TURBOCHARGING AS AN APPROACH TO BETTER ENGINE VOLUME UTILIZATION

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A thesis report submitted to the department of mechanical Engineering for the partial fulfillment of the Degree of Bachelor of Science in Mechanical Engineering

A thesis by
MD.MAHBUR RAHMAN

UGC & Govt. Approved
Sonargaon University [SU]
সোনারগাঁও ইউনিভার্সিটি (এসইউ)
WE WILL RISE UP WE WILL SHINE

DEPARTMENT OF MECHANICAL ENGINEERING

SONARGAON UNIVERSITY (SU)

January2020

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January2020

ACKNOWLEDGMENTS

This thesis would not have been possible without the support of many people .Many thanks to our adviser, Md. Hasibul hasan, who read me numberous revisions and helped make some sense of the confusion .Also thanks to our committee members, Md. Mahbur Rahman,S.M Shahin Reza, who offeed guidance and support. Thanks to the sonargaon university for awarding me a dissertation completion thesis, And finally, thanks to my all teacher and friends who endured this long process with us, always offering support and love.

ABSTRACT

energy coming from engine is divided as follows in figure 1 Turbocharging technology is increasing the power of engine Without increase of piston displacement. Therefore, this Technology has a Name general name “Downsizing” that is the most efficient way for Reduction of fuel consumption in internal combustion engines. The history of Turbocharging backs as long as the history of the firs automobile invention or evencreation of internal combustion engine block. The first prototype or the father of turbochargers was the first supercharged engine by Gotlieb Daimler[1]. Even today, turbocharger is classified in some sources as type of supercharger but I believe that even they have much in common they are totally different products. The working principle behind turbocharger is quite simple but naturally aspired engines .

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Chapter 1

INTRODUCTION

1.3 Background

A turbocharger contains a gas turbine coupled to a compressor. Both the turbine and the compressor are keyed to the same shaft. Whenever the turbine rotates, the compressor is operated.

Exhaust gases from the engine is allowed to fall on the gas turbine. The turbine rotates. This makes the compressor work.

The compressor compresses air (in case of petrol engines) or air-fuel mixture (in case of diesel engines) that is to be fed to the engine. This raises the pressure of air or air-fuel mixture above atmospheric pressure. Such an increase in pressure fuels the output power of the engine. It facilitates smooth operation of the engine in different ambient conditions.

1.2 purpose of using a turbocharger

1. It increases the output power produced.
2. It Turbocharger increases the volumetric efficiency of the engine.
3. the intake of fuel or air-fuel mixture.
4. It allows the engine to work smoothly in various ambient conditions.
5. The kinetic energy of exhaust gases is fed back to the engine and used beneficially.

CHAPTER 2

FRAME OR REFERENCE

2.1 Turbocharger :Operatong principle and component.

If you know how a jet engine works, you're halfway to understanding a car's turbocharger. A jet engine sucks in cold air at the front, squeezes it into a chamber where it burns with fuel, and then blasts hot air out of the back. As the hot air leaves, it roars past a turbine (a bit like a very compact metal windmill) that drives the compressor (air pump) at the front of the engine. This is the bit that pushes the air into the engine to make the fuel burn properly. The turbocharger on a car applies a very similar principle to a piston engine. It uses the exhaust gas to drive a turbine. This spins an air compressor that pushes extra air (and oxygen) into the cylinders, allowing them to burn more fuel each second. That's why a turbocharged car can produce more power (which is another way of saying "more energy per second"). A supercharger (or "mechanically driven supercharger" to give it its full name) is very similar to a turbocharger, but instead of being driven by exhaust gases using a turbine, it's powered from the car's spinning crankshaft. That's usually a disadvantage: where a turbocharger is powered by waste energy in the exhaust, a supercharger actually steals energy from the car's own power source (the crankshaft), which is generally unhelpf

Fig.Compressor and turbine

How does turbocharging work in practice? A turbocharger is effectively two little air fans (also called impellers or gas pumps) sitting on the same metal shaft so that both spin around together. One of these fans, called the turbine, sits in the exhaust stream from the cylinders. As the cylinders blow hot gas past the fan blades, they rotate and the shaft they're connected to (technically called the center hub rotating assembly or CHRA) rotates as well. The second fan is called the compressor and, since it's sitting on the same shaft as the turbine, it spins too. It's mounted inside the car's air intake so, as it spins, it draws air into the car and forces it into the cylinde

2.2Principle of compressor analysis.

If your engine is turbocharged, the turbo itself becomes the heart of the engine. All of the engine’s intake air enters through the compressor, while the turbine end sees all of the exhaust, and the engine’s lubricating oil runs through the bearing system. A properly performed turbocharger autopsy can reveal a great many things about the turbo system, the engine’s overall condition, its maintenance routine, and even issues regarding the quality of the turbo and supporting turbo system dynamics.

