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JUDUL: **DESIGN OF A BLOW OFF VALVE FOR TURBOCHARGED ENGINE APPLICATION**

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Saya **MOHD FADHLI BIN MOHD NASIR**
(HURUF BESAR)

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1149 JALAN 1D/1,
BDR BARU SG BULOH, 47000 SG BULOH
SELANGOR DARUL EHSAN

MOHD FAIRUSHAM BIN GHAZALI
(Nama Penyelia)

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Date : 23 NOVEMBER 2007

DESIGN OF A BLOW OFF VALVE FOR TURBOCHARGED ENGINE APPLICATIONS

MOHD FADHLI BIN MOHD NASIR

A project report submitted in partial fulfillment of the
requirements for the award of the Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

NOVEMBER 2007

I declare that this thesis entitled "Design of a Blow off Valve for Turbocharged Engine Applications" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : Mohd Fadhli Bin Mohd Nasir

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This work is dedicated to my beloved ones,
My Father Mr Mohd Nasir Mohd Yasin,
My Mother Mrs Seniah Lakim,
My Sister Siti Nor Baeyah,
My Brother Mohd Fitri and Mohd Faiz,

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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".

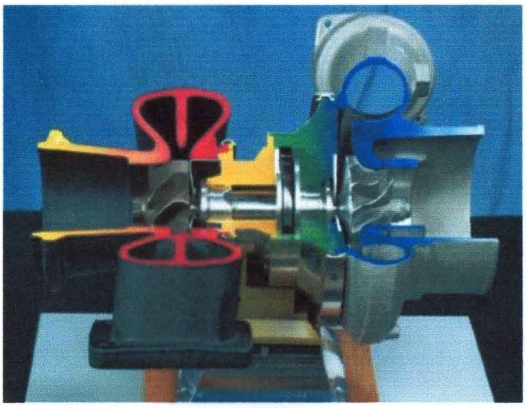


Figure 2.1: Cut away view of turbocharger

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.

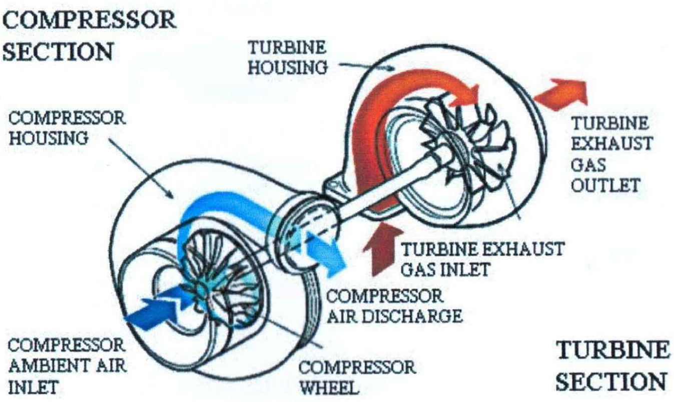


Figure 2.2: Parts of the turbocharger

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.

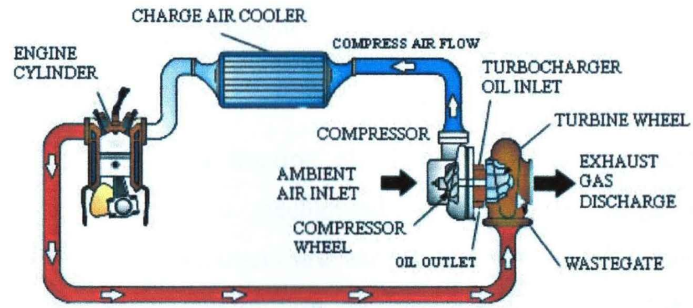


Figure 2.3: Turbocharger Principle of Operation

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.

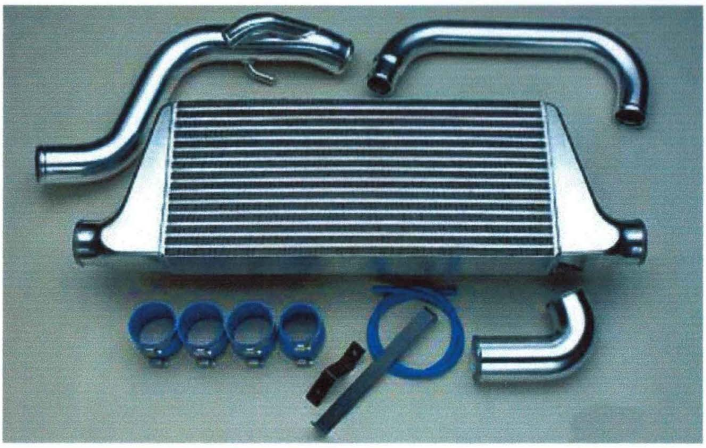


Figure 2.6: Intercooler and its components

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.

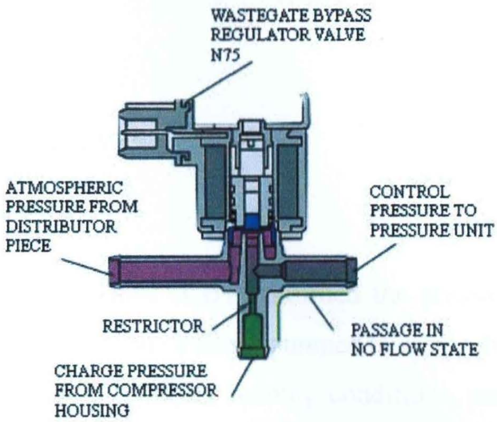


Figure 2.7: Cut away view of a wastegate

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.

2.4 Pressure Release Valve

A pressure release valve is a vacuum-actuated valve designed to release pressure in the intake system of a turbocharged or centrifugally supercharged car when the throttle is lifted or closed. There are two types of pressure release valve which Compressor Bypass Valve Pass (CBV) and Blow off Valve (BOV).

2.4.1 Compressor Bypass Valve

Compressor Bypass Valve (CBV) returned the pressurized air to the turbo compressor inlet for reuse, instead of being dumped to atmosphere. The bypass valve is open under normal low-load engine running conditions, and closes firmly when positive pressure is present in the inlet manifold. When on-boost and changing gear (throttle lift is off), a sudden lower pressure condition is created in the manifold and the valve is pulled open again, directing pressurized air back to the turbo inlet.

A CBV is a closed system, any loss of air for which fuel has already been metered by the movement of the airflow sensor plate, will result in an over-rich condition and possible backfire. A CBV is found on many "OEM" original engine manufactured EFI turbo systems.

Bosch style valves are compressor bypass valves CBV (Figure 2.8), and are open most of the time under engine vacuum (idle, cruise, throttle lift-off), but close firmly under positive (boost) pressure. This open style returns the air quietly back to the turbo compressor inlet or air cleaner area.

Figure 2.8: Bosch Style CBV

2.4.2 Blow off Valve

A blow-off valve (also called a compressor bypass valve or diverter valve) is a valve, generally a piston type, which is placed between the turbo compressor and the throttle to bypass the pressurized air on a closed throttle, either plumbing it back into the turbo inlet for silent operation, or to the atmosphere to make the signature blow-off valve whoosh. Figure 2.9 shows the Blow off Valve in turbochargered system.

The unique sound sometimes comes at a price. On a car with a mass airflow sensor, doing this confuses the engine control unit (ECU) of the car. The ECU is told it has a specific amount of air in the intake system, and injects fuel accordingly. The amount of air released by the blow-off valve is not taken into consideration and the engine runs rich for a period of time.

When your turbocharged car is on boost, the entire intake system is filled with pressurized air; from the turbo compressor, through the throttle body and inlet manifold and into the combustion chambers. When the throttle is closed, this pressured air can no longer enter the engine. The only path available for the air is to try to flow back the way it came, through the turbo compressor the wrong way. This creates a fluttering noise on the blades of the still-spinning turbo compressor.

In addition to making this fluttering noise, a noise that is probably unwanted in a nice new turbo car. It is often claimed that the load placed on the turbocharger from this pressurized air flowing through it the wrong way can cause premature wear or damage. It's quite difficult to directly attribute a turbo failure to not having a blow-off valve fitted. Typically this isn't a major issue, but sometimes it can lead to hesitation or stalling of the engine when the throttle is closed. This situation worsens with higher boost pressures. Eventually this can foul spark plugs and destroy the catalytic converter.

Blow-off valves are used to prevent compressor surge. Compressor surge is a phenomenon that occurs when lifting off the throttle of a turbocharged car with a non-existent or faulty bypass valve. When the throttle plate on a turbocharged engine running boost closes, high pressure in the intake system has nowhere to go. It is forced to travel back to the turbocharger in the form of a pressure wave. This results in the wheel rapidly decreasing speed and stalling. The driver will notice a fluttering air sound. In extreme cases the compressor wheel will stop completely or even go backwards. Compressor surge is very hard on the bearings in the turbocharger and can significantly decrease its lifespan. In addition, the now slower moving compressor wheel takes longer to speed up when throttle is applied. This is known as turbo lag. 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.

There are many other reasons car manufacturers fit blow-off valves to their cars, mainly to do with emissions, fuel economy and drivability. In aftermarket applications though, the main reasons for fitting a BOV are to hold higher-than-standard boost levels, to give better throttle response than a factory BOV (OEM) by staying closed whenever it's not venting, and of course to make noise.

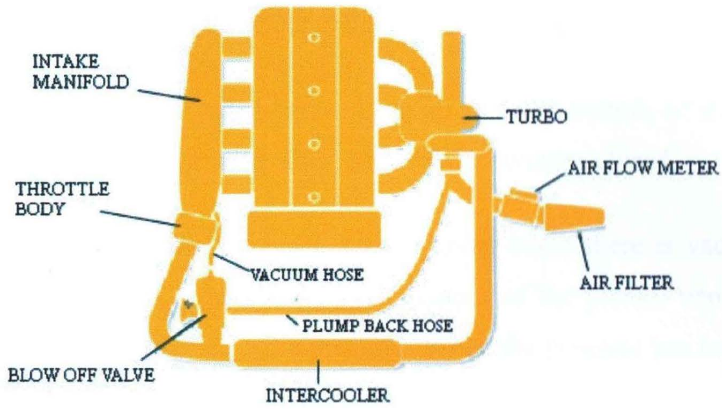


Figure 2.9: Blow off valve in turbocharged system

2.4.2.1 How a Blow off Valve Works

A blow-off valve is vacuum/pressure actuated piston-type valve. It uses vacuum/pressure signals to tell the piston when to open and close.

At idle there is engine vacuum on the top of the BOV piston trying to suck it open, and no vacuum or pressure on the bottom of the piston. Since a vent-to-atmosphere BOV needs to be shut at idle to avoid air being drawn in through it, there is a spring inside a BOV with the job of holding the piston closed. The spring preload adjustment is to allow for differences in engine vacuum from car to car, and variations in atmospheric pressure at different elevations.

On airflow metered cars the air drawn in through an open vent-to-atmosphere BOV at idle would confuse the ECU and cause over-fuelling and stalling and in any case, the air drawn in is unfiltered.

Under cruise conditions (off boost) the BOV is experiencing similar conditions to when the car is at idle, but there is less vacuum present on top of the piston because the throttle is partly open. If the BOV spring has been adjusted to keep the piston closed at idle, it will also be closed at cruise.

On boost there is boost pressure on both top and bottom of the BOV, the forces from which counteract each other, so the BOV remains closed.

Immediately after the throttle is closed under boost there is vacuum on the top of the piston and boost pressure on the bottom of the piston, which together, quickly opens the BOV to release the pressure. When the pressure has been released, the BOV closes.

The spring holds the valve closed, but if enough pressure reaches the BOV inlet, it will be forced opens (Figure 2.11). When the throttle is closed and vacuum is supplied to the front of the BOV diaphragm, it releases the pressure from the turbo (Figure 2.10).

