MATHEMATICALLY ANALYSIS ON TWO STROKE UNIFLOW SCAVENGING SYSTEM

MOHD ZAIMATULAKMAL BIN ABDULLAH

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Universiti Malaysia Pahang

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ABSTRACT

Conventional 2-stroke engines are commonly used for two-wheeled and marine vehicles that have small engine displacement. However problems such as unstable combustion, high fuel consumption rate, high hydrocarbon (HC) emission need to be resolved. Beside that, the two stroke engines also have its advantages over the four stroke engines such as higher torque and power, being more compact and lighter. In order to solve these problems without compromising these advantages, a new 2-stroke engine was designed with numerical simulations to produce what is called a two stroke engine uniflow scavenging system. In this study, the performance of the uniflow scavenging engine was researched, and considerations concerning fuel consumption and exhaust gas emissions were made. These findings were then compared with the earlier research to consider gas flow and diffusion of fuel inside the cylinder. This study also describes the effects of the scavenging ports configuration to the flow pattern, the scavenging efficiency and the scavenging pressure, in case of uniflow scavenging two-stroke engine. In this research we will analyses all the parameters of the two stroke uniflow scavenging system based on of the geometry of the intake and exhaust port design, by applied mathematical formulas using of graphical dynamic system simulation software which is MatLab.

ABSTRAK

Enjin 2-lejang biasanya digunakan oleh motosikal dan kapal yang mempunyai kuasa kuda yang rendah. Walau bagaimanapun terdapat pelbagai masalah yang dihadapi seperti pembakaran yang tidak lengkap, kadar penggunaan minyak yang yang banyak dan tidak effisien, pencemaran udara yang tinggi disebabkan oleh pembebasan hidrokarbon(HC) yang perlu diatasi.Selain itu,enjin 2-lejang juga mempunyai kelebihannya berbanding enjin 4-lejang seperti daya kilas dan kuasa yang tinggi, reka bentuk yang kemas, padat dan ringan.bagi mengatasi masalah tanpa menjejaskan kelebihan-kelebihan tersebut, muncullah reka bentuk enjin 2-lejang yang baru dengan menggunakan simulasi berangka yang dikenali sebagai "two stroke engine with uniflow scavenging system". Dalam kajian ini, prestasi enjin baru ini akan dikaji dan pertimbangan tentang penggunaan minyak dan pencemaran gas-gas disebabkan oleh ekzos akan dipantau. Penemuan ini akan dibandingkan dengan kajian-kajian yang dijalankan sebelum ini dengan mempertimbangkan pengaliran udara dan peresapan minyak dalam enjin silinder. Kajian ini juga akan menerangkan tentang susunan kesan-kesan liang penghapus sisa kepada corak pengaliran udara, kecekapan penghapus sisa and tekanan udara bagi penghapus sisa dalam hal enjin yang baru direka ini.Dalam kajian ini juga, kami akan menganalisis semua parameter-parameter yang terlibat dalam enjin ini berganung kepada reka bentuk liang kemasukan dan pengeluaran udara,dengan mengaplikasikan formula matematik menggunakan sistem grafik berkomputer iaitu Matlab.

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LIST OF SYMBOLS

TDC	-	Top Dead Center
BDC	-	Bottom Dead Center
RPM	-	Revolutions per Minutes
YPVS	-	Yamaha Power Valve System
AETC	-	Automatic Exhaust Timing Control
m_i	-	Fresh charge mass
m_r	-	Residual mass
m_t	-	Real charging mass
m_{th}	-	Theoretical charging mass
β	-	Exhaust gas purity
λ_s	-	Delivery ratio
η	-	Scavenging efficiency
$\eta_{s,M}$	-	Scavenging efficiency of the mixing zone
η_c	-	Charging efficiency
ρ	-	density
e	-	Exhaust
i	-	Intake
t	-	Actually in the cylinder
th	-	Theoretical
P	-	Pressure
T	-	temperature
U	-	Particle Velocity
V	-	Volume
R	-	Gas Constant for Given Gas
q	-	Heat Transfer rate per unit mass of fluid
δx	-	Spatial Discretization Step
$\delta\theta$	-	Time Discretization Step

γ(Cp/Cv)	-	Ratio of Gas Specific Heat Ratio
θ	-	Time

CHAPTER 1

INTRODUCTION OF THE STUDY

1.1 Introduction

Two strokes cycle engine has a great potential of commercialized and being the main source of internal power of the future. The main advantages of two strokes engine are higher thermal efficiencies, simple construction thus reduced their weight and their compactness. But two stroke engine usually treated as high hydrocarbon emissions, high fuel consumptions and noisy. Because of these factors, the usage of the two stroke engine was limited and their functions had been replaced by four stroke engine.

