DESIGN OF A BLOW OFF VALVE FOR TURBOCHARGED ENGINE APPLICATIONS

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ABSTRACT

On a turbo engine, the Blow of Valve (BOV) is used to relieve the pressure from the turbo output when the throttle is closed. Without the BOV, when the throttle is closed the turbo is suddenly trying to pump air against a closed throttle plate. This creates pressure spike in the turbo output hose and will send back the pressure to the turbine and can damage the turbo engine. When the throttle is opened again, the turbo has to spin up again, creating turbo lag. So, the present of the BOV will opened when the throttle is closed and pressurized the pressure spike to the air to avoid those phenomena. So, good flow of the air inside the BOV is important, the air will smoothly pressurized to the atmosphere if there is no back pressure inside the system. Computer aided design (CAD) and computational fluid dynamic (CFD) software were used as a tool for the design. This design is the improvement of the aftermarket design. The piston surface, size of vent, inlet ports, outlet ports, and also spring plays the role in the BOV. The design analyzed using CFD so can see the flow trajectories of the air inside the BOV.

ABSTRAK

Di dalam sistem turbo, Blow off Valve (BOV) digunakan untuk melepaskan tekanan udara yang terkandung di dalam sistem apabila pendikit tertutup. Tanpa BOV, tekanan udara tadi akan tetap memberi tekanan untuk keluar dari sistem. Ini akan menyebabkan terjadinye tekanan didalam sistem bertambah dan tekanan udara ini akan mengalir semula ke turbin dan akan menyebabkan kerosakan berlaku pada enjin. Apabila pendikit terbuka semula, turbin akan berputar semula dan ini akan menyebabkan phenomena "turbo lag". Dengan kehadiran BOV, tekanan udara didalam sistem tadi boleh dilepaskan ke udara ketika pendikit tertutup. Jadi, pengaliran udara adalah sangat penting untuk memastikan supaya tiada tekanan udara yang mengalir semula ke dalam sistem. Computer aided design (CAD) dan computational fluid dynamic (CFD) adalah perisian yang digunakan didalam penyelidikan ini. Dengan penambahbaikan daripada model-model BOV yang telah sedia ada di pasaran, maka terciptalah model ini. Bahagian seperti permukaan piston, saiz alur didalam BOV, tempat masuknya udara kedalam BOV, tempat keluarnya udara dari dalam BOV dan juga spring masing-masing memainkan peranan didalam sesuatu BOV. Untuk melihat pengaliran udara di dalam BOV, CFD digunakan.

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CHAPTER 1

INTRODUCTION

1.1 Background

On a turbo engine, the Blow of Valve (BOV) is used to relieve the pressure from the turbo output when the throttle is closed. These valves are only used on engines with the blow-through turbo setup.

While in boost, the valve remains closed and the turbo pumps air into the engine normally. Without the BOV, when the throttle is closed the turbo is suddenly trying to pump air against a closed throttle plate. This creates a pressure spike in the turbo output hose and sends a pressure "wave" crashing back and forth between the throttle plate and the turbo compressor blades. The pressure spike quickly slows down the turbo and the pressure wave can actually damage the turbo.

When the throttle is opened again, the turbo has to spin up again, creating turbo lag. If a BOV is present, the BOV will open as soon as the throttle is closed, releasing the pressure spike into the air box and avoiding the pressure wave phenomena.

This study was carried out to get the comparison between the numbers of blow off valve type available in the market for the suitable performance for the turbocharged engine. It will include project definition, the engineering development, concept/idea generation and come out with own blow off valve design.

1.2 Problem Statement

When people talk about race cars or high-performance sports cars, the topic of turbochargers usually comes up. A turbo can significantly boost an engine's horsepower without significantly increasing its weight. But there is some problem will occur.

When the throttle body closes - the stream of pressurized air created by the turbocharger is now cut off from the inlet manifold. The only way it can escape is back up the intake stream, surging into the turbo compressor. This reversal of intake charge pulse can put additional strain on the turbo components, as well as reducing the compressor wheel's rotational velocity. This means that the turbo will take longer to spool up when the throttle is opened again.

So, there is a valve placed before the throttle body cures this problem by allowing the pressurized charge to escape the intake system, keeping the compressor spinning and reducing turbo lag. This creates a very distinctive sound desired by many who own turbocharged sports cars. Some blow off valves is sold with trumpet shaped exits that amplify the "Psshhhh" sound; these designs are normally marketed towards the keen boy racer. So there are many types of blow off valve available in the market.

Therefore the need to study the concept, designs and components of the pressurize release system present in the turbocharged engine is significant. Study also will be done base on reverse engineering on a number of a different blow off valve type available in the market. The CAD modeling and Flow Simulation also will be done to complete this study.

