and the experience Chrysler obtained in observing turbochargers in real-world conditions has allowed them to further turbocharger technology with the PT Cruiser Turbo, the Dodge SRT-4 and the Dodge Caliber SRT-4.

Aircraft Applications

Turbochargers are used in reciprocating aircraft engines which are designed for high altitude use. As an aircraft climbs in altitude, the density of the air surrounding it decreases. As the density of the air decreases, so does the drag on the airframe and the power of the engine. With this in mind, turbochargers were developed for aircraft to keep the pressure of the air entering the engine equivalent to a normally aspirated engine at sea level. In this case the system is called a *turbo-normalizer*. Other systems use the turbocharger to boost the engine manifold pressure to much higher than sea level pressures; in the area of 35 to 45 inches of mercury; and this is called *turbo-boosting*. In either case, an automatic or manually-controlled wastegate is used to vary the turbocharger output according to operating conditions.

Relationship to Gas Turbine Engines

Prior to World War II, Sir Frank Whittle started his experiments on early turbojet engines. Due to a lack of sufficient materials as well as funding, initial progress was slow. However, turbochargers were used extensively in military aircraft during World War II to enable them to fly very fast at very high altitudes. The demands of the war led to constant advances in turbocharger technology, particularly in the area of materials. This area of study eventually crossed over in to the development of early gas turbine engines. Those early turbine engines were little more than a very large turbocharger with the compressor and turbine connected by a number of combustion chambers. The cross over between the two has been shown in an episode of the TV show Scrapheap Challenge where contestants were able to build a functioning Jet Engine using an ex-automotive turbocharger as a compressor.

Consider also, for example, that General Electric manufactured turbochargers for military aircraft and held several patents on their electric turbo controls during the war, then used that expertise to very quickly carve out a dominant share of the gas turbine market which they have held ever since.

Advantages and Disadvantages

Advantages

- More specific power over naturally aspirated engine. This means a turbocharged engine can achieve more power from same engine volume.
- Better thermal efficiency over both naturally aspirated and supercharged engine when under full load (*i.e.* on boost). This is because the excess exhaust heat and pressure, which would normally be wasted, contributes some of the work required to compress the air.
- Weight/Packaging. Smaller and lighter than alternative forced induction systems and may be more easily fitted in an engine bay.
- Fuel Economy. Although adding a turbocharger itself does not save fuel, it will allow a vehicle to use a smaller engine while achieving power levels of a much larger engine, while attaining near normal fuel economy while off boost/cruising. This is because without boost, only the normal amount of fuel and air are combusted.

Disadvantages

- Lack of responsiveness if an incorrectly sized turbocharger is used. If a turbocharger that is too large is used it reduces throttle response as it builds up boost slowly. However, doing this may result in more *peak* power.
- Boost threshold. Turbocharger starts producing boost only above a certain rpm due to a lack of exhaust gas volume to overcome inertia of rest of turbo propeller. This results in a rapid and nonlinear rise in torque, and will reduce the usable power band of the engine. The sudden surge of power could overwhelm the tires and result in loss of grip, which could lead to understeer/oversteer, depending on the drive train and suspension setup of the vehicle. Lag can be disadvantageous in racing. If throttle is applied in a turn, power may unexpectedly increase when the turbo winds up, which can induce wheel, spin.

- Cost. Turbocharger parts are costly to add to naturally aspirated engines. Heavily modifying OEM turbocharger systems also require extensive upgrades that in most cases requires most (if not all) of the original components to be replaced.
- Complexity. Further to cost, turbochargers require numerous additional systems if they are not to damage an engine. Even an engine under only light boost requires a system for properly routing (and sometimes cooling) the lubricating oil, turbo-specific exhaust manifold, application specific down pipe, boost regulation, and proper gauges (not intrinsically necessary, but very highly recommended). In addition inter-cooled turbo engines require additional plumbing, whilst highly tuned turbocharged engines will require extensive upgrades to their lubrication, cooling, and breathing systems; while reinforcing internal engine and transmission parts.

ALTERNATOR

An **alternator** is an electromechanical device that converts mechanical energy to alternating current electrical energy. Most alternators use a rotating magnetic field but linear alternators are occasionally used. In principle, any AC electrical generator can be called an alternator, but usually the word refers to small rotating machines driven by automotive and other internal combustion engines. In UK, large alternators in power stations which are driven by steam turbines are called turbo-alternators.

