# DESIGN AND DEVELOPMENT OF PISTON-CONTROLLED INTAKE PORT FOR 4-STROKE ENGINE

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## ABSTRACT

In a two stroke engine, piston control the intake port opening and closing that combine the intake and compression stroke in 180° crank rotation. The operational concept of two stroke engine is applied to the existing four stroke engine cylinder head. The four stroke engine cycle is more fuel-efficient, clean burning and higher engine power output due to higher volumetric efficiency, higher combustion efficiency and low sensitivity to pressure losses in exhaust system. However, the four stroke engine is high manufacturing cost due to more components compared to the two stroke engine. The objective of this work is to study the existing base four stroke engine valvetrain, design and develop piston controlled intake port for the base Modenas engine. The work also describe the concept design process using theoretical calculation and Solidworks software with the animation and basic CFD simulation to indicates the flow pattern and compare to the original design. From the theoretical calculation is observed that, the torque and power increased up to 34.8% and 7.5% compare to the base engine. Flow simulation done at the intake stroke shows that there is improved in flow pattern with more uniform swirl generated but this new cylinder head design did not much different in velocity and pressure flow pattern. The power losses in the valvetrain will be reduce due to less energy output from crankshaft needed to drive the upper crank arm. Furthermore, the upper piston will provide power during power stroke and instead of building whole new engine, replacing the existing cylinder head with this new cylinder head can significantly reduce cost, time to market and improve existing product reliability.

# ABSTRAK

Dalam enjin dua lejang, pembukaan dan penutupan injap masuk dikawal oleh piston yang mana mengabungkan proses pengambilan dan mampatan dalam 180$^{o}$ putaran engkol. Konsep enjin dua lejang diaplikasikan keatas kepala silinder enjin empat lejang yang sedia ada. Kitaran enjin empat lejang adalah lebih baik dalam kecekapan bahan bakar, pembakaran yang bersih, kuasa pengeluaran enjin yang lebih tinggi disebabkan oleh kecekapan isipadu, kecekapan pembakaran yang tinggi dan kepekaan yang rendah terhadap kehilangan tekanan dalam sistem ekzos. Walaubagaimanapun kos pembuatan enjin empat lejang adalah tinggi disebabkan oleh jumlah komponen yang banyak jika dibandingkan dengan enjin dua lejang. Objektif utama kerja ini adalah untuk mempelajari rangkaian injap enjin empat lejang, mereka dan membentuk injap masuk yang dikawal oleh piston pada enjin Modenas. Dalam kerja ini juga menerangkan tentang proses konsep rekaan menggunakan teori pengiraan dan perisian Solidworks berserta animasi dan simulasi CFD untuk melihat pembentukan pengaliran dan perbandingan terhadap rekaan asal. Melalui teori pengiraan didapati bahawa, daya kilas dan kuasa meningkat naik sehingga 34% dan 7.5% dibandingkan dengan rekaan asal. Simulasi pengaliran telah dijalankan semasa lejang pengambilan dan menunjukan peningkatan dalam pembentukan pengaliran dengan membentuk swirl yang sekata tetapi rekaan baru kepala silinder ini tidak banyak perubahan dalam bentuk pengaliran halaju dan tekanan. Kehilangan tenaga dalam rangkaian injap akan berkurangan disebabkan oleh kurangnya jumlah tenaga keluaran dari aci engkol yang diperlukan untuk memacu lengan aci dibahagian atas. Lebih lagi, piston dibahagian atas akan membekalkan tenaga semasa lejang kuasa dan dari memghasilkan keseluruhan enjin baru, mengantikan kepala silinder yang sedia ada dengan rekaan ini nyata dapat mengurangkan kos, masa untuk pemasaran dan menigkatkan kepercayaan terhadap barangan sedia ada.