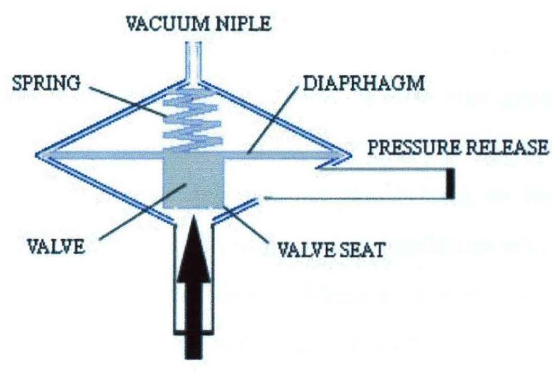


Figure 2.10: BOV condition when the throttle is close

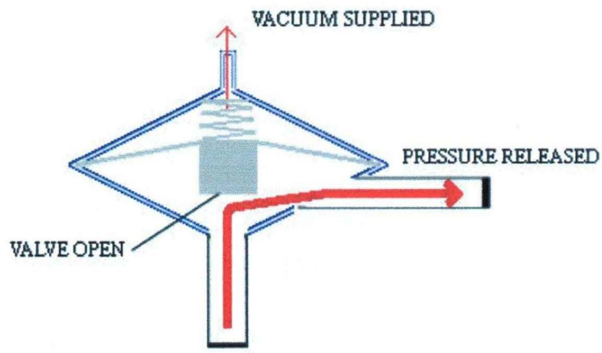


Figure 2.11: BOV condition when the throttle is open

2.4.2.2 APS High Volume Twin Vent Blow off Valve

It is an ideal enhancement for applications using the standard turbocharger up to large 600 hp units. Its huge capacity the APS blow off valve gives the ultimate in turbocharger durability and improved turbo response particularly during gear changes. The large primary vent is designed to plumb back to the standard entry point which ensures the best drivability during cruise conditions and cures the erratic idle and engine's rich condition (transition) problems seen with after market external single venting blow off valves. And for large turbochargers running high boost pressure levels, the APS twin vent blow off valve continues to vent through to the second stage port.

The operation of the APS High Volume Twin Vent Blow off Valve (Figure 2.15):

i. **Ports Closed** - Under open throttle conditions where turbocharger boost pressure is required, the bronze BOV piston is held shut in order to supply the maximum amount of charge air to the engine (Figure 2.12)

ii. **Primary Port Open** - Under light load conditions where the throttle opening has been reduced or shut, the piston moves partially up the bore travel and opens the primary port to vent charge air back into the inlet tract. This ensures smooth engine operation and alleviates the rich condition and subsequent backfire when utilizing a BOV construction that vents100% of charge air to atmosphere (Figure 2.13)

iii. **Both Ports Open** - Under high load conditions where the throttle has been shut, the piston travels fully so that both the primary and the wide mouth secondary ports open to vent the maximum charge air possible. Air vented through the primary port is routed back into the inlet tract. In addition, additional excess charge is air vented through the wide mouth secondary port to atmosphere (Figure 2.14)

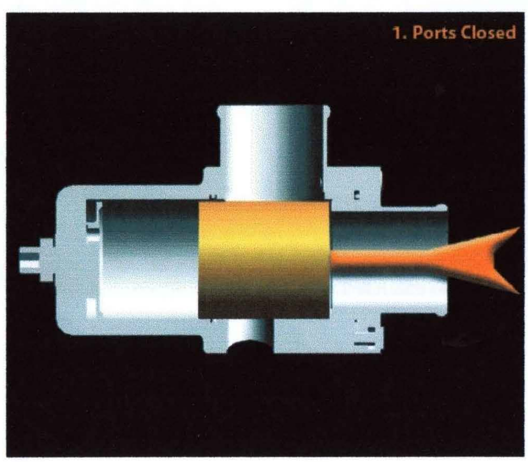


Figure 2.12: Ports Closed

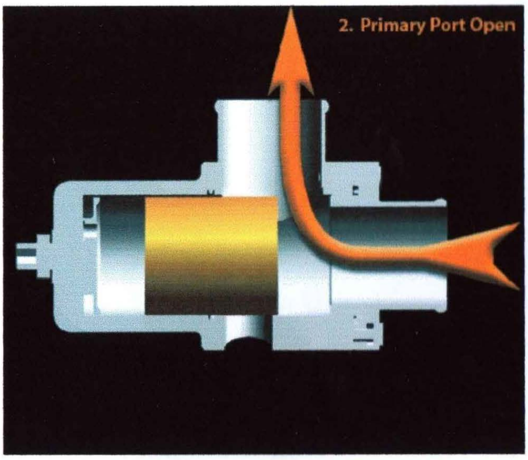


Figure 2.13: Primary Port Open

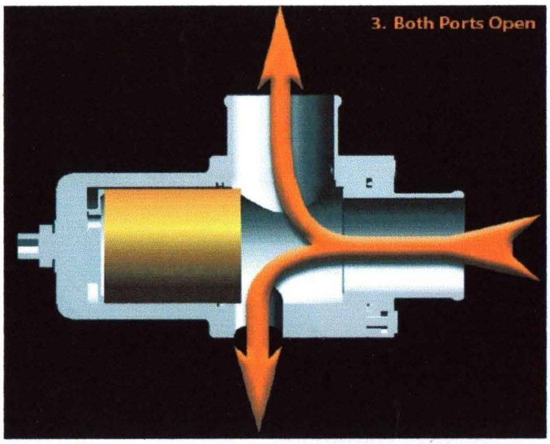


Figure 2.14: Both Ports Open

Figure 2.15: APS High Volume Twin Vent Blow off Valve

2.4.2.3 Universal HKS Super Sequential BOV

The HKS Super Sequential Blow off Valve (SSQV) is a dual stage pull type relief valve as shown in Figure 2.16. Unlike other blow off valves that are push type, the SSQV will not leak under high boost conditions or under vacuum at idle. Being of a pull type valve structure, the SSQV can not physically leak under any level of boost because boost pressure also keeps the valve closed against its seat. The SSQV is actuated by pressure alterations only, not by the rate of pressure or vacuum in the line, which ensures a quick valve response and complete closure during idle. On typical blow-off valve designs, a large valve is utilized in order to accommodate high boost / high horsepower applications. However, these large valves tend to react slowly and require high activation pressure to open, therefore are not able to activate and prevent compressor surge at light-load conditions. For Universal SSQV applications, weld-on flanges are available in steel and aluminum for custom installation.

Figure 2.16: The HKS Super Sequential Blow off Valve (SSQV)

2.4.2.4 Greddy Type "Rs" Blow Off Valve

With the use of the high quality valve and diaphragm control system, the Type-RS was created to be the most reliable Blow off Valve system available (Figure 2.17). These designs allow for high capacity and performance that rival high performance Blow-off Valve, while being more compact and lighter-weight. The unique 8 discharge ports in the Computational Numerical Control (CNC) machined aluminum discharge funnel draws surrounding air to amplify the blow-off sound. The CNC machined aluminum valve is coated with a hard anodizing, to withstand extreme friction, maintain an airtight seal and increase durability. To ensure a proper valve movement, a durable, air tight, pressure resistant Bellofram diaphragm is used. The short valve stroke allows a compact top housing design. This smaller top housing volume also adds improved valve response. Its dual spring system can prevent premature discharge under high boost pressure and increases valve speed for quick response application. But its must come with carefully selected spring rate. Other than that, the discharge funnel can be replaced with an optional Re-circulation Hose Adapter to allow for re-routing the discharged air back in the air intake system.

Figure 2.17: Greddy Type "Rs" Blow Off Valve

CHAPTER 3

METHODOLOGY

3.1 Specification Definition

In order to achieve the objectives of the project, a design process had been developed under some circumstances. There are many types of Blow off Valve available in market. Each type has its own unique specification and design. In this project, a Blow off Valve for turbocharged engine will be designed by following the proper design process.

3.1.1 Collecting Data and Literature Review

Data collecting from the internet, journals, books, articles and other references have plays the important role in finishing this project. The data collected from the relevant sources, may generate a better idea while ensure a better results and make this project success. Other than that, the reverse engineering helps most in this stage. A number of Blow off Valve used in this method.

3.1.2 Requirements

The requirement of this project must be set up from the beginning of the design process. From this entire requirement, the best design of Blow off Valves can be made. Below is the list of requirement lead to next stages of the design process:

i. Capability to withstand high boost (up to 2.5 bar)
ii. Not leak under vacuum at idle
iii. Good valve response
iv. Easy to install
v. Long turbine lifetime
vi. Unique sound

3.1.3 Engineering Specification

In this stage, the parameters had been developed. These parameters are the measures of the requirement that had been chosen. This is the engineering specification for the design of the blow off valve:

i. Dual stages
ii. SSQV
iii. Single port
iv. Diaphragm or piston
v. Push/pull type
vi. Dual spring
vii. Single piston

3.2 Reverse Engineering

To get a good design of Blow off Valve, reverse engineering was made. Three type of Blow off Valve in aftermarket chosen in this method. There are:

i. APS Type
ii. SSQV (Super Sequential Blow off Valve) Type - (Monza)
iii. SSQV (Super Sequential Blow off Valve) Type - (Taiwan)

3.2.1 APS Type

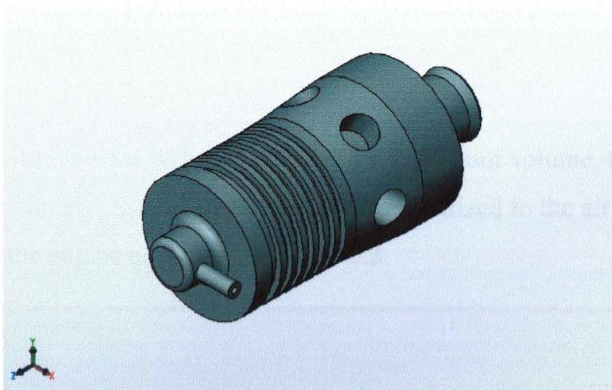


Figure 3.1: APS Type Blow off Valve

This is APS Type Blow of Valve (Figure 3.1). This type is ideal for applications using the standard turbocharger engine. The large primary vent is designed to plumb back to the standard entry point which to ensures the best drivability.

The operation of the APS Type Blow off Valve:

i. **Port Closed**: Under opened throttle condition, when the boost is below than 2.5 bar, the piston is held shut in order to supply the maximum pressure to the engine. Shown in Figure 3.2.

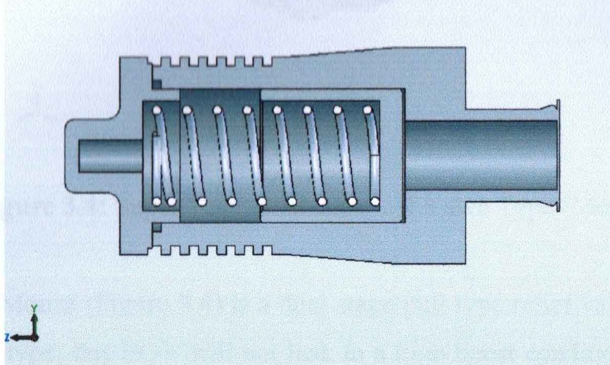


Figure 3.2: APS BOV condition when port closed

ii. **Port Fully Opened**: When the boost in a maximum volume, the cylinder will push maximally. So the boost can easily pressurized to the air without turning back to the engine as shown in Figure 3.3.

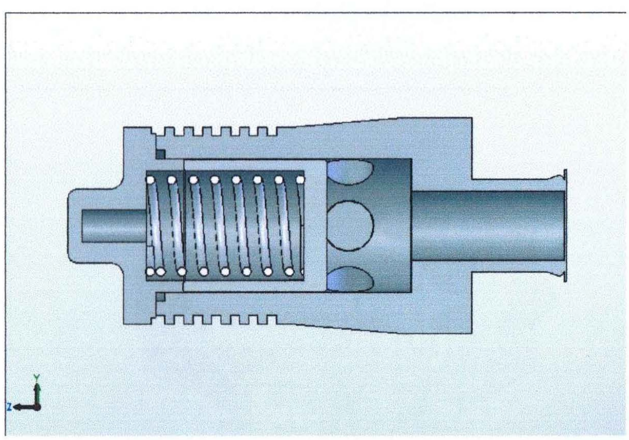


Figure 3.3: All APS BOV ports fully opened

3.2.2 SSQV (Super Sequential Blow off Valve) Type – (Monza)

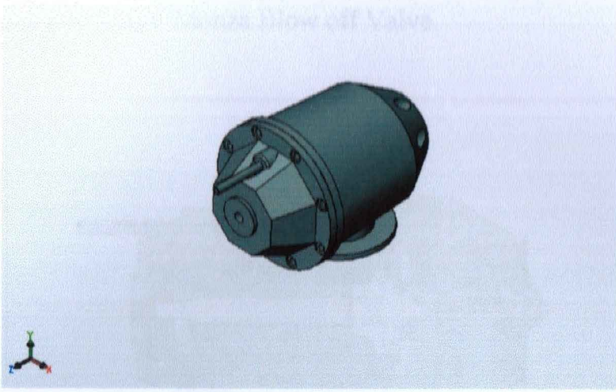


Figure 3.4: Super Sequential Blow off Valve Type (Monza)

SSQV Monza (Figure 3.4) is a dual stage pull type relief valve. Unlike other BOV are push type, this BOV will not leak in a high boost conditions. It is because the boost pressure also keeps the valve closed against its seat. However, the huge valves tend to react slowly and required high activation pressure to open.

