

Twostroke pipe building



A Guide for beginners and advanced
from
Martin Kieltsch
(mechanical engineer)

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Intro

This document deals with all aspects of twostroke pipe manufacturing and is intended to encourage anxious people to give it a try.

I started this on 2011 as a complete autodidact and since then I successfully build half a dozen pipe sets for RD350 & RD500.

As I distributed lasered parts to fellow enthusiasts, I hopefully infected more than a dozen people all over Germany.

Tools

If you want to start pipe building you'd need the following list of tools

- Computer/Software for layout/printing the angled cones
- Suitable welding device (preferably TIG)
- Suitable welding rods (diameter close to sheet thickness)
- Welding helmet with automatic visor (as you need both hands to weld)
- Tin snips (preferably electrical)
- Slip roll
- Belt or plate sander
- Rods with welded spheres in different sizes
- Hammer, pliers
- Emery cloth #60 ... #120
- Blueprint paper, drawing board
- Training sheet material (flat and rolled)
- A lot of gas (a set of pipes needs about 10-15 l of Argon)

Concept

At the beginning you have the problem of getting "good" pipe dimensions which I solved by using "proven" dimensions and just modify them to my needs.

In the simplest case you measure them on existing hardware (I call that the "Chinese parametrization"). My first try was a JL that I made with some longer sections to reduce peak rpm.

Other methods are to search the net if other people would supply their dimensions or get a twostroke simulation software and try own designs.

At the beginning this basic layout is straight and you need to divide it into shorter cones with angled joint faces to create the desired bends.

One suitable method for a first paper layout is the following:

Get a thick copper wire (2.5 mm ground wire) that has the straight length of the pipe and bend it into the desired form using the bike as a jig.

In the luxurious form you use small cardboard circles taped to the wire at the appropriate position to give you a hint for the outer shape of the pipe.

This 3D form can easily be transferred to paper and there you can measure the necessary angles.

Example: The header ought to get a length of 288 mm, so you mark that position on the wire. You measure the angle of the tangent at that point to the starting tangent of the wire (at the cylinder). In my case that was some 111 deg.

Now you decide how many segments you'll use. As a rule of thumb you should not exceed 20 deg per seam.

In our example that would be a minimum of 6 segments but I chose 8 because a smaller included angle yields into a smoother shape which is somehow important for optimum performance (I have information that it's worth a 1.x hp in a 50 hp engine to carefully smoothen the header)

Now you use a spreadsheet and the intercept theorem to calculate each segment start/end diameter and length. If your math skills are a limitation you can still draw the full straight cone on a piece of paper, draw 90 deg intersections at the appropriate positions and measure the diameters of each segment with a ruler.

Caution: Each mating surface **MUST** have the same angle on each side. If you cut a cone at an angle you get an ellipse and that will be different for different angles. If the joint face shape and length is different you'll have a very hard time in welding that together.

At this point you have all the necessary cone angles/lengths and would just transfer them to cardboard.

The cone layout can be easily done with the freeware "cone" from www.pulsrate.com.

You enter the dimensions and can print out the developed view (i.e. the "flat" cone outer surface). Then blueprint it to cardboard, bend cones, glue/tape them together and test if the "proto-pipe" fits the bike.

The desired 3D direction of each section can be varied if you rotate the cones against each other.

Here cardboard has the advantage that it's much easier to cut & glue/tape if you need to fine tune some angles to make the fit better.

