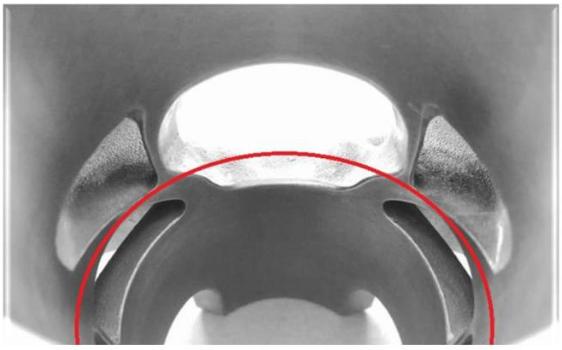
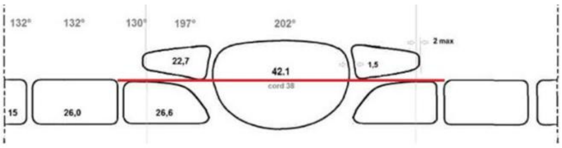
Make sure the divider is wide enough to maintain a sufficient oil film to prevent friction between it and the piston. I compensated with Boyesen ports of a very reasonable size to compensate for the original size intake.

Chapter 9 – Cylinder: Blowndown

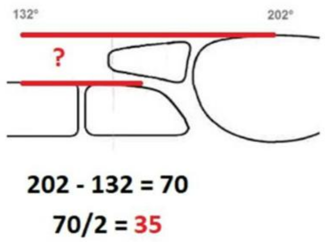
9.1 Introduction

Blowdown is an engine parameter little known to tuners and often mistakenly ignored. This is because the literature rarely addresses the subject, and when it does, it fails to explain why or how it influences two-stroke engine performance. Blowdown can be called relief time, as it controls the length of time the exhaust port remains open before the transfers open and the final combustion gases are released. Therefore, blowdown can also be measured by angle, as can the exhaust and transfer port times.





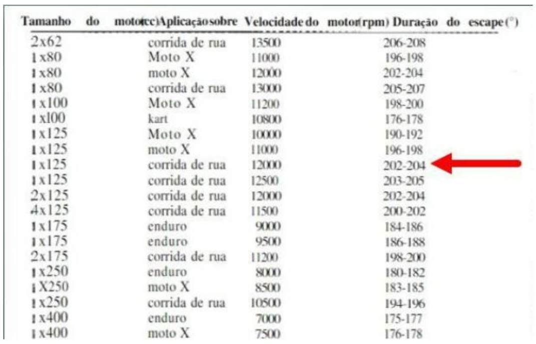
After measuring the exhaust and transfer port graduations, we can calculate the blowdown very simply. We subtract the exhaust graduation from the transfer rate, and divide the resulting value by two. In the case of the Aprilia RSA, the blowdown angle is 35°, which we'll see later is quite high. When we consider a high blowdown , we're imagining a very fast and efficient exhaust discharge.



We can also consider the desired blowdown when considering the application strategy for this engine. In this case, we'll apply the tuning method here, considering the exhaust port and transfer ratio graduations in accordance with the blowdown. We need to understand that blowdowns close to 20 degrees spread the powerband, while those close to 35 degrees concentrate and generate a lot of

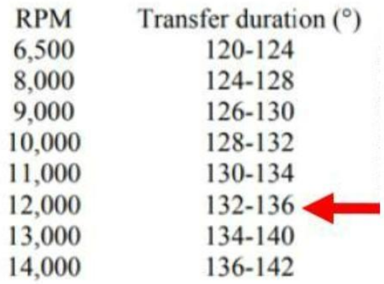
Graham Bell suggested exhaust port degrees for certain applications based on the best power zone. Below we see that he suggested 202 to 204 degrees for a 125cc engine for racing applications.

And the transfer port duration used by Aprilia was 132 degrees. Note that in both tables, the angle indicates the 12,000 RPM range. Is it a coincidence that the RSA power graph shows 12,500 RPM as the best torque zone?