The operation of the SSQV Monza Blow off Valve:

i. **First Stage**: When the boost is very low, the SSQV Monza is in First Stage which is the valve only open a little to pressurize the low boost to the air as shown in Figure 3.5.

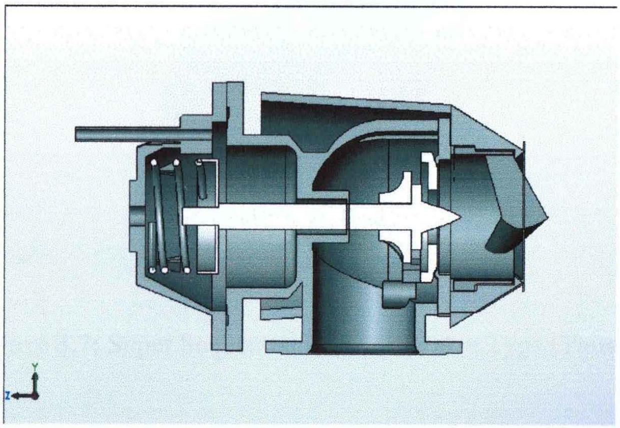


Figure 3.5: SSQV Monza first stage

ii. **Second Stage**: In a high boost condition, the SSQV Monza valve will fully opened to maximizing the boost pressurize to the air. Figure 3.6 showed the second stage of SSQV Monza Blow off Valve.

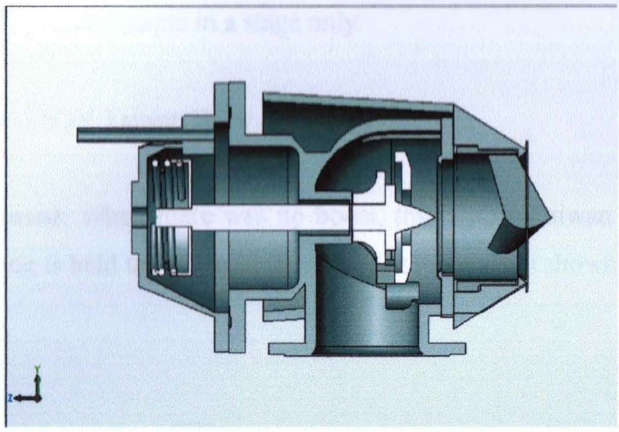


Figure 3.6: SSQV Monza valve is fully opened (second stage)

3.2.3 SSQV (Super Sequential Blow off Valve) Type – (Taiwan)

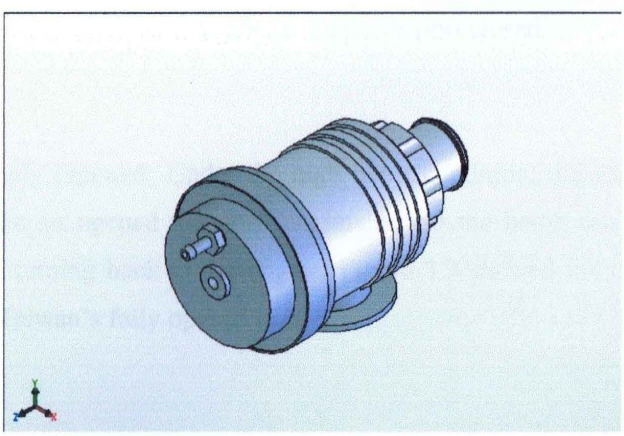


Figure 3.7: Super Sequential Blow off Valve Type (Taiwan)

Same as the Super Sequential Blow off Valve Type (Monza) as shown in Figure 3.4, the vent is a like each other, the size are almost the same but there is one different thing. It is its valve. This SSQV Taiwan (Figure 3.7) is different then SSQV Monza. SSQV Monza's valve can make that model operated in 2 stages. But this SSQV Taiwan only can operate in a stage only.

Operation of the SSQV Taiwan Blow off Valve:

i. **Port Closed**: When there was no boost, this SSQV Taiwan is fully closed. The spring is held the valve so it can stay at its seat. As shown in Figure 3.8.

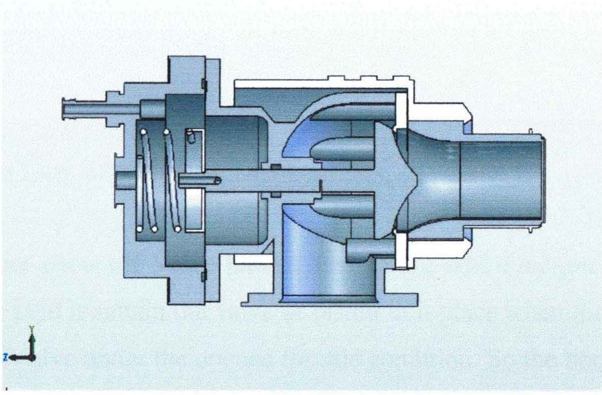


Figure 3.8: SSQV Taiwan's port closed

ii. **Port Fully Opened**: Under the high boost condition, the vacuum will suck the valve an opened the port maximally. So the boost can be pressurized without turning back to the engine. Figure 3.9 showed the condition of the SSQV Taiwan's fully opened port.

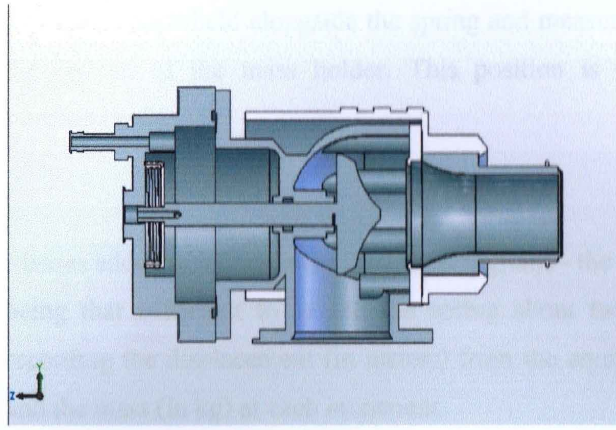


Figure 3.9: SSQV Taiwan's port fully opened

3.3 Hooke's Law Experiment

The entire Blow off Valve has its own spring. The function of the spring in Blow off Valve is to maintain the valve or piston in it place when there is high boost in the Blow off Valve under the opened throttle condition. So the boost will not leak. Other than that, spring is used to returned back the valve or piston to its initial place. When the throttled closed, spring will push back the valve or piston back to the initial place. So, spring play the role in the Blow off Valve. The spring preload adjustment is to allow for differences in engine vacuum from car to car and variations in atmospheric pressure.

Below are the procedures to handle the Hooke's Law experiment:

i. Begin by hanging one end of a spring from the ring stand. A mass holder hangs from the other end of the spring and adds sufficient weights to stretch the spring a distance of one or two centimeters.

ii. The meter stick held alongside the spring and measures the height of the bottom of the mass holder. This position is the equilibrium position (x=0).

iii. Masses added in increments of 0.0 to 30.0 grams - the exact increment being that sufficient to stretch the spring about two centimeters - recording the displacement (in meters) from the equilibrium position and the mass (in kg) at each increment.

iv. The recorded mass is the mass required to stretch the spring from the equilibrium position, i.e., the mass added beyond that in 1. The data enter in columns 1 and 2 of the appropriate table. A total of about 10 measurements should be made.

v. Full-page graph of the force vs. displacement drew. The displacement is the independent variable and is to be plotted along the horizontal axis

vi. The best straight lines found to fit the data and determine the slopes of the lines. The slope corresponds to the spring constant of the spring

vii. $F = -kx$

3.4 CFD Simulation of the Aftermarket Blow off Valve

The process of designing the Blow off Valve continues to achieve the criteria set earlier in the concept stage. Simulations need to be done to save time and cost of designing the Blow off Valve. As the air flow in Blow off Valve is governed by fluid mechanics, the simulation of fluid motion would be needed to analyze the Blow off

Valve. A computational method is chosen to analyze the air flow inside the Blow off Valve, by using a commercial CFD package, CosmosFloworks 2005.

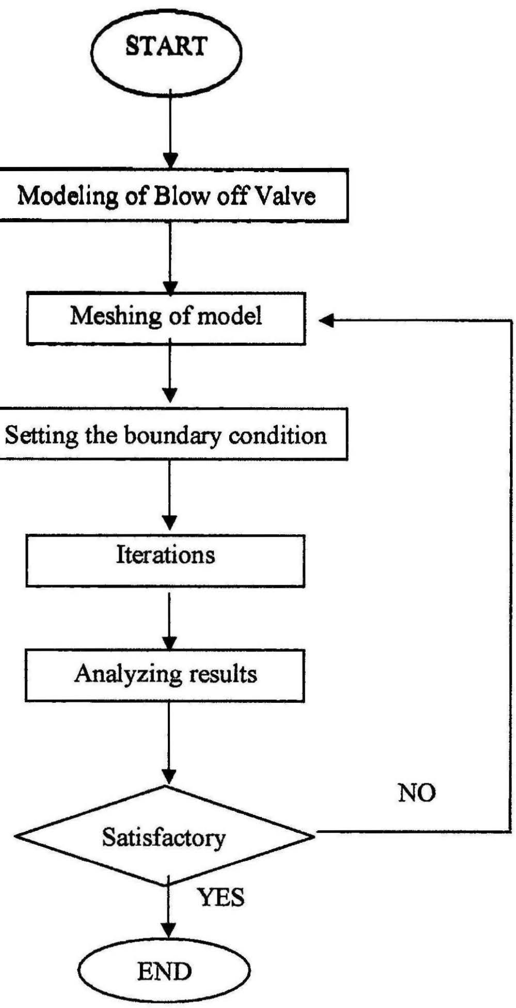
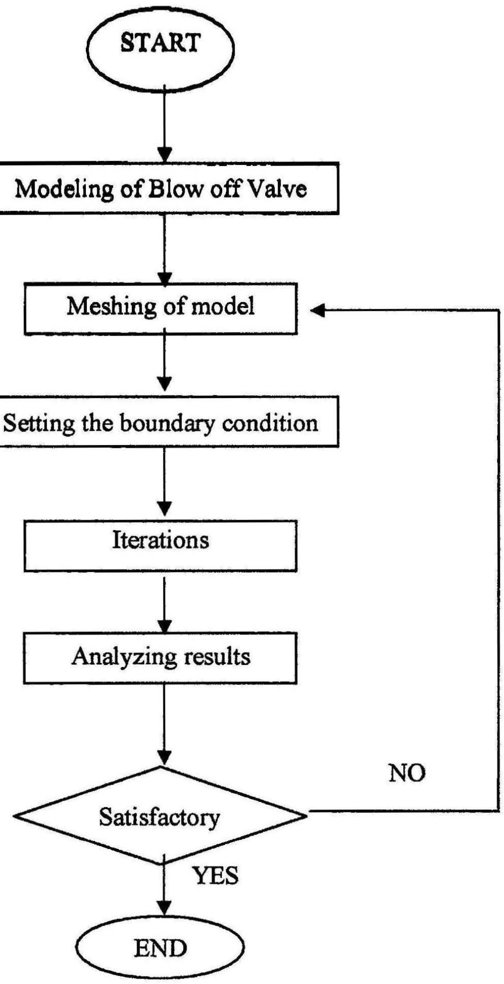


Figure 3.10: Simulation steps for the simulation

After modeling the Blow off Valve with CAD, the CFD analysis continues with mesh modeling. The meshing will divided the volume of the fluid inside the model into certain size. It will split the volume into small volume. This volume is called mesh and iterates the calculation for each volume. The CFD package uses rectangular mesh to the volume of the fluid in the design.

Valve. A computational method is chosen to analyze the air flow inside the Blow off Valve, by using a commercial CFD package, CosmosFloworks 2005.



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After the specific mesh was built in the volume, the Blow off Valve boundary conditions input was given to the CFD software. Then the analysis will run and begin the calculations. The accuracy of the boundary is so important because it can affect the simulation outcomes.