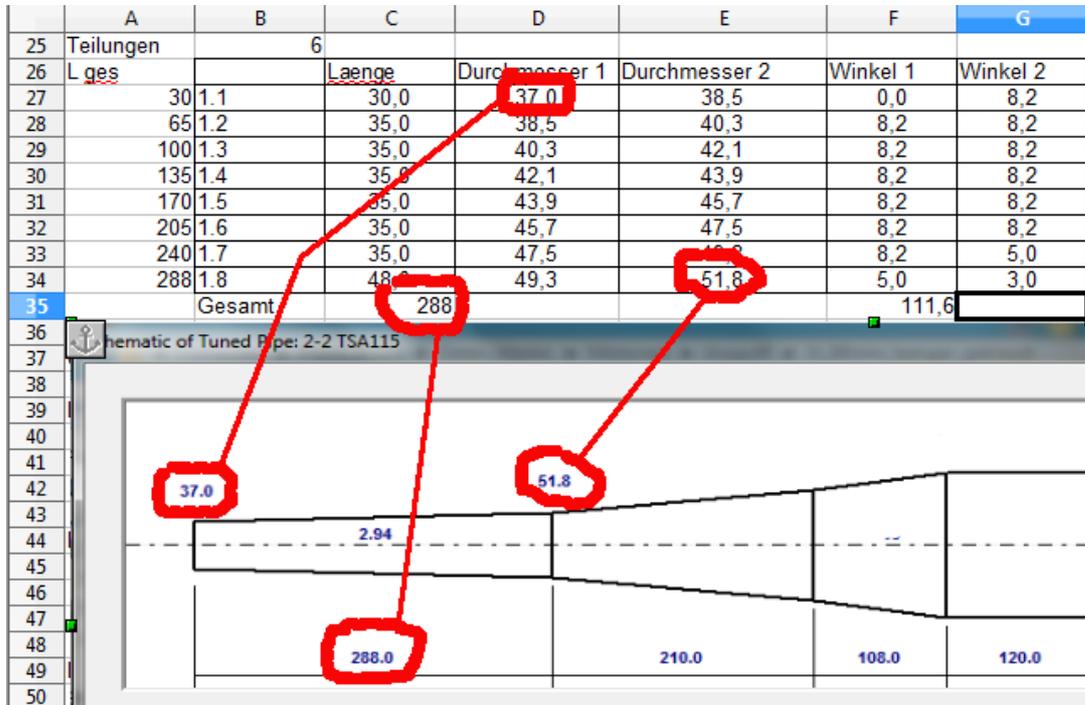


Figure 1 : Layout-Spreadsheet



Figure 2 : Header Yamaha RD350 and paper model

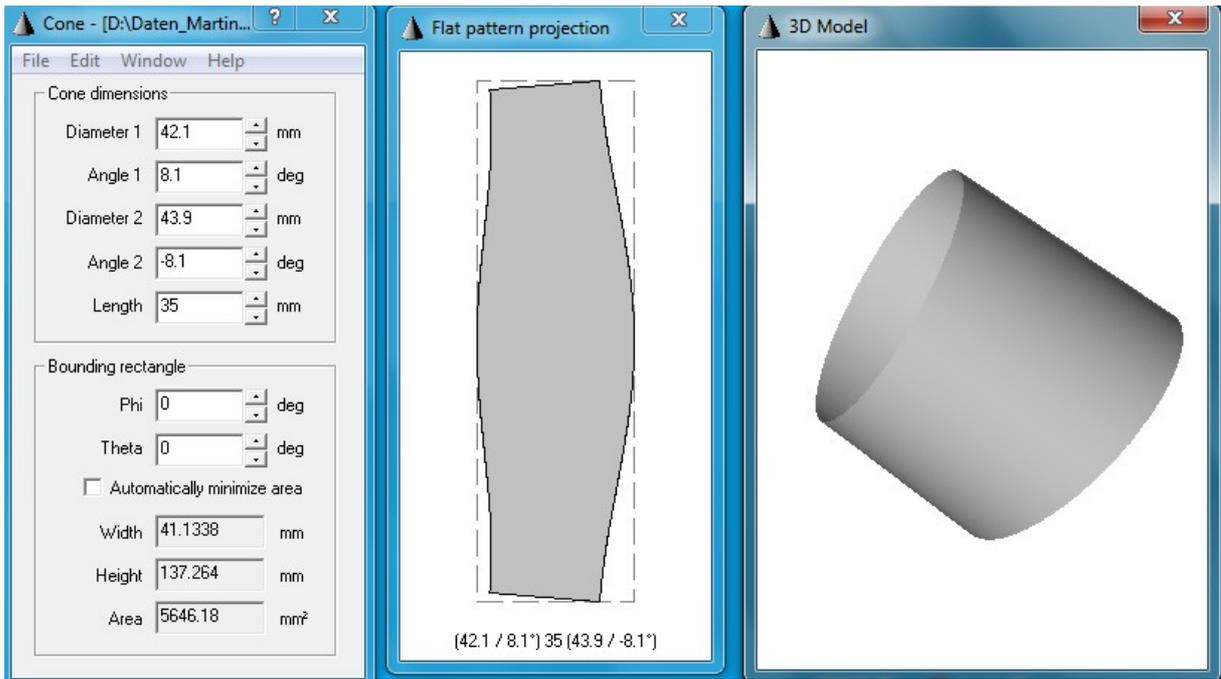


Figure 3 : Screenshot cone Software

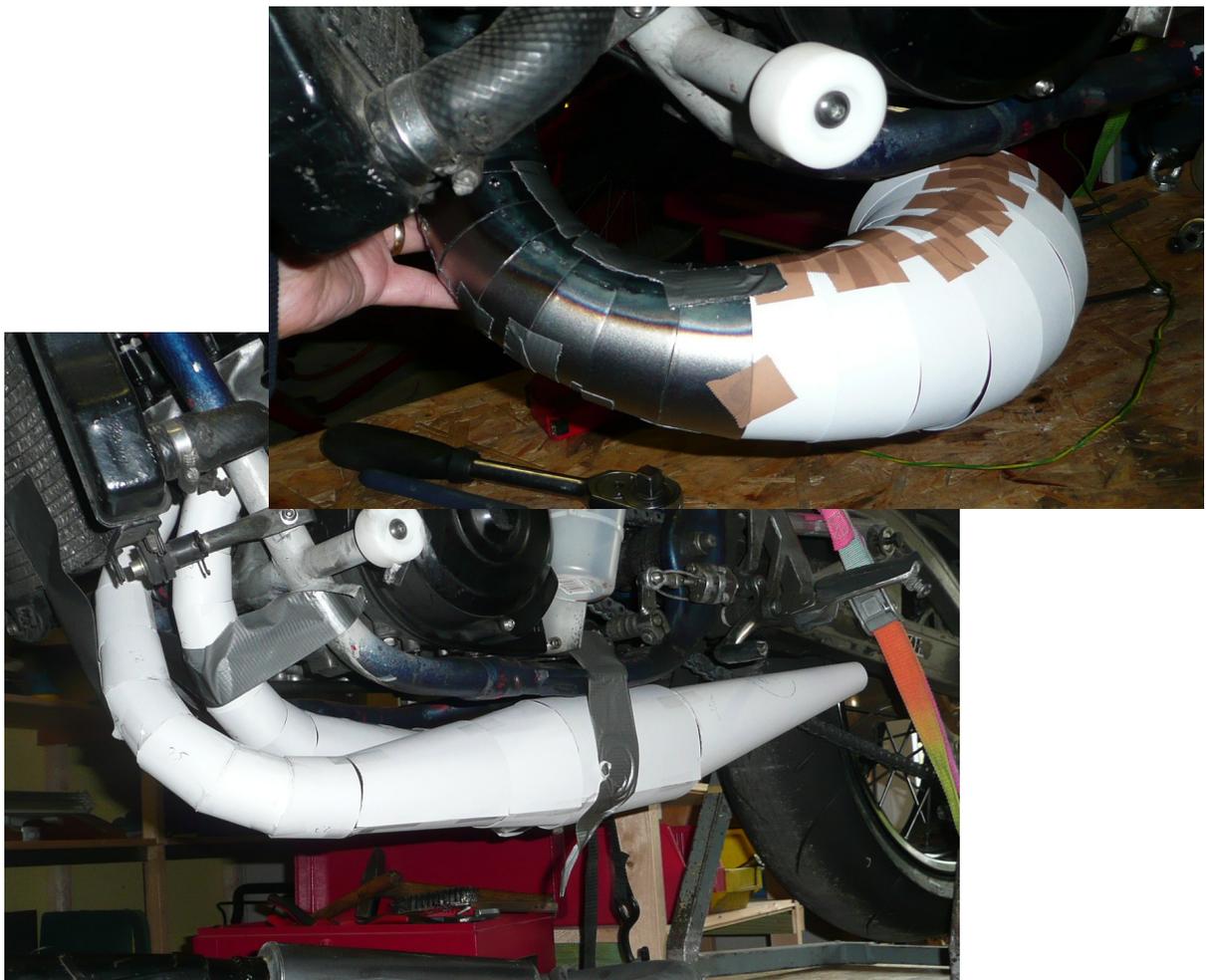


Figure 4 : Pipe concepts in paper

The pipe routing is not the only constraint you have to follow. Often things like side stand or suspension linkage have to be avoided

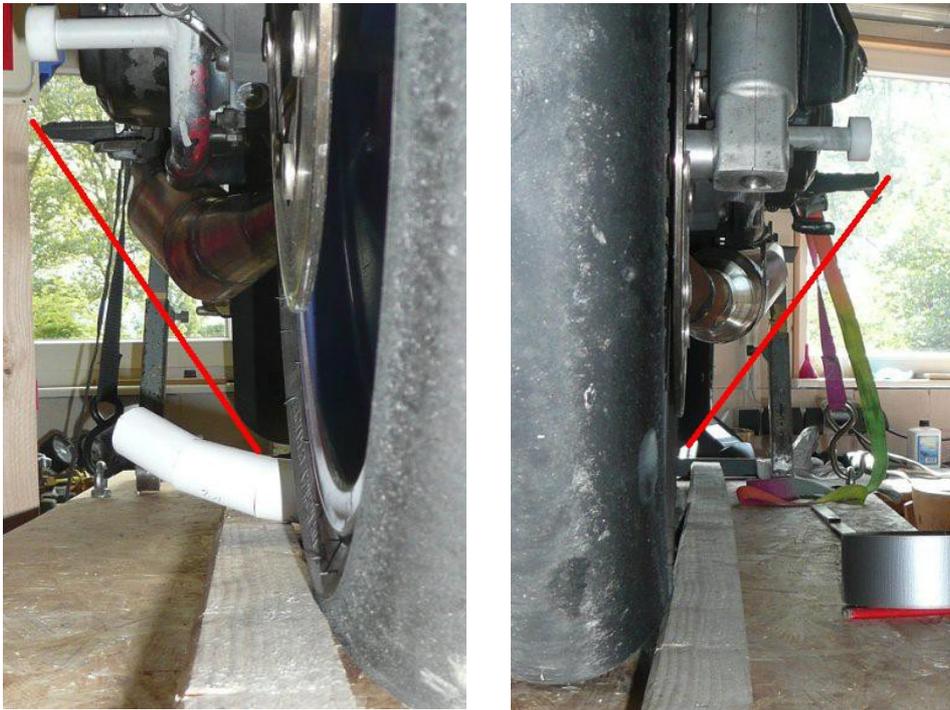


Figure 5 : Don't forget to check the cornering clearance !



Figure 6 : RD350 problem zones r

Sheet metal work

Now as you have the concept you have two ways to get the parts in sheet metal form

- 1) Export dxf files with cone and have them laser cut
- 2) Print out the cones and transfer the shape to sheet metal and cut it out with tin snips

#2 is pretty easy as you already did that with cardboard. Just exchange that with appropriate sheet metal. You need to cut out the shapes very very carefully because every little gap between the cones will need additional reworking or creates holes during welding.

The straight edges on each cone must be dead straight for the same reason. It needs to fit without any gap after rolling the cone.

#1 may be pretty expensive if you handle each part separately. For that reason I negotiated a 365x365 mm layout with my laser workshop that carried several parts in it. The contour was done as open cuts; i.e. I used a CAD package to create small (1mm) connections between the cone part and the surrounding.

The Software "DraftSight" is available from Dassault in a free version for private usage.