A newly two stroke engine had been produced and developed with the objective to improve the performance of two stroke engines including their scavenging and blow-down process, emissions, and overall efficiencies. The process began with the production of new two strokes engine design using MatLab software. By using this software, the flow pattern will be analyse. This paper will concentrate in investigating the flow pattern and its characteristics in scavenging process especially in uniflow scavenging, which is one of the major criteria that affect the performance of two strokes engine.This paper also will discuss about the parameters that involve in the uniflow scavenging system on two stroke engine that effect all the performance of the engine such as the trapping efficiency, scavenging efficiency, delivery ratio and other else.

1.2 Problem Statement

The design of the intake and exhaust porting is very important in two stroke engine system. In order to minimize the engine weight and simplify the design of the two stroke engine, cylinder sleeve and piston is use to control the intake and exhaust stroke. During the intake and exhaust stroke, different porting design would create different scavenging process. For analysis purpose, it would be expensive and very time consuming to create an actual uniflow scavenging model. So, this research will help manufacturers in testing the best porting parameter for two stroke engine especially in uniflow scavenging system using the mathematical approach. This research will use the software that easily the manufacturer to calculate all the parameters that involve in the Uniflow scavenging system in two stroke engine.

1.3 Objectives of the Study

The main objectives of this study are as following:

1.2.1 To analyses the performance of the uniflow scavenging system in the two stroke engine.

1.2.2 To simulate the flow pattern in uniflow scavenging system using mathematical approach.

1.4 Scopes of the Study

1.3.1 Study and transform the related equations to simulate the uniflow scavenging system.

1.5 Problem Solution

In order to solve the problem, the numerical method is building to easier the manufacturer to get the output of the engine without making the actual engine. With the numerical method techniques all the parameter will analyses the performance of the engine such as the efficiency of the engine, trapping efficiency and the scavenging efficiency for the scavenging engine. We also use the Matlab software in this research, with this software the manufacturer will easily to calculate all the parameter without making mistake and wrong calculation. Because this software will calculate automatically all the calculation, the user only have to key in the basic data and in a few second later the result will display automatically. By this way, the time consuming to do this calculation will decrease and its can saving the manufacturer time and the cost.

1.6 Project Outline

Chapter 1 is explanation about the background of the project. In this chapter also include the objectives, problems statement, and the scope of the project.

Chapter 2 discusses details about the literature review of Uniflow Scavenging System in Two Stroke Engine. This study based on the journals, website and text books.

Chapter 3 provides the project methodology of the Uniflow Scavenging System in Two Stroke Engine This chapter includes of the method to solve all the parameter in the uniflow scavenging system.

Chapter 4 discusses on the experimental result of Uniflow Scavenging System in Two Stroke Engine using Matlab Software and derivation of the all parameters involved in Uniflow Scavenging System in Two Stroke Engine.

Finally, Chapter 5 The conclusion of the result from the experimental and a little recommendation is provided to improve the system for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main purpose of this chapter is to give the overview information about the the title of this research which is "Mathematical Analysis on Two Stroke Uniflow Scavenging System". This chapter will give the details explanations about the two stroke engine system, mathematical analysis on two stroke engine and about the uniflow scavenging system in two stroke engine. This chapter will also discuss about the parameters that involve in the Uniflow Scavenging system that can effect the performance of the two stroke engine such as the scavenging efficiency, trapping efficiency, delivery ratio and other else. The software that is used in this research also will also describe in this chapter.