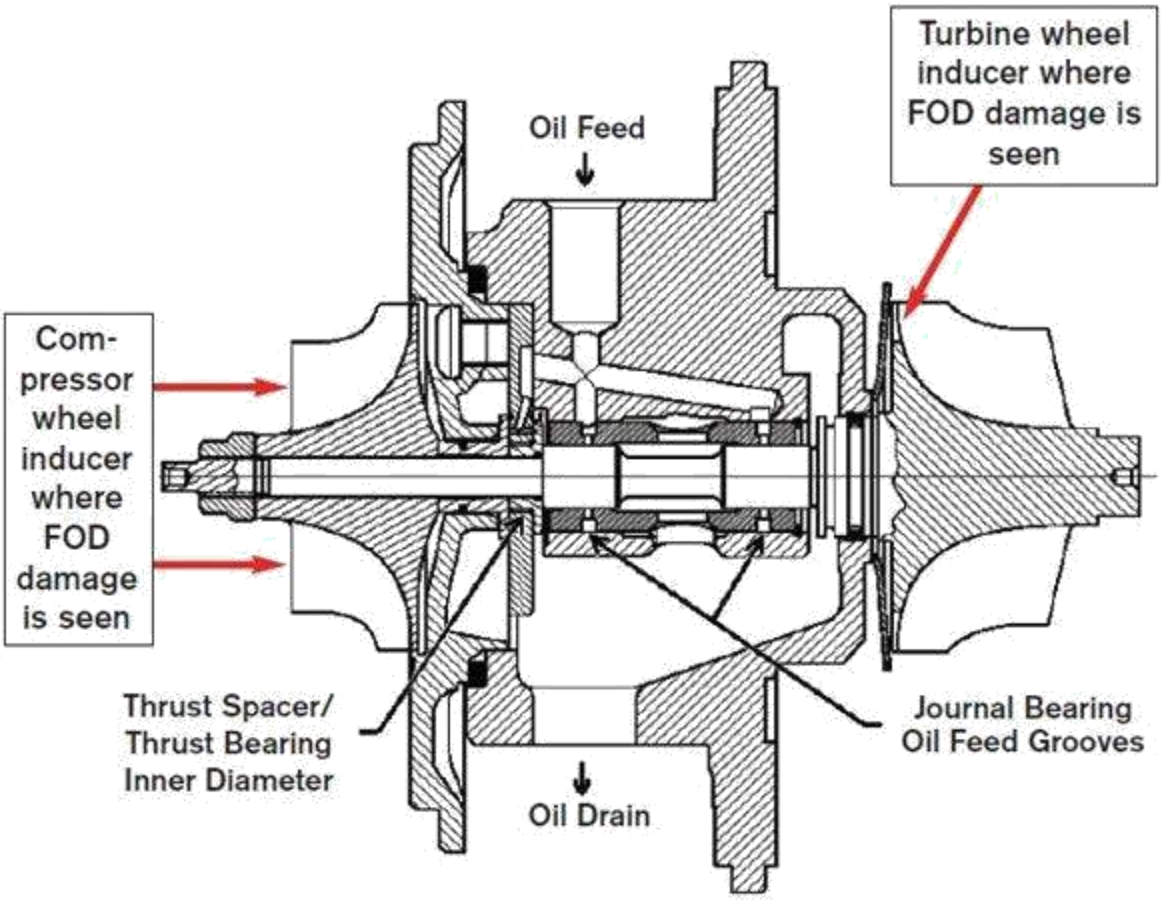


Fig.This illustration highlights the areas where foreign objects impact the compressor and turbine wheel inducers causing turbo failure. (Courtesy Honeywell Turbo Technologies)

Many who sell and service turbochargers cannot perform an accurate failure analysis. This includes most auto parts stores and heavy truck dealers. However, many specialist independent turbocharger distributors will employ at least one senior technician trained in failure analysis. To many people, the very concept of telling which part of the catastrophic failure was the cause is extremely puzzling. However, just as medical experts can perform an autopsy on a cadaver to determine cause of death, a trained technician can analyze the turbocharger’s components and discover the likely cause of failure. In this way, failure analysis can be invaluable to help correct the conditions and therefore avoid a repeat failure.

While there are many types of turbocharger failures and reasons for these failures, the law of 80/20 applies as it does to most statistical situations. About 20 percent of the failure reasons cause 80 percent or more of the failures that occur. While there are certainly some very confusing failures that can be puzzling for even the most experienced turbo technician, most reasons for failure can be conclusively determined so that corrective measures can be taken.

This chapter is dedicated to the diagnosis of turbocharger failure, and more importantly to the interpretation of these failures, and how to apply the findings and rectify the situation. While most commercial failure analysis reference manuals apply themselves to commercial diesel applications, this section uniquely takes performance applications into account as well, forming a reference for both the performance enthusiast and turbo service industry professional.