# TABLE OF CONTENTS

**CHAPTER 4 COMPARISON**



**CHAPTER 5 CONCLUSION AND RECOMMENDATION**

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF FORMULA

# LIST OF SYMBOLS

| | |
|---|---|
| ml | Milliliter |
| kg | Kilogram |
| min | Minutes |
| cc | Centimeter of cubic |
| Kpa | Kilo Pascal |
| m/s | Meter per second |
| kW | Kilo Watt |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ABDC | After Bottom Dead Center |
| ATDC | After Top Dead Center |
| BBDC | Before Bottom Dead Center |
| BDC | Bottom Dead Center |
| BTDC | Before Bottom Dead Center |
| CAD | Computational Aided Design |
| CFD | Computational Fluid Dynamics |
| CMM | Coordinate Measuring Machine |
| CR | Compression Ratio |
| EC | Exhaust Closed |
| EGR | Exhaust Gas Recycled |
| EO | Exhaust Open |
| FEM | Finite Element Method |
| FVM | Finite Volume Method |
| NOx | Nitrogen Oxide |
| TC | Transfer Closed |
| TDC | Top Dead Center |
| TO | Transfer Open |

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

An engine is a machine that convert heat energy to mechanical energy. The heat from a burning fuel produce power that move the vehicle and sometimes engine called *power plant*. Automotive engine are internal combustion engines because fuel that run the mechanism burned internally, or burned inside the engine. They are two type which is reciprocating and rotary engine. Mostly automotive engine are reciprocating. Reciprocating engine have piston that moved up and down or reciprocate in the engine which called piston engines. Rotary engine have rotor that spins, or rotate and the type of engine can also be used in the automobiles such as Wankel engine.

## 1.2 PROBLEM STATEMENT

From the previous study of four stroke and two stroke engine, it is notice that both have own advantages and disadvantages. The performance of the two stroke engine are better than four stroke due to stroke difference and the amount of power loss created by the valve train in four stroke engine but in term of exhaust emission four stroke engine are better, the demand of higher power output are needed but to build a new engine with the specific high power output are costly.

This study will increase the amount of output power and torque by removing the valve train on cylinder head and develop piston that controlled intake port, maintaining the four stroke engine while adding another piston with two strokes that

replacing the cylinder head. The engine displacement will increase due to two reciprocating piston operating at the same time and created the combustion chamber more displacement at the same time the piston becoming more positive power contributors and the loss of power due to the valve train can be eliminated.

## 1.3 OBJECTIVE

The objective for this project is:

i. Study of Modenas Kriss 110 Engine valve train.
ii. Design and develop piston controlled intake port for Modenas Kriss 110 engine

## 1.4 SCOPES

The following study include in the study and development of single cylinder four stroke engine:

i. Literature review on two stroke, four stroke and intake port.
ii. Define the Modenas Kriss 110 engine parameter.
iii. Simulation engine parameter using GT-VTrain
iv. Design of concept model of piston control intake port using CAD.
v. Design and performance comparison