1.3 Objective Of The Project

The objectives of the project are:

i. Study the existing blow off valve designs and components.
ii. Design a pressure relief valve for turbocharged engine applications.

1.4 Scope Of Project

The scopes of this project include three main parts:

i. Study the concepts, designs and component of the pressure release system present in the turbocharged engines.
ii. Reverse engineering on the number of different blow off valve type available in the market.
iii. CAD modeling and Flow simulation using SolidWorks 2005 and COSMOS FloWorks 2005/PE

CHAPTER 2

LITERATURE REVIEW

2.1 Turbocharger

A turbocharger is a dynamic compressor, in which air or gas is compressed by the mechanical action of impellers, vane rotors which are spun using the kinetic movement of air, imparting velocity and pressure to the flowing medium. A turbocharger is basically a device that uses exhaust gasses produced by the engine to blow air back into the engine as shown in Figure 2.1. The additional air is supplemented with fuel by the ECU (engine control unit). This causes the engine to produce much more power since it is being supplied with more air and fuel than it possibly could without it. With this setup, the most air pressure that can enter the combustion chamber of the engine is a bit less than the current atmospheric pressure. With the turbo, air is being blown into the chamber with positive pressure so that much more air and fuel can enter. A typical turbocharged engine will generate 7 to 10 psi of maximum positive pressure, or "boost".

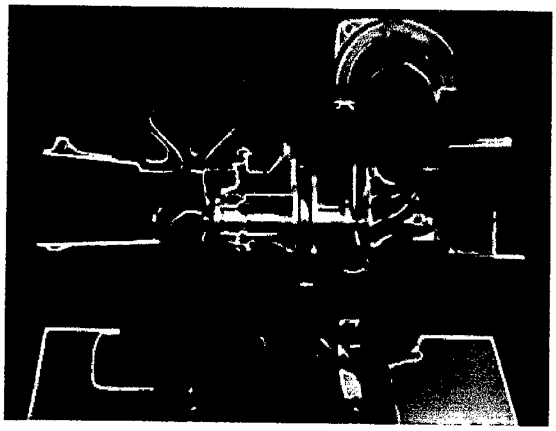

Figure 2.1: Cut away view of turbocharger

The turbocharger, or "turbo", is mounted directly to the exhaust manifold, where exhaust gasses pass over a turbine impeller that is attached to a short shaft. On the other side of this shaft is a compressor turbine, which pulls outside air in through the air filter and blows it into the intake manifold. Figure 2.2 illustrates the parts in turbocharger. So basically, the energy from the expelled exhaust gasses, which would normally be wasted on engine, is being used to pump air back into the engine. The shaft is supported by a bearing housing that is lubricated and cooled by an oil line from the engine. Since engine exhaust has such high temperatures, the exhaust side of the turbo can reach thousands of degrees F. This is why it is so critical that the engine oil be changed religiously, because old oil can burn and leave deposits in oil lines and housings, called "coke". Coking can be virtually eliminated by using synthetic oil and changing it frequently. This did little to keep temperatures down while running, but it had a huge effect after the engine was shut off. Without the coolant passage, the oil would drain when the engine was shut off and the turbo bearing housing would reach incredibly high temperatures from the heat transferring out of the exhaust manifold. This took its toll on the life of the bearings. The presence of the water keeps the housing cool.

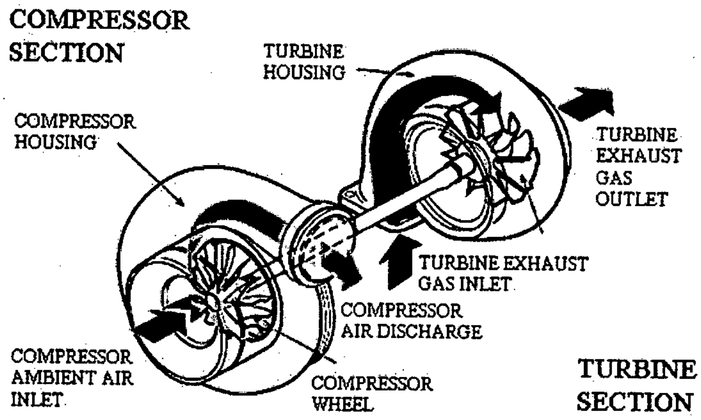

Figure 2.2: Parts of the turbocharger

When the engine has been idling or at low speed for a while, the turbo is not spinning or is spinning very slowly because there is very little exhaust leaving the engine. When the throttle is opened, the engine produces more exhaust, which spins the turbo faster. A faster spinning turbo means more air and fuel is being blown into the engine, therefore even more exhaust is being produced, which makes the turbo spin even faster and so on. Figure 2.3 illustrates the principle of the turbocharger operation. This cycle is known as turbo "spool-up", which feels like a sudden surge in engine power and appears on boost gauge as a sudden increase in pressure. The time before the surge, when the turbo is spooling up but the engine doesn't have much power yet, is called turbo lag. A large turbocharger can produce more air flow and pressure, but will have more lag because of its increased size. A small turbocharger will have a smaller amount of lag, but will not be able to move as much air.