Tamanho do motor(cc)	Aplicação sobre	Velocidade do motor(rpm)	Duração do escape(°)
2x62	corrida de rua	13500	206-208
1x80	Moto X	11000	196-198
1x80	moto X	12000	202-204
1x80	corrida de rua	13000	205-207
1x100	Moto X	11200	198-200
1xl00	kart	10800	176-178
1x125	Moto X	10000	190-192
1x125	moto X	11000	196-198
1x125	corrida de rua	12000	202-204
1x125	corrida de rua	12500	203-205
2x125	corrida de rua	12000	202-204
4x125	corrida de rua	11500	200-202
1x175	enduro	9000	184-186
1x175	enduro	9500	186-188
2x175	corrida de rua	11200	198-200
1x250	enduro	8000	180-182
1X250	moto X	8500	183-185
1x250	corrida de rua	10500	194-196
1x400	enduro	7000	175-177
1x400	moto X	7500	176-178

TABLE 3.2 Transfer Port duration



RPM	Transfer duration (°)
6,500	120-124
8,000	124-128
9,000	126-130
10,000	128-132
11,000	130-134
12,000	132-136
13,000	134-140
14,000	136-142

```
thu 03-01-2013          F O S   Engineering       Holland          13:01
   A-RSA125            Copyright (C) Frits Overmars 2012
 9010  19.56
 9516  21.57
10015  23.61
10517  25.24
11019  26.53
11265  26.96
11517  27.96
11767  28.81
12020  29.74
12265  29.66
12517  29.75
12764  29.45
13007  29.17
13263  28.50
13509  27.72
13766  26.74
14011  25.46
14268  24.26
14471  22.90
```

Measured Power at 2nd gearbox shaft	54 Hp @ 13000 rpm
Torque	29,75 Nm @ 12517 rpm
BMEP	17 bar

From what we can see here, Aprllia tuned all cylinder windows according to Bell's suggestion. We can therefore assume that both graduation tables serve as a very close reference to reality.

There is a very important parameter to consider here, which is the exhaust length, which we will look at in more depth in the exhaust module, but we should know that it affects the speed of the shock wave and can change the torque zone.

Therefore, when tuning an engine, we need to consider this parameter as well. But for now, we'll just look at the graduation.

The literature suggests that we use blowdown as follows:

20 to 25 degrees: when we want to spread the engine's torque zone across a fairly wide RPM range. Recommended for everyday engines that require torque before and after the best power zone.