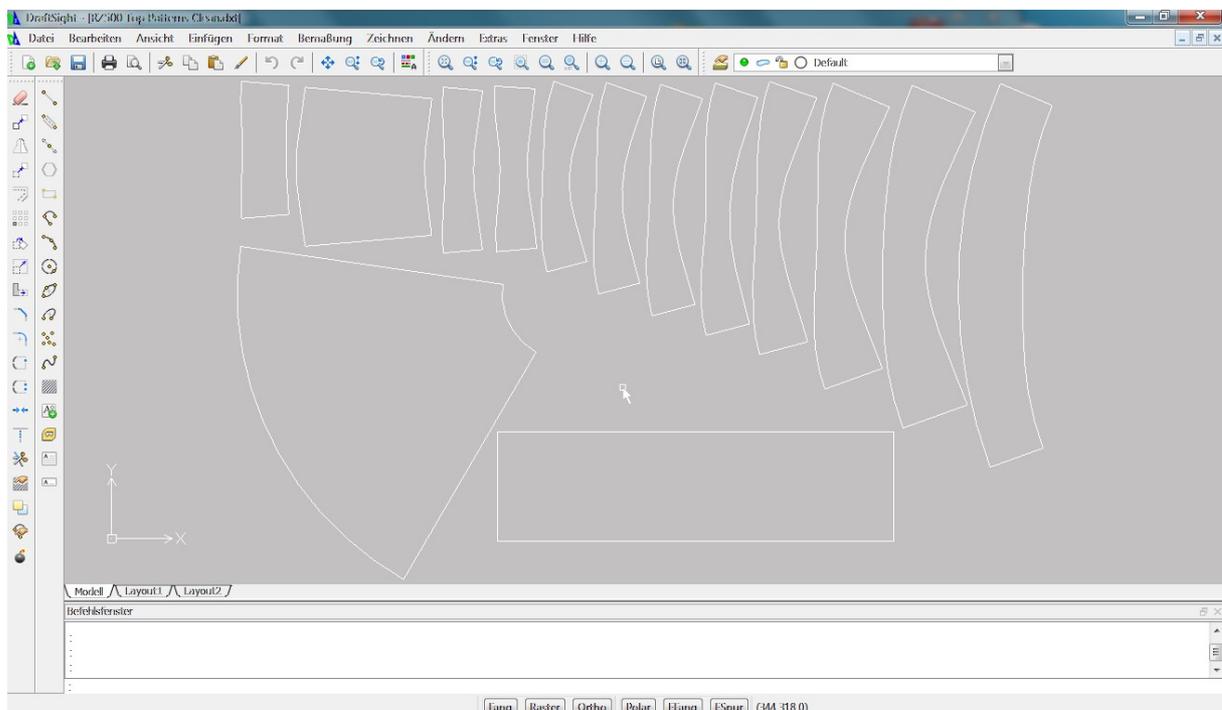


Figure 7 : Screenshot DraftSight

In both cases I prefer DC01 material (deep-draw sheet) in 0.8 – 1.0 mm thickness. This is easy to cut, roll and weld. The finished pipes are stiff enough and still very lightweight.

Example: The JL for the RD350 had approximately 5 kg, my DIY version had 5.5 kg. Stock pipes weight around 11 kg.



Figure 8 : Hand cut cones



Figure 9 : Laser cut cones

Stainless steel of equal thickness is much harder to bend and what's worse: you need to bend more than the end-condition as it springs back a noticeable amount. In addition the puddle is "more liquid" than with mild steel which one hand gives you very nice welds but on the other a higher risk of holes.

Manufacturing the cones requires a slip roll which is available for around 150 Eur on ebay.

This device consists of three rolls, two that guide and drive the sheet material and the third that adjusts the bending radius. The upper of the two front rolls is adjustable to cope with different sheet thickness and it can be driven by a handle which transports the sheet when rotating.

You adjust the third roll to create a slight bending and repeat that in several steps until your cone contour is closed. Note that you may need to adjust a slightly higher bending (i.e. cone ends overlap) because the material "springs back" when releasing the cone from the slip roll. This effect is higher with higher material stiffness (stainless, titanium).

The more conicity is required the more difficulties you'll experience when rolling the cone.

Parallel rolls create a cylinder and not a cone. This is accomplished a) by different setting at each end on the adjuster roll (i.e. you misalign it deliberately) or b) by manually re-adjusting the sheet direction while it's being pulled through the rolls. In the latter case you try to hold the outer surface perpendicular to the driving rolls.

This can be very difficult with huge parts with large difference between start/end diameter (like the last cone of the pipe that had 103 and 30 mm diameters in my application).

Here I used the help of some plies to hold back the small end and let the big end being pulled through faster. Adjusting the driving roll very tight helps to develop more torque here.

The second way to skin the cat is to additionally push the side with the large diameter by hand. This feeds the material faster on that side which has the same effect than slowing it down on the other side with plies.

If you prefer that method you may loosen the thickness adjustment roll in order to ease the manual pushing.

As an ideal result the cone is all the way round and the mating edge matches or is at least close and parallel.



Figure 10 : Slip roll



Figure 11 : Rolled raw cones

Welding technique

Welding thin sheet can be done with a couple of methods like MAG welding or acetylene. My absolute favorite is TIG (tungsten inert gas) because of the plain welds, it's clean and silent and compared to acetylene/oxygen the argon is cheap stuff.

For rookies I'd recommend weldingtipsandtricks.com as a how-to reference.

As an example they encouraged me to let the needle stick out much more (like 5-10 mm) that you usually find in the literature (2.4 mm for a 2.4 mm needle). With this method you still have nice welds but you can see the puddle area much better.

