Summary

Preface

My story with two-strokes began in childhood, when I saw my classmates and friends riding mopeds and imagined how much freedom I would have if I had one too. But my father prioritized my studies and those of my two brothers. That way, there wasn't any time left to fulfill this dream we so earnestly begged him for. One day, he took us to a motorcycle shop that still exists today and showed us a gold 1979 Garelli T50, which my twin brother and I rode until the end. After that, we each bought a moped, then an RX125, and an RD135, until one day we gave them up to buy our first cars.

This was dormant within me, and in a conversation with my brother in 2013, we reminisced about those times, and I felt a deep sense of nostalgia. I ended up buying a 1980 Caloi moped, which I refurbished and happily rode for a long time. But that 60 km/h top speed started to bother me a lot, so I started researching about preparation and really missed a preparation course or book in my own language that was up-to-date. I ended up reading Gordon Jennings, Graham Bell, and so many others and got started in the world of preparation. I can't even tell you how many cylinders of that AV10 engine I ruined, but I'm very persistent, and after so many mistakes, I ended up building a moped that broke the time record in that category and awakened my desire to tell this story. I created an Instagram account, now called @Professor2t, and I felt a huge need for people to contact me, wanting to learn too. I helped many people, but that profile grew too large, and I ended up not being able to teach and help through messages. That's when a follower suggested I create a course so I could share everything I knew on a much larger scale. I created the "Master in 2 strokes" course, which is still a success today and provided the foundation for my current course, which, after more than 4,000 students, has taught me a lot and is eager to help.

Chapter 1 – Introduction

1.1 What is tuning?

Tuning means adjusting each component of the engine so that they work together harmoniously, enhancing results.

Often, what I see are people trying to improve an engine with just one isolated part. They add a larger carburetor or a competition exhaust, but leave the rest of the engine completely stock. The engine will still run, but it won't unleash the true potential of the installed part.

Consider the exhaust, for example. It's one of the main factors in a two-stroke engine's performance. But if you add a custom-sized exhaust to a stock engine, the gain will be small because the other components—cylinder, head, ports, carburetor—aren't equipped to work with that exhaust. The engine is "out of tune."

Tuning is understanding that each component influences the other and that only when they are all adjusted together does the engine reach its true potential.

1.2 The Tuning Method – Exponential Theory

This is where the method I developed, which I call the Exponential Theory of Preparation, comes in. It's not linear. It's not a simple addition. It's a process in which each adjustment enhances the other, generating multiplied gains.

Imagine a stock 17-horsepower engine. If you simply rework the cylinder head and generate 10% more power, the engine will reach 18.7 horsepower. The gain was 1.7 horsepower. Now, if that same head is applied to an engine that already has 20 horsepower because it has received other adjustments—well-crafted ports, a correct exhaust, a resized carburetor—that same 10% represents 2 horsepower. The gain is greater because the results multiply.

This logic is the essence of two-step preparation. Every piece, every adjustment, needs to be in sync so that the results are not just added together, but multiplied. It's an exponential process.

1.3 2-stroke engine operation

The two-stroke engine is fascinating because it can complete the entire cycle in just one revolution of the crankshaft. While a four-stroke engine requires two revolutions for intake, compression, combustion, and exhaust, a two-stroke engine does it all in one revolution of the crankshaft.

As the piston rises, it compresses the mixture in the cylinder toward the combustion chamber. At the same time, a vacuum is created in the crankcase, drawing fresh mixture through the carburetor.

Before the piston reaches top dead center, the spark plug ignites the spark. This is necessary because combustion isn't instantaneous—it takes a few milliseconds to propagate through the chamber. Thus, when the piston actually reaches TDC, pressure is already built and ready to push it down with maximum force.

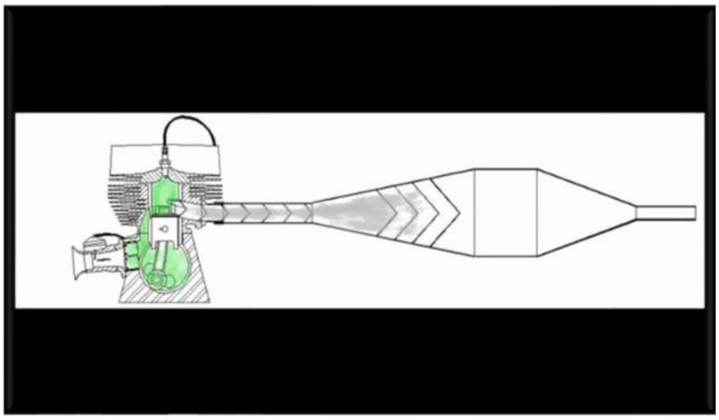
The explosion then pushes the piston down, generating power, and at the same time compresses the new mixture in the crankcase.