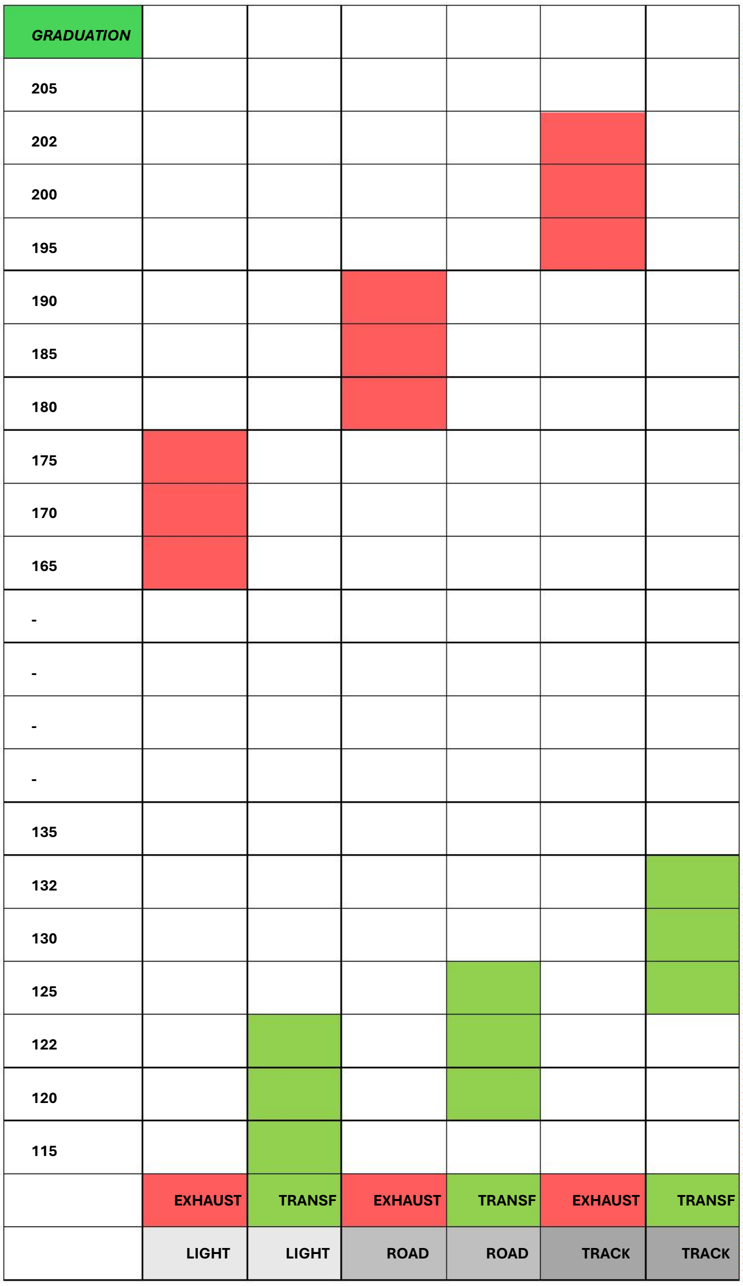
25 to 30 degrees: when you don't exactly need a flatter curve and are looking for a little more performance. Suitable for medium-duty setups.

30 to 35 degrees: When we seek maximum power, narrowing the curve into a more concentrated peak.

I split the BD tracks for a starting point.

BLOWDOWN	LIGHT	ROAD	TRACK
35			🟩
34			🟩
33			🟩
32			🟩
31			🟩
30			🟩
29		🟩	
28		🟩	
27		🟩	
26		🟩	
25		🟩	
24	🟩		
23	🟩		
22	🟩		
21	🟩		
20	🟩		

To make it easier to understand, let's simulate some DB possibilities on top of some applications:



GRADUATION						
205						
202					🟥	
200					🟥	
195					🟥	
190			🟥			
185			🟥			
180			🟥			
175	🟥					
170	🟥					
165	🟥					
-						
-						
-						
-						
135						
132						🟩
130						🟩
125				🟩		🟩
122		🟩		🟩		
120		🟩		🟩		
115		🟩				
	EXHAUST	**TRANSF**	**EXHAUST**	**TRANSF**	**EXHAUST**	**TRANSF**
	LIGHT	**LIGHT**	**ROAD**	**ROAD**	**TRACK**	**TRACK**

Examples:

Engine with light daily tuning and CVT transmission: We can narrow the power curve depending on the transmission and use the BD range for light application in the table, but in the highest zone, which is 25. In this case, we will select the highest transfer ratio indicated in the table, which would be 120 degrees, and apply the BD of 25, resulting in an exhaust port graduation of 170 degrees. Here, we use the higher ranges because the transmission accepts a slightly narrower curve.

Street-tuned engine with shifter: We can't narrow the power curve much due to the gearing, but the setup is for the street, so we'll use the BD range in the middle of the BD chart, which indicates 27 degrees. We'll select the transfer ratio indicated in the intermediate ratio chart, which would be 12 degrees, and apply the BD of 27, resulting in an exhaust port ratio of 179 degrees.