2.2 Mathematically

Mathematics is the science dealing with measurement, numbers, quantities and shapes. It usually expressed in the forms of symbols and always related with many equations for solving problems. While the mathematically mean anything relating to, or using mathematics in any situation.

2.3 Analysis

Analysis of something is the process of identifying and examining each element or feature of it in detail in order to under stand it or in other word its is a statement of the results of this kind of detailed examined on what we want to know.

2.4 Two Stroke Engine

2.4.1 Introduction

The two stroke engine is a reciprocating action of pistons. The reciprocating means that the piston is moves in a linear motion in vertical or horizontal way. Meanwhile, one stroke means one linear motion of the piston in one direction but when the piston moves in the opposite direction, that is counted as another stroke and for a two stroke engine, the piston has to move up, and then down to complete one cycle of the engine. One of the most prominent features of a two stroke engine is the presence of air intake ports on the cylinder liner that will enable fresh air to be led in for combustion. These air inlet ports are cut into the cylinder liner somewhere at the lower end of the latter. In a typical design, the air inlet ports are located about 35° from the Bottom Dead Center (BDC).

In many designs, the fresh air that is introduced into the cylinder is also used to drive out the spent exhaust gases inside it. Many designs make use of scavenging air fans like electric blowers or turbochargers to slightly pressurize the intake air before the latter is introduced into the cylinder. In order to allow the exhaust gases to be expelled from the cylinder, exhaust ports are often cut into the cylinder just like the air intake ports. A typical design will have the exhaust port located about 50 degrees from Bottom Dead Center (BDC). In some designs, the exhaust gases are removed through an exhaust valve, located at the cylinder head and very similar to the 4-stroke engines. This type of scavenging is called uniflow scavenging. The timing of the valve opening and closing will be controlled by a camshaft, push rods, rocker arms or other similar devices.

2.4.6 Two Stroke Application

There are many application in our daily life that using the two stroke engine that can easier our daily work and others activities that involve movement or other else. The common that we can see today is such as the smallest gasoline engines are usually two-strokes. They are popular due to their simple design and very high power-to-weight ratios. The biggest disadvantage is that the engine lubricant is almost always mixed in with the fuel, thus significantly increasing the emission of pollutants. For this reason, two-stroke engines are being replaced with four-stroke engines in as many applications as possible.

Two-stroke engines are still commonly used in high-power, handheld applications where light weight is essential, primarily string trimmers, chainsaws. To a lesser extent, these engines may still be used for certain small, portable, or specialized machine applications. These include small outboard motors, high-performance, small-capacity motorcycles, mopeds, underbones, scooters, snowmobiles, karts, model airplanes (and other model vehicles) and lawnmowers. In the past, two-stroke cycles were experimented with for use in diesel engines, most notably with opposed piston designs, low-speed units such as large marine engines, and V8 engines for trucks and heavy machinery.

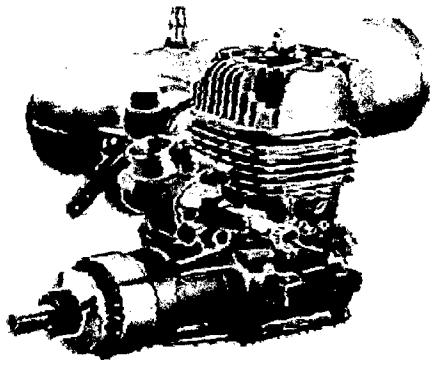

Figure 2.1: 2-Stroke Small Engine (Chainsaw)

Figure 2.2: 2-Stroke Big Engine (Vehicle Engine)

2.4.3 Cycles of Two Stroke Engine

In two stroke engine there are two stroke of operation per cycle, each of them corresponding to the upward and downward stroke of the piston in the combustion cylinder in the two stroke engine. It also means that there are two strokes per cycle happen in the cylinder during the process of combustion happen. The cycles start from Bottom Dead Center (BDC), at here the piston, with the full of fresh air that supply from the carburetor/injection, moves up the cylinder liner until it covers up the air intake port. Then, the air intake process will stops and the piston will moves further up continuously until It then covers up the exhaust port on the cylinder liner. The exhaust process stops. Then, the piston moves further up. The air inside the combustion space is compressed and becomes hot because the high pressure that compress by the piston moving. The piston has nearly reached Top Dead Center at this point. The highly atomized fuel is then injected into the combustion space and the combustion process will occur that will supply the energy to move the piston and move the vehicle..