During descent, the piston opens the exhaust port, releasing the burnt gases. Soon after, the transfer ports open, and fresh mixture enters the cylinder, replacing the burnt gases. This process is called "swabbing."

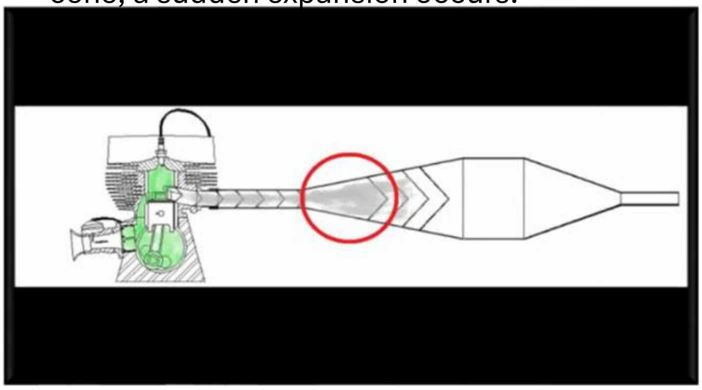
This arrangement ensures high specific power, but also makes the engine very sensitive to any changes. A small change in port, exhaust, or compression directly impacts performance.

But the operation of the 2-stroke engine is intrinsically linked to the exhaust and I will demonstrate in detail what this relationship between the two is like below.

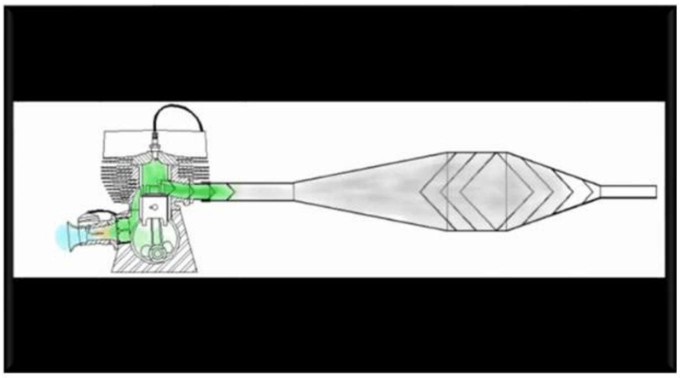
When the exhaust port opens, a shock wave flows through the exhaust.



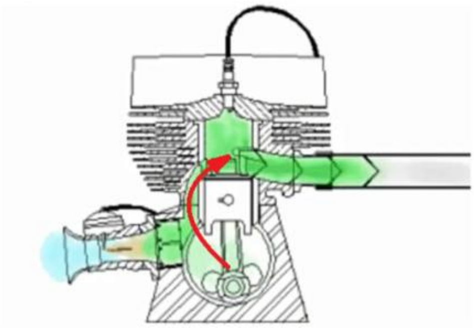
When it reaches the diffuser, that is, the first cone, a sudden expansion occurs.



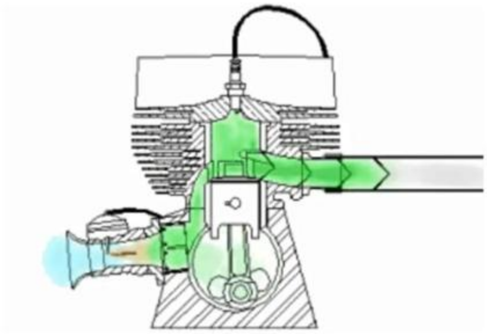
As the shock wave expands, it generates a vacuum pulse that returns to the exhaust port, helping to draw fresh mixture from the crankcase.



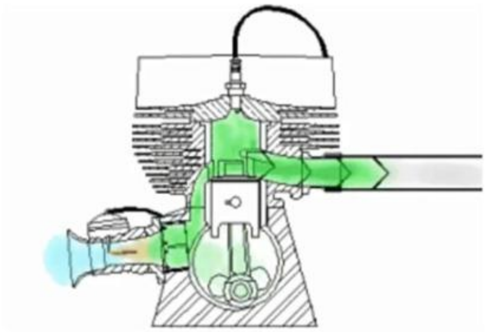
This vacuum wave is so powerful that, in the tuning phase, it is more efficient than the pressure created by the piston itself as it descends.