Same applies for holding the torch. Most people stay with the standard position as you need to press the button to switch on/off

For example I had cases where I held it like a big felt pen in connection with a remote control (foot pedal).

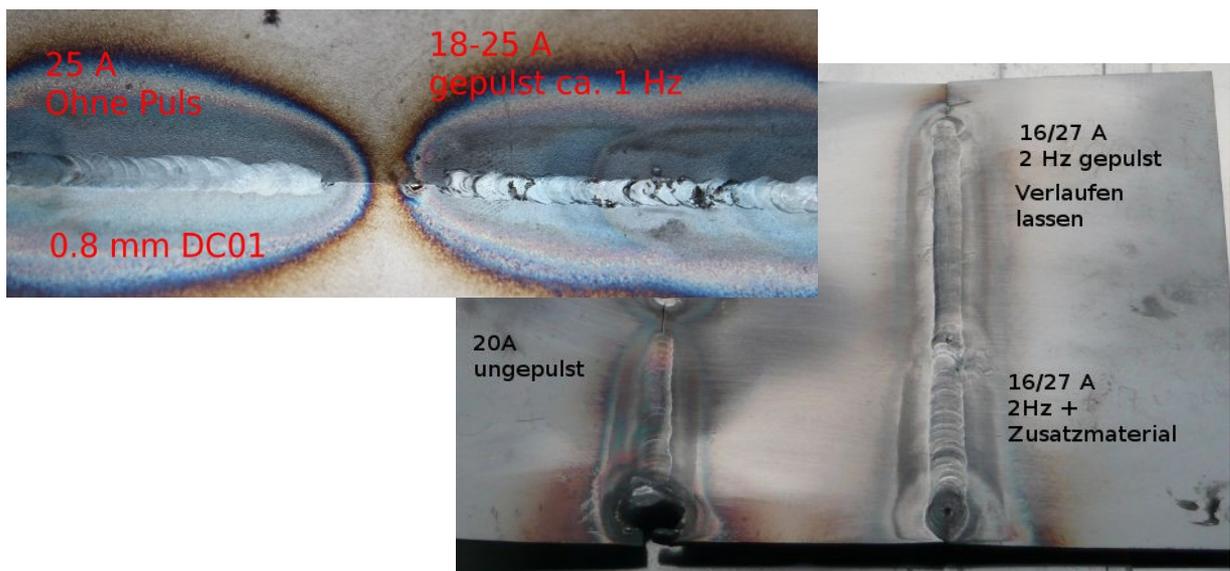


Figure 12 : Material samples

Before you start to fuck up your valuable rolled cones, you should test your necessary machine settings and welding technique on some flat sheet material. Here the holes don't matter ...

The main welding parameter is the current. For my machine it was around 15-34 A, partly pulsed between a valley and peak current.

Mild steel (DC01) preferred a constant current whereas stainless wanted it pulsed.

At first I used needles of 2.4 mm for everything which gave not too bad results (and you didn't need to change the needle when welding other things than pipes).

Later I ended up with 1.6 and 1.0 mm needles as they reduce the width of your welds and as a result it looks more elegant.

After a lot of trying my favorite needle material for steel sheet is WL15 (gold color).

On higher quality welding machines you can adjust 2 cycle and 4 cycle mode.

2 cycle: Press and hold torch button = arc active ; release button = arc off

4 cycle: Press & release torch button = arc active ; Press torch button again = arc off

I prefer 2 cycle to tack things together and 4 cycle for longer welds. With the 4 cycle mode it's easier to hold the torch differently as you're not forced to have the thumb on the button all the time.

As we talk about quality: Cheap welding helmets filter a fixed intensity of light which is designed for standard welding operations like steel with 100 A. If you weld with just 15 A, you may want to see more and better pick helmets with adjustable level.

After using a cheap one, I ended up with a Speedglas 9x series helmet.

As a welding gas I used Argon 4.6 with a flow rate of around 5-7 l/min with jets between 5 and 7

For stainless or titanium you'll need a gas lens which is available in different sizes.

No matter what your wife says: Up to my experience in this case size matters!

Rule of thumb: The bigger the gas lens, the better you keep oxygen away from the hot zone and the prettier the weld.



Figure 13 : Gas lens XXL and stainless test sheet

Very important for both of these materials is the so called purging (i.e. techniques to keep oxygen away from the back side of the welding seam).

If you don't do that with stainless, the backside develops a structure that looks like cauliflower which is the starting zone for cracking.

If it's in the header area, it'll have a negative influence on performance and you'll have to grind it down.

There are a couple of professional ways of purging like gas, paste, tape that are all very expensive. For the DIY'ers it's the easiest to get a simple T inside the gas line and flood the welding object with Argon from the inside.

A positive side effect is that even the front side of the seam benefits from purging. It's smoother and the annealing colors are less distinct.