2.3 Understanding Turbocharger Failure Analysis

The key to understanding turbocharger failures and making accurate diagnoses involves understanding basic engine operation theory, turbocharger operation theory (including how the components interact with each other and to their environment), and a firm grounding in common causes of what can and does fail turbochargers under various operating conditions.

Similar to a medical diagnosis, the turbocharger has two primary ways to potentially determine its cause for failure. In medicine, a practitioner attempts to use observed symptoms to look for a specific bug that can be isolated. Once the problem is found, the correct remedy can be applied. When a condition exists in a patient where no specific bug can be found, diagnosis is done by exclusion. In other words, you use the process of elimination. You eliminate everything that did not cause the failure, until you’re left with what did.

Turbochargers can be similarly treated. The typical way to perform a turbo failure analysis is to begin by examining the complete unit before it’s disassembled to look for obvious signs of trouble, and then systematically analyze the components as it’s disassembled. Frequently, an obvious series of clues will reveal themselves and certain telltale signs will be evident, similar to isolating a bug. But in a fewer cases, there may not be obvious signs of exactly what happened. Therefore certain modes of failure must be assumed and the rest of the parts reviewed to either confirm or deny each assumption, until one can be selected. Several failure causes could be assumed in this manner until the most logical reason is determined. For this reason, all of the information surrounding the application, use of the engine, the type of turbo system, and a description of what was happening at the time of failure are all of great importance in helping to determine the probable cause.

Fig.Faillur turbine

1) Foreign object damage
2) Contaminated lube oil

3) Lack of lubrication (including coking and sludge buildup)

4) High exhaust temperatures

While these four reasons account for most all failures, there are many more reasons to discuss. It’s possible to make the mistake of looking at one failed component and draw an early conclusion incorrectly. This often happens when a failure begins in one place, moves on to the next part and the next, until there is significant damage throughout the turbocharger. Then determining which came first can be the difference between a correct and an incorrect determination of cause. The objective for this chapter is to help teach the fundamental approach to correctly determine the cause for failure so that corrective measures can be taken to avoid unnecessary repeats. While there will undoubtedly be failure modes not addressed in this chapter, we’ll get to upwards of 90 percent, making this as comprehensive a guide as presently exists on the open market.

2.4 Beginning the Analysis: The External Examination and Notation

Once the turbocharger is removed or received from a customer, take a careful look at it from all angles. Don’t be too quick to disassemble the turbocharger before you have reviewed all of the external clues that may exist. Look to see if there are any obvious contaminants or obstructions in the oil inlet. Has either end housing been saturated in oil, showing an obvious excess of engine oil leakage? Use a probe such as a small screwdriver with a clean white rag to wipe into the oil inlet and oil drain cavities to inspect for any obvious dirt or abrasives present.

Does the turbine wheel spin freely, or is it locked up or broken? Has either the compressor wheel or turbine wheel broken apart or broken loose from its shaft connection? Are all the parts there and intact, but the compressor wheel nut loose and backed off? If the turbine wheel and shaft assembly spin freely, and if thrusting each wheel back and forth do not produce excessive end play (typically 0.002–0.004 inch) then the turbo may or may not be failed. If the cause for removal was due to an oil leak, remember that most turbos do not have positive oil seals, but rather use dynamic seal rings that seal the pressurized boost and turbine gases from entering the engine’s crankcase. If either end housing is wet with oil, or the rotor spins freely and appears to have proper end thrust signifying an intact bearing system, the turbo may not be failed at all. Refer to the troubleshooting guide at the end of this chapter where it discusses excessive crankcase pressure and its causes. Treat the turbo carefully as it may be capable of returning to service. Turbo removal due to oil leakage is very common, but oil leakage is very often a symptom, not the cause.

Disassembly

Begin by removing both end housings. This can be done by removing either the bolts that tighten the clamp tabs that hold the turbo together, or by loosening the V-band clamps. Once the housings are removed, the remaining assembly is called the CHRA or cartridge. If FOD (foreign object damage) is the cause of failure, it will be obvious at this point. Foreign object damage is a conclusive diagnosis at this point and is perhaps the easiest and quickest to determine. If that’s the case, no further disassembly is really necessary at this point. However, look at the turbine side carefully if this is the side where damage is seen. There are failure modes that can appear similar in nature to FOD on the turbine end inducer. Become familiar with the characteristic differences between an impact trauma and over speed or over temp failures to turbine wheels. This will be discussed in greater detail.