Contents

- Theory of operation
- Synchronous speeds
- Automotive alternators
- Marine alternators
- Brushless Alternators
    - Terminology
    - Construction
    - Main Alternator
    - Control System
    - AVR
- Hybrid automobiles
- Radio alternators

Alternating current generating systems were known in simple forms from the discovery of the magnetic induction of electric current. The early machines were developed by pioneers such as Michael Faraday and Hippolyte Pixii. Faraday developed the “rotating rectangle”, whose operation was heteropolar. The first public demonstration of a more robust "alternator system" took place in 1886. Large two-phase alternating current generators were built by a British electrician, J.E.H. Gordon, in 1882. Lord Kelvin and Sebastian_Ferranti also developed early alternators, producing frequencies between 100 and 300 hertz. In 1891, Nikola Tesla patented a practical "high-frequency" alternator (which operated around 15,000 hertz). After 1891, polyphase alternators were introduced to supply currents of multiple differing phases. Later alternators were designed for varying alternating-current frequencies between sixteen and about one hundred hertz, for use with arc lighting, incandescent lighting and electric motors.

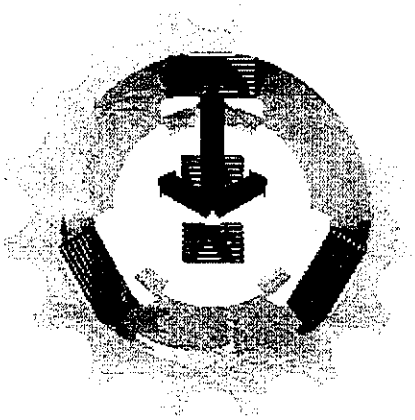
Theory of operation

Alternators generate electricity by the same principle as DC generators, namely, when the magnetic field around a conductor changes, a current is induced in the conductor. Typically, a rotating magnet called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an electrical current, as the mechanical input causes the rotor to turn.

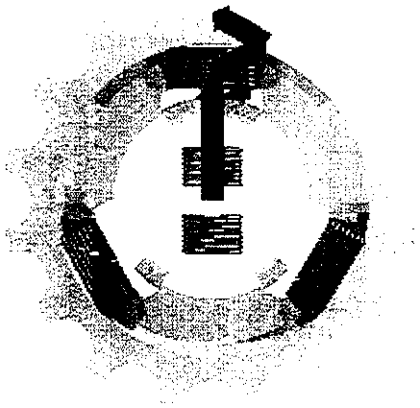
The rotor magnetic field may be produced by induction (in a "brushless" alternator), by permanent magnets (in very small machines), or by a rotor winding energized with direct current through slip rings and brushes. The rotor magnetic field may even be provided by stationary field winding, with moving poles in the rotor. Automotive alternators invariably use a rotor winding, which allows control of the alternator generated voltage by varying the current in the rotor field winding. Permanent magnet machines avoid the loss due to magnetizing current in the rotor, but are restricted in size, owing to the cost of the magnet material. Since the permanent magnet field is constant, the terminal voltage varies directly with the speed of the generator. Brushless AC generators are usually larger machines than those used in automotive applications.

A *rotating magnetic field* is a magnetic field which periodically changes direction. This is a key principle to the operation of *alternating-current motor*. In 1882, Nikola Tesla identified the concept of the rotating magnetic field. In 1885, Galileo Ferraris independently researched the concept. In 1888, Tesla gained U.S. Patent

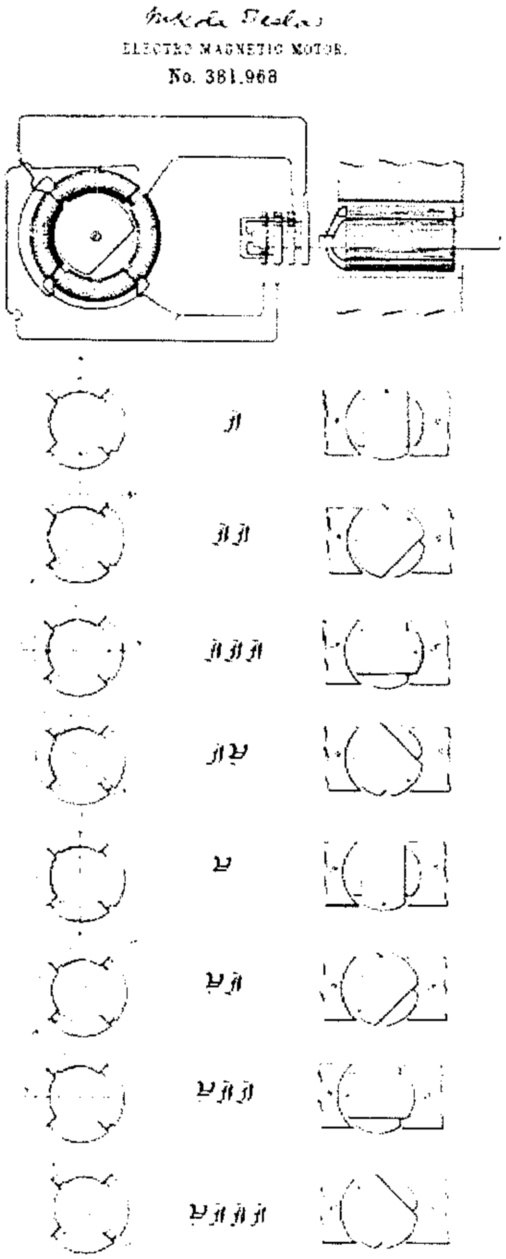
0,381,968_ for his work. Also in 1888, Ferraris published his research in a paper to the *Royal Academy of Sciences* in Turin.