Track-tuned engine and CVT transmission: Here, we assume our CVT transmission can be adjusted to operate at high RPMs. Therefore, we'll select a high transfer ratio of 132 degrees, for example, and apply 32 degrees of BD. In this case, our exhaust port would be 196 degrees. This configuration is exactly the same as the one I used on the moped that broke the track time record in this category. This engine had a 105cc displacement, and a single run on the dyno showed 21.6 hp at the wheel.

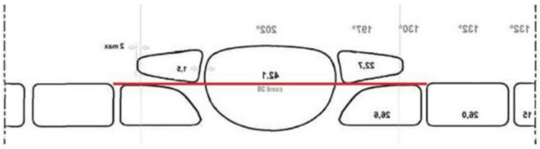
9.2 Applications

The ideas I presented were examples of how we can think about the strategy for graduating the engines we are designing according to the application we want.

Note that I always think about the transfer first, which would be the part of the cylinder we won't touch, adjusting this parameter through gaskets and flanges as I suggested in the last module. Then we think about the BD according to the power curve we want, and the exhaust port graduation is a final consequence.

Another factor to consider is the DB area. The larger the area, the greater the DB's influence on engine behavior. We need to consider the size of the exhaust port and how much open area we have before the transfer ports open. An exhaust port with boosters will have a much larger blowdown area than a simple oval port.

Understand that if we always increase the width of the exhaust port or increase the graduation without changing the transfer height, we will be amplifying the influence of the BD, which is narrowing the power curve.



But why does the DB affect engine behavior so much? The answer is simple! It increases or slows the shock wave's exit velocity. In other words, the larger the DB's area, the faster the shock wave can exit and enter the exhaust.

And why does it increase power? Because by concentrating the pulse, we achieve a stronger and narrower return wave, which explains why the BD with a large angle creates peaks in the power curve.

Another detail to note is that the rapid release of gases allows us to have lower pressure inside the cylinder as the transfers are opened, avoiding counter-pressure competing with the crankcase pressure.

It's no coincidence that the Aprilia RSA uses a 35-degree blowdown with an extremely large area. They were aiming for maximum power, despite the engine having a shifter gearbox . However, since the application is for the track and this engine only operated at high RPMs, the strategy worked. We'll never see such a large DB with so much area on a street-legal shifter engine . A DB area and angle like the RSA's would usually be impractical for everyday use.

That's why choosing the right BD is so important when using the engine. Making a mistake here will cost you dearly in terms of engine use, either by losing power or taking away power from where it shouldn't be.

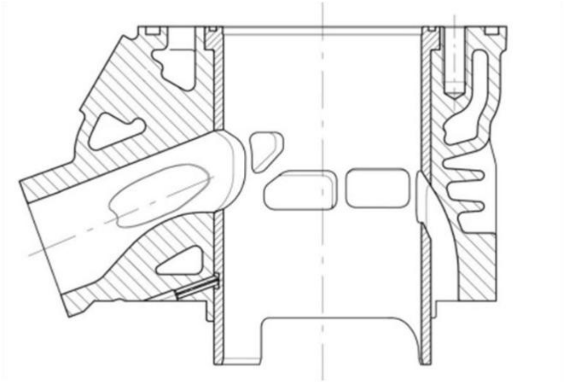
9.3 Case studies

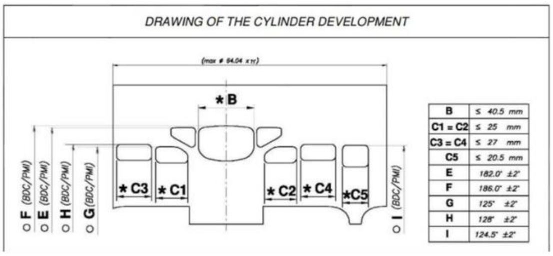
Let's compare the sizing of two IAME X30 cylinders. One with a direct shift and the other with a shifter. They are called Super (direct) and Super Shifter (with shift). We'll see that the sizing and BD strategy is different for both applications.