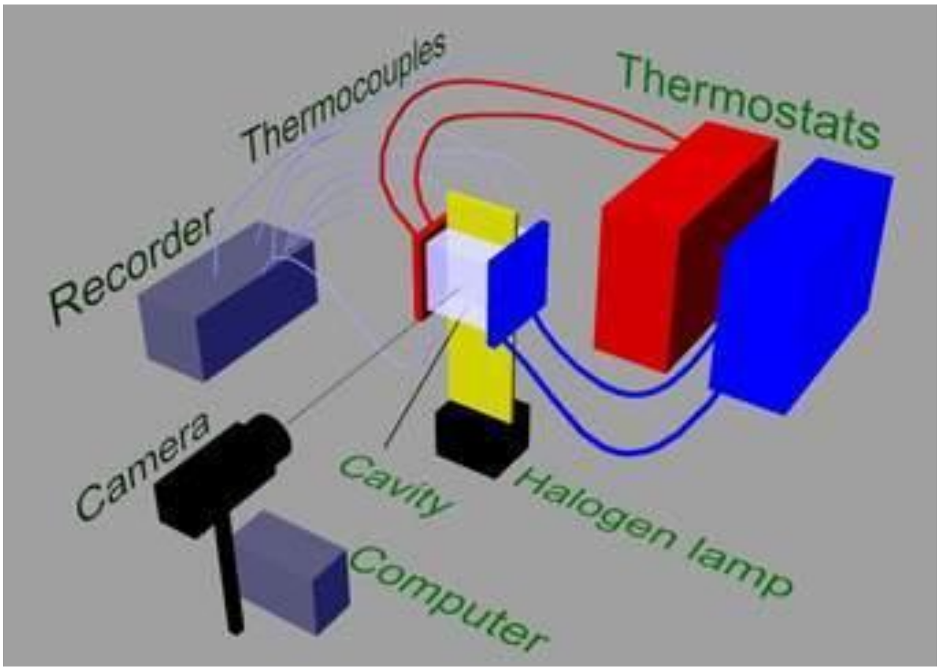


Fig.Note the even damage around the inducer area and the metal wiped and shredded from the repeated impact of a foreign object. (Courtesy Honeywell Turbo Technologies)

Compressor End

If the compressor wheel inducer shows damage, the object may or may not be found in the intake system. If the engine is equipped with a charge-air aftercooler, the foreign object, or parts of it, will most likely be located in the cooler. Many an aftercooler has saved an engine from critical damage by acting as a catch net for foreign objects that got ingested into a turbo's compressor. The small tubes and turbulators present in most aftercoolers will act as a filter of small particles, preventing them from entering the engine to cause even more damage. For this reason, it's arguably not necessary to remove the cooler at all. However, it is advisable to remove the cooler to attempt a reverse flush to dislodge any remaining parts that may be found. This not only remove

- A threaded fastener, nut or bolt, that was inadvertently dropped.
- A mechanic’s shop rag stuffed into the air intake to keep it clean.
- A wrench or other tool left in the intake system.
- Parts of a failed air cleaner (a filter that is too small or extremely dirty may cause this).
- Parts of a previously failed compressor wheel due to a fatigue or wheel burst that were not adequately cleaned out during service.
- Rock(s) and/or other airborne abrasives allowed to enter due to a missing or failed air filter that distorted thus allowing unfiltered air to enter the intake air stream.

Fig.Faillure compressor

In rare cases, and on non-aftercooled engines, a small object like a 1/4-20 nut can be ingested through the compressor, parts of which pass through the engine and impact the turbine wheel as well, but this is rare. In such cases, it’s most probable that some degree of engine damage will also have occurred, the least of which would be a bent valve. Foreign objects will tend to cause somewhat even damage around the wheel and metal will shows signs of impact and tears or obvious lines from the rubbing that took place.

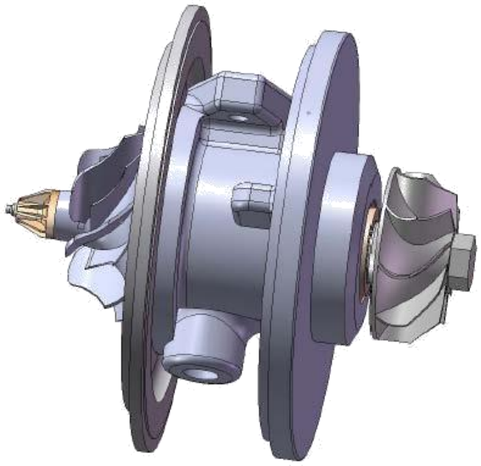
Chapter 3

3.1 Experiment setup:

The way people travel is about to change. Since the early beginning of the twentieth century, to nowadays, the automobile has become the most prolific transportation form. The propulsion is done by an internal combustion engine which convert thermal energy, by burning diesel or petrol, into mechanical energy. However, due to several reasons such as economical, environmental among others, there is a tendency to replace the internal combustion engine by electrically powered motors. Electrical motors have many interesting properties. One of them is its efficiency. An electric motor can easily reach an efficiency above 80% against the average 40% for internal combustion engines. Nevertheless, at the present, there are serious limitations regarding electric engine cars proliferation. Their acquisition cost and autonomy are still two major restrictions. Even if the former aspect can be attenuated by proper tax reduction policies, the later is strongly dependent of technical issues, i.e. the development of faster charging methods, longer life batteries, etc.

