XP Extreme Power

TWO STROKE ENGINEERING SOLUTIONS

Niklas XP Tip
Tuning manual for SAAB 2-strokes

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www.classicsaabracing.com

Västergatan 3B
SE-411 23 Göteborg
Tel/Fax +46 (0) 31 137262

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Introduction

You have now in your hand my tuning manual for SAAB's two stroke engines and their cars.
This manual is intended to de a living document that continually improves and expands as knowledge and experience, bout others and mine, grows and is collected here.

Therefore you should not be surprised if some part seams unfinished, it will hopefully be bettered in due time.

In this manual I will contemplate on both simple and difficult things, but sometimes it is difficult to be simple so I will also use examples and diagrams.

The intention is that everyone shall be able to find something of value, booth in the form of increased knowledge and in the form of increase horsepower's in their engine.

Your understanding of the two-stroke engine will hopefully increase and my intention is that you should cope with a simple calculator to find the right values for your own engine.

Presentation

My name is Niklas Enander and I have been driving two strokes ever since my first moped when I was eleven years old. I am presently working as a two-stroke engine simulation and research engineer at Husqvarna Engine Research in Jonsered outside Gothenburg after having worked with multicylinder engine development at Volvo and engine development at Volvo Truck.

I have over the years gained some experience with both my own and friends two stroke engines in mopeds, scooters and SAAB´s. I have studied a Master of Science degree in mechanical engineering at Chalmers and have there specialized in vehicles and engine lore.

At the moment I own about a dozen of two strokes some to mention is my first moped, a sprinter Vespa that beats a HD sportster on the drag way, an office chair that does over 85 km/h, a short nose and regretfully not my beloved 21, my long nose from 65 that got seriously ill at the SAAB festival 2001 due to overpowering and under steering and has now gone to the last special course.

My personal reason to spend weeks of work on a manual like this is to be able to spread the knowledge of how to tune two strokers so that more people can hear the wonderful sound of a stroker that revs it way to the horizon.

By spreading this information I also get more information in return, and by charging a fee for my work I can motivate my self to spend the hours and get financing to develop new products for the SAAB tuner.

My goal is to put in at least two hours of work for every manual that is sold so that it will grow and develop and every new customer shall have some information that last months customer did not get as well as you get the information that all previous customers paid to give you.

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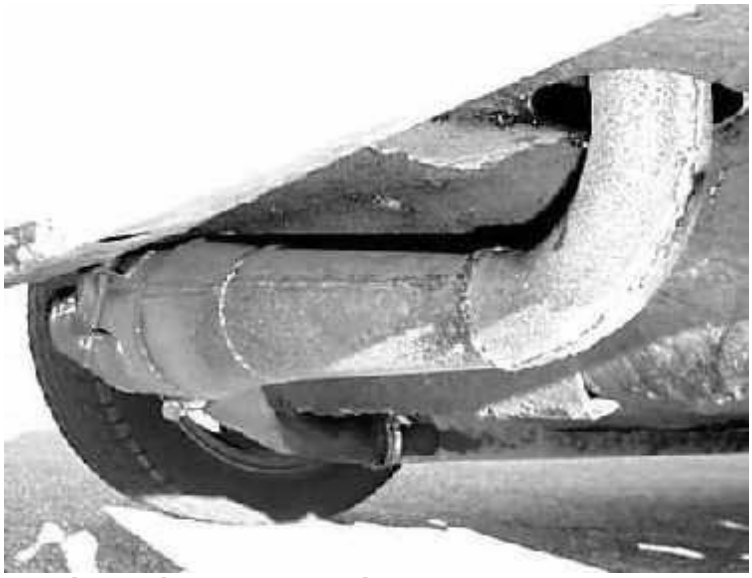
Function of the tuned 3 to 1 exhaust system



Tuned XP-exhaust system ready to go

The tuned 3-1-exhaust system works in two ways.
First it helps the engine to get rid of exhaust gas and secondly it helps the engine by putting back some of the scavenge loss that has entered the exhaust manifold. If we first study the tree cylinder two strokes with a common exhaust manifold it gets easier to understand how it does this.

On a standard 1965 engine the exhaust port is opened 49 mm below the top dead center, and the scavenge port is opened 59 mm below tdc. This gives an exhaust port duration of 155°, i.e. the exhaust port has the possibility to flow 155° of the total of 360° on one turn.

The scavenge ports opening 59 mm from tdc gives us a duration of 116°.

The blow down period, the period from exhaust opening to scavenge opening is then
(155-116)/2 = 19,5°.
This also means that the exhaust port is open 19,5° after that the piston, on its way up on the compression stroke, has closed the scavenge port.

We can now se that the engine is able to empty it self of pure exhausts during the first 19,5° of the exhaust port opening and during the remaining 135,5 degrees there is also the possibility for scavenge losses of air and fuel to leave the cylinder.

As the engine has three cylinders with evenly spaced ignition timings, we know that the next exhaust port will open 360/3= 120 degrees after the last one.
If we now assume that cylinder 1 is just opening its exhaust port, that has a duration of 155 degrees, then we also know that the cylinder 2 will open its exhaust port when cylinder 1 has 155-120= 35 degrees left until it is closed again.