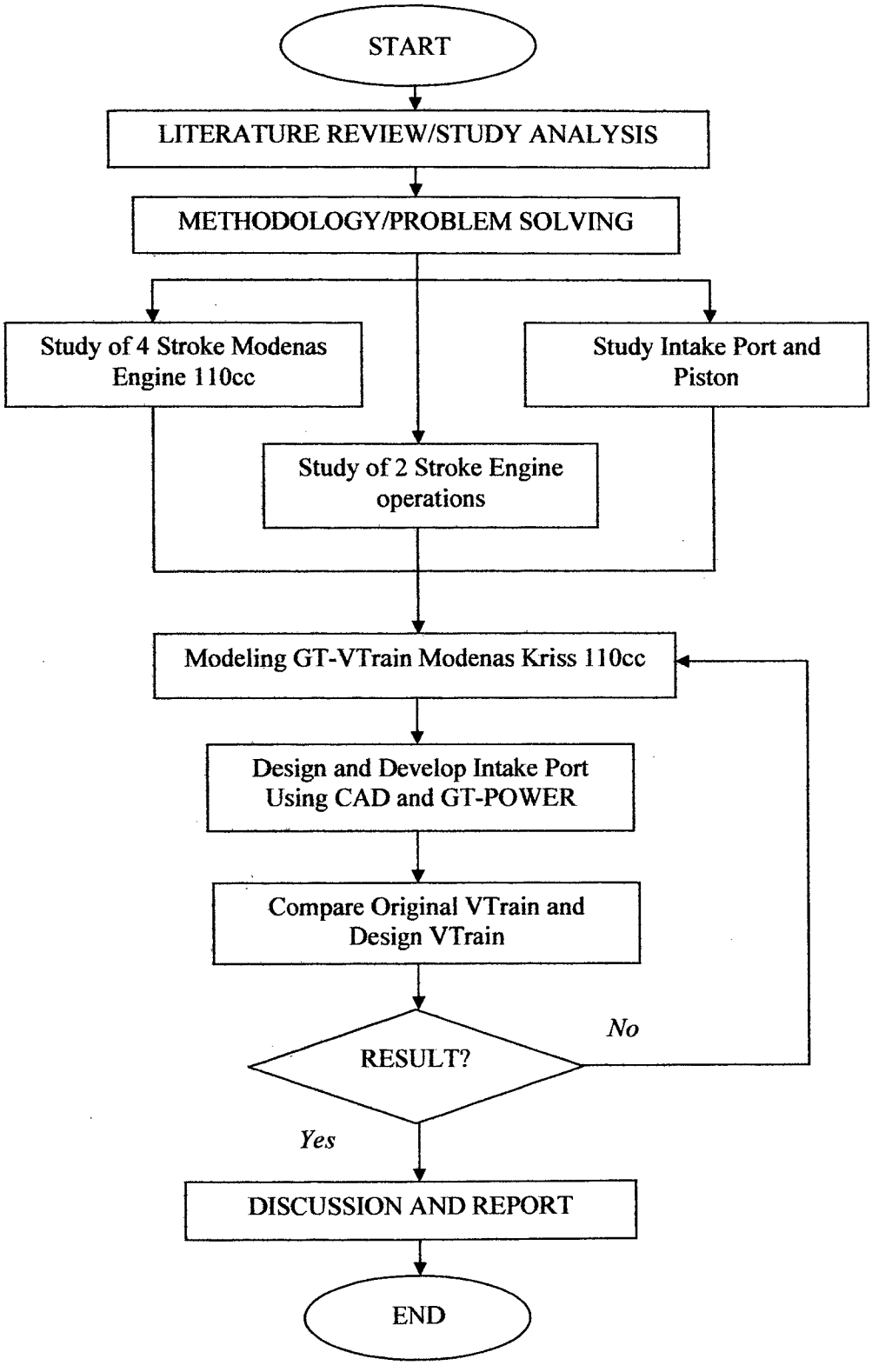



**Figure 1.1** The division of work and study

# CHAPTER 2

# BACKGROUND STUDY

## 2.1 DEVELOPMENT OF INTERNAL COMBUSTION ENGINE OPERATION

The automotive industry experience the revolution due to the design and development of internal combustion has two approaches in operating concept that develop since 1990s to improve energy and emission to gain environmental efficiency.

The fist approach capture the waste heat generated in Otto cycle by develop additional two stroke after the four stroke to design cooling system by injecting water air fresh air into the combustion chamber. The currently notable six stroke engine designs include Crower's six stroke engine, the Bajulaz engine and the Velozeta Six-stroke engine. This engine reduces fuel consumption by at least 40%; improve the cooling system and two expansions work in six strokes [1].

Another approach employed by *Helmut Kottmann* that invented The German Charge pump engine and *Malcolm Beare* that invented the Beare Head. This two inventions design with pairs of piston working together, the Beare used second piston in each cylinder moves half of the main piston which create four stroke main piston and additional two stroke of upper piston makes six stroke engine. Similar in design Beare head, a piston charger replaces the valve system. The piston charger charges the main cylinder and simultaneously regulates the inlet and the outlet aperture leading to no loss of air and fuel in the exhaust. This approach replacing valve with piston control intake, more power generated and better fuel consumption [2] [13]. This approach suited to alternative fuels due to no corrosion left on valve.