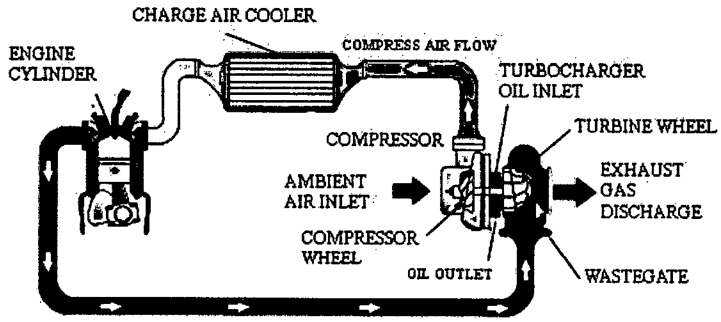

Figure 2.3: Turbocharger Principle of Operation

2.2 Comparisons between Turbocharging and Supercharging

The term supercharging technically refers to any pump that forces air into an engine - but in common usage, it refers to pumps that are driven directly by the engine as opposed to turbochargers that are driven by the pressure of the exhaust gasses.

Positive displacement superchargers may absorb as much as a third of the total crankshaft power of the engine, and in many applications are less efficient than turbochargers. In applications where engine response and power is more important than any other consideration, such as top-fuel dragsters and vehicles used in tractor pulling competitions, positive displacement superchargers are extremely common. Superchargers are generally the reason why tuned engines have a distinct high-pitched whine upon acceleration.

There are three main styles of supercharger for automotive use:

- Centrifugal turbochargers (Figure 2.4) - driven from exhaust gasses.
- Centrifugal superchargers (Figure 2.5) - driven directly by the engine via a belt-drive.

- Positive displacement pumps (such as the Roots and the Lysholm (Whipple) blowers).

The thermal efficiency, or fraction of the fuel/air energy that is converted to output power, is less with a mechanically driven supercharger than with a turbocharger, because turbochargers are using energy from the exhaust gases that would normally be wasted. For this reason, both the economy and the power of a turbocharged engine are usually better than with superchargers.

The main advantage of an engine with a mechanically driven supercharger is better throttle response. With the latest Turbo Charging technology, throttle response on turbocharged cars is nearly as good as with mechanical powered superchargers. Especially considering that the vast majority of mechanically driven superchargers are now driven off clutched pulleys, much like an air compressor.

Keeping the air that enters the engine cool is an important part of the design of both superchargers and turbochargers. Compressing air makes it hotter so it is common to use a small radiator called an intercooler between the pump and the engine to reduce the temperature of the air.

Turbochargers also suffer from so-called turbo-lag in which initial acceleration from low revolution per minute (RPM) is limited by the lack of sufficient exhaust gas pressure. Once engine RPM is sufficient to start the turbo spinning, there is a rapid increase in power as higher turbo boost causes more exhaust gas production - which spins the turbo yet faster, leading to a belated "surge" of acceleration. This makes the maintenance of smoothly increasing RPM far harder with turbochargers than with belt-driven superchargers which apply boost in direct proportion to the engine RPM.

Turbo-lag is often confused with the term Turbo-spool. Turbo Lag refers to how long it takes to spool the turbo when there is sufficient engine speed to create boost. This is greatly affected by the specifications of the turbocharger. If the turbocharger is too large for the power band that is desired, needless time will be wasted trying to spool the turbocharger.

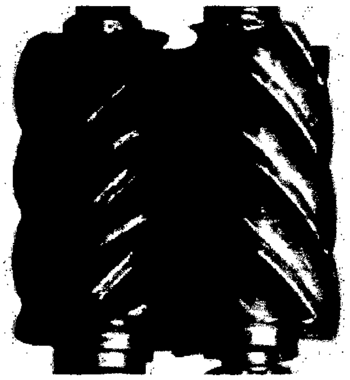

Figure 2.4: Supercharger

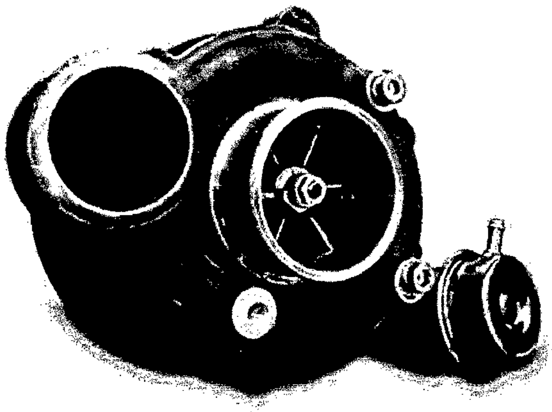

Figure 2.5: Turbocharger

2.3 Turbocharger Components

Turbocharger system has many components such as pressure release valve, intercooler, wastegate and a turbocharger unit itself. Each component has its own function and specification.