Let's start with the X30 Super. It has staggered transfer rates, with 128 on the B, 125 on the A, and 124.5 on the C. The center exhaust port is at 186 degrees, and the boosters are at 182 degrees.

In this case, the BD is 29 degrees. For a racing engine, this BD is low, but here the intention is to spread the powerband, since this engine has no gearbox and the pinion is connected directly to the wheel.

We see a large 4-degree tilt from the boosters to the main port, which would be the same as arching the exhaust port, even though it appears flat. As we'll see later, this engine uses the exhaust to help further spread the powerband.

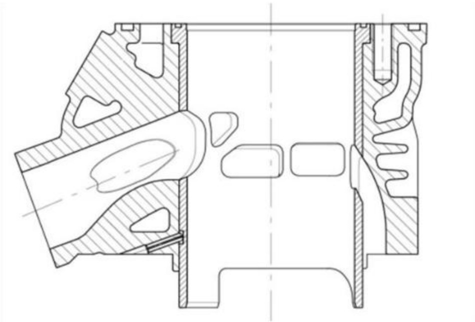


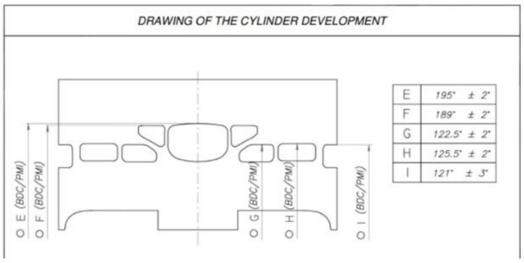


B	≤ 40.5 mm
C1 = C2	≤ 25 mm
C3 = C4	≤ 27 mm
C5	≤ 20.5 mm
E	182.0° ±2°
F	186.0° ±2°
G	125° ±2°
H	128° ±2°
I	124.5° ±2°

Now let's talk about its sibling, the X30 Super Shifter. Here we have a similar shift ratio, but at different heights. We see 125.5 degrees in the B, 122.5 degrees in the A, and 121 degrees in the C. And in the exhaust port, we have 195 degrees in the main and 189 degrees in the boost. This is more gear ratio than in the X30 Super, which is 6 here. The BD here is higher, at 34.75 degrees. We can see that the intention is to narrow the power in a very specific RPM zone. However, usability here is acceptable, as the engine operates only at high rpm and constant gear changes.

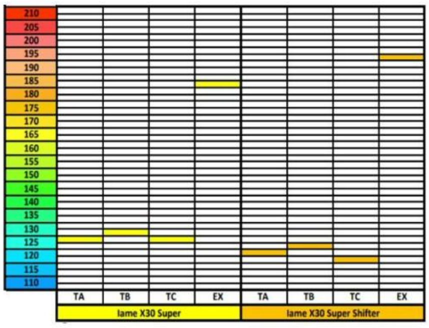
Here the exhaust is designed to work in conjunction with this strategy, featuring a peak exhaust design.





E	195° ± 2°
F	189° ± 2°
G	122.5° ± 2°
H	125.5° ± 2°
I	121° ± 3°

Here we have a graduation comparison of the two IAME engines next to our graduation table that was suggested in the exhaust port and transfer chapters.



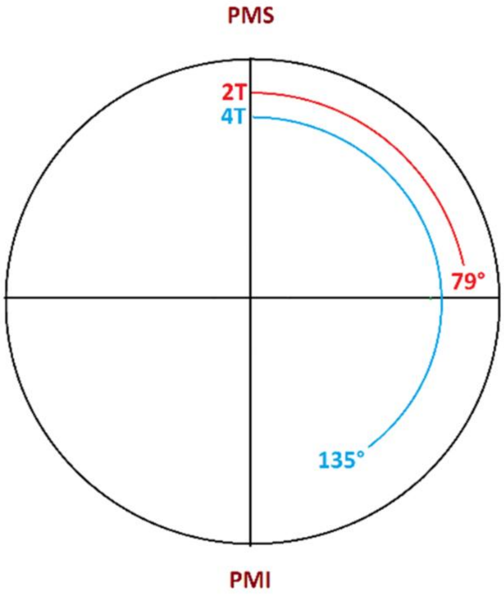
9.4 Final considerations

Now that we understand how graduation affects the engine, I want to put a “flea in your ear”.