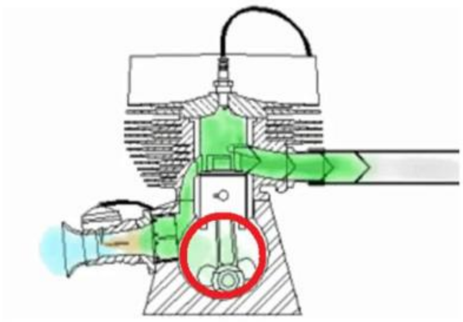
Note the blue flow at the carburetor inlet. Also note that there is a clear passage from the exhaust to the carburetor.



The vacuum pulse is so efficient that it can even admit more mixture into the crankcase through the carburetor.



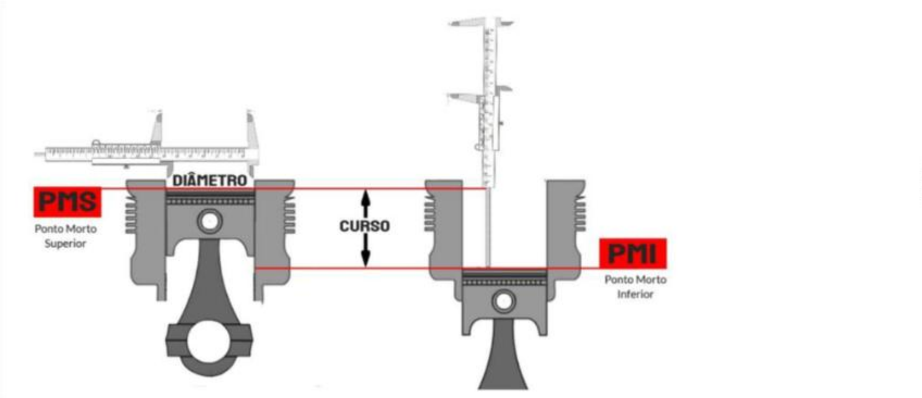
This is the reason we don't worry about compressing the crankcase. The larger it is, the more mixture is available to be admitted.



This theory was presented by Gordon Blair in his work called Design and Simulation of Two-Stroke Engines from 1994.

1.4 Displacement Calculation

The displacement of any engine is calculated by a simple formula using two engine data points: cylinder bore diameter and crankshaft stroke. In this course, we will use the European method, which considers crankshaft stroke when calculating displacement.



The formula we use in the course is:

Displacement = (π × (bore ÷ 2)^2 × stroke) ÷ 1000

This calculation gives us the value in cubic centimeters (cm^3).

Practical example:
Ex. Piston 58mm and stroke 50mm (RD 135 engine)

We then have: 29 x 29 x 3.14 x 50 = 132cc

So, this is a 132 cubic cc engine

1.5 Importance of Compression Ratio

The compression ratio defines how much the mixture is compressed before ignition. Higher compression results in more efficient combustion and more power. However, if it's too high, it causes detonation.

Detonation is spontaneous combustion before the spark plug ignites. It's destructive because it generates violent pressure waves that break the piston, rings, and even the cylinder head. Therefore, the preparation must seek the highest possible compression without detonation.

This balance depends on the fuel, chamber shape, operating temperature, carburetion settings, ignition timing, among others.

1.6 Gearboxes - Separating 2T engines by gearbox type

I usually separate 2T engines by the type of gearbox they use.

They are: CVT, Shifter and direct.

CVTs are all those that have a centrifugal clutch and a transmission with a variable belt and pulleys. Examples include the moped and the jog.

Shifters are all those with a clutch (centrifugal or disc) but with gears defined by gears. Examples of these are the RD135 and DT200 .

Direct-drive engines can have a centrifugal or direct-drive clutch and are gearless, meaning the engine pinion is connected directly to the wheel. Examples include go-kart engines without gears.

Separating 2T engines by gearbox type is vital so that we can direct the type of preparation of all engine parts so that they work well together with the gearbox.

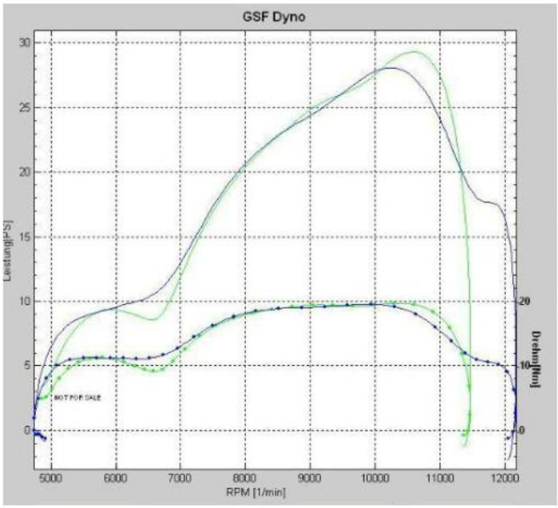
A CVT engine works fixedly in a single engine speed range, so all tuning can be focused on delivering maximum efficiency in that RPM zone.

