Tuning Single Cylinder Two Stroke Engine Using Expansion Chamber

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Abstract
Expansion chamber is an exhaust system used for power tuning in two strokes engines. The important of designing appropriate expansion chamber is for power tuning in two stroke engine to ensure the engine to produce more power output with a reduction of polluted emission as well. The two stroke engine does not utilize an exhaust stroke or complicated valve to emit the burnt gases from cylinder like four stroke engine. The incoming mixture charged is used to help push the burnt gases out of the exhaust port. This is not an efficient process since some of the burnt gases remained in the cylinder and may be some of the new mixture charge escaped through the open exhaust port. Thus expansion chamber enhances and control the flow through the engine by using pressure pulse. Two-stroke engines complete the process cycle in one crankshaft revolution: the scavenging process takes place when the piston is close to the bottom dead center, with the opportunity to open and close the cylinder ports by means of the piston motion, greatly reducing the number of moving parts. This solution however, typically used in small engines, imposes a symmetrical timing with respect to the bottom dead center, leading to a lower scavenging efficiency than a four-stroke engine. Except for the short rpm range of dynamic tuning, two-stroke engines are affected by the short-circuit of fresh air-fuel mixture during the scavenging process: this phenomenon results in a fuel loss, subsequent lower torque and higher specific consumption, and also in an inevitable increase in pollutant emissions. Thus expansion chamber enhances and control the flow through the engine by using pressure pulse. The design of an expansion chamber will have an effect on the pressure movement. The design was based on different cross section and length, depending on the requirement of the type of engine. Expansion chamber will be design using empirical design process. By experimentation using 'test dyno', result obtained will be used to ensure better engine performance.

Keywords: two stroke engine, expansion chamber, 'test dyno'

Introduction

Basically after completing one revolution for each cycle, burnt gases and fresh mixture (unburned gases) will pull out from cylinder. These high pressure gases which exit through the cylinder initially flows in the form of a wave front and subsequently enter a piped called expansion chamber which is already occupied by gas from previous cycle. The gas from the previous cycle will be pushed ahead and this will cause a wave front. Although gas flow itself stops, the wave still goes on by passing the energy to the next downstream until it reaches the end part of the pipe. However if the wave encounter any changes in cross section or temperature, it will reflect a part of its strength in the opposite direction it travel which practice the wave dynamics principle. Thus, expansion chamber will be design by using this basic principle since its diameter (cross section) and length are varied as a way to push back the fresh mixture back into the cylinder at the desired times in cylinder.

As the piston moves from top to the bottom dead center, uncovering the intake ports, the burned gases are pushed into the exhaust port by the incoming flow of fresh mixture (air and fuel). This is not an efficient process since some of the burnt gases remaining in the cylinder and some of the fresh air or fuel charge escape through the open exhaust port. At this point in time, the opening just begins to form, and as a result the flow in the combustion chamber changes dramatically. As the piston drops down and begin its return motion back to top dead center the burned gases are pushed into the exhaust duct. Thus by modifying the exhaust system such as modifying the exhaust gas velocity (by changing exhaust tube diameter and length) it can detract the "ideal" scavenging effects, and reduce fuel consumption as well as increase the power output. The two stroke engine does not utilize an exhaust stroke to evacuate the burnt gases from the cylinder like a four stroke engine. The incoming air/fuel charge is use to help push the burnt gases out of the exhaust port. This is not a very efficient process with some of the burnt gases remaining in the cylinder and maybe some of the new air/fuel charge escaping through the open exhaust port. The expansion chamber enhances and controls the flow through the engine by using negative and positive pressure pulse. The pressure pulse or wave is created when the exhaust port is first opened. As the wave travels down an expansion chamber it travels at the local speed of sound. It remains unchanged until it reaches the diffuser cone or megaphone section (Figure 1). As the pipe diameter expands it reflects a negative pressure wave back towards the engine. The original wave however continues to travel down the pipe until it encounters the reversing cone. At this point the wave is reflected back towards the engine but remains a positive pressure wave