In order to circumvent some of this operational aspects, hybrid vehicles, that combining thermic engines with electric propulsion, begin to be available in the market. Currently some of the major car manufacturers are selling hybrid cars, such as: Toyota Prius, Honda Jazz, Citroën DS5, Peugeot 3008 Hybrid, just to mention a few.

An important thing to note is that, at least for now, the internal combustion engine will not be completely overhauled by its electric counterpart. They will coexist until all the major electric car issues are completely solved. Since the Diesel engine is more efficient than the Petrol one, the former is a stronger candidate to be incorporated into hybrid autos. However Diesel motors requires larger air mass than their counterparts for the same engine cylinder volume. In order to do that, modern Diesel motors are coupled to a rotating machine that compress the engine inlet air inside the cylinders. This rotating machine, usually a turbocharger or supercharger, is colloquially known as Turbo.



3.1 TURBOCHARGING OVERVIEW

A turbocharger is nothing more than an air compressor driven by the kinetic energy of exhaust gases. His internal structure is composed by two wheels, the compressor and the outlet turbine. Both are mechanically coupled via a shaft. Figure 1 represent a turbocharger cartridge, showing two wheels: the compressor impeller (left side) and the turbine (right side). Exhaust gases kinetic energy are used to spin the outlet turbine and, due to the mechanical coupling between the two wheels, the centrifugal compressor also turns with the same rotation speed.

Fig. 1. Picture of a turbocharger cartridge. The left wheel concerns the impeller and the right one is the turbine.

The main turbocharger objective is to improve the engine volumetric efficiency. This is done by increasing the intake air density. During his rotation, the centrifugal compressor absorb air at ambient pressure (approximately 100 kPa) and increases it pressure, around 140 to 160 kPa, before it enters the intake manifold. With this strategy, at each intake stroke, larger air mass enters into the cylinders. This air mass increase improves the vehicle performance in several ways: torque increase and fuel efficiency are two of them.

Due to the different engine regimes, and since there is a indirect mechanical link between the crankshaft and turbo rotor angular velocity, modern turbochargers are internally equipped with strategies in order to regulate inlet air pressure for distinct engine rotations. This kind of machines are designated by variable-geometry turbochargers.

Among other approaches, a variable-geometry turbocharger possesses a set of vanes in the exhaust housing in order to maintain a constant gas velocity across the turbine. Figure 2 presents the nozzle image of the turbocharger used in this setup. An external ring mechanically synchronises all the internal vanes

and his angular position are controlled externally by a lever.

Fig. 2. Internal aspect of the “hot” part of a GT1749 variable-geometry turbocharger. Each of the eleven small levers controls a vane.

Usually this lever position is changed by a pneumatic actuator. The pneumatic signal used to control this actuator is modulated by the Engine Electronic Unit (ECU). By gathering the information collected by an array of sensors, for example the mass air flow sensor (MAF) and crankshaft sensor just to name a few, the ECU is able to compute the “ideal” turbocharger rotation.

Sometimes other components are added to improve the turbocharger efficiency. One of them is the intercooler. When air is compressed, it heats and expands. Hence a part of the pressure increase results from heating the air before it goes into the engine. This pressure increase is not accompanied by increased air mass. The inter-cooler objective is to transform hot air at a given pressure to cold air at the same pressure since cold air is denser than hot one.

Computing the exact turbocharger size for a particular engine is a multi-criteria problem. There is always a tradeoff between engine power, fuel consumption and political environmental impositions. This problem is way outside the scope of this paper. Indeed, the major motivation of this work is to test a particular control strategy for angular vanes regulation on a variablegeometry turbocharger. This system has multiple operating points with different dynamics including many non-linearities. Due to usual simplifications used in the models, for this work one has decided to build a control rig having, in it’s core, a true comercial turbocharger: the Garrett’s GT1749v turbocharger scavenged from a Renault Laguna 1.9 DCI (120 hp). The system, that will be discussed in the following sections, will be used as a test bench for several different control algorithms.

3.2 THE TURBOCHARGER RIG

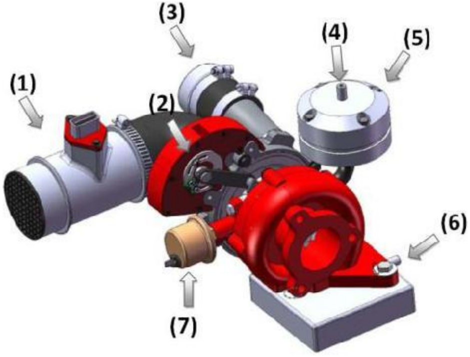
In order to operate, a turbocharger must be coupled to an internal combustion engine. However, for experimental purposes, acquiring and running an engine inside a laboratory has severs drawbacks. First of all economical since it is necessary to buy and maintain the engine and modify a room with proper soundproofing, ventilation, etc. So one has devised a way to replace a true engine by a mathematical model while maintaining a real turbocharger. A 3D model of the system rig initially envisioned is illustrated in figure 3. The exhaust gases that make the turbocharger spin are replaced by compressed air. In the referred figure the inlet pointed by number (6) concerns the turbine compressed air intake. The kinetic energy stored in compressed air is used to turn the turbine. Upstream the compressor input port a mass air flow (MAF) sensor is installed and the air pressure exiting port (3) is measured by a sensor.