### 2.1.1 Positive Aspects of the Development

The two approached in six stroke engine give improvement in design and application. The positive aspect and improvement of these two concepts are different from other but gain the same objective which is to improve the performance of the engine. In the design of Bruce Crower called "Crower Six Stroke Engine" or *Dyer cycle* concept that adding another two stroke in the end of four stroke cycle, the third down-stroke is a "steam stroke" water is injected directly into the heated combustion chamber created steam that force the piston down create power stroke. The third up-stroke is the exhaust stroke force the steam out. This approach claimed that no cooling system needed since the energy that is dissipated in conventional arrangements by the radiation cooling system has been converted into additional power strokes.

In the Malcolm Beare design consist of two reciprocating piston that acting together in one cylinder called "Beare Cylinder Head" , by removing the valve train and replace with piston that control intake develop a moveable displacement and these approach improved the displacement of the engine. In the combustion stroke, both pistons acting to transmitted power to crankshaft via timing chain. Base on the experiment done by Malcolm Beare claims that the upper crank and piston become positive power, thus increase the amount of output power up to possible 35%. The design is simple and less expensive manufacturing and tooling. The exhaust emissions reduce due to less fuel being consumed and lower maintenance cost due to less wearing part. [2] [13].

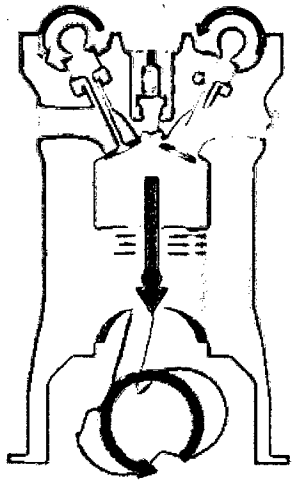
## 2.2 FOUR STROKE ENGINE

Engine commonly classified to two stroke and four stroke engine, in 1876 a Germany Engineer named Nicolas Otto invented first four stroke engine (Otto cycle) that now commonly used in the automobile and industry purpose. The four stroke engine consists of four cycles. The cycle is more fuel-efficient, clean burning, low fuel consumption and higher engine power output due to higher volumetric, higher

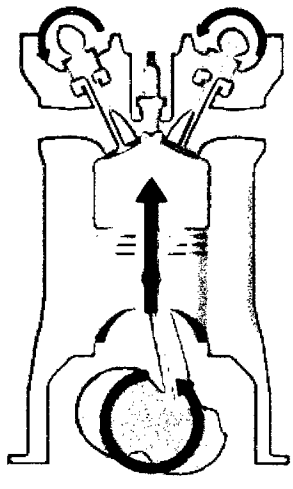
combustion efficiency and low sensitivity to pressure losses in exhaust system but high manufacturing cost and complex design. [12]

### 2.2.1 Four Stroke Cycles Engine Operations

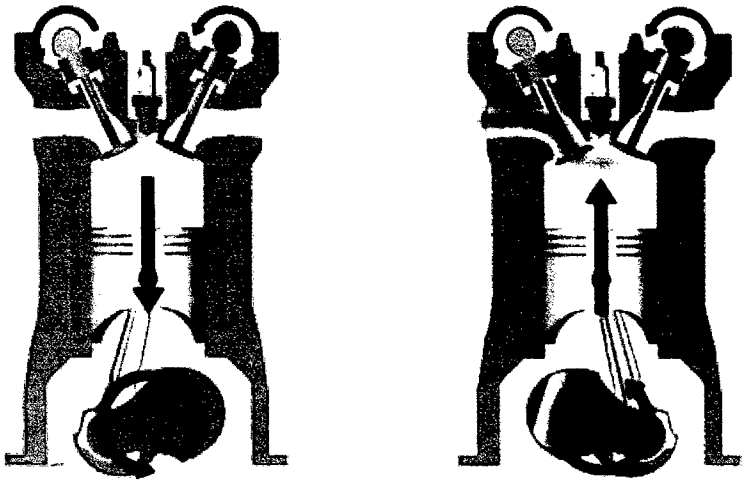
Four stroke cycle engine carried out four cycle strokes during one combustion cycle, the strokes is intake stroke, compression stroke, power stroke and exhaust stroke. During the intake stroke the intake valve is opened and the piston moves toward the crank shaft **(Figure 2.1a).** The movement of the piston creates a negative pressure in the combustion chamber. The air or fuel mixture is sucked into the chamber. If the Bottom Dead Center (BDC) is reached the intake valve is closed and the piston moves upwards for the compression stroke **(Figure 2.1b).** The air or fuel mixture is compressed. A short period before the Top Dead Center (TDC) is reached the spark plug ignites the air/fuel mixture. Temperature and the pressure into the combustion chamber increased rapidly and high pressure drives the piston downward for the power stroke **(Figure 2.1c).** At the end of the power stroke at the BDC the exhaust valve is opened and the piston is moved upward so that the gases in the combustion chamber will be pushed through the exhaust valve for the exhaust stroke **(Figure 2.1d)** [11] [12] [14].