As cylinder 2 is opening and expelling its exhaust gasses a pressure wave is formed that with the speed of sound spreads it self trough the exhaust manifold to cylinder one. When the pressure wave reach cylinder one the pressure in the exhaust manifold exceeds the pressure in the cylinder and some of the fresh charge that has escaped the cylinder is pressed back in the cylinder.

The fact that this portion of fresh charge is pressed back is the reason why the SAAB three-cylinder engine in standard form has relatively low fuel consumption and a high and wide torque curve around 3000-4000 rpm.

As the pressure wave, that is rather short, travels with the speed of sound, the time it takes to travel from cylinder to cylinder is about the same independent of the speed of the engine.

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This means that the wave will arrive to early to do any good at really low engine speeds and when you rev a standard engine over 5000 rpm it arrives to late to do any good so the engine power drops and it has not enough torque to rev any further under load.

The standard exhaust system gives an exhaust backpressure that is comparably high to counter high scavenge losses and thus it gives low fuel consumption. But it also gives to high back pressure at maximum power and the engine is not able to breathe as freely as one would like.
This is usually countered by the SAAB tuner by using a sports exhaust with two standard diameter exhaust pipes or an 2” pipe that will get free breathing exhaust with higher power at the cost of higher fuel consumption.

The exhaust system that was recommended by SAAB in the end of the sixties consists of a modified SAAB Sport front silencer with a suction cone and a 2” exhaust pipe under the car to minimize the exhaust backpressure. The suction cone that is not longer than about 10 cm has an end diameter of about 8 cm. Until this day I have not seen a tuning instruction were the measures actually are written down.

When a pressure wave reaches a wall, like in a closed pipe, the wave bounces back as a reflection of it self and with the same sign, like a pressure pulse turns back as a pressure pulse. If you instead of a wall close the pipe with a cone the bounce will be extended to a lower but a longer returning pressure wave.
In the same way a pressure wave that reaches a cone that increases in diameter is reflected back as a suction wave.
Such a cone was previously called a megaphone but in now suction cone as it is not the end of the system.

When the pressure wave from the exhaust port opening reaches the suction cone in the SAAB´s tuning system a suction wave that is designed to reach the cylinder around the bottom dead center at around 5000 rpm is sent back. The suction pulse eases the scavenging and gives a higher airflow and higher power.
The problem is that at 4000 rpm the suction comes to early to do any good an at 6000 rpm its almost to late.

The exhaust system that is recommended by SAAB has a perforated reverse cone after the suction cone. This reverse cone has the purpose to destroy the remaining pressure waves in the system, otherwise there would be a scarp reflection against the front silencers rear wall.

It is very common to choke modern mopeds with a plate in the exhaust system that has an opening of half of the pipe area. That means that half of the pressure wave is reflected back as suction wave from the hole, and so you have cut of the reflection and killed the tuning in the exhaustion system.
The function for the reverse cone with holes, is to break the remaining pressure waves in the exhaust system in much the same way.
In the XP-system there is no such cone, because these reflections are used to reach a higher engine power.

In the tuned 3-1 XP exhaust system the exhaust pipe area begins to expand already from the exhaust manifold. This early expansion sends back a prolonged suction wave to the cylinder and assists it to empty its exhausts. The suction cone is further separated in two sections to get a larger width of the tuned rpm’s.

After a straight section comes a reverse cone that sends back a pressure wave to the cylinder.
This pressure wave is added on to the pressure wave from the nearest ignited cylinder and assists in lowering the scavenge losses by increasing the pressure in the exhaust port towards the end of the scavenging before the exhaust port closes.

The pressure wave from the XP exhaust system is tuned towards working at higher rpm to widen the drivable area and to raise the engine power.

If we reach the same torque, but at 10% higher engine speed, we will get 10% higher power.

The pressure wave can even manages to push back some of the fuel and air that has escaped in to the exhaust manifold.
As the mixture is detained in the cylinder the engine power goes up as well as the fuel consumption is lowered.

The exhaust back pressure from the exhaust system also assists in holding scavenge gases in the cylinder, but if the back pressure becomes to high the engine will not be able to successfully flush out the

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exhaust from the cylinder, and the engine will lose power at high rpm's. A large amount exhaust gases remaining in the cylinder will heat the scavenge gases and cause knocking and holed or ceased pistons.

The reason to using a 2" system instead of an original 34 mm system is because the backpressure in the front silencer is about half with a 2" system.
I have measured backpressure towards 0,18 kilos with an original exhaustion system.

Generally on a tuned two-stroke pipe, the silencer stinger diameter is 0,6 to 0,7 times the diameter of the exhaust port.

On a really tuned group II engine the area of the exhaust port corresponds to a diameter of 42 mm witch gives a recommended end diameter of 25 to 29 mm on a tuned pipe.

As these recommendations is on an engine with one pipe per cylinder we should have an area of three times this and will thus have a exhaust pipe diameter of some 44-50 mm. As a 2" system usually has an inner diameter of 51 mm it seams to be a good choice. The diameter seams a bit big, but it is compensated by its great length.

If one would choose a diameter lesser than 44 mm on a highly tuned engine the risk for knocking an overheated pistons is evident.
The sport systems two pipes of 34 mm has an area of a pipe with a diameter of 34 mm times the root of two witch is 48 mm and that corresponds well with later recommendations.