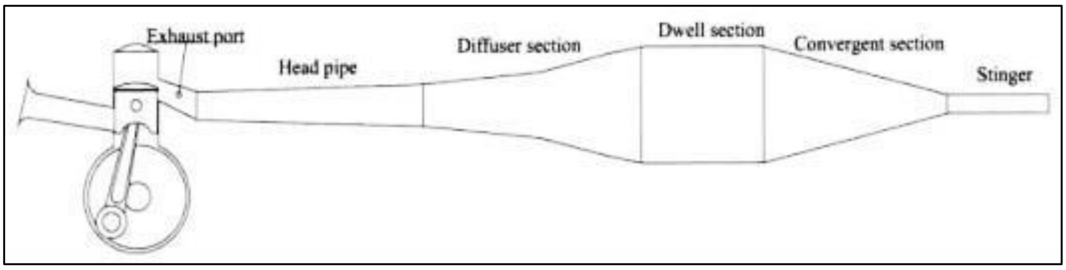

Figure 1: Diffuser Cone or Megaphone Section

Calculation for length conventionally discussed in mm units. The data inserted and produced by the calculation are stated in those units. The data which is required for the calculation are engine bore, stroke, connecting rod length, exhaust ports, maximum width of each exhaust port, and radius in the corner of each exhaust port. These data allows the calculation of the exact port area. Thus, the exhaust port flow area is equivalent to an exhaust diameter, D_x. The empirical calculation describes thus as the ideal exhaust pipe initial diameter. The value of tuned length, LT is based on the plugging pulse within the exhaust period. The reflection period is decreed to be the exhaust period and the speed of wave propagation is local speed of sound in the pipe mid – section. Thus, the time, t taken for double length travel along the tuned length, LT must equal to the reflection period, where:

$$t = \left(\frac{EP}{360}\right) \times \left(\frac{60}{RPM}\right) = 2 \times \frac{\left(\frac{LT}{1000}\right)}{Ao} \quad (1)$$

Rearranging the pipe length in mm units:

$$LT = (83.3 \times EP \times (Ao/\ RPM) \quad (2)$$

Next is the step to calculate the length of the pipe:

$$LP1 = 0.1 \times LT \quad (3)$$

$$LP2 = 0.41 \times LT \quad (4)$$

$$LP3 = 0.41 \times LT \quad (5)$$

$$LP4 = 0.11 \times LT \quad (6)$$

$$LP5 = 0.24 \times LT \quad (7)$$

$$LP6 = LP5 \quad (8)$$

Then, step to obtain the diameter of each cross section are:

$$D1 = k1 \times Dx \quad (9)$$

$$D2 = D3 \times [L2/(L2/L3)]^{1.33} \quad (10)$$

$$D3 = k2 \times Dx \quad (11)$$

$$D4 = k3 \times Dx \quad (12)$$

The value for k1, k2, and k3 as bellow:

Table 1: List of Ratio and Coefficient

Item	Ratio and Coefficient
Tail Pipe Diameter Coefficient, k3	Endure (1.125)
	Road Racing (1.050)
Flange Diameter Ratio, k1	Endure (2.25)
	Road Racing (3.25)
Mid-Section Diameter Coefficient, k2	Endure (0.700)
	Road Racing (0.600)
	Motocross (0.650)

The objective of this research is to design and fabricate the suitable an expansion chamber to obtain maximum power of a two stroke engine at a desired speed range. Method of testing that will be done to test the engine performance is by using dyno (dynamometer) testing. The testing will include the engine with designated expansion chamber (tuned exhaust system). A dyno is a tool that loads an engine as if it were being run in a vehicle. It measure (some dyno calculate) an engine's torque output and transmit the result to a software program that control the dyno. The software program calculates horsepower and supplies a wealth of other information to the operator that includes details insight into the operation and efficiency of the engine.