(a) Intake



(b) Compression



(c) Combustion/Power (d) Exhaust

**Figure 2.1:** The conventional four stroke engine operation [14]

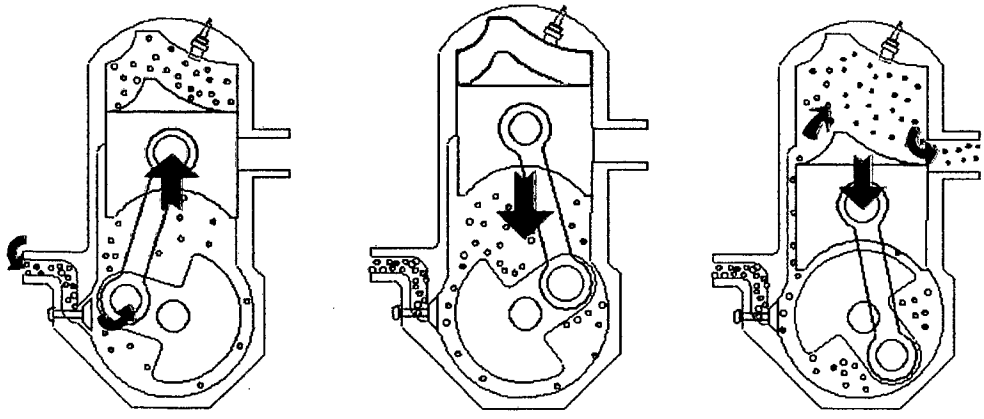
## 2.3 TWO STROKE ENGINE

The first two stroke engine was gas engine that invented by Etienne Lenoir in 1860, and the two stroke diesel engine invented by Sir Dugald Clerk in England at 1878 and used similar head of four stroke engine but using reed valve for intake and rotary disc valve while four stroke using poppet valve. The cycle according to four strokes which is intake, compression, combustion and exhaust but done in two cycle only. Throughout the 20th century, many small motored devices such as chainsaws, and outboard motors were usually powered by two-stroke designs [12].

They are popular due to their simple design (and therefore, low cost) and very high power-to-weight ratios. However, varying amounts of engine oil in traditional designs mixes with the air-fuel mixture, which significantly increases the emission of pollutants. For this reason, two-stroke engines have been replaced with four stroke engines in many applications, though some newer two-stroke designs are as clean as four-strokes.

### 2.3.1 Basics Operation of Two Stroke Engine

In two stroke engine, the application of scavenging and cylinder to archive all the Otto cycle in two power strokes only. The two strokes concept is by combining intake and compression cycle in one cycle and power and exhaust in one cycle. The process starts when the piston moving from upward, the piston rises driven by flywheel momentum and compresses the fuel mixture. At the same time air or fuel mixer down to the crankcase by the pressure vacuum created by the moving piston through a poppet valve or reed valve **(Figure 2.2a).** After the piston compress the air and fuel mixture up to the level the spark plug ignites and create the power stroke force the piston move down-ward. The poppet or reed valve closed and creates the pressure to the air and fuel mixture make it compressed in the crankcase **(Figure 2.2b).** After Toward the end of the stroke, the piston exposes the intake port, allowing the compressed fuel/air mixture in the crankcase to escape around the piston into the main cylinder. This expels the exhaust gasses out the exhaust port, usually located on the opposite side of the cylinder. Unfortunately, some of the fresh fuel mixture is usually expelled as well **(Figure 2.2c)** [7] [11] [12].