The fuel burns rapidly causing an explosion inside the combustion space. The explosion causes a tremendous rise in pressure and the piston is pushed down

towards BDC. As the piston moves down, the exhaust ports uncover about 50 degrees from BDC. Exhaust gases are thus led out from the cylinder. The pressure inside the cylinder drops immediately. The piston moves further down. At 35 degrees from BDC, it uncovers the air intake port. Fresh air is then led into the cylinder. The piston then reaches BDC. Because of the momentum created from the force of the explosion, the piston reverses in direction and moves upwards towards Top Dead Center (TDC).Then, the process are repeats itself until the engine is stopped.

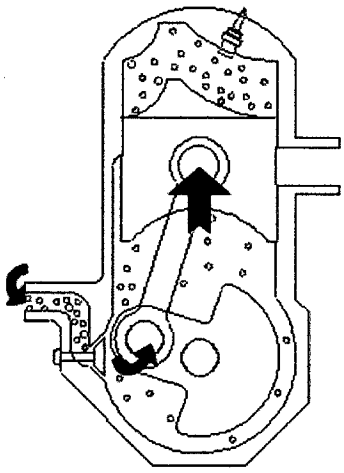

Figure 2.3: Intake Cycle

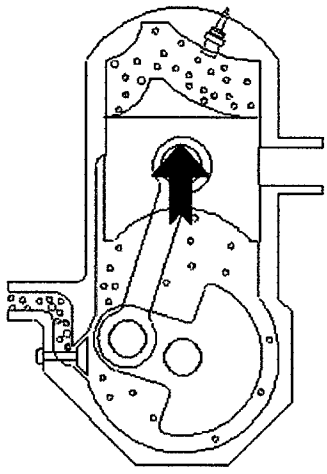

Figure 2.4: Compression Cycle

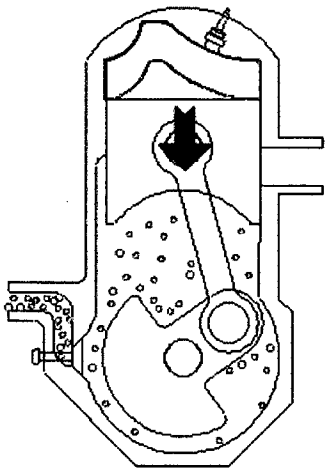

Figure 2.5: Power Cycle

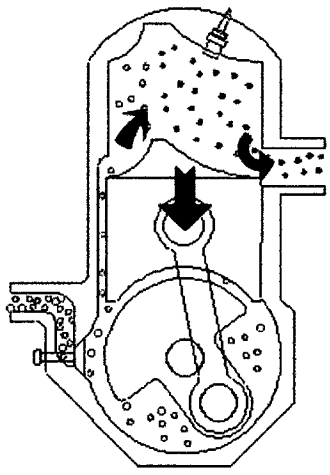

Figure 2.6: Exhaust Cycle

Two-stroke cycle engines operate in two strokes; it can be simplified into two cycles per stroke as following:

1. **Power/exhaust**: This stroke occurs immediately after the ignition of the charge. The piston is forced down. After a certain point, the top of the piston passes the exhaust port, and most of the pressurized exhaust gases escape. As the piston continues down, it compresses the air/fuel/oil mixture in the crankcase. Once the top of the piston passes the transfer port, the compressed charge enters the cylinder from the crankcase and any remaining exhaust is forced out.

2. **Compression/intake**: The air/fuel/oil mixture has entered the cylinder, and it begins to move up. This compresses the charge in the cylinder and draws a vacuum in the crankcase, pulling in more air, fuel, and oil from the carburetor. The compressed charge is ignited by the spark plug, and the cycle begins again. In engines like the one described above, where some of the exhaust and intake charge are in the cylinder simultaneously the gasses are kept separate by careful aiming of the transfer ports such that the fresh gas has minimal contact with the exiting exhaust which it is pushing ahead of itself.