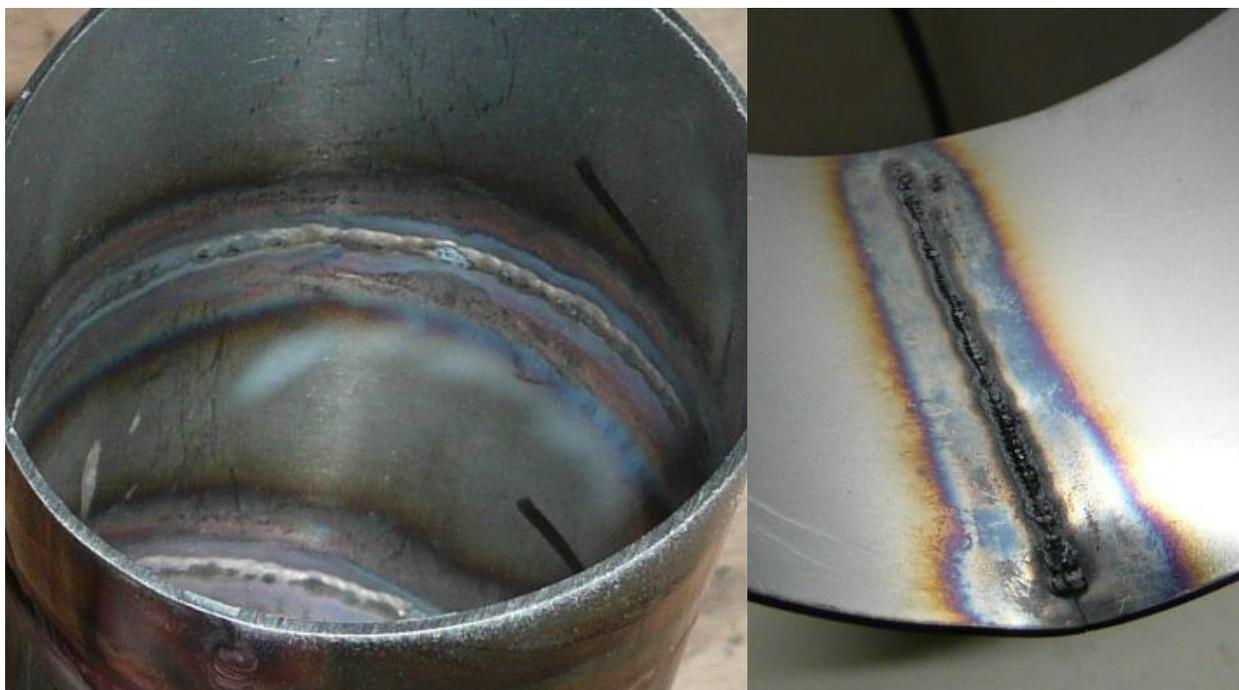


Figure 14 : Inner side with purge gas (left) and “cauliflower” without purging (right)

Just for curiosity I got myself some titanium sheet for testing as you always read it would be so difficult to weld.

If you ask me I'd rate it even easier than steel or aluminum as it “flows” very nicely and builds up pretty welds without much effort.

The important thing here is to check for signs of overheating (deep blue annealing color). This initiates changes in internal material structure that'll promote later cracking in that region.

Practical hint to reduce costs: Titanium rods will cost you a fortune. If you have sheet material left, just cut it to thin stripes and you have short rods for free ...



Figure 15 : Header in titanium

The main trick with all thin sheet material is seam preparation over and over. Your target is absolutely no visible gap.

Every visible gap will result in a hole that needs to be filled later (which costs a lot of time and doesn't look very nice). So better spend your time on preparation than on filling holes.

If you require small drops of rod at some locations I used very thin stuff like 1.6 mm.

For tacking a cone I put them on a flat surface and press it along the circumference to match the longitudinal edges first. Then I tack it two times for short cones and multiple times for the bigger ones (about 1 tack per inch).

After that I put it on a mandrel, hammer the seam flat & close and do the final welding. Leave some mm at start & end, otherwise you'll fabricate ugly holes (you'll finish that later when putting the pipe together)

Now I use a flat belt grinder or a DIY plate to create exactly flat mating surfaces between the cones. (#80-#120 sand paper was just fine)

In order to connect the single segments I match the contour as good as possible and tack it where the match is best. After that I hammer the seam to create a perfect match on the whole length of the later weld.

The best way to hammer these round structures is a DIY mandrel where I used a 30 mm rod and welded/screwed different spheres at one end. You position the seams to be exactly over the sphere, the other end goes into the vise and you have a fine "anvil".