(a) Compression/Intake (b) Combustion/Power (c) Exhaust and Transfer.

**Figure 2.2:** The conventional two stroke engine operation [14]

## 2.4 COMPARISON BETWEEN TWO STROKE ENGINE AND FOUR STROKE ENGINE

**Table 2.1**: Advantages and disadvantages of four stroke and two stroke engine

| **Four Stroke Engine** | **Two Stroke Engine** |
|---|---|
| **Advantages** | **Advantages** |
| 1. Cycle is completed | 1. Simple engine component |
| 2. Low emission produced | 2. Produce one power stroke for every one crankshaft revolution |
| 3. Lower fuel consumption rate | 3. Light and compact engine design |
| 4. Higher engine power output because of higher volumetric, thermal and part load efficiencies. | 4. Lower initial manufacturing cost due to simple and complexity of the engine components |
| 5. Lower back pressure at exhaust system | 5. Intake and exhaust port is control by the cylinder head |
| 6. Lesser cooling and lubrication requirement | 6. Applicable to both SI and CI engine |
| 7. Better control of the valve opening mechanism | |
| 8. Applicable to both SI and CI engines | |
| **Disadvantages** | **Disadvantages** |
| 1. Complex engine design | 1. Cycle is incompletes |
| 2. Lower initial power produced caused by one power stroke in every two engine revolution. | 2. Higher emission produced |
| 3. Heavy and bulky | 3. Higher fuel consumption rate |
| 4. Higher initial manufacturing cost | 4. Lower engine combustion output because lower volumetric, thermal and back load efficiencies |

## 2.5 CYLINDER HEAD

Heads are cast from the cast iron or aluminum alloy and they are machined to take the various parts that are attached or installed in the head. The cylinder head forms the top of combustion chamber. The piston and rings from bottom of each basics combustion chamber shapes produce specific effect. The wedge creates turbulent of the burning mixture, but high exhaust emissions. The hemispheric provides relatively slow burning. The cup of blow in piston improved the turbulent and the greater the turbulent was the better and fast burning rate of the air fuel mixture. In cylinder head consist a part that acting to operate the intake exhaust and combustion starter which is valve, rocker arm, spring valve and spark plug for the conventional engine [11][12].

## 2.6 VALVE

In internal combustion engine many approach and type of valve that play significant role in intake and exhaust port. Valve is plugs with long stems that control the opening and closing of the intake and exhaust port in the cylinder head. There are different type of valve but most widely used poppet for four stroke engine and reed valve for two stroke engine due to the advantages and approach of the operation.

### 2.6.1 POPPET VALVE

Poppet valves are used in most piston engines to open and close the intake and exhaust ports in the cylinder head. The valve is usually a flat disk of metal with a long rod known as the valve stem out one end. The stem is used to push down on the valve and open it, with a spring generally used to close it when the stem is not being pushed on. The shape and position of the cam determines the valve lift and when and how quick or slow the valve is opened. The cams are normally placed on a fixed camshaft which is then geared to the crankshaft, running at half crankshaft speed in a four-stroke engine.