2.4.6 Two Stroke Design Types

In order to understand the operation of the two-stroke engine it is necessary to know which type of design is in question because different design types operate in different ways.

The design types of the two-stroke cycle engine vary according to the method of intake of fresh air/fuel mixture from the outside, the method of scavenging the cylinder (exchanging burnt exhaust for fresh mixture) and the method of exhausting

Disk rotary valve engines can be tailored to deliver power over a wider RPM range or higher horse power over a narrower RPM range than either piston port or reed valve engine though they are more mechanically complicated than either one of them.

iv. Exhaust Valve in head

Instead of the exhaust exiting from a hole in the side of the cylinder, valves are provided in the cylinder head. The valves function the same way as four-stroke exhaust valves do but at twice the speed. This arrangement is common in two-stroke Diesel locomotive engines.

v. Power Valve Systems

Many modern two stroke engines employ a power valve system. The valves are normally in or around the exhaust ports. They work in one of two ways, either they alter the exhaust port by closing off the top part of the port which alters port timing such as Yamaha YPVS, Suzuki AETC system or by altering the volume of the exhaust which changes the resonant frequency of the expansion chamber, such as Honda V-TACS system. The result is an engine with better low end power without losing high rpm power.

2.4.5 Operation of Two Stroke Engine

There are variations in 2 cycle engines found in other applications like snowmobiles, chainsaws and another else. However, the fundamental 2 stroke engine principles are still the same. For starters, below is a cutaway illustration showing a typical 2 cycle engine design.

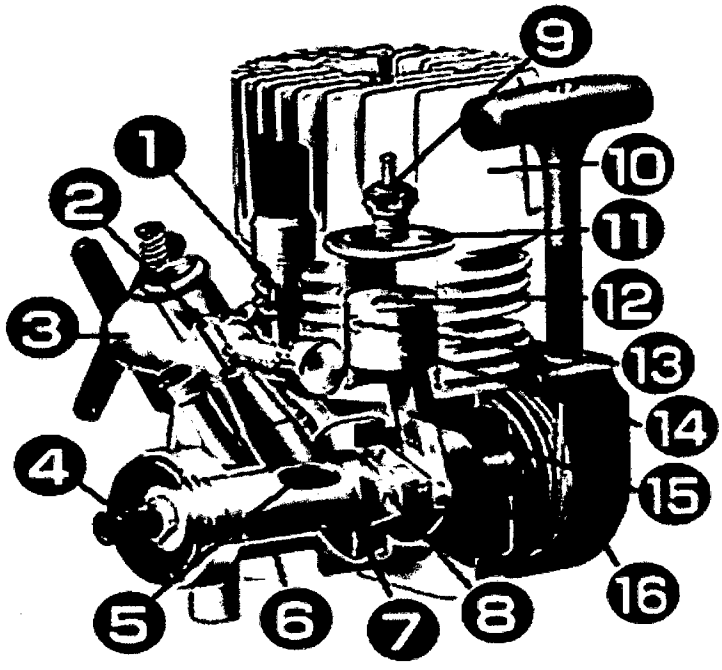

Figure 2.7: Cutaway Illustration of 2-Stroke Engine

1. Carburetor fuel needle valve.
2. Carburetor throttle barrel.
3. Carburetor assembly.
4. Crankshaft end.
5. Crankshaft inlet port.
6. Crankcase.
7. Crank Counterbalance.
8. Crank Pin.
9. Glow Plug.
10. Cylinder head.
11. Cylinder head button.
12. Piston crown.
13. Piston Pin.
14. Piston.
15. Connecting Rod.
16. Recoil pulls start

As the piston rises upward, this creates a vacuum/suction in the engine crankcase area. Air and fuel are mixed in the carburetor and then drawn into the 2 stroke engine through the crankshaft port inlet (see #5 above).The air-fuel mixture then travels through a passage within the crankshaft. The crankshaft is hollow on type of rc nitro engines, and this acts as a transfer passage/tunnel between the carburetor and crankcase. As the crankshaft spins around, the crankshaft inlet port is

covered and then uncovered. While spinning, this crankshaft inlet port acts as a rotary valve for this type of 2 stroke engine.