2.3.1 Pressure Valve Release

There are two types of pressure release valve. Compressor bypass valve and blow off valve. Commonly CBV is found on many original engine manufactured turbo engine while BOV in advanced turbocharged engine. For the further information please refer Section 2.4.

2.3.2 Intercooler

An intercooler is a heat exchanger as shown in Figure 2.6, positioned between the turbocharger and the intake manifold. It is a device used on turbocharged and supercharged internal combustion engines to improve the volumetric efficiency, increase the amount of charge in the engine, and lower charge air temperature thereby increasing power and reliability. The intake may cooled by the ambient air, engine jacket water, iced water, low temperature liquid as cooling medium.

Intercooler could reduce the intake charge temperature to the cooling medium without any drop in pressure while reach 100% efficiency. But the perfect (100%

efficient) is not possible in this actual world because of there will be a pressure drop through the intercooler and it is not possible to lower the charge temperature to that cooling medium temperature. The cooling medium and intercooler design averagely available at 70% to 75% efficiency in common.

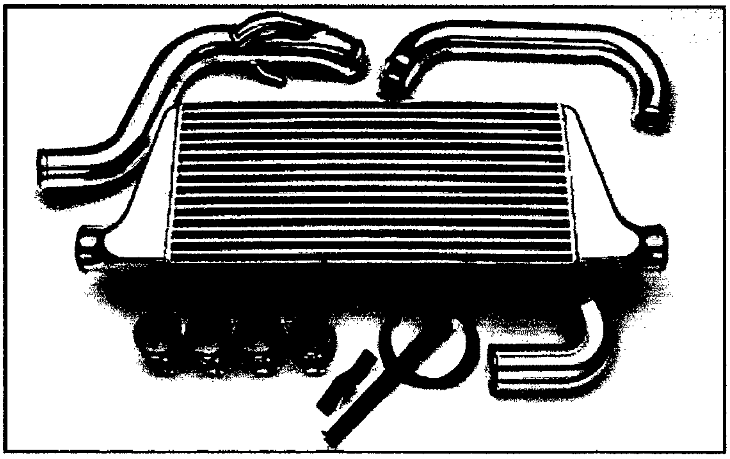

Figure 2.6: Intercooler and its components

2.3.3 Wastegate

A wastegate is used to control the exhaust gas flow rate to the turbine (Figure 2.7). There is a valve that diverts exhaust gases away from the turbine wheel in a turbocharged engine system. Actually the primary function of the wastegate is to stabilize boost pressure in turbocharger systems, to protect the engine and the turbocharger. Normally wastegate is controlled by a wastegate actuator.

There are two types of wastegate in the market which are the internal wastegate and the external wastegate. An internal wastegate is an integral part of the turbine housing. The wastegate actuator is commonly attached to the compressor housing with a metal bracket. A flapper valve is generally used by internal wastegate. While an external wastegate build separate self-contained mechanism typically used with turbochargers that do not have internal wastegate. It requires a specially constructed turbo manifold with a dedicated runner going to the wastegate and may be part of the exhaust housing itself. External wastegates are commonly used for regulating boost levels more precisely than internal wastegates in high power applications, where high boost levels can be achieved.

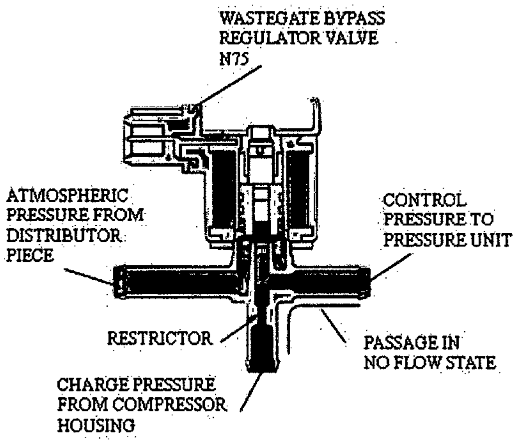

Figure 2.7: Cut away view of a wastegate

2.3.4 Turbocharger Unit

The most important in turbocharger system is turbocharger unit itself. When improved performance and the power level from a particular engine were desired, increasing its displacement can achieve satisfying result. So, turbocharger is one of the alternative ways to achieve this desire. The detail of the turbocharger unit shown in Section 2.1.