If we raise the exhaust port, it means we're reducing the engine's displacement. That's right, we're reducing the size of the compression section, which, in practice, reduces the engine's size, since when the exhaust port is opened, we have enough compression to generate a shock wave that enters the exhaust.

A four-stroke engine harnesses all this compression force by pushing the piston until the cylinder pressure drops to the point where it's no longer efficient, opening the exhaust valve so that the next piston stroke releases the gases. Two-stroke engines don't have this benefit because they need to open the exhaust port much earlier.

But so far, what we've seen is that whenever we increase the cylinder rating, we gain power, right? Yes, but there's a limit to this gain.



We'll rarely see engines exceeding 200 degrees at the exhaust port. The racing cylinders we've seen so far use 202 degrees, as in the case of the Aprilia RSA. Therefore, let's assume that this should be our limit and that trying to exceed this level of exhaust port graduation would not be beneficial.

To give you a visual idea of what I'm talking about, on the side we have a graduated disc showing the compression stroke of a 4-stroke engine versus a 2-stroke engine with an exhaust port angle of 202 degrees.

In some cases, the literature covers the exhaust port graduation from TDC to its opening, so I think it's important to learn how to calculate it. It's simple: just subtract the window graduation from 360 degrees and divide the result by two.

That is: 360 – 202 = 158. Therefore 158/2 = 79 degrees.

We can see here that a two-stroke engine spends less than a quarter of its life under compression to rotate the other three-quarters solely on the inertia created in this short period. This also explains to some extent why lower-rated engines generate more torque at lower RPMs.

Finally, I don't usually use the Japanese method because the literature barely talks about it, but it makes us think about the efficiency of 2-stroke engines.

Even "reducing engine displacement," what we see is the opposite: more power. But this occurs, as I've already explained, due to the delivery of a stronger pulse. However, this benefit is either non-existent or ineffective when we don't use a properly sized exhaust. If we increase the exhaust port graduation on a two-stroke engine with a stock exhaust of the type not intended for supercharging, little or no benefit is gained.

Another factor that increases power with a higher exhaust port height is the fact that we send the pulse earlier than we would otherwise. This means it returns sooner, forcing the engine to tune to a higher RPM. When we increase RPM, we're consequently increasing power, since the formula for calculating an engine's horsepower includes RPM.

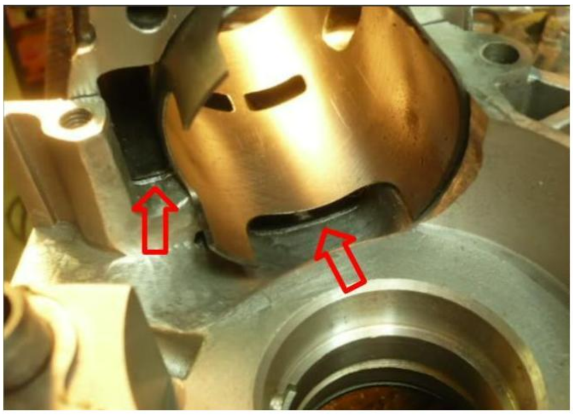
Therefore, we see that nothing is isolated, and that whenever we gain on one side, we will also lose on the other. But it makes a big difference to understand what we gain and what we lose, so we can then decide which side of the scale we place more weight on.

Understanding all these dynamics of the 2-stroke engine is what I propose here.