Sine wave current in each of the coils produces sine varying magnetic field on the rotation axis. Magnetic fields add as vectors.



Vector sum of the magnetic field vectors of the stator coils produces a single rotating vector of resulting rotating magnetic field.



A diagram from a Tesla patent (U.S. Patent 381968) showing a revolving magnetic field created by two phase currents and two sets of field windings.

A symmetric rotating magnetic field can be produced with as little as three coils. Three coils will have to be driven by a symmetric 3-phase AC sine current system, thus each phase will be shifted 120 degrees in phase from the others. For the purpose of this example, magnetic field is taken to be the linear function of coil's current.

The result of adding three 120-degrees phased sine waves on the axis of the motor is a single rotating vector. The rotor (having a constant magnetic field driven by DC current or a permanent magnet) will attempt to take such position that N pole of the rotor is adjusted to S pole of the stator's magnetic field, and vice versa. This magneto-mechanical force will drive rotor to follow rotating magnetic field in a synchronous manner.

A permanent magnet in such a field will rotate so as to maintain its alignment with the external field. This effect was utilized in early alternating current electric motors. A rotating magnetic field can be constructed using two orthogonal coils with 90 degrees phase difference in their AC currents. However, in practice such a system would be supplied through a three-wire arrangement with unequal currents. This inequality would cause serious problems in standardization of the conductor size and in order to overcome it, three-phase systems are used where the three currents are equal in magnitude and have 120 degrees phase difference. Three similar coils having mutual geometrical angles of 120 degrees will create the rotating magnetic field in this case. The ability of the three phase system to create a rotating field utilized in electric motors is one of the main reasons why three phase systems dominated in the world electric power supply systems. Because magnets degrade with time, synchronous motors and induction motors use short-circuited rotors (instead of a magnet) following a rotating magnetic field of multicoiled stator. (Short circuited turns of rotor develop eddy currents in the rotating field of stator which (currents) in turn move the rotor by Lorentz force).

Note that the rotating magnetic field can actually be produced by two coils, with phases shifted 90 degrees. In case two phases of sine current are only available, four poles are commonly used.

Synchronous speeds

The output frequency of an alternator depends on the number of poles and the rotational speed. The speed corresponding to a particular frequency is called the *synchronous speed* for that frequency. This table gives some examples:

Poles	**RPM at 50Hz**	**RPM at 60Hz**
2	3000	3600
4	1500	1800
6	1000	1200
8	750	900
10	600	720
12	500	600
14	428.6	514.3
16	375	450
18	333.3	400
20	300	360

Key

- Rotational speeds are given in revolutions per minute (RPM)
- Frequencies are given in Hertz (Hz)