Figure 16 : DIY grinding plate

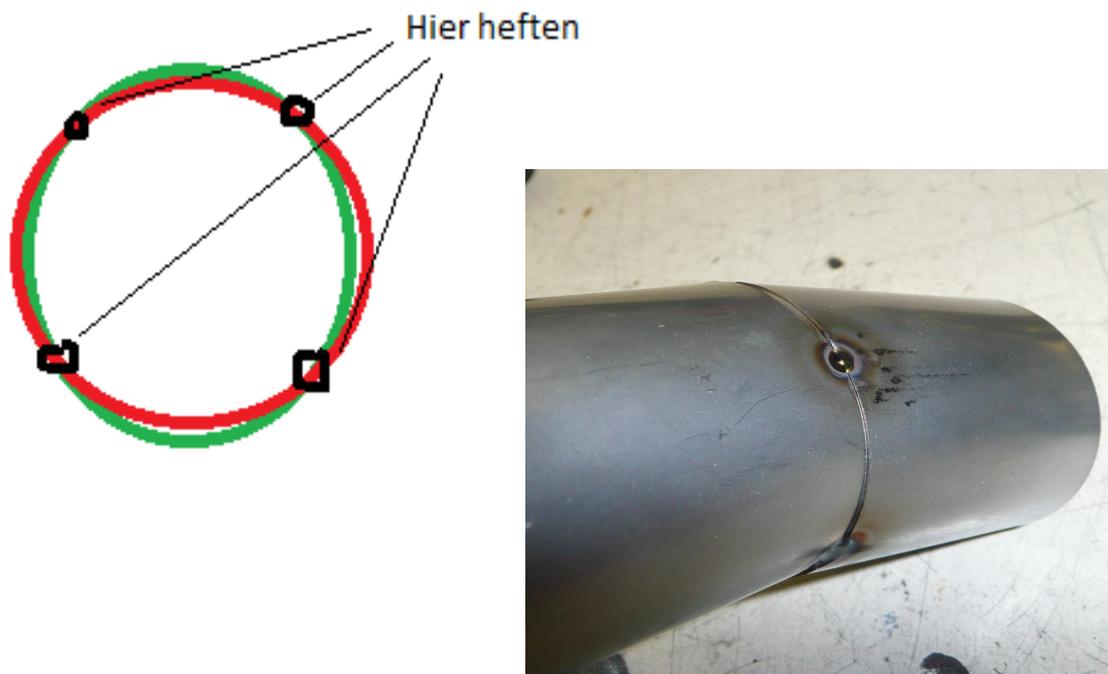


Figure 17 : Tack segments at best fit locations



Figure 18 : Hammer after tack-weld and desired perfect (=gap-less) seam.



Figure 19 : Mandrel for hammering round seams



Figure 20 : Finished weld before and after hammering

If you position the cones, try to avoid cross-joints as they'll likely result in holes. Instead you can rotate the segments slightly for just a few mm offset.

After that preparation you can weld without any additional rod. You just pass the torch over the desired area with an appropriate speed. I try to weld as long as possible in one operation (without having to stop/restart) because that way the annealing colors are the most even.

To have a reference, I start at at the first segment of the header with the flange part not attached. So you can fine-tune the later routing and at the end you finally fix the flange-part.

For he flanges it's the easiest to buy off-the-shelf units like JL and Jolly Moto offer. For around 25-30 Eur the Jollys are made from aluminum and have an o-ring. The JLs come with a single + o-ring or double tube (design changed from time to time)

My own version was a single tube without o-ring that used silicone seal agent.

All flanges attach the pipe with at least 2 springs. You need that to de-couple the pipe from the engine vibrations. If you directly weld the pipe to a flange it'll develop cracks withing a short period of time.

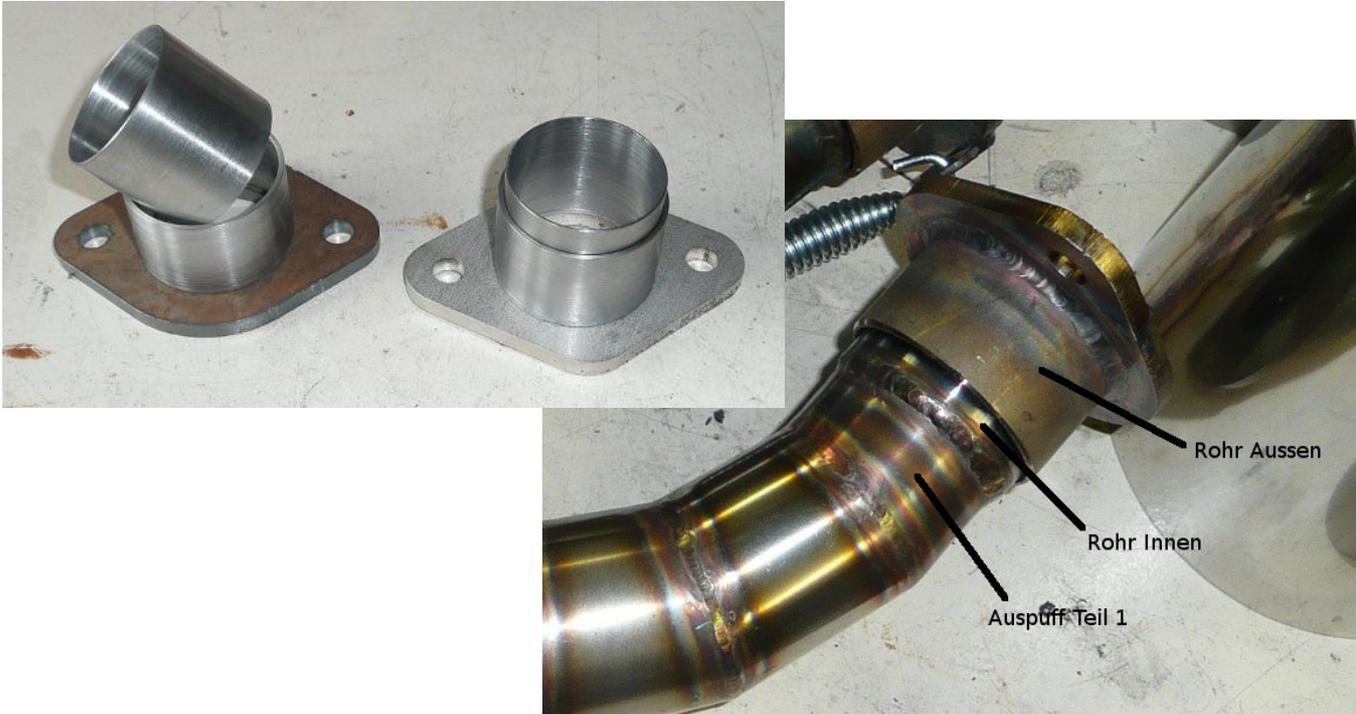


Figure 21 : Cylinder flanges (DIY)



Figure 22 : Cylinder flanges with O-Ring (left: JL, right: Jolly Moto)



Figure 23 : Welded segments

With the above method the pipe would grow from the front to the back. On the last cone you'd have the issue that you couldn't hammer the seam after tacking as you can't use the mandrel through the small stinger opening.