Methodology

Piping Design

Method that has been chosen to design an expansion chamber is using the empirical approach. The information used in the calculation was taken from the books 'The Basic Design of the Two Stroke Engine's written by Professor G.P Blair of Queens University Belfast'. The entire empirical design process is found in a very simple equation and in an experimental development of expansion chamber for racing engines. However, an empirical approach is not a precise calculation. The principal aim of the empirical design process is, to phase the plugging reflection correctly for the engine speed desired for peak power, which mean calculating the turning length from piston face to tail pipe entry, LT. Then, to proportion the tail pipe exit area as a function of the exhaust port area so that the pipe will empty in a satisfactory manner before the arrival of the next exhaust pulse. And then to locate the end of the diffuser and the beginning of the tail nozzle so that the spread of the suction and plugging effect are correctly phased. Lastly, to locate the second half of the diffuser so that the reverse deflection of the plugging pulse from it, and the primary reflection of it from the exhaust port, can be recombine with the next outgoing exhaust pulse, thereby producing the resonance effect

Dyno (Dynamometer) Testing

A dyno or dynamometer is a tool that loads an engine as if it were being run in a vehicle. It measure (some dynos calculate) an engine's torque output and transmits the results to a software program that control the dyno. The program calculates horsepower and supplies a wealth of other information to the operator that includes detailed insights into the operation and efficiency of the engines. Dynos are commonly used for engine development, performances testing, tuning, and as a diagnostics tool.

The 11's design number and type of dynos measure the power output of the engine. Most dynos fall into two categories, first is absorption and second is inertia. With an absorption dyno, the mechanical energy produced by an engine is converted by some medium into heat energy.

Engine Specification

Type of engine and cylinder use in dyno testing is as follow:

Table 2: List of Engine Specification

Attribute	Object Value
Engine Type	Two Stroke Engine
Number Of Cylinder	Single Cylinder
Cylinder Geometry	Bore = 51mm
	Stroke = 53 mm
	Displacement = 108.27 cc
	Connecting Rod Length = 95 mm
Exhaust Port Total Opening Period, EP	99 deg (Ref: [5])
Effective Port Diameter	28 mm
Effective Port Area	615.75 mm @ 616.0 mm

Common Parameters

Table 3 below shows the List of BMEP and average of exhaust temperature.

Table 3: List of BMEP and Average Exhaust Temperature

Engine Type	BMEP	Average Exhaust Temperature
Road Racing	11+	450
Motocross	9 to 10	600
Enduro	8	300
Others	5	250

Summary of Design for Tuned Exhaust System

Table 4 below shows the tuned length for Enduro Type and Road Racing Type Design for Tuned Exhaust System.

Table 4: Design for Tuned Exhaust System

DESIGN NO. AND TYPE	ENDURO TYPE	ROAD RACING TYPE
Tuned Length (mm)	989.00	494.00
LP1 (mm)(including Lx)	98.90	49.40
LP2 (mm)	405.6	202.5
LP3 (mm)	138.5	69.20
LP4 (mm)	108.8	54.40
LP5 (mm)	237.4	118.56
Dx (mm)	28.00	28.00
D1 (mm)	31.50	29.40
D2 (mm)	42.62	61.57
D3 (mm)	63.00	91.00
D4 (mm)	19.60	16.80

Result and Data Analysis

During the process of testing the newly designed expansion chamber using dyno test, the main aspect that has been taken into consideration is the Power (kW) obtained on every Speed (RPM). Through the dyno testing, the findings will be shown in graph figure. The data of each case obtained will also be shown. From the graph and data, it can be identified at which speed the power attains.