3.4.1 APS Type

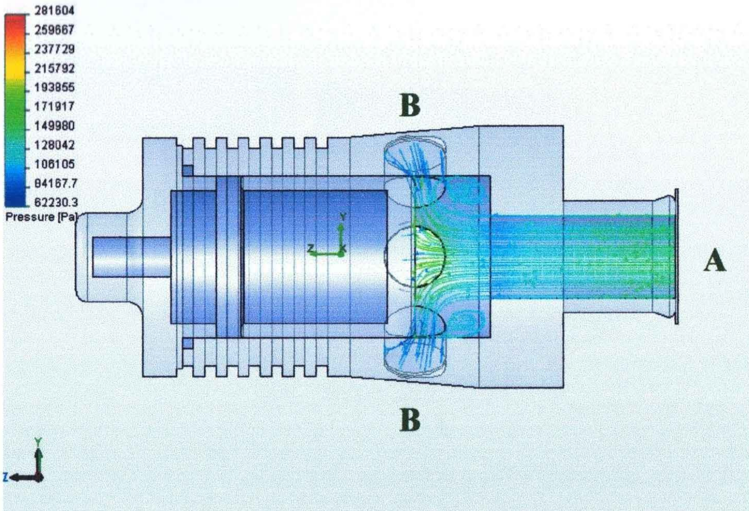

Figure 3.11: Example of analysis using CFD on APS Type BOV

For the simulation of APS Type (Figure 3.11), the initial mesh level 3 is used. In this analysis there are 2 boundary conditions was setup. There are Static Pressure Inlet and Static Pressure Outlet. For Static Pressure Inlet, the pressure of 150kPa, 200kPa and 250kPa was used. It is because; the minimum of the boost in the turbocharger engine is not less than 101.3kPa which is the atmosphere pressure. Besides, the maximum of the pressure in turbocharger engine is around 250kPa to 300kPa. The Static Pressure Inlet for APS Type is at A, which is connected to the throttle hose from the turbocharger itself. And the Static Pressure Outlet for APS

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3.4.1 APS Type

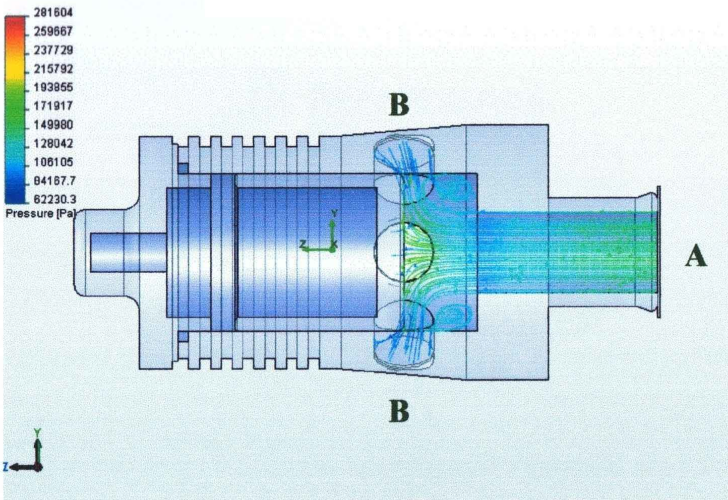

Figure 3.11: Example of analysis using CFD on APS Type BOV

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Type is at B, which is the outlet of the boost. After all this mesh and boundary condition was setup, the simulation can be started. Its will began to iterate the calculations of each volume inside. After a several minutes, the calculations solved and the desired result can be obtained by clicking the option in CFD. For this thesis, the flow trajectories must be display to see the air flow of this model.

3.4.2 SSQV (Super Sequential Blow off Valve) Type – (Monza)

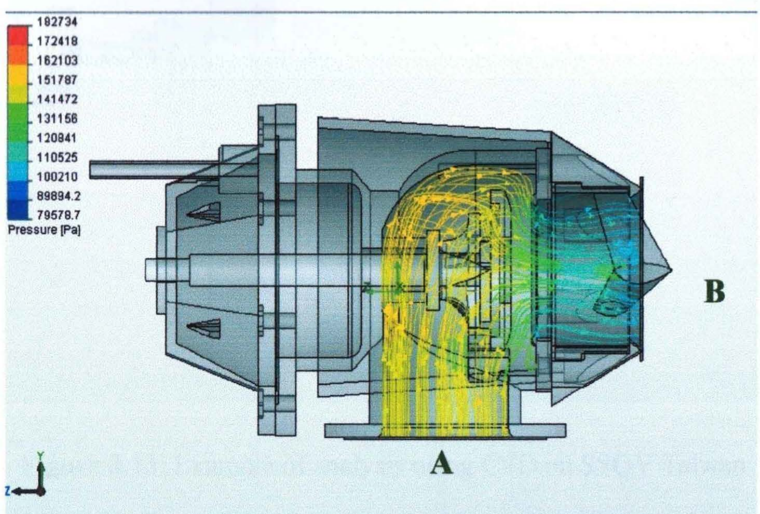

Figure 3.12: Example of analysis using CFD on SSQV Monza

As same as the APS Type, the SSQV Monza (Figure 3.12) also was simulating with the initial mesh level 3. In this type, there are 2 boundary conditions was setup which are Static Pressure Input and Static Pressure Output. The Static Pressure Input was setup at the inlet of the boost (A) which is setup with 150kPa, 200kPa, 250kPa. Then Static Pressure output was setup at the output of the boost to the air (B) which is setup with 101.3kPa (atmosphere pressure). Next step is same as the model before which is run the simulation and wait for the calculation solved and have the desired result by clicking the option in CFD. For this thesis, the flow trajectories must be display to see the air flow of this model.

3.4.3 SSQV (Super Sequential Blow off Valve) Type – (Taiwan)

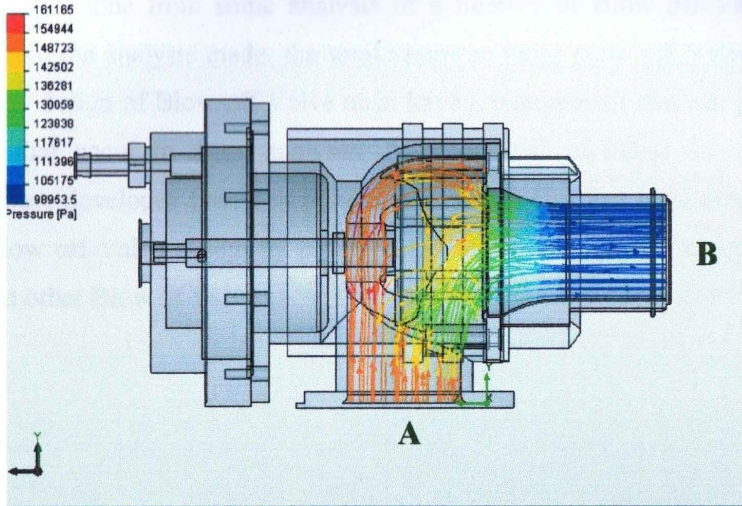

Figure 3.13: Example of analysis using CFD on SSQV Taiwan

Each steps of the simulation for the model is nearly the same each other. For the SSQV Taiwan simulation (Figure 3.13), the initial mesh is also 3. And it also has 2 boundary conditions setup which is Static Pressure Inlet, was setup at the inlet of the boost from bottom (A). The second boundary condition is situated at the right end of the model which is called Static Pressure Outlet (B). At Static Pressure Inlet, the 150kPa, 200kPa, 250kPa was setup while only 101.3kPa at the Static Pressure Outlet. The simulations run when all the setup was ready. The desired result can be performing when the calculations solved. For this thesis, the flow trajectories must be display to see the air flow of this model.

3.5 Conceptual Design

A concept is an idea that is sufficiently developed to evaluate the physical principles that govern its behavior. So, conceptual design is important to make this project achieve the objectives perfectly. The concept for the design must be right when try to design the product by sketching. This conceptual design is the critical stage of this Blow off Valve design project. The initial idea for the shape of the Blow off Valve was done from some analysis of a number of Blow off Valve in the market. From the analysis made, the weaknesses of those Blow off Valve detected. So, the new design of Blow off Valve must have a requirement that can prevent the problems that occur in those analyses. After that, the sketches are made. The sketches were developed based on the design criteria. This had been predetermined for the Blow off Valve design by considering the requirement that can prevent the problem in other Blow of Valve.

3.5.1 General Concept

There were certain parts in Blow off Valve must be considered before the conceptual design through to the next stage. The combination of the concept will produce the best conceptual design of the Blow off Valve. The list below is the component in Blow off Valve:

i. Piston
ii. Port/vent
iii. Diaphragm
iv. Spring
v. Material
vi. Adjustable mechanism
vii. Vacuum signal mechanism

3.5.2 Make Concept Decision

From the all conceptual design of the Blow off Valve, the comparisons between them are made. The best conceptual design will be choose to proceed to the product development stage.

3.6 Product Development

In this stage, the concept that developed in previous stage is transformed into product that can perform the desired function. There are two steps to complete this product development stage and it is engineering drawing process and product simulation process.

3.6.1 Engineering Drawing

Nowadays, there are many kind of software to create a drawing before the product in the market such as Solid Work, Catia, AutoCAD software. In this project, the software that will be used to design the model is Solid Works. This software had been choose as it is possible for designer to sketch the design, produced model and detailed drawing. Solid Works enables us to design the models much more quick and precise.

3.6.2 Own Design Blow off Valve

After all stages had successfully done, the specification, requirement, conceptual design, general concept, and lastly product development, here is the best Blow off Valve that can prevent all the problem occurs in the simulation with the aftermarket BOV.

This BOV designed to meet the requirement of the BOV itself, the capability to withstand high boost (up to 2.5 bar), not leak at under the vacuum idle, dual stages and it also attractive.

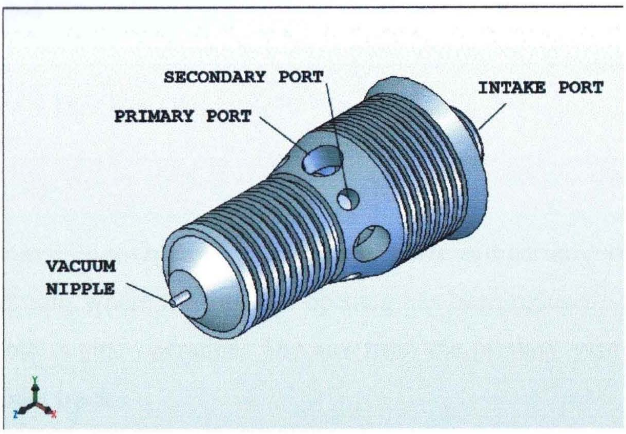

Figure 3.14: Own Design BOV

3.6.3 Operation of the Designed BOV

For the operation my own design (Figure 3.14), it operates under three conditions. Refer Figure 3.15, Figure 3.16 and Figure 3.17 for those conditions.

i. **Both Ports Closed**: Under opened throttle condition, when the boost is below than 2.5 bar, the piston is held shut in order to supply the maximum pressure to the engine.

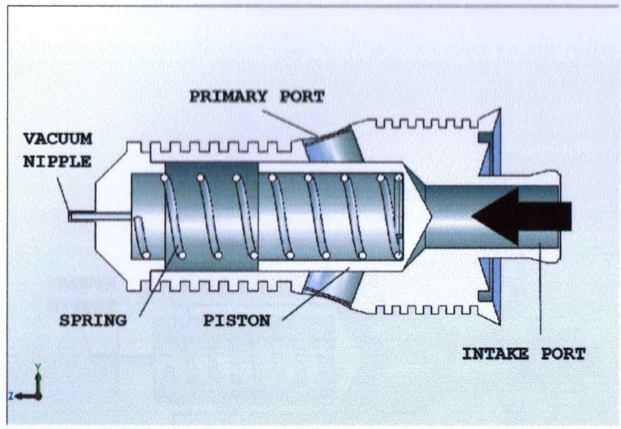

Figure 3.15: Own Design BOV condition when both ports closed

ii. **Primary Port Opened**: The primary ports will partially open under light conditions where the throttles opening has been reduces. This ensures the smooth engine operation. The airs from the primary vent flow back into the inlet track.