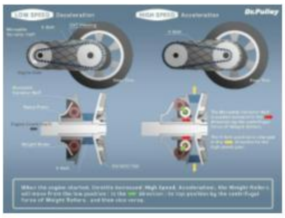
An engine with a gearbox, on the other hand, operates with a useful range of 1,000 RPM on average and needs to have torque throughout this entire engine speed range. The tuning needs to be more open to meet this gearbox requirement. Direct drive engines do not have a gearbox, so they need to be as good as possible in all RPM ranges since between a curve and a straight line, the engine speed changes significantly.

1.6.1 CVT Transmission

The CVT transmission allows us to build a "pipe" peak engine because the clutch allows the engine to freely increase RPMs close to the optimum torque range. The variator, on the other hand, maintains the

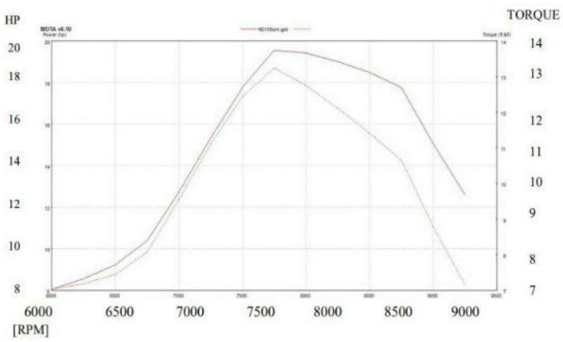
RPM within the selected range regardless of the motorcycle's speed. The graph below was taken from an engine with a CVT transmission, and you can see that maximum power is at a peak and in the 10,500 rpm range.

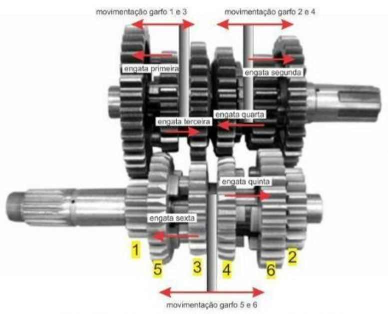




Shifter Gearbox

Gearboxing requires a little more care in preparation because the engine's torque range needs to be within the usable range from one gear to the next. If the engine is built to generate power in a very narrow range, we'll have to constantly shift gears to keep the engine within that specific peak zone. The graph below shows the power curve of an RD135. Usable range from 7500 to 8500 RPM.

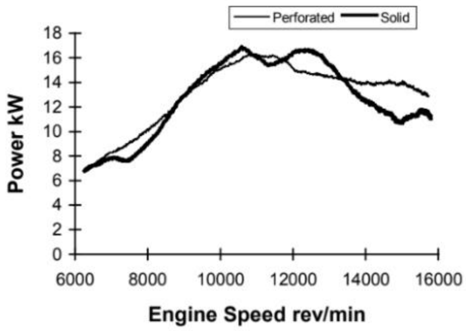




Câmbio de seis marchas na posição Neutro

1.6.3 Direct Exchange

Direct transmission is used in a specific category of karts where the engine shaft is connected directly to the wheel. This type of setup requires great care in the setup's construction to spread the torque range as much as possible. The engine needs to have torque on corner exits while still maintaining torque at high rpm for efficiency on the straights. The graph shows flat torque across various RPM ranges.



1.6.4 Preparation according to exchange rates

It's worth noting that whenever we try to spread the torque zone across different RPM ranges, we're also distributing the power. The most powerful engines are those where we can concentrate power in a narrow RPM range and somehow adjust the transmission to that effect. That's why CVT transmissions are our allies, tuners. Knowing this is the first step to differentiating ourselves in the market.

1.7 The first steps in preparation

Tip 01 – The first thing we need to do, before anything else, is understand the engine's purpose. If the engine belongs to a customer, ask what use the project will be made of. Ask plenty of questions to understand not only the purpose but also its usability and all the conditions the engine will be exposed to. If the project is for everyday use, you need to consider durability and fuel economy. If the project is for weekend fun, you can go further with the preparation. And if it's for track use, anything is possible. If the engine is yours, ask yourself.