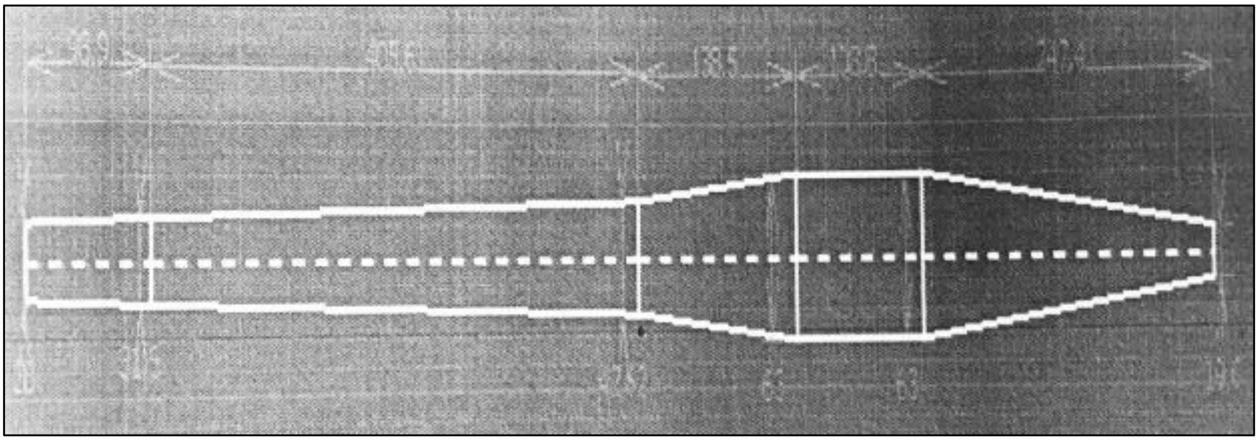

Figure 2: Tuned Exhaust System for Enduro Type

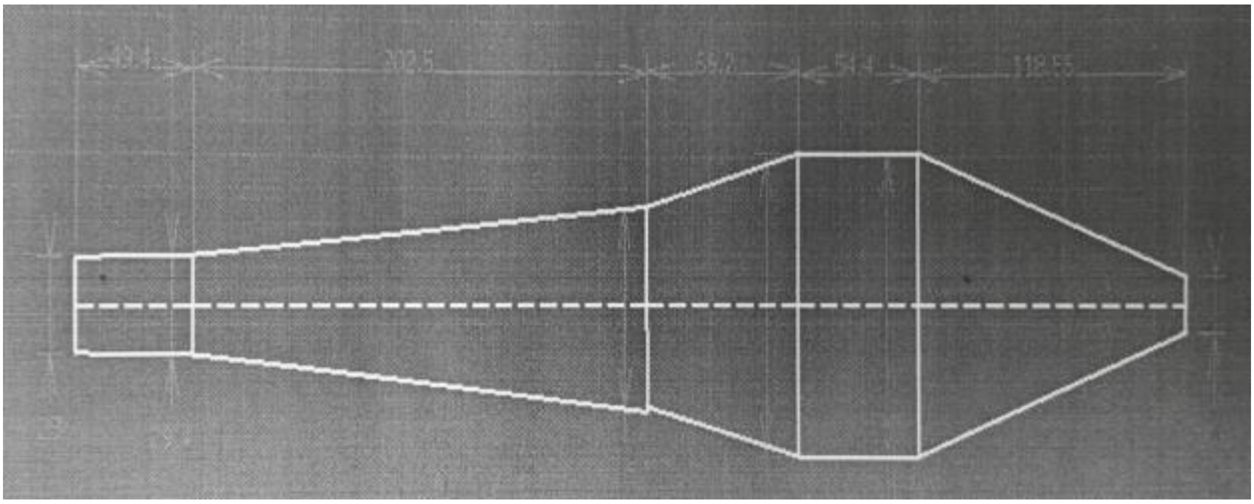

Figure 3: Tuned Exhaust System for Road Racing Type

Engine with Tuned Exhaust System (Enduro Type)

Table 5: Enduro Type

Speed (rpm)	Brake Power (kW)
500	0.49
1000	0.50
1500	0.53
2000	1.75
2500	-1.56
3000	-1.62
3500	3.15

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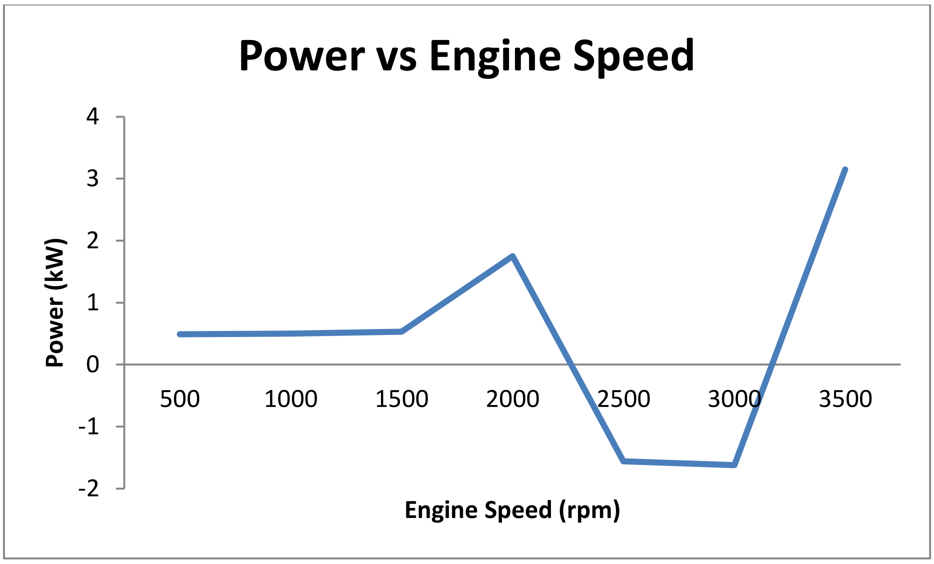