Fig. 3. The model of the turbocharger rig. (1) MAF sensor, (2) stepper motor, (3) compressor outlet, (4) compressing air intake, (5) diaphragm pump, (6) compressor air turbine inlet, (7) Oil pressure sensor.

Other original turbocharger modification was the replacement of the pneumatic actuator by a stepper motor. The electronic control of a stepper motor is simpler and more precise than the pneumatic counterpart. In this setup a “tin can” stepper motor with 7.5oof resolution was used. The motor axis was mechanically linked to the vanes control lever.

One of the major challenges was to devise a way to maintain oil under pressure inside the turbocharger gasket. The reason of this requirement is due to the turbo mechanical conception: the rotor friction is reduced, not by ball bearings, but by journal bearings. This kind of bearing need constant oil under pressure to ensure proper operation. In order to solve this problem, and to avoid a electrical or mechanical pump, a diaphragm type pump was designed. In this case the oil does not flow inside the turbocharger. It remains static at a pressure regulated by the compressed air pressure applied to the input port (4).

Since a fail in the bearing can rapidly cause rotor wear a oil pressure sender (7), in this case the FAE14540, was fitted into the oil circuit. Oil pressure needs to be between 275 and 310 kPa at the maximum engine



3.3 WORKPIECES

The aim of this section is to document the process used to build the custom made parts that will be assembled into the turbocharger. First of all, all the workpieces were tailored from compact aluminium blocks using a computer numerical control machine (CNC). The 3D models, drawn in Solid Works R , were used to derive the CAM files which, in turn, control the CNC milling cutters. The photographs presented in Figure 4 illustrate the milling process. In the left a picture of the CNC machine used in the manufacturing process: a Dekel Maho DMC 63V. In the right a detail of an almost finished piece (in this case one of the stepper motor fittings).

Fig. 4. The milling process: at left the CNC machine

More than a dozen parts were designed and built. Some of them using a machine-tool. The rest using the computer numerical control machine mentioned above.

Figures 5 and 6 illustrates some of the more challenging parts built. The first of them represent the stepper motor housing. This part will be attached to the turbocharger “cold” side and is composed by three pieces. The ring represented in the assembly top will be used to define the stepper zero position. This position information will be sent to the data acquisition card by a Hall switch mounted over this ring.

Fig. 5. The stepper motor housing assembly. In the left an exploded view of the 3D model and, at right, the referred part already fitted in the turbocharger.

Figure 6 show a seccional cut of the oil pump devised. Compressed air enters the upper chamber and transmit pressure to the oil chamber through a diaphragm.

The final system, completely assembled, is represented in Figure 7.

Fig. 6. Seccional view of the oil pump. (1) compressed air chamber, (2) diaphragm, (3) oil chamber.

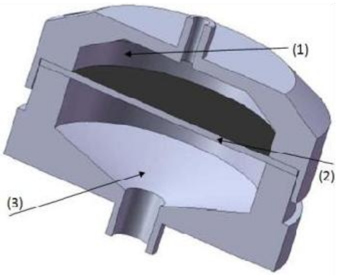
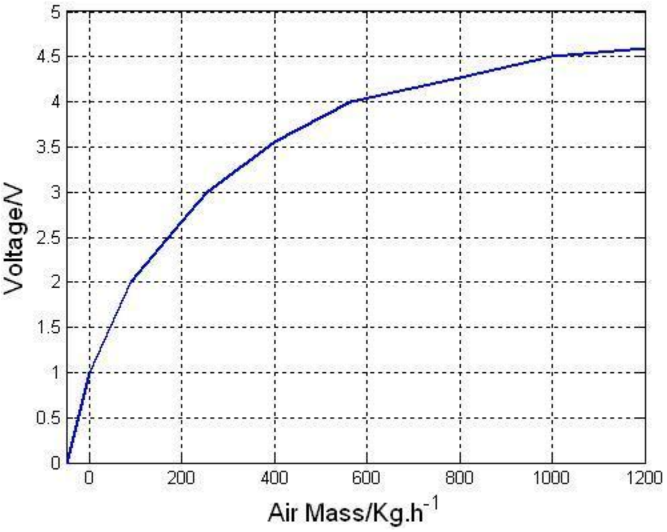


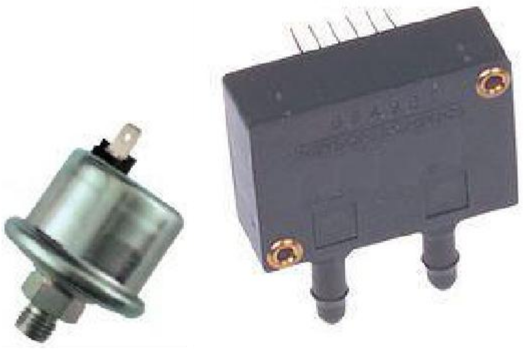
Fig. 7. The turbocharger completely assembled.