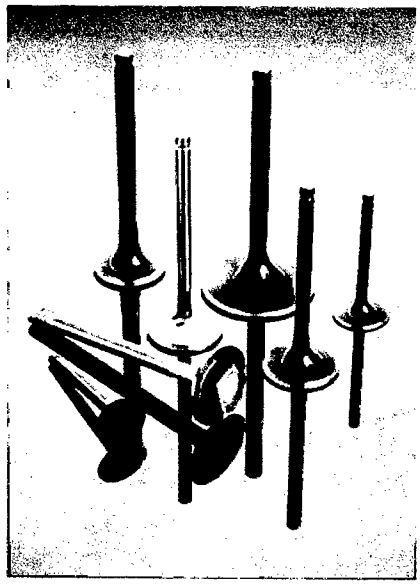


**Figure 2.3**: Poppet Valve

### 2.6.2 REED VALVE

Reed valve also known as diaphragm valves, primarily used in two stroke engine for controlling gas transfer in the intake port (**Figure 2.4**). These valves have elastic reeds that rest on a basic body. The reeds are self acting and open when vacuum builds up in the engine crankcase so that the air or fresh mixture can enter freely. As the pressure increased in the crankcase up to pressure in intake manifold, the reeds automatically close, thus preventing backflow of the induced charge. This enable long opening times and optimum utilization gas dynamic effect at high engine speeds without showing the typical shortcomings in the lower speed range.

The reed valve primary employed in two stroke engines. Tests have been carried out on four stroke engine and have resulted in more than 30% torque improvement. However the large space requirement remains problematical. There are several types of reed valve and classified according to the application, the most commonly used is V-block and Single Petal (**Figure 2.5**).

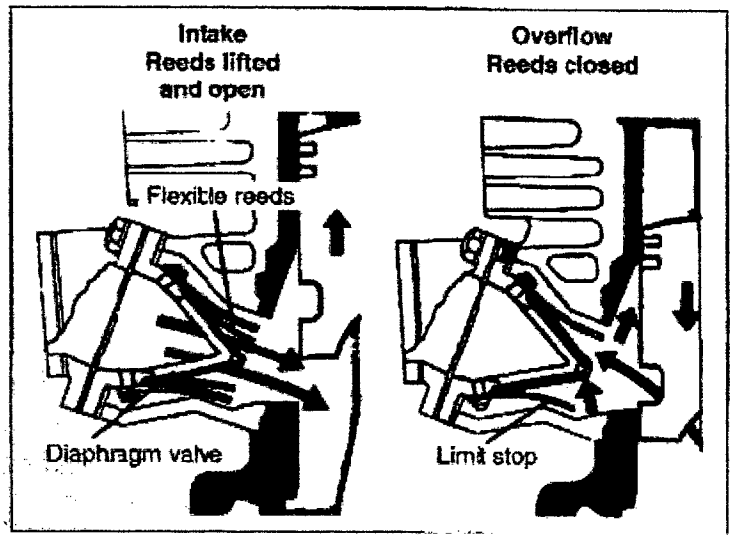
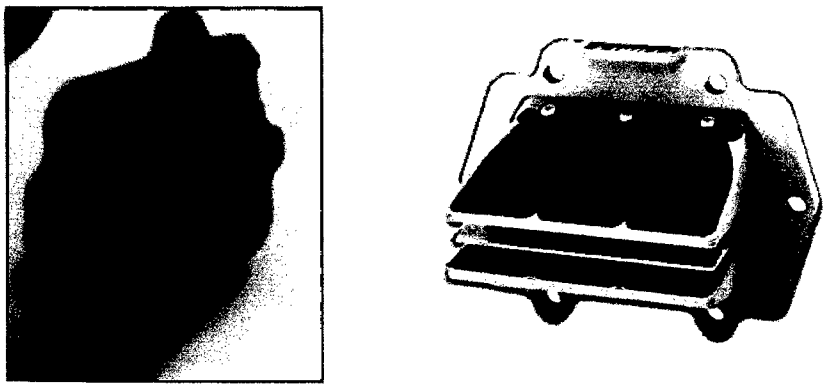



**Figure 2.4**: Reed valve in two stroke engine.

For the high performance application most of the reed valve design in V-blocks. Both of the faces V contain port opening over which the reed valve petals are located. The petal either made from spring steel or more commonly a fiber reinforced composite material. Fixed metal stops are often provided to limit the operating motion of reed valve. The fixed metal also determines the maximum valve opening [3] [11].



a) Single Petal b) V-block

**Figure 2.5**: Types of Reed Valve