Automotive alternators

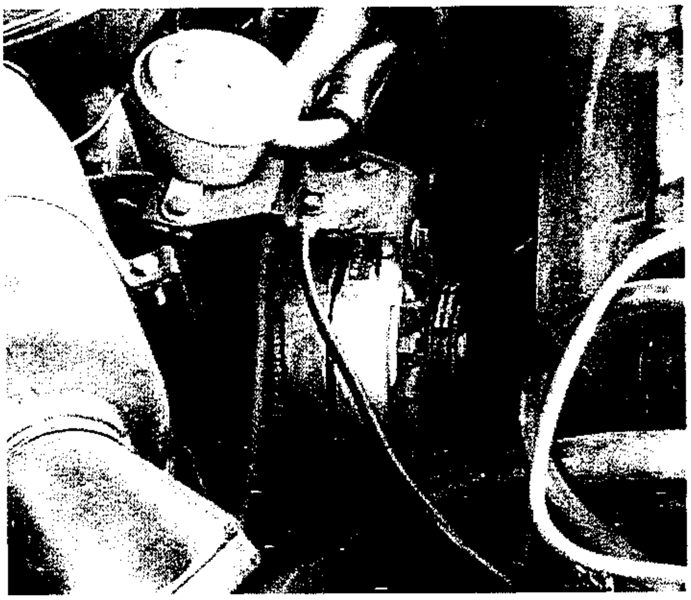
Alternators are used in automobiles to charge the battery and to power a car's electric system when its engine is running. Alternators have the great advantage over direct-current generators of not using a commutator, which makes them simpler, lighter, less costly, and more rugged than a DC generator. The stronger construction of automotive alternators allows them to use a smaller pulley so as to turn twice as fast as the engine, improving output when the engine is idling. The availability of low-cost solid-state diodes from about 1960 allowed car manufacturers to substitute alternators for DC generators. Automotive alternators use a set of rectifiers (diode bridge) to convert AC to DC. To provide direct current with low ripple, automotive alternators have a three-phase winding.

Typical passenger vehicle and light truck alternators use Lundell or claw-pole field construction, where the field north and south poles are all energized by a single winding, with the poles looking rather like fingers of two hands interlocked with each other. Larger vehicles may have salient-pole alternators similar to larger machines. The automotive alternator is usually belt driven at 2-3 times the engine crankshaft speed.

Modern automotive alternators have a voltage regulator built into them. The voltage regulator operates by modulating the small field current in order to produce a constant voltage at the stator output. The field current is much smaller than the output current of the alternator; for example, a 70-amp alternator may need only 2 amps of field current.

Efficiency of automotive alternators is limited by fan cooling loss, bearing loss, iron loss, copper loss, and the voltage drop in the diode bridges; at part load, efficiency is between 50-62% depending on the size of alternator, and varies with alternator speed. In comparison, the best permanent magnet generators, such as those used for bicycle lighting systems, achieve an efficiency of around only 60%.

The field windings are initially supplied via the ignition switch and charge warning light, which is why the light glows when the ignition is on but the engine is not running. Once the engine is running and the alternator is generating, a diode feeds the field current from the alternator main output, thus equalizing the voltage across the warning light which goes out.



A typical automotive alternator mounted in a spacious pickup truck engine bay.

The field windings are initially supplied via the ignition switch and charge warning light, which is why the light glows when the ignition is on but the engine is not running. Once the engine is running and the alternator is generating, a diode feeds the field current from the alternator main output, thus equalizing the voltage across the warning light which goes out. The wire supplying the field current is often referred to as the "exciter" wire. The drawback of this arrangement is that if the warning light fails or the "exciter" wire is disconnected, no priming current reaches the alternator field windings and so the alternator will not generate any power. However, some alternators will self-excite when the engine is reved to a certain speed. The driver may check for a faulty exciter-circuit by ensuring that the warning light is glowing with the engine stopped.

Very large automotive alternators used on buses, heavy equipments or emergency vehicles may produce 300 amperes. Very old automobiles with minimal lighting and electronic devices may have only a 30 ampere alternator. Typical passenger car and light truck alternators are rated around 70 amperes, though higher ratings are becoming more common. Very large automotive alternators may be water-cooled or oil-cooled.

Many alternator voltage regulators are today linked to the vehicle's on board computer system, and in recent years other factors including air temperature (gained from the mass air flow sensor in many cases) and engine load are considered in adjusting the battery charging voltage supplied by the alternator.

Marine alternators

Marine alternators as used in yachts are normally versions of automotive alternators, with appropriate adaptations to the salt-water environment. They may be 12 or 24 volt depending on the type of system installed. Larger marine diesels may have two or more alternators to cope with the heavy electrical demand of a modern yacht. On single alternator circuits the power is split between the engine starting battery and the domestic battery (or batteries) by use of a split-charge diode or a mechanical switch. Because the alternator only produces power when running, engine control panels are typically fed directly from the alternator by means of an auxiliary terminal. Other typical connections are for charge control circuits

Brushless Alternators

Terminology

The stationary part of a motor or alternator is called the stator and the rotating part is called the rotor. The coils of wire that are used to produce a magnetic field are called the field and the coils that produce the power are called the armature. The coils of wire that are used to create the field and the armature are sometimes referred to as the "windings".