The following section describes the main characteristics of some of the used sensors. More specifically the mass air flow sensor, the oil and air pressure sensors.



3.4 SENSORS AND CALIBRATION FUNCTIONS

Correct engine operation lays on information provided by an array of multiple sensors scattered throughout the automobile. In the devised setup some of the sensors are real and others are emulated by software (during engine operation). In this work the following variables are effectively measured: • Turbocharger rotation speed; • Intake air temperature; • Turbocharger air mass flow; • Outlet air pressure; • Oil pressure. The turbocharger rotor speed is measured using a Hall sensor switch mounted near the turbine center where a magnet was placed. The information regarding intake air temperature is provided by a 10K NTC thermistor. The air mass flow measure is taken care by a Bosch 0 281 002 421 MAF, the outlet air pressure is measured by Honeywell’s AWM330V and the oil pressure by a FAE14540. These last three sensors operation will be described below in greater detail.



3.5 The Mass Air Flow Sensor

In electronic fuel injection engines, the vehicle ECU depends on the information provided by the mass air flow sensor to compute the exact amount of fuel to be delivered to the engine cylinders. In the present setup the ais mass flow is sensed by Bosch’s 0 281

002 421 air mass meter. This sensor, based on hotfilm technology, provides a voltage proportional to the air mass flow. The sensor external aspect is illustrated in Figure 8 and his calibration curve is presented in Figure 9.

Fig. 8. External aspect of Bosch’s hot-film mass meter.

Fig. 9. Calibration curve for Bosch’s hot-film mass meter.

It was possible to approximate the calibration curve, with a relative error of less than 3% using the following function: $v(\varphi) = v1(\varphi) - v2(\varphi) + 2.033$ (1) where φ refers to the air mass flow in $kg \cdot h^{-1}$, v a voltage in Volts and, $v1(\varphi) = 0.475 \cdot \log(0.036\varphi + 3.19)$ (2)

and

$v2(\varphi) = 1.43 \cdot \exp(0.262 - 0.00342\varphi)$ (3)

3.6 The Oil Pressure Sensor

The oil pressure inside the turbo cartridge is measured using the FAE 14540 sensor. This is a resistive type sensor capable to measure pressures in the rage from 0 to 1 GPa. Figure 10 illustrate the external sensor aspect.

Since the sensor is specially designed for automotive application the fitting is done through a 12 mm/ 1.5 mm screw and one of the resistor poles is the sensor metallic housing.

Fig. 10. External aspect of the FAE14540 oil pressure sensor. From the data provided by the manufacturer it is possible to see that the calibration curve standard deviation was too high, i.e. there are major differences in the sensor electric characteristics after the manufacturing process. For this reason a new calibration curve was derived as shown in Figure 11.

Fig. 11. FAE14540 calibration curve.

The relationship between the sensor output resistance R and oil input pressure P, expressed in kPa, can be modelled by the following first order parametric equation: $R(P) = -0.313421 \cdot P + 265.1024$ (4)

From the measured data, and taking into consideration that the oil pressure will be between 150 and 250 kPa, the modelling error is lower than 5%.

5.3 The Air Pressure Sensor

The air pressure, at the turbocharger outlet, will also be measured. In this case the HCX005 from Sensor Technics is used. This sensor already integrates the signal conditioning stage and has the appearance illustrated in figure 12.

After proper polarization, the relationship between air pressure and output voltage is described by the following equation:

$v(P) =$

4 500

$P + 0.5$ (5)

where v is the sensor output voltage expressed in Volt and P is the air pressure in kPa.

Fig. 12. External appearance of the HCX005 air pressure sensor.

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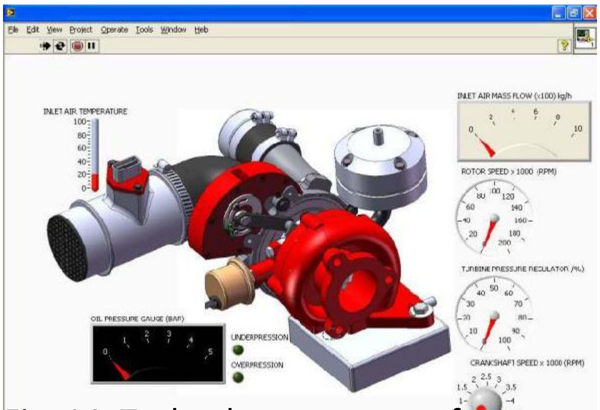

Fig. 14. Turbocharger system front pannel developed in Lab view.