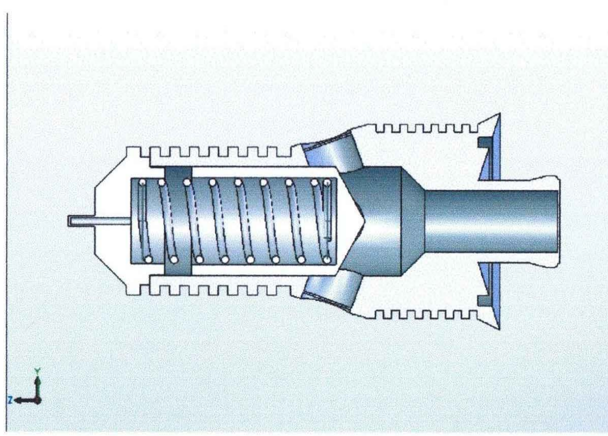

Figure 3.16: Own Design BOV condition when primary port partially opened

iii. **Both Ports Open**: both of the primary and secondary port will widely open under high load conditions. Air vented through the primary port is routed back into the inlet react while air vented through the secondary port will charged to the atmosphere.

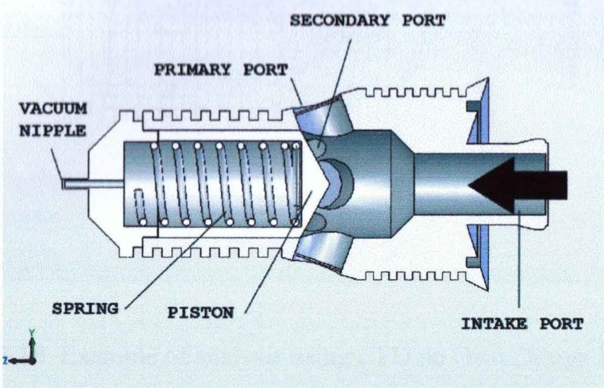

Figure 3.17: Own Design BOV condition when both ports opened

3.6.4 CFD Simulation of the Designed BOV

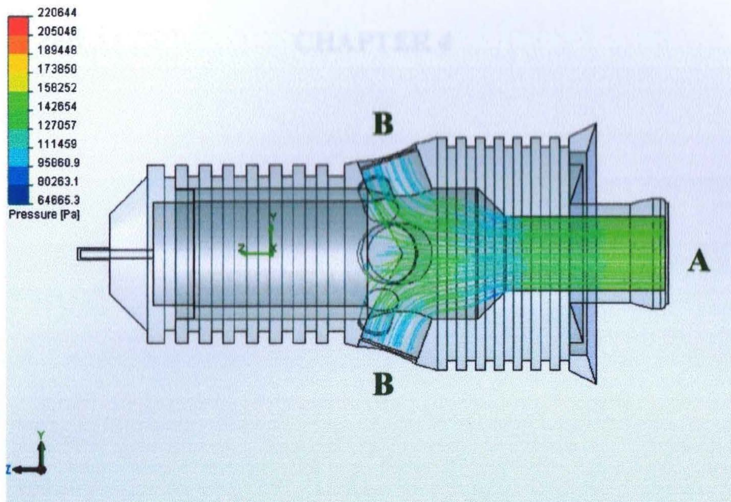

Figure 3.18: Example of analysis using CFD on Own Design BOV

On this model (Figure 3.18), initial mesh level 3 used. For the Boundary condition, there was Static Pressure Inlet (A) with 150kPa, 200kPa, 250kPa used. Then the second boundary condition is Static Pressure Outlet (B) which is setup with 101.3kPa (atmosphere pressure). After all the setup of simulation was ready, the simulation started. In a few minute, the solver had done the all calculation. The trajectory is click under the option to get the flow line such as in Figure 3.18.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This is the crucial part of this thesis. All the result obtained will be discussed in this chapter. Some calculation and tables also will be discussed in this chapter. The result from the CFD will be shown and discussed. Next, there are analysis results of CFD simulation of the air flow line. The COSMOS Floworks CFD software is used to analyze the flow. The analysis is more on the air flow inside the Blow off Valve which is from the intake inlet through the outlet port.

4.2 Hooke's Law Experiment

The objective of this experiment is to determine the stiffness of the spring in Blow off Valve. There were three springs which is owned each the aftermarket Blow off Valve (Please refer 3.2: Reverse Engineering).

4.2.1 APS Type's Spring

This data collected from the Hooke's Law Experiment using the APS Type's spring.

Table 4.1: Data collected from the APS type's spring

Meter Stick Reading (cm)	Displacement from Equilibrium (cm)	Mass (g)
66	0	0
63.5	2.5	5
60	6	10
57.5	8.5	15
54	12	20
52	14	25
48.5	17.5	30

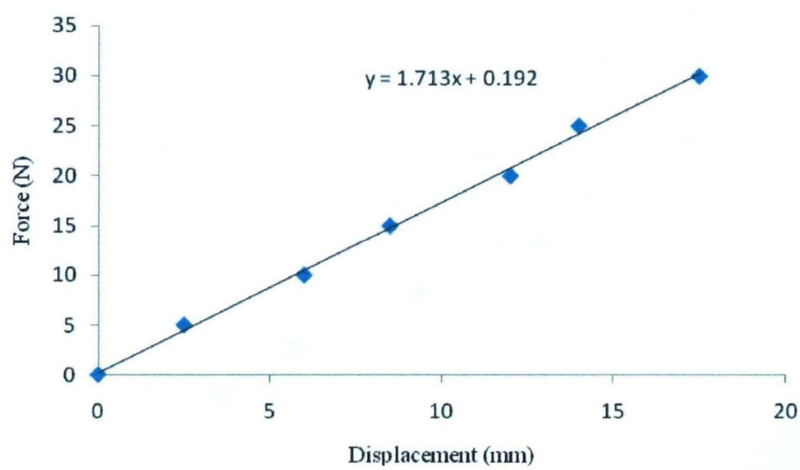

Figure 4.1: Graph force vs displacement for APS type's spring

4.2.2 Super Sequential Blow off Valve Type's Spring (Monza)

This data collected from the Hooke's Law Experiment using Super Sequential Blow off Valve Type's spring (Monza).

Table 4.2: Data collected from super sequential blow off valve type's spring (Monza)

Meter Stick Reading(cm)	Displacement from Equilibrium (cm)	Mass (g)
32	0	0
29.5	2.5	5
28	4	10
25.5	6.5	15
23	9	20
22	10	25
20	12	30

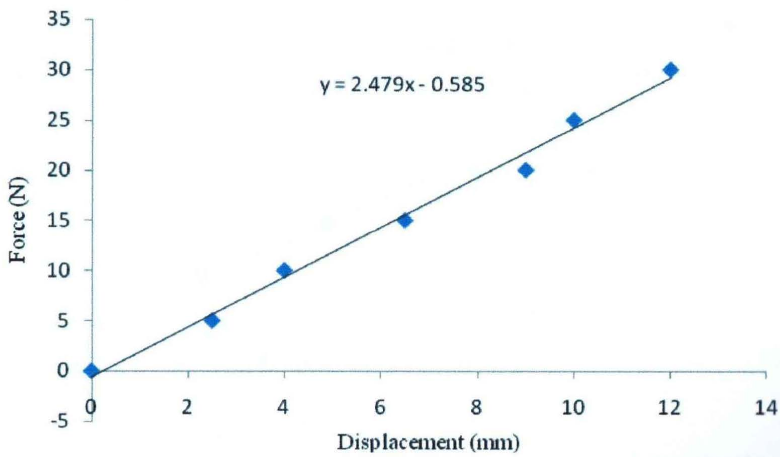

Figure 4.2: Graph force vs displacement for super sequential blow off valve type's spring (Monza)

4.2.3 Super Sequential Blow off Valve Type's Spring (Taiwan)

This data collected from the Hooke's Law Experiment using Super Sequential Blow off Valve Type's spring (Taiwan).

Table 4.3: Data collected from the super sequential blow off valve type's spring (Taiwan)

Meter Stick Reading (cm)	Displacement from Equilibrium (cm)	Mass (g)
34	0	0
31.5	2.5	5
28.5	5.5	10
25	9	15
23	11	20
21	13	25
19	15	30

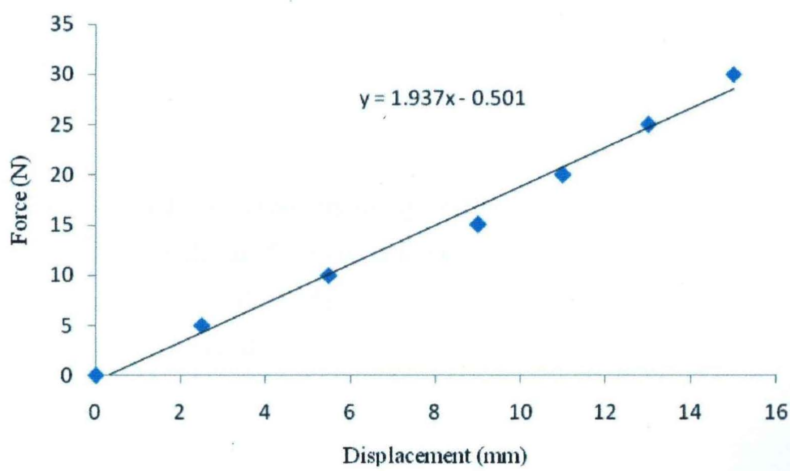

Figure 4.3: Graph force vs displacement for super sequential blow off valve type's spring (Taiwan)

4.2.4 Discussion of the Hooke's Law Experiment

The experiment showed that the values of the stiffness are different each other.

APS Type's spring	:	1.713 Nm
Super Sequential Blow off Valve Type's Spring (Monza)	:	2.479 Nm
Super Sequential Blow off Valve Type's Spring (Taiwan)	:	1.937 Nm

From this experiment know that, SSQV Monza's spring is stiffer than SSQV Taiwan and APS Type. This is because; SSQV Monza is a dual stages pull type Blow off Valves. The SSQV Monza will not leak under high boost conditions. Other than that, SSQV Monza needs the stiffer spring to maintain the valve and keep it closed to the seat. For APS Type, the spring is longer than other type. This is because, the piston needs to travel more distance to open the port to pressurize the boost to the atmosphere.

4.3 CFD CosmosFloworks Analysis Result

The analysis used is CFD and by using CosmosFloworks software. The purpose of the study is to study the air flow inside the Blow off Valve. There are two criteria that will discussed, first is about the opening of the valve, and second is about the pressure applied to that model.

4.3.1 Variable Opening of the Valve

Here will discuss about the variable opening of the valve. There are two variables made which are moderate opened valve and fully opened valve at 250kPa.

4.3.1.1 Moderate Opened Valve

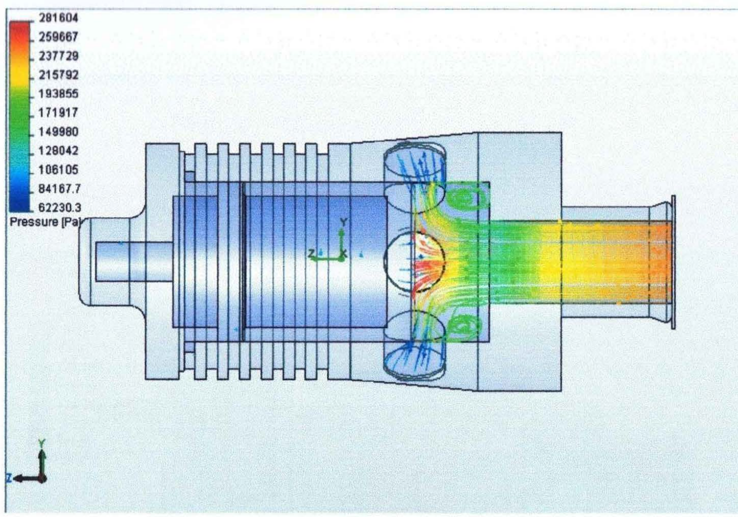

Figure 4.4: Simulation flow trajectories of APS Type – Moderate Opened (250kPa)

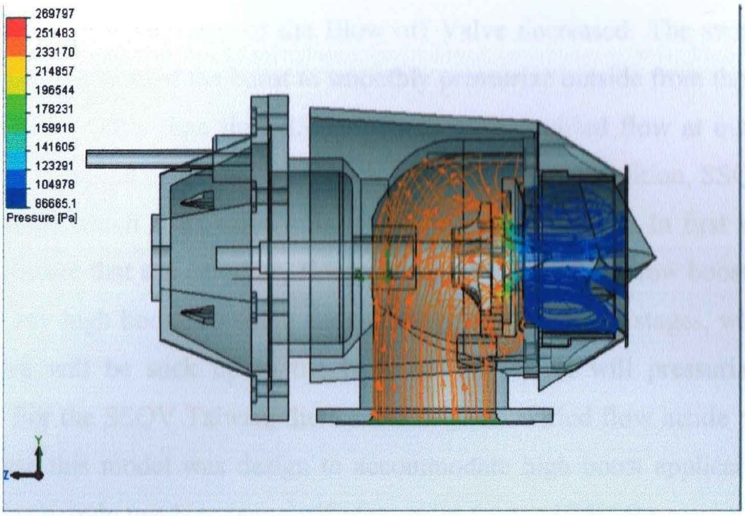

Figure 4.5: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Monza) - Moderate Opened (250kPa)