Figure 4: Power (kW) vs Engine Speed (RPM) for Enduro Type

Engine with Tuned Exhaust System (Road Racing Type)

Table 6: Enduro Type

Speed (rpm)	Brake Power (kW)
500	0.86
1000	0.80
1500	0.77
2000	2.00
2500	3.10
3000	4.10
3500	4.20

Based on the result obtain at Figure 4, the maximum value of power that gained is at the speed of 3500 RPM with the value of 3.15kW. The lowest value of power is at the engine speed 2500 RPM with the value of -1.562 kW (The negative value caused by the back pressure of the engine). In between engine speed 2000 RPM to 3000 RPM the value of the power are continuously decreased. From the Figure 5, the maximum values of power are 4.5 kW at engine speed 3500 RPM and the lowest value of power are 0.77 kW at engine speed of 1500 RPM. At the engine speed range between 500 RPM to 2000 RPM, the value of power gained are quiet similarly constants or there is small increased in the value. The values of power are dropping at the range engine speed of 2500 RPM to 2800 RPM.

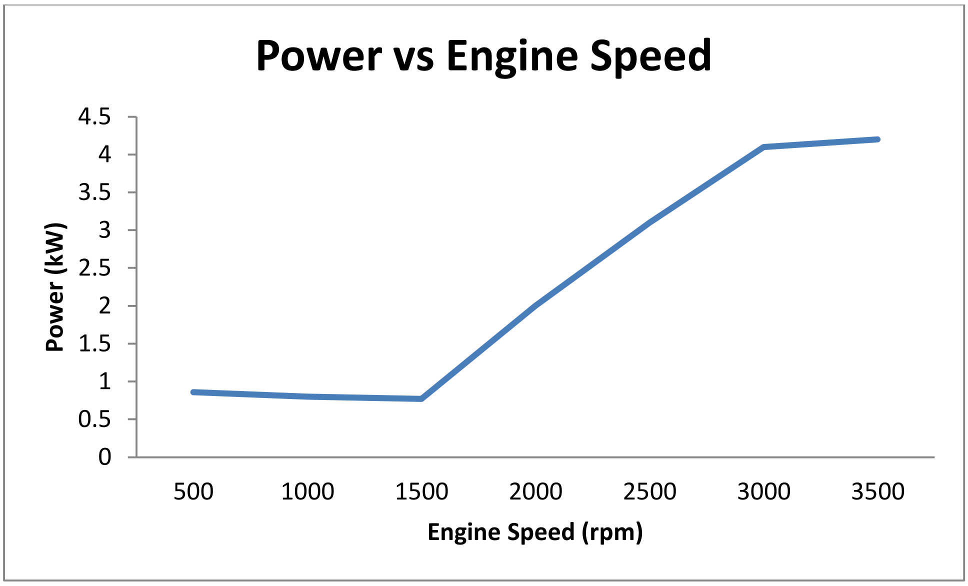

Figure 5: Power vs Engine Speed for Road Racing Type

This can be concluded that, at the engine speed between 2500 rpm to 3000 rpm, would have an exhaust pipe that would carry a positive pressure wave of exhaust pulse down the pipe to the open end. There it would collapse and create a negative pressure wave that would return back up the pipe. If the negative wave arrives back at the exhaust valve just before it closes, it will suck more of the exhaust gases out of the cylinder. This lowers the pressure inside the cylinder and makes the next intake stroke more efficient.