Besides this graphical user interface, the software must also emulate the engine operation and do all the math regarding the controller.

Chapter 4

Result and Discussion

4.0 Result and Discussion

today. “Decreasing the waste produc esources, in general, become increase of efficiency” turned up to be the main slogan of any industry and this plays key role behind the development of any company, plant

and enterprise. The like scene is in automobile industry and what is particularly important is in powertrain manufacturing. There are a lot advanced technologies in powertrain manufacturing today andTurbocharging is not an exception. Moreover, turbo technologies in powertrain are now regarded as the most effective way of engine downsizing. A Turbocharger is a device that increases the power output of engine by allowing more air per intake to combustion chamber of powertrain. A turbocharger is more efficient and eco-friendly technology than compared to naturally charged atmospheric pressure engines as turbines forces more air and proportionally more fuel. The main purpose of

	Volume (cc)	Bore and strock (MM)	Compression
2.0FST 1984	82.5*92.8	11.5:1	
2.0 FST turbo 1984	82.5*92.8	10.5:1	

As one can see from table 1 that both engines have the swept volume and use the same bore and stroke. They also have much in common as high pressure direct fuel injection (“FSI”), the same number of cylinders and so on.

Moreover, the naturally aspirated engine uses a compression one ratio higher than the turbo engine and the turbo engine develops 34 per cent more peak power than the naturally aspirated design. So far, – apart from the very high compression ratio of the turbo engine – all is as it has been for more than two decades of turbocharging Therefore, when driving the turbo car, the engine requires far fewer gear downchanges (either manually or via an auto gearbox) and so stays at lower engine revs more often. Despite having a lot more power at the top end, for economy it is the power available at the bottom-end of the rev range that really matters – and the Turbo 2.0 FSI has it in spades. To go further, in order to prove that the turbo is more efficient than compared to its naturally aspired opponent Skoda took the same 2 liter engines and compared it with 1.8 l turbocharged engine the figures again amazed. 1.8 liter turbo TSI, that is exactly what Volkswagen/Skoda have done.

	VOLUME(CC)	BORE AND STROCK	COMPRESSION RATIO	POWER (KW AT RPM)	TORQUE (Nm AT RPM)
2.O FSI	1984	82.5*92.8(mm)	11.5:1	110 AT 6000	200 Nm AT 3500
2.O FSI TURBO	1984	82.5*92.8(mm	10.5:1	147 AT 5100-6000	280 Nm AT 1800-5000
1.8 TSI TURBO	1798	82.5*84.2(mm)	9.6:1	118 KW AT 5000-6200	250 Nm AT 1500-4200

The table 4. Comparison of engine with 1.8 TSI Turbo engine

So, even though it’s a smaller engine, the turbo 1.8 easily outperforms the naturally aspirated 2 liter at the critical-for-economy bottom end of the rev range. And of course, it does even better on fuel economy – 7.7 liters/100km and CO2 emissions of 184 grams/kilometer. In fact, in terms of power production, you can see that the engine could probably be smaller still – say, a 1.5-liter turbo. However, that is more important for today is the question of fuel efficiency and here turbocharger outperforms the naturally aspired engines. In the Australian government test cycle, the naturally aspirated Skoda 2.0 FSI has a fuel consumption of 8.5 liters/100km while the turbo 2.0 FSI has a tested economy of 8.1 liters/100km! That is right; the car with more power is also more economical! The CO2 emissions are also as you would by now expect – 203 grams/kilometer for the naturally aspirated engine and 193 for the turbo.*6+

Ever more stringent emissions regulations across the world are challenging automotive manufacturers to create engines that meet the needs of the environment whilst still satisfying the demands of consumers for vehicles that are fun to drive. Turbocharger producing companies are working closely with its customers on partnership programs that focus on engine downsizing, emissions control and fuel economy – but not at the expense of drivability. These goals are complementary and bring together the performance qualities to make an automobile safe, clean and fun to drive. Honeywell turbochargers deliver significant benefits to end users: Safer

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Conclusions

A turbocharger remedies this problem by compressing the air back to sea-level pressures (turbo-normalizing), or even much higher (turbo-charging), in order to produce rated power at high altitude. Since the size of the turbocharger is chosen to produce a given amount of pressure at high altitude, the turbocharger is oversized for low altitude. The speed of the turbocharger is controlled by a wastegate. Early systems used a fixed wastegate, resulting in a turbocharger that functioned much like a supercharger. Later systems utilized an adjustable wastegate, controlled either manually by the pilot or by an automatic hydraulic or electric system. When the aircraft is at low altitude the wastegate is usually fully open, venting all the exhaust gases overboard. As the aircraft climbs and the air density drops, the wastegate must continuously close in small increments to maintain full power. The altitude at which the wastegate fully closes and the engine still produces full power is the *critical altitude.* When the aircraft climbs above the critical altitude, engine power output decreases as altitude increases, just as it would in a naturally aspirated engine.

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