Construction

A brushless alternator is composed of two alternators built end-to-end on one shaft. Smaller brushless alternators may look like one unit but the two parts are readily identifiable on the large versions. The larger of the two sections is the main alternator and the smaller one is the exciter. The exciter has stationary field coils and a rotating armature (power coils). The main alternator uses the opposite configuration with a rotating field and stationary armature.

Main Alternator

The main alternator has a rotating field as described above and a stationary armature (power generation windings). With the armature stationary, the high current output does not have to go through brushes and slip rings. Although the electrical design is not complex, it results in a much more reliable alternator because the only parts subject to wear are the bearings.

Control System

Varying the amount of current through the stationary exciter field coils controls the strength of the magnetic field in the exciter. This in turn controls the output from the exciter. The exciter output is fed into the rotating field of the main alternator to supply the magnetic field for it. The strength of the magnetic field in the main alternator then controls its output. The result of all this is that a small current, in the field of the exciter indirectly controls the output of the main alternator and none of it has to go through brushes and slip-rings.By varying excitation only reactive power is controlled , system voltage is improved .

AVR

AVR is an abbreviation for Automatic Voltage Regulator. An AVR serves the same function as the "voltage regulator" in an automobile or the "regulator" or "controller" in a home power system.

Hybrid automobiles

Hybrid automobiles replace the separate alternator and starter motor with a combined motor/generator that performs both functions, cranking the internal combustion engine when starting, providing additional mechanical power for accelerating, and charging a large storage battery when the vehicle is running at constant speed. These rotating machines have considerably more powerful electronic devices for their control than the simple automotive alternator described above.

CONSTRUCTION AND WORKING PRINCIPLE

The main components of the EGUS are turbine, compressor and alternator. The turbo charger is one of the main unit, which is already available. The turbine is designed with blades at an angle of 20*.this angle is more important in rotation of blades, while the exhaust is allowed into the turbine. In turbine usually two openings are provided, one for exhaust inlet and another one for exhaust outlet.

The exhaust gas with high temperature and pressure entered into the turbine exhaust inlet, the pressurized exhaust forced to rotate the turbine because the exhaust entering angle and turbine blade angles are opposite, so that the blade rotates.

The turbine blade shaft is coupled with the compressor and the shaft Is provided with movement, this movement is more needed during the rotation, the unit is coupled by means of single shaft and the compressor end is provided with impeller, and this is a centrifugal compressor. This compressor works on the principle of centrifugal force.

The turbine is made up of cast iron, because it has high strength to withstand high pressure and high temperature. So therefore the cast iron casting is used. The compressor is made up of aluminium, because of its valuable properties like thermal conductivity, light weight, flexibility etc.

The compressor end is coupled with alternator, this arrangement can be made by centering the axis. This can be made by bush and axis arrangement.

The alternator has two outputs, usually alternator rotated for its power production. D.C current is normally produced. This can be used further the D.C current is some what fluctuating, when it is needed with pure D.C, the filters are used. And to convert it into A.C rectifiers are used.

Advantages and Disadvantages

Advantages

- More specific power over naturally aspirated engine. This means a Turbocharged engine can achieve more power from same engine volume.
- Better thermal efficiency over both naturally aspirated and supercharged engine when under full load (*i.e.* on boost). This is because the excess exhaust Heat and pressure, which would normally be wasted, contributes some work required to compress the air.
- Weight/Packaging. Smaller and lighter than alternative forced induction systems and may be more easily fitted in an engine bay.

Fuel Economy. Although adding a turbocharger itself does not save fuel, it Will allow a vehicle to use a smaller engine while achieving power levels of Amuch larger engine, while attaining near normal fuel economy while off boost/cruising. This is because without boost, only the normal amount of fuel and air are combusted.

Disadvantages

- Lack of responsiveness if an incorrectly sized turbocharger is used. If a turbocharger that is too large is used it reduces throttle response as it builds up boost slowly. However, doing this may result in more *peak* power.
- Cost. Turbocharger parts are costly to add to naturally aspirated engines. Heavily modifying OEM turbocharger systems also require extensive upgrades that in most cases requires most (if not all) of the original

APPLICATIONS

- This mechanism can be mainly applianced in automobiles.
- It can be applianced in marine ships.
- It can be fitted to the chimneys.
- All the diesel engines can be employed with EGUS.
- This system is mainly with the idea of employing in long travel buses and the
- Power produced can be used to operate a mini water doctor.
- And so on.