Chapter 10 – Cylinder: Marriage with the crankcase

The cylinder-to-sump alignment is crucial for smooth transfer upshifts. Steps cause turbulence and do not benefit the cylinder's feed flow.

The easiest way to copy the transfer pattern from the cylinder to the crankcase or from the crankcase to the cylinder is through the gasket or flange, if applicable. The pattern that will be copied is always the larger one, regardless of whether it's the cylinder or the crankcase. The important thing is to break the step and avoid turbulence as the mixture rises.



In the example below, I used a moped engine, but the technique applies to any two-stroke engine, whether using a flange or gasket. If the engine doesn't use a flange, the gasket will serve as a template to transfer the crankcase shape to the cylinder and vice versa. I fitted the flange to the cylinder and inserted the cylinder into the crankcase as shown.

Using an overhead projector, I draw the outline of the transfer case riser on the flange. I do this on both sides and also on the rear transfer case, alternating between the two sides of the crankcase.

After drawing, I compare the cylinder transfer lift with the crankcase lift and see which one is larger. The larger one stays as is, and I already know I need to open the smaller one.

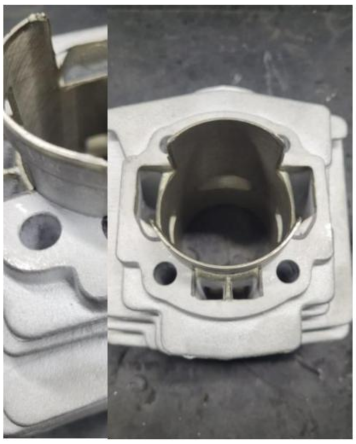
After marking, I remove the cylinder flange and use a grinder to open the flange transfers. Be careful not to exceed the mark and remove material beyond the mark.

If you prefer, open it almost to the limit and place the flange on the crankcase, carefully opening it only as far as necessary. If the template is a gasket, simply cut it out with scissors.

On the side, you can see what it looks like after opening. Place the flange on the crankcase to see if any additional material needs to be removed to ensure it's exactly the same. It usually requires touch-ups until it's perfect.

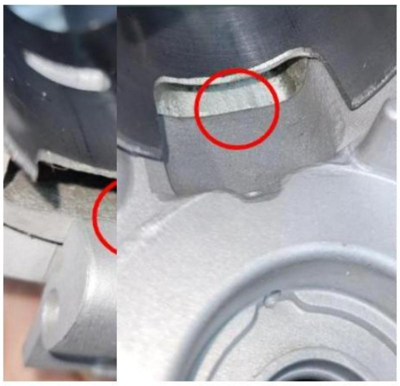
With the flange open, we will transfer it to the cylinder, which will serve as a template for us to draw where it will need to be opened.

Make sure the cylinder stud holes are perfectly aligned with the flange. Alternatively, use bolts of the same diameter as the studs to align the flange and then mark them.



After marking, open the cylinder with the grinder, always checking the opening against the flange. Take your time here; it's easy to overshoot since there's usually little material to remove.

The final work must be symmetrical from one side to the other and as long as the flange or gasket matches the shape of the cylinder and the crankcase, we will have a perfect match between the two.



Considering that we increased the height of the cylinder, we will also have a greater distance between the piston and the cylinder head.

We can fix this in two ways:

Making a pass at the top of the cylinder: We can lower the height of the cylinder with a plane at any engine grinding shop.

Machining the head: We can machine the head and lower the squish so that it fits inside the cylinder and corrects the height.

Chapter 10 – Cylinder – Piston

10.1 Introduction

The piston is a critical item in a two-stroke engine and is usually the one that will suffer damage if errors are made during normal use or when preparing the engine.

It's made of aluminum due to its weight, as it travels inside the engine, accelerating and decelerating at incredible speeds. We have a speed of 20 m/s as a physical limit to how much it can accelerate, unless we use high-quality materials in its construction. Exceeding this speed limit can cause it to fracture and break.