Tip 2 – Consider the type and quality of the transmission you'll be using when preparing your engine. It's easy to build a high-RPM engine and, upon installation, discover that the CVT is of poor quality and won't adjust to meet the engine's demands. If your motorcycle has gears, be aware that some engines have stepped transmissions, and there's a significant difference between the second-to-last gear and the last. This can result in a lack of power to "push" the top gear.

Tip 3 – Always try to offer entry-level tuning, at the Start level of our mandala. Believe me, your client is usually satisfied with a 20 or 30% gain. And this is achieved with just a few engine adjustments. Working this way allows you to advance the tuning process, scheduling other future work for this client. Providing super advanced tuning will also make them happy, but you'll only see them once. It's also important to consider that a significant increase in power considerably shortens the lifespan of engines. You don't want this client coming to your shop with a broken engine every time.

Tip 4 – Before starting the rebuild, it's important to assess the condition of the engine you intend to rebuild. If the engine already has a lot of mileage or you don't know how much mileage it has, suggest rebuilding it. And especially using quality parts. Rebuilding a worn-out engine or one with substandard parts is risky and can break down within a few hours. If the customer refuses to invest even the minimum amount, which is a guarantee of the quality of the parts, I suggest not working on the engine.

Tip 5 - Always use quality oil. The difference in engine durability between high-quality oils and those using comparable oils is enormous. I recommend Motul 800 at 15ml/liter for everyday use and 20ml/liter for extreme use when using regular or podium gasoline. For alcohol or methanol, I recommend Dimethyl at 20ml/liter for everyday use and 25ml/liter for extreme use. By extreme, I mean track use.

Tip 06 - Whenever possible, I recommend installing a temperature sensor in the engine. This helps you fine-tune the carburetion and prevents breakdowns due to poor fuel, lack of oil, clogged jets, incorrect ignition timing due to a dislocated magneto, or anything else wrong with the engine. 2-stroke engines typically show their problems by increasing their temperature. I recommend air-cooled engines operate at 120 to 140 degrees Celsius for gasoline and 110 to 130 degrees Celsius for ethanol. Water-cooled engines should always operate below 90 degrees Celsius.

When assembling an engine, several factors can cause overheating, and it takes a little patience and persistence to find the cause. I'll list the main ones below:

very advanced ignition point;

very high compression ratio;

increase in dynamic engine compression when we improve the exhaust system;

high back pressure due to the stinger being very restricted;

low fuel octane;

spark plug too hot;

Wrong carburetor adjustment;

Tip 7 – Persist! Not everyone gets it right the first time, and making mistakes is part of the process. I've made dozens of mistakes in everything imaginable. But I'm here today because I never gave up.

Tip 08 – Be aware that you don't know everything, no one does. I don't know everything myself, and what will be presented here may be obsolete tomorrow. Remember that we are dealing with an engine that essentially works through physics. And as human beings, we don't fully understand what happens when we deal with so many variables.

Tip 9 – Never stop reading and researching the subject. Sometimes, we learn or understand certain effects better when we're willing to learn a little each day. The learning process about 2T may begin here, but it should by no means end at the end of this course.

Tip 10 - Take advantage of my experience and willingness to help you. When I started, I came across manuals in English, French, Italian, and so on. Each one had 200 pages to translate. Your path will certainly be shorter and less winding than the one I took. But it's up to you to commit to absorbing all the knowledge presented in this course.

1.8 Final Considerations

Tuning means understanding that everything in a two-stroke engine is interconnected. The exhaust depends on the ports, which depend on the cylinder head, which depend on the carburetor, which depend on the ignition.

When each element is adjusted together, the gain is multiplied. This is the essence of the tuner method and exponential theory.

The two-stroke engine is simple in construction, but extremely sophisticated in operation. Small details make a huge difference. Therefore, a true tuner isn't someone who swaps parts, but someone who understands the logic behind each component and can make them work in harmony.

And last but not least, although somewhat obvious, it bears remembering that the content presented here was taken from serious and proven studies. It also comes from the author's experience, but always based on the concepts of physics and supported by logic, common sense, and personal perception.

- Bibliography:
- Design and simulation of two stroke engines – Gordon P. Blair
- Two Stroke Tuners Handbook - Gordon Jennings
- Two-Stroke Performance Tuning – A. Graham Bell
- Le gonflage des cyclomoteurs - Didier THOMAS
- Dragonfly – Michael Forrest
- Study of the influence of exhaust manifold geometry – Ariel Kaplan
- Between others

Chapter 2 – Carburetor

2.1 Introduction to the Carburetor

This is a very debatable topic, but we will approach it with case studies and bibliographical references that support our thinking.

According to Michael Forrest, the carburetor must be sized so that the air/fuel mixture is formed by