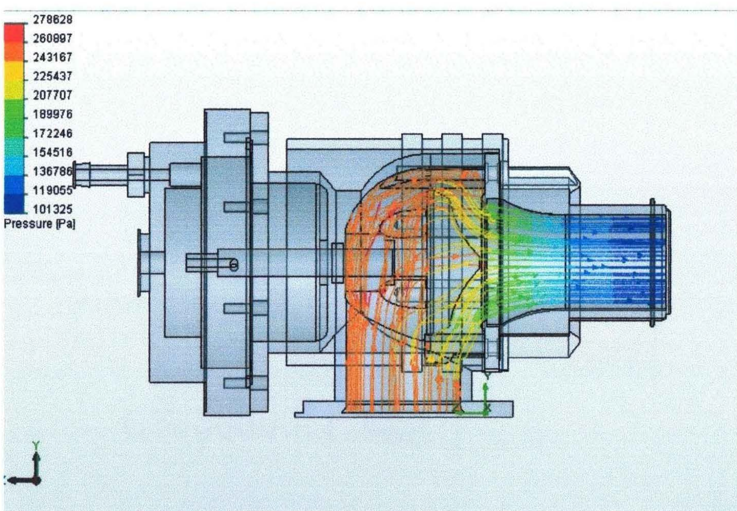

Figure 4.6: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Taiwan) – Moderate Opened (250kPa)

From Figure 4.3, Figure 4.4, Figure 4.5 found that the trajectories flow of each model are different each other. The same pressure inlet was setup in this analysis. It is 250kPa. APS Type's flows have a more air swirl than other model. This can make the efficiency of the Blow off Valve decreased. The swirled flows will disturbed the flow of the boost to smoothly pressurize outside from the engine to the atmosphere. Other than that, SSQV Monza has a swirled flow at outlet of the boost at the right end of the model. This is because, in this condition, SSQV is only in a first stage which is its valve only opened the outlet a little. In first stages, the suitable pressure that can smoothly flow through this stage is the low boost pressure. If there is any high boost, its valve automatically do the second stages, which is the entire valve will be suck up to the back and the boost will pressurize outside smoothly. For the SSQV Taiwan, there are nearly no swirled flow inside the model. It is because this model was design to accommodate high boost applications. This SSQV Taiwan, only needs to open half of its valve to stand 250kPa.

4.3.1.2Fully Opened Valve

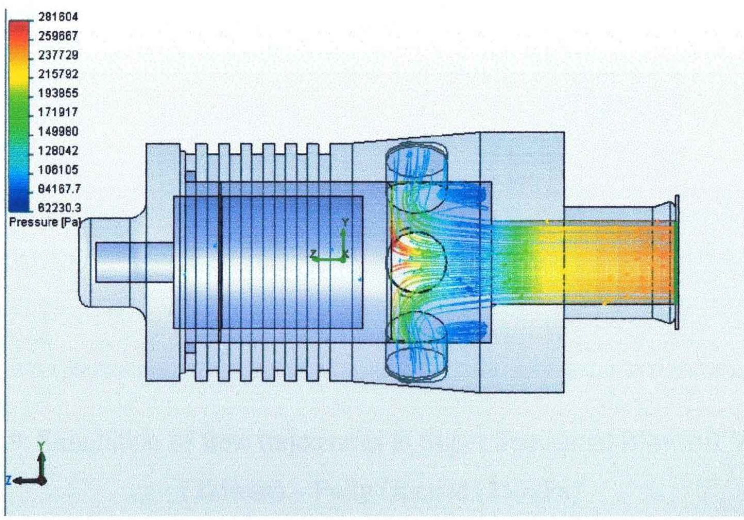

Figure 4.7: Simulation flow trajectories of APS Type – Fully opened (250kPa)

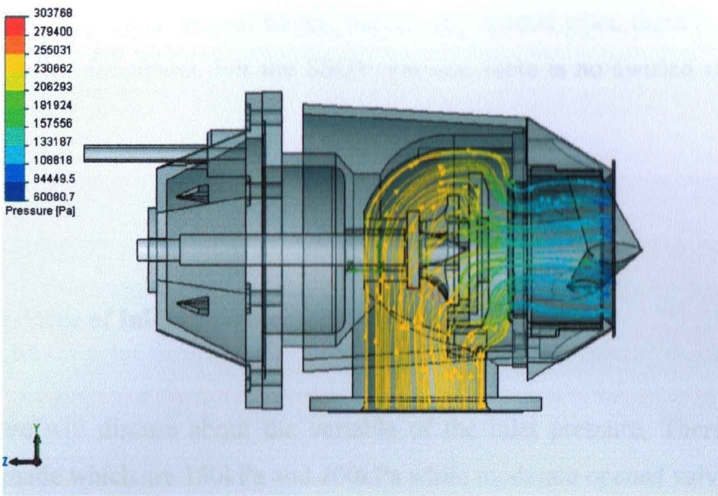

Figure 4.8: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Monza) – Fully Opened (250kPa)

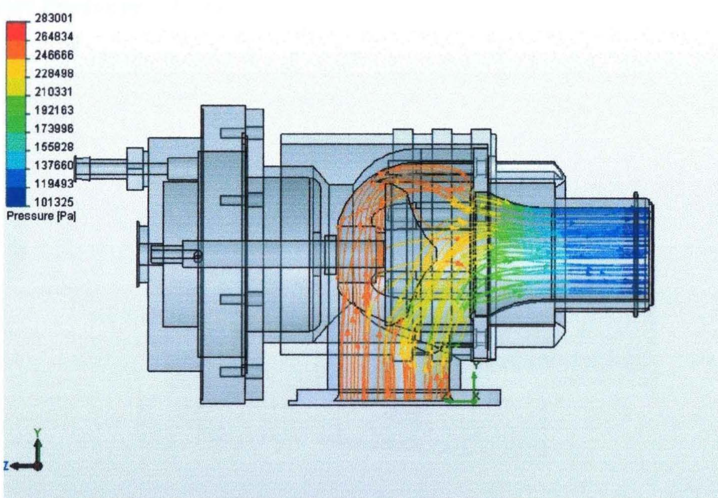

Figure 4.9: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Taiwan) – Fully Opened (250kPa)

From the Figure 4.7, Figure 4.8, Figure 4.9 found that, only APS Types BOV has a swirled air in the model. This is because the outlet port and the inlet port are perpendicular. Its will destruct the air flows outside smoothly. So the air swirls inside the model. For the SSQV Monza, the air flow inside this model is perfectly smooth. There is no swirled air like in the first stage before (Refer 4.2.1.1 Moderate Opened

Valve). This SSQV is in second stages, which only operate when there is high boost condition inside the model. For the SSQV Taiwan, there is no swirled air exists in the model.

4.3.2 Variable of Inlet Pressure

Here will discuss about the variable of the inlet pressure. There are three variables made which are 150kPa and 200kPa while moderate opened valve.

4.3.2.1 Inlet Pressure – 150kPa

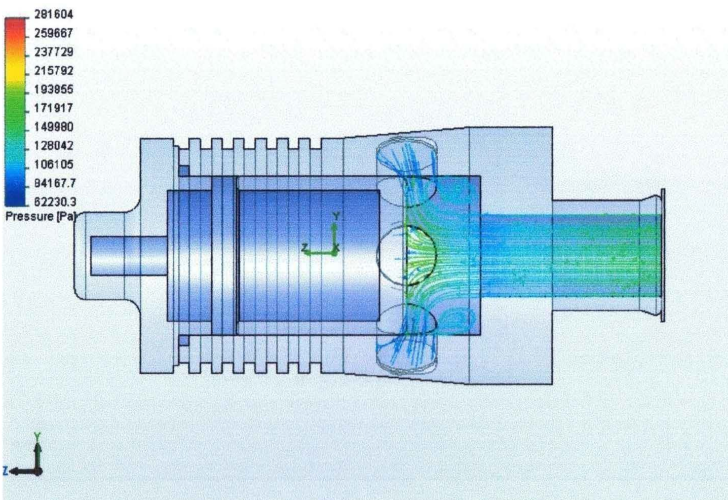

Figure 4.10: Simulation of flow trajectories in APS Type – Moderates Opened (150kPa)

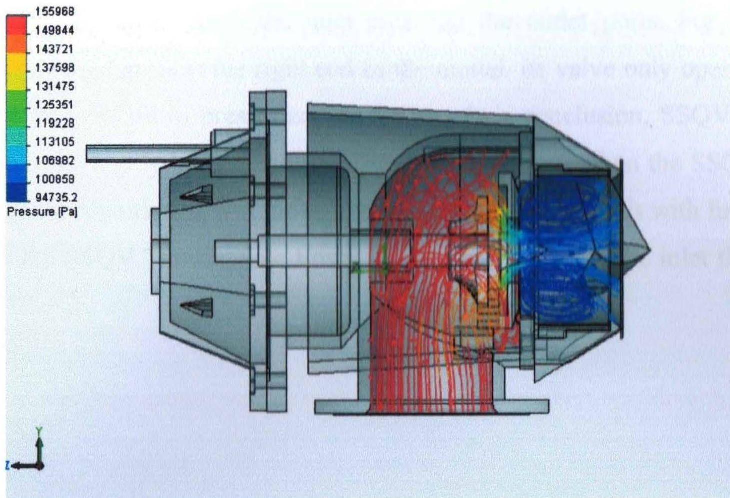

Figure 4.11: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Monza) – Moderates Opened (150kPa)

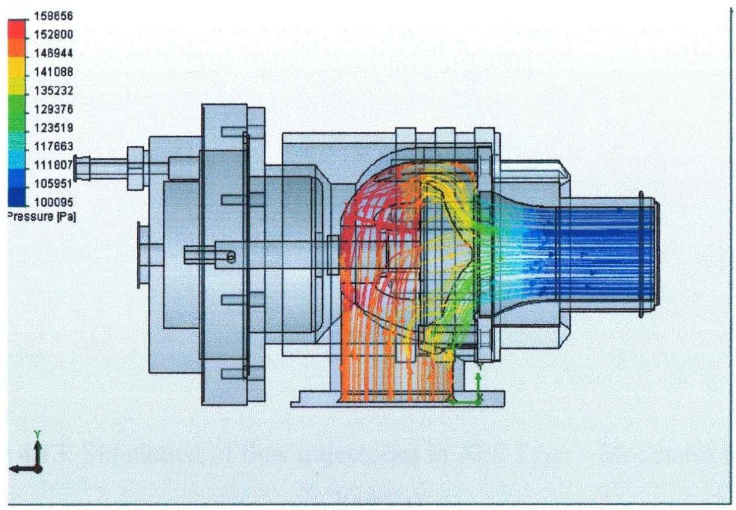

Figure 4.12: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Taiwan) – Moderates Opened (150kPa)

From Figure 4.9, Figure 4.10, Figure 4.11 found that APS Type and SSQV Monza have a swirled air in the model. SSQV Taiwan shows a smooth flow from the inlet through the outlet. The APS Type problem is the same. The swirled flow caused by the perpendicular between the inlet port and the outlet ports. For the SSQV Monza, the swirled air is at the right end of the model. Its valve only opened a little, so that the air difficult to pressurized to the air. As a conclusion, SSQV Monza is suitable with the highly boost condition usage. It is because when the SSQV Monza in highly boost condition, it will move to the second stage which is with fully opened valve. For the SSQV Taiwan, The flow is flow smoothly from the inlet through the outlet.