LIST OF PARTS

S.NO	NAME OF THE PARTS	QTY
1.	TURBINE	1
2.	COMPRESSOR	1
3.	ALTERNATOR	1
4.	BUSH	1 SET
5.	STAND	1
6.	PIPES	2
7.	WIRES	1 ROLL

COST ESTIMATION

S.NO	NAME OF THE PARTS	COST
1.	TURBINE	1200
2.	COMPRESSOR	800
3.	ALTERNATOR	650
4.	BUSH	55
5.	STAND	400
6.	PIPES	150
7.	WIRES	100

TOTAL - Rs 3355 /-

Project planning

Project selection

Discussion with guide

Synopsis and drawing preparation

Analysis of temperature and pressures of diesel engine exhaust

Parts purchased

Fabrication work for stand

Assembling

Project report prepared

CONCLUSION

Thus our project had overcome all the disadvantage which we have mentioned. Mainly we concentrated on the power production and moreover there is no struggle for the engine in charging the battery and the efficiency of the engine is increased considerably. And the performance of the turbo charger also not affected so much. The application of the EGUS is wide and advantageous.

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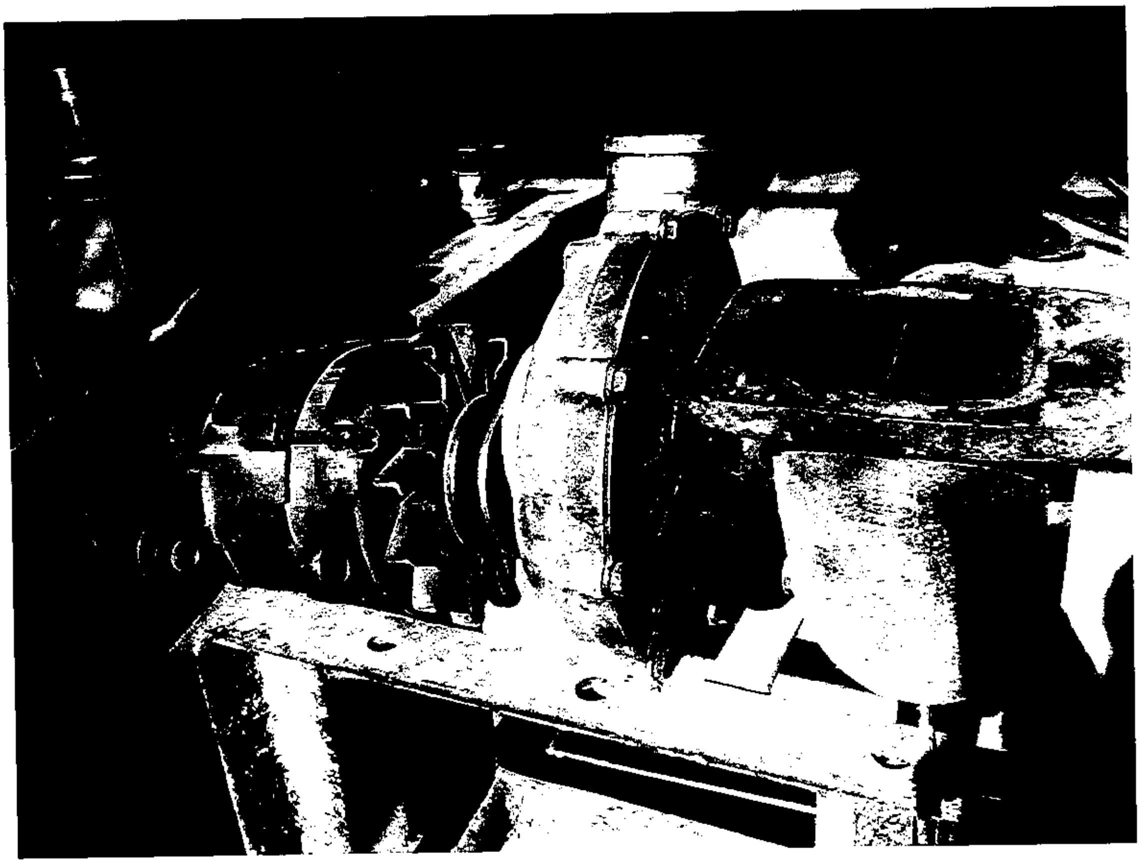

PHOTOGRAPHY

DESIGN & FABRICATION OF EXHAUST GAS UTILIZATION SYSTEM(EGUS)