As the piston goes down, the crankcase is pressurized as the underside of the piston goes downward and compresses the air/fuel mixture in the crankcase below. As the piston moves further down, the inlet port in the cylinder wall is uncovered and the pressurized air/fuel mixture is forced into the combustion chamber.

As the crankshaft continues to spin and the piston changes direction and begins to move upwards, more air & fuel are drawn into the crankcase. At the same time, the air/fuel mixture that is trapped above the piston in the combustion chamber is compressed. Then the spark plug fires and ignites the air/fuel mixture. The hot expanding gases from the combustion process drive the piston downward. As the piston moves downward further, an exhaust port in the cylinder wall is uncovered and exhaust gases are allowed to escape out the exhaust port and out into the exhaust system. As the pistons continue to move downward after the power stroke, more air/fuel mixture is pressurized and pushed up into the combustion through the inlet port. Then the cycle begins all over again. The exhaust system on a 2 cycle engine is a very important key to maximizing performance.

In the cutaway view above, it's hard to see all the details clearly. One of the things that are not clear in the cutaway picture above is the inlet and exhaust ports in the cylinder wall. Below is another picture showing some additional details of 2 stroke engines: the different components, and a better view of the inlet and exhaust ports. The 2 cycle engine is like a pump that pumps in fresh air/fuel mixture for combustion, and afterwards pumps out the exhaust gases.

A two stroke engine produces 1 power cycle for every 2 strokes, and this is how a two stroke got its name. On 2 cycle engines, there is a power stroke for every revolution of the crankshaft. That is 2 times as many power cycles as a four stroke engine. As a result, the additional combustion gives the 2 stroke engine a potential for producing more power in a unit that is more compact in size than a typical 4 stroke engine. Good power, compact size, and light weight makes these type of 2 stroke engines a good choice for rc nitro scale models and other applications where this high power to weight ratio is useful.

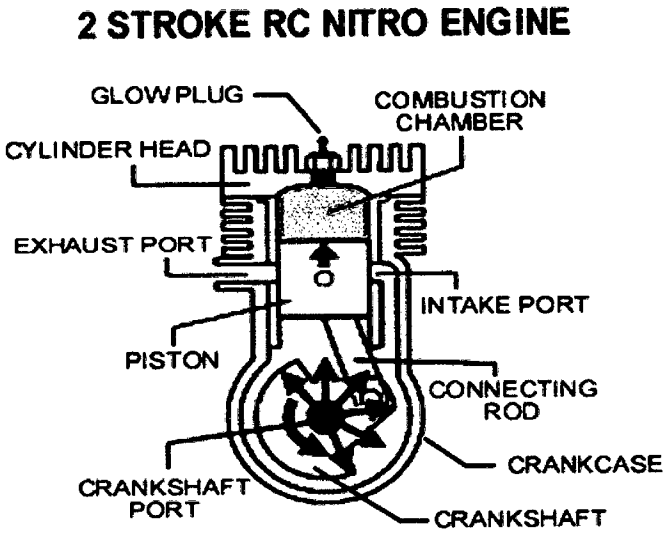

Figure 2.8: 2-Stroke RC Nitro Engine

2.4.5.1 Two Stroke Engine Expansion Chamber Tuned Pipes

Tuned pipes have been used to increase performance on 2 stroke engine for many years. Another term that is used to refer to a tuned pipe is: expansion chamber. It was discovered that a specially shaped exhaust system that was tuned for a specific 2 stroke engine could significantly boost power output. This technology is employed on stroke engines used in applications such as motorcycles, scooters, snowmobiles, personal watercrafts, and just about anywhere a 2 cycle engine is used and additional performance is desired. On smaller applications like chainsaws, leaf blowers, or weed eaters, a tuned pipe is not normally used but rather a small muffler.

There is usually not room on these handheld equipment applications to have an expansion chamber tuned pipe sticking out. Not to mention, a protruding exhaust would be more likely to cause burns on these handheld power equipment. Since most hobby nitro powered vehicles also have 2 stroke engines, tuned pipes are also used in