4.3.2.2 Inlet Pressure – 200kPa

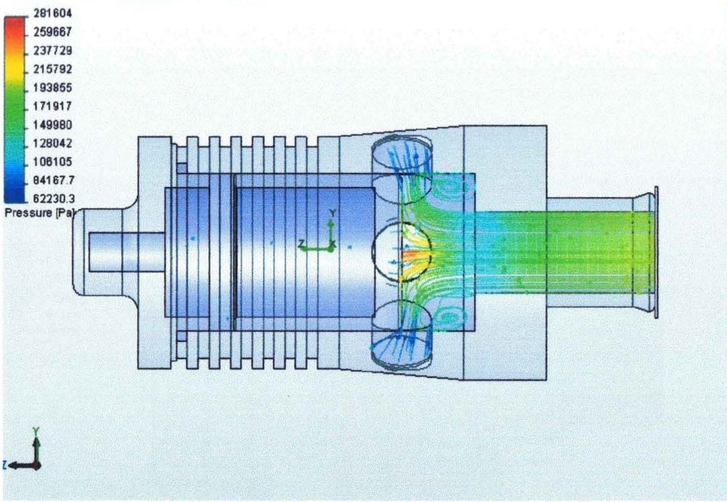

Figure 4.13: Simulation of flow trajectories in APS Type – Moderates Opened (200kPa)

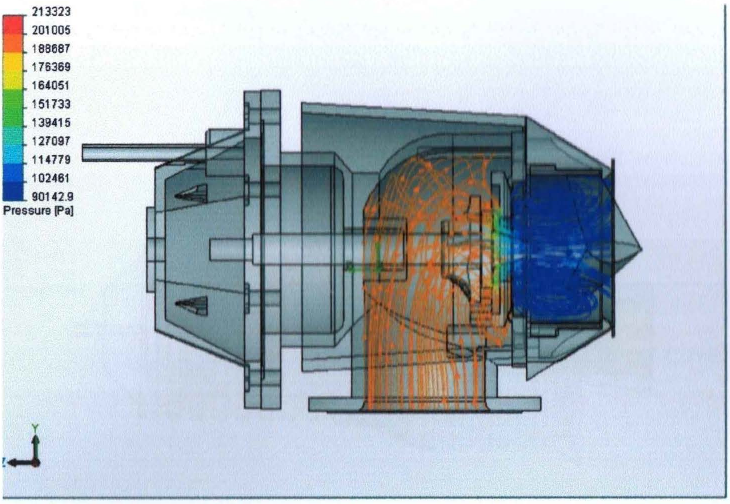

Figure 4.14: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Monza) – Moderates Opened (200kPa)

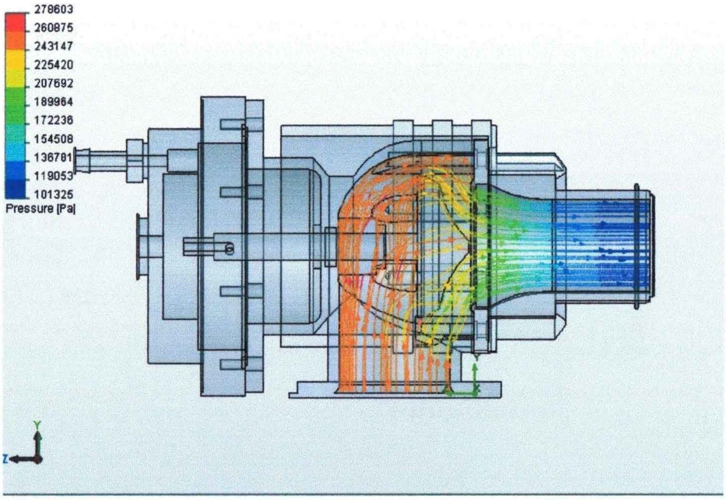

Figure 4.15: Simulation of flow trajectories in Super Sequential Blow off Valve Type (Taiwan) – Moderates Opened (200kPa)

From Figure 4.12, Figure 4.13, Figure 4.14 found that the nearly same problem occurs and nearly the same flow trajectories exist such as in analysis before (4.2.2.1 Inlet Pressure – 150kPa).

4.4 The Own Design Analysis

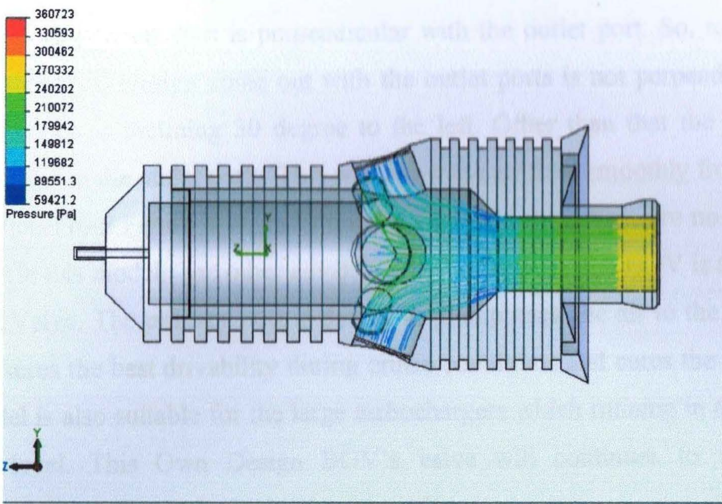

Figure 4.16: Simulation of flow trajectories in Own Design Blow off Valve – Fully Opened (250kPa)

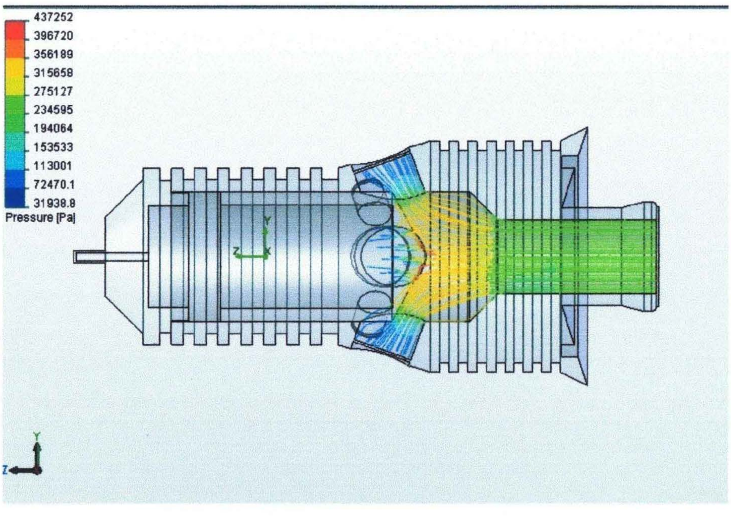

Figure 4.17: Simulation of flow trajectories in Own Design Blow off Valve – Moderate Opened (250kPa)

From the problems occur in previous analysis (reverse engineering analysis), this Own Design BOV designed to prevent the problem. The problem in APS Type (Figure 4.4) is the inlet port is perpendicular with the outlet port. So, to solve this problem, this Own Design come out with the outlet ports is not perpendicular with inlet port which is inclining 30 degree to the left. Other than that the piston was design parallel to the outlet ports. This will allow the air flow smoothly from the inlet to the outlet. From Figure 4.16 and Figure 4.17 found that, there are no swirled air exists inside this model. The other advantage is the Own Design BOV is a dual stage Blow off Valve. The primary port is design to plump back the air to the entry point which ensures the best drivability during cruise conditions and cures the erratic idle. This model is also suitable for the large turbochargers which running in a high boost pressure level. This Own Design BOV's valve will continues to vent to the secondary port when it in the highly boost condition.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In the process of designing the Blow off Valve, it can be deduced that the design has reached the objectives set. The flow of the air is smoothly flow from the inlet through the outlet. No more swirled air inside the design. So, no air will flow back to the engine which can cause the wear and stalling to the engine. Besides, this design can stand the higher boost pressure from any turbocharger car up to 250kPa.

CFD also is a very good tool to analyze the Blow off Valve and is a form to reduce the cost. From the simulations, the material, dimension of the design is not finalized. So that, the good Blow off Valve or any product can be design without any loss.

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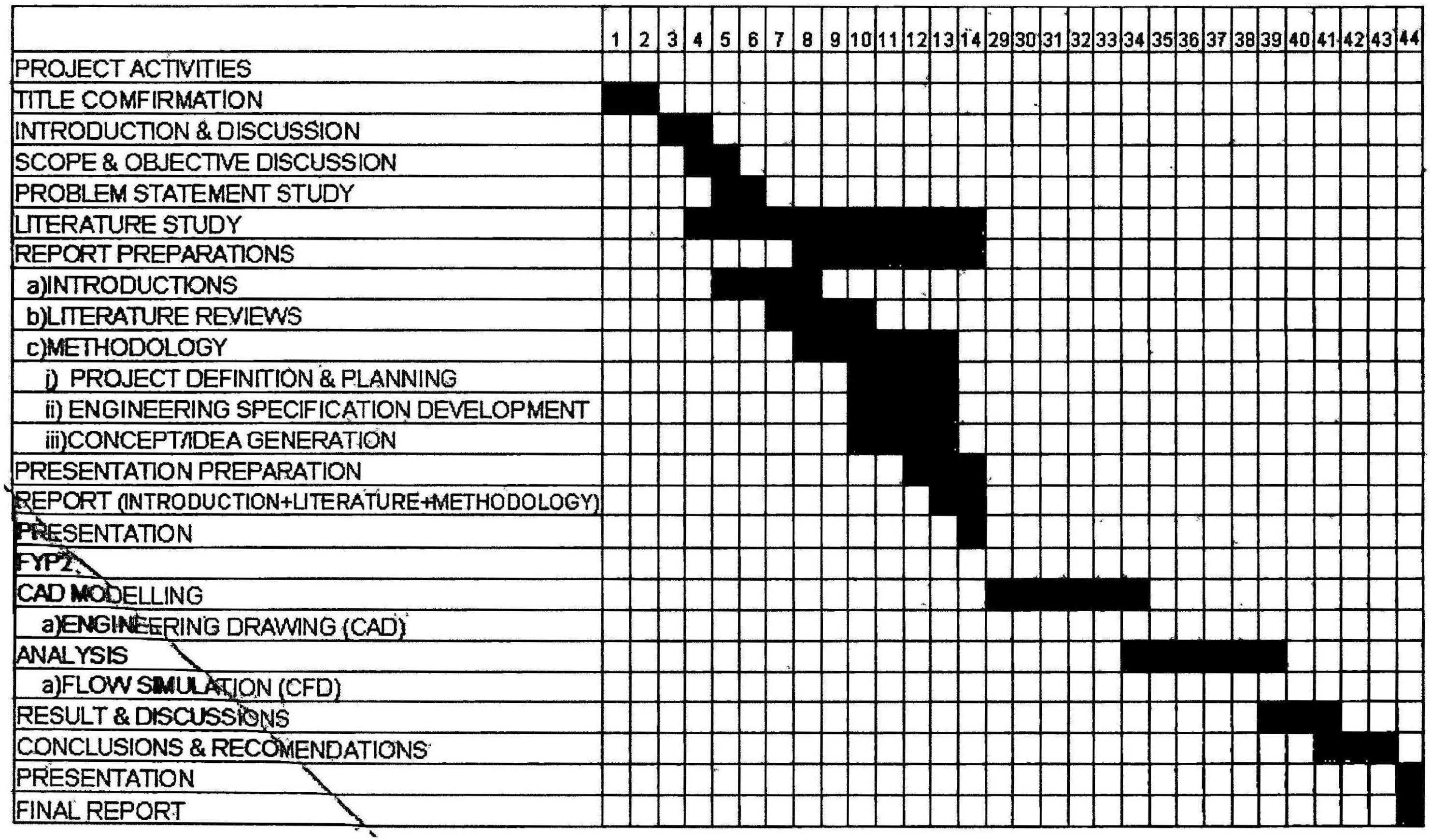
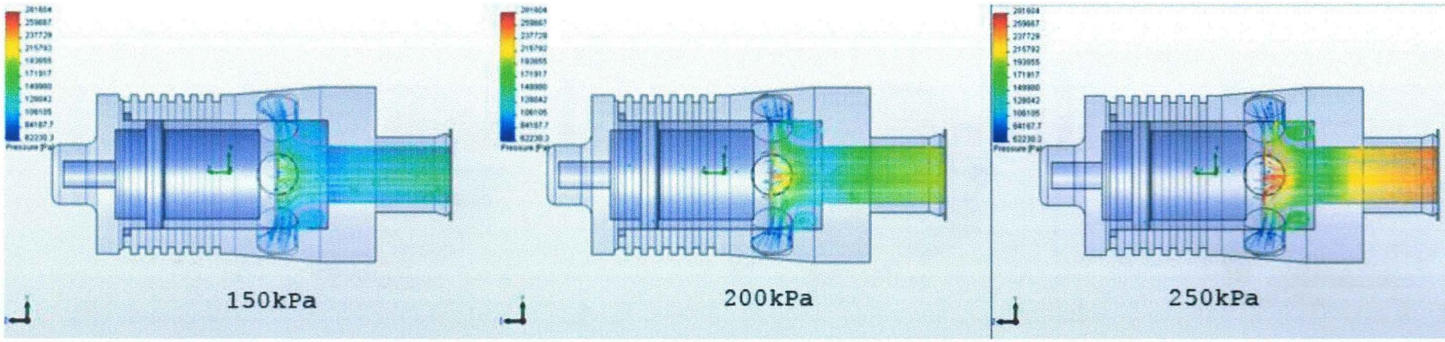
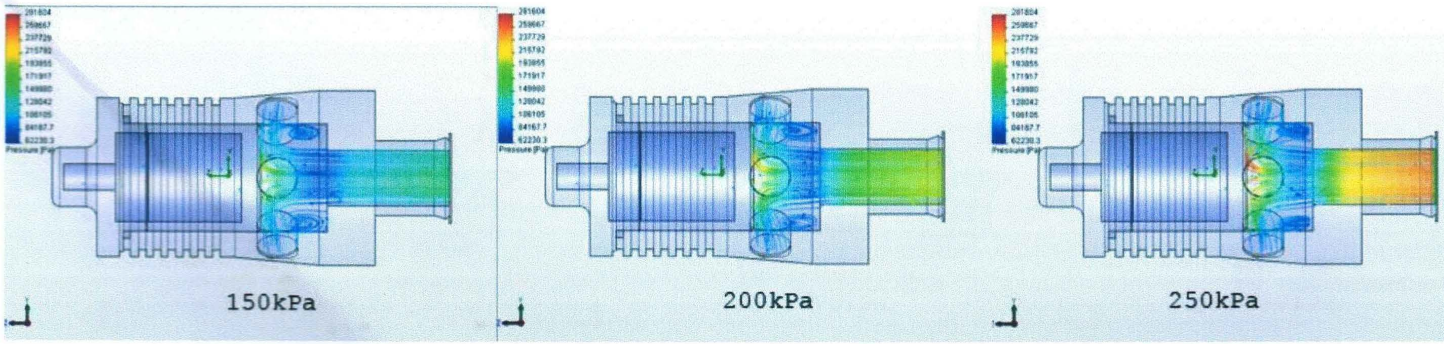
Appendix A
Gantt Chart