In between 3000rpm to 3500 rpm, the intake valve begins to open while the exhaust valve is still off its seat. This is valve overlap. This allows the negative exhaust pulse (the reflection of the positive pulse) to actually pull more fresh mixture past the intake valve and into the cylinder. When the combustion cycle begins, the piston is forced downward; this is the power stroke. Near the bottom of the power stroke the energy is mostly spent and the exhaust valve starts to open. It will actually start to open slightly before bottom dead center. The exhaust charge then begins to rush out the exhaust pipe.

The exhaust gases rushing out are further assisted by the piston pushing up on the exhaust stroke. This forms a stream of hot gas in very rapid motion away from the cylinder. This stream of hot gas has inertia and it will tend to continue moving in the same direction out the exhaust pipe even after the piston stops pushing it. This creates a region of reduced pressure in the vicinity of the exhaust valve.

Conclusion and Recommendation

The goal of designing an expansion chamber is to tune a two stroke engine in order to obtain power at certain engines speed as well as to improve breathing capabilities by increasing the volumetric efficiency.

According to Gustaffson [2], engine with tuned exhaust system will give a better performance. Based on the result from Figure 4 and Figure 5, we can see the different output power at engine speed 3500 RPM, where for endure type obtain power 3.15 kW and for racing type obtain power of 4.5kW. we also can see for endure type, there is negative value at engine speed 2500 RPM due to the back pressure of the engine.

The exhaust tuning of a 2-stroke is designed to preserve the positive pulse going down the pipe and reflect that positive pulse back up the pipe. A racing engine exhaust system uses an expansion chamber at the end of the pipe which is basically two cones that reverse themselves prior to the end "stinger" where the spent exhaust is allowed to exit the chamber.

That sort of expansion chamber creates a very strong positive wave reflection back up the exhaust pipe, and this positive pulse will reduce the amount of fresh charge escaping out the exhaust port, and in some cases, force back into the cylinder any charge that may have escaped before the positive pulse arrives.

The shape of the exhaust pipe is not simply that of a constant diameter pipe, such as on a 4-stroke engine. The pipe on our tuned 2-strokes is gradually expanding in diameter from the engine to the point where it enters the muffler. It is shaped like an elongated cone when viewed from the side. That shape is an important part of the exhaust tuning.

The length of the exhaust pipe, prior to the muffler, is another important factor due to the speed of the pressure waves mentioned earlier. The length must be such that the exhaust pulse can travel to the end of the cone and be reflected back up the pipe to arrive at the exhaust port just before it closes.

References

Blair G. P. (1968). “The Basic Design Of Two – Stroke Engines” the Queen’s University of Belfast, Society of Automotive Engineers, Warrendle, Pa.

Cengel Y. A. & Cimbala J. M. (2006). “Fluid Mechanics – Fundamental and Applications International Edition 2006” McGraw – Hill Companies 2006.

Cengel Y. A., Turner R. H., (2005). “Fundamental Of Thermal – Fluid Science Second Edition”, Singapore: Prentice Hall

Ganesan V., (2004). “Internal Combustion Engine – Second Edition”, Singapore:Prentice Hall.

Gustafsson R. U. K., “A Practical Application to Reduce Exhaust Emission on a Two – Stroke Engine with a Tuned Exhaust Pipe”, SAE paper 2006 – 32 – 0054, JSAE 20066554.

Gustafsson R. U. K., Blair G. P., Jonsson B. I. R., “Reducing Exhaust Emission and Increasing Power Output Using a Tuned Exhaust Pipe On a Two – Stroke Engine” , SAE Paper 2001 – 01 – 1853 / 425.

Pulkrabek W. W., (2004). “Engineering Fundamentals Of The Internal Combustion Engine – Second Edition” , University Of Wisconsin – Platterville, USA: Pearson Prentice Hall.

Torregrosa A. J., Galindo J., Payri R. & Climent H., “Modelling The Exhaust System In Two – Stroke Small Engines” , SAE Paper 2001 – 01 – 3317.