Thesis Gantt chart for the whole project

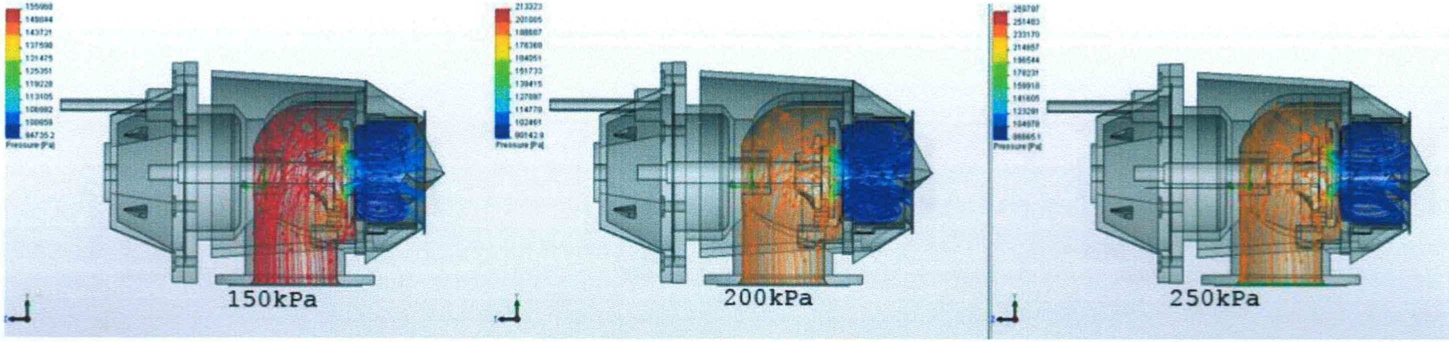


Moderate Opened



Fully Opened

Simulation for APS Type BOV



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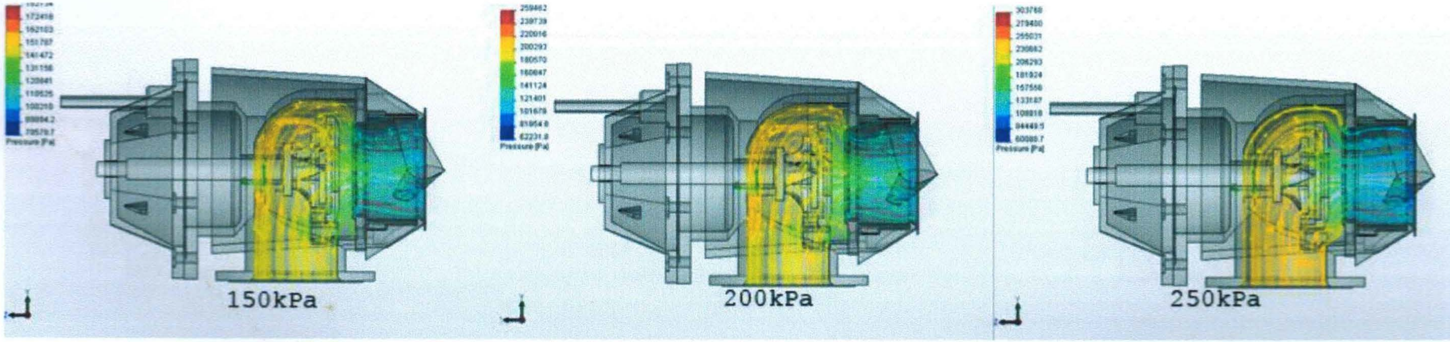

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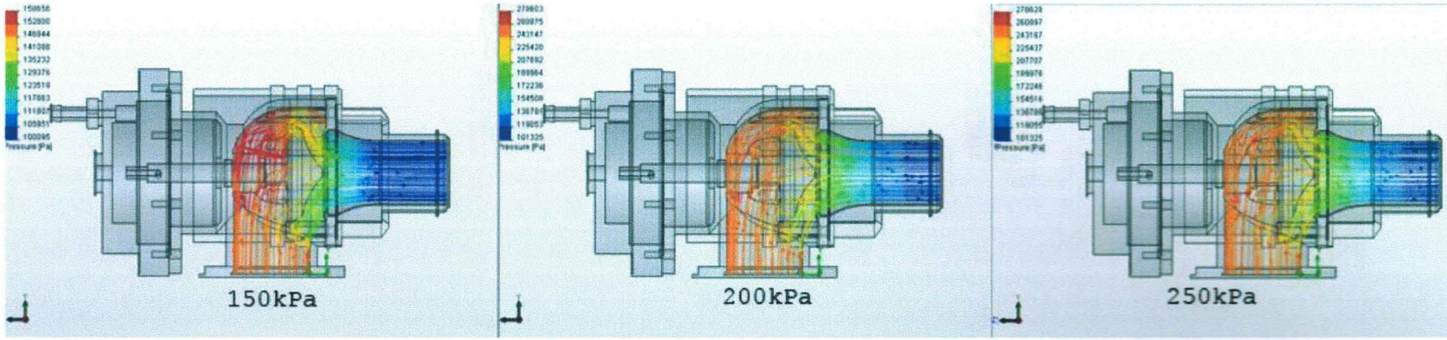
Simulation for SSQV Monza



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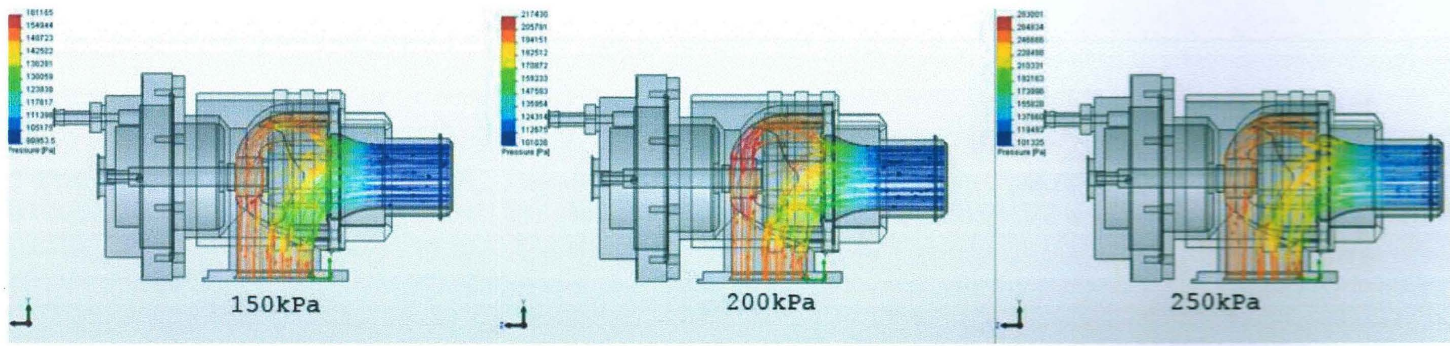

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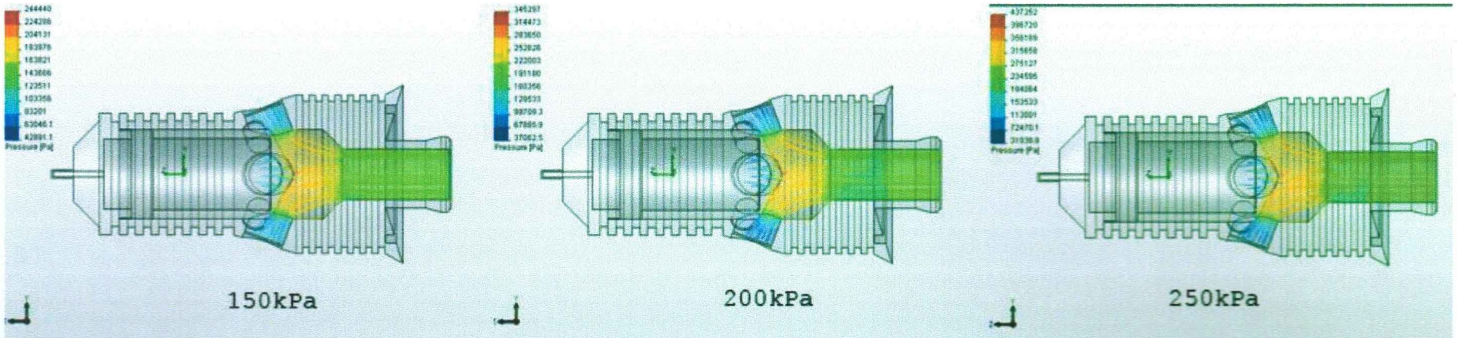
Simulation for SSQV Taiwan



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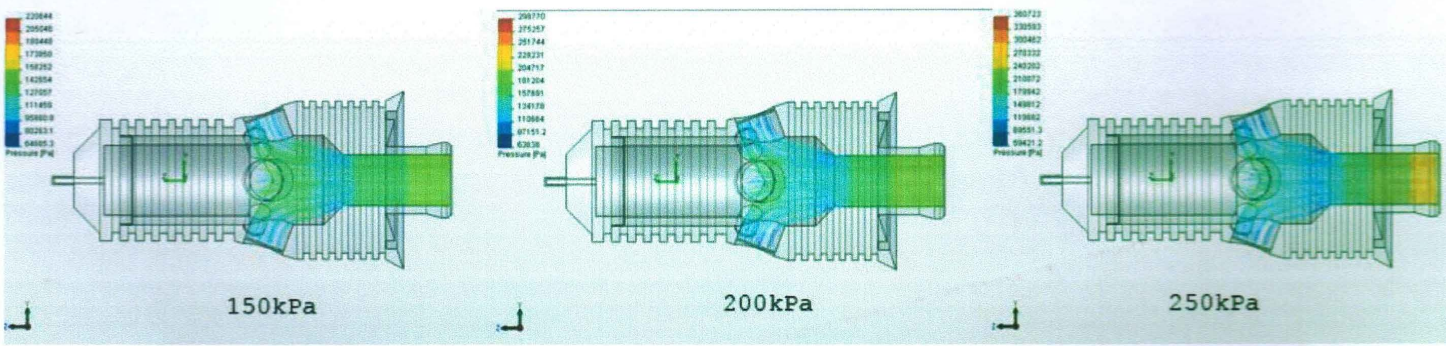

Fully Opened

Simulation for Own Design BOV