Even worse: The big diameters don't match that good anyway and they warp if you weld on the other end. Consequence: You likely will need to add some rod and the weld will look worse compared to the rest of the pipe. And that in THE region that visible the most.

I solved this dilemma by leaving out one weld at the end of the header (or one of the first expansion cone parts). Here the diameter is half way small and thus can be welded later without the above negative results. For the following parts you continue to weld.

This leaves an opening in the pipe for the last cone where you can preprocess the seam in the necessary way.



Figure 24 : RD500 DIY pipes (Design: Wayne Wright, 2013)

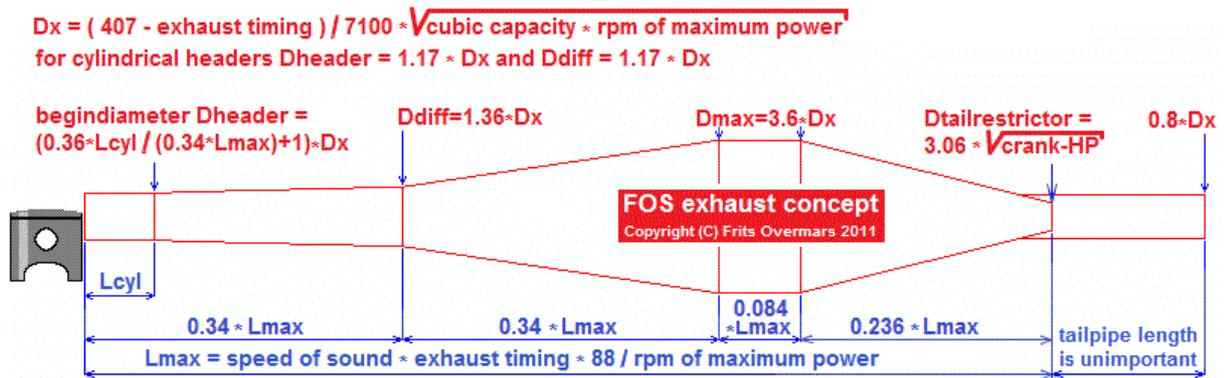


Figure 25 : Frits Overmars pipe concept (note that the stinger is VERY small here and I usually use bigger diameters)

Engine setup

After building the pipes you can gain or waste a lot of performance with the wrong setup.

For those who think they may get away with the stock ignition and PV control, I recommend using stock pipes and save the effort of building.

As the changed pipe works in a different rpm region, you WILL need to adjust ignition curve and PV actuation rpms.

Appropriate devices are available at ignitech.cz and zeeltronic.com.

My very first pipe was mounted to my EFI'd RD and I didn't change neither fuel maps not ignition/PV.

The result was rather disappointing; the rough spot at around 4.5k was gone, but performance-wise the result did not cover the effort for building.

Luckily I had a mate nearby with similar setup who already used JL pipes and the bike was already optimized for that. He mounted them to his bike and they just ran fine.

So I ramped up the ignition advance over 9k and opened the PV later (9.5 instead of 8k). That felt better, but I you asked me at that time I'd have said maybe some 3 HP more than before.

A few days later we did a side-by-side acceleration test which ended in a tie (up to 160 kmh). His bike was dynoed with 78 crank HP, so my pipe couldn't have been too bad.

The reason for the initially disappointing performance was clear: The bike was optimized to the 1WW (F2) pipes which hardly rev over 9k and require "special" settings around 4.5k. Now you mount different pipes (peak at close to 10k) and expect it to work better than before ?

Mainly you have 3 points to cover that you ought to solve separately and one after another:

- 1) Ignition curve.
- 2) Power-Valve
- 3) Carb setup

Concerning a "good ignition curve" I liked this writeup from the late Bill Givens:

“So what is correct timing. Correct timing in my mind is running the least amount of advance that you can to reach a maximum cylinder pressure around 10-15 degrees ATDC.

Yes you are right...spark strength effects timing. The stronger the gap current the more ionized the flame front becomes and this will cause it to burn quicker. To compensate for this quicker burn and to reach our goal of max cylinder pressure at 10-15° ATDC we would need to retard the timing some.

The faster the burn rate of the fuel the less advance I need to reach my goal and the higher the octane rating the more compression I can run. You are looking for a balance of compression, octane and burn rate and your timing will be based on the application and fuel you have available. Again each situation is slightly different.

Whatever I do to speed up the burn rate requires less advance and that is a good thing, because the less advance I can run, the less negative work my piston must fight against.

Speaking of compression... the higher the compression the more heat that I generate and unless I have a way of getting rid of that heat I can only go so far with that parameter... no matter what the octane rating is! I can run considerably more compression in a water cooled than an air cooled for that reason. The higher the compression the less timing I need to reach my ATDC goal because it takes less time for the burn. So a water-cooled engine can run more compression and would normally require less advance.

As we all know head geometry plays a major roll in all of this also. Shape and size of the dome... squish effect, etc all figure into the burn time. If you increase the MSV you will increase the burn rate... faster burn rate requires less advance.

So why do people associate that more timing is a good thing...quiet simply they don't know anything about it and a lot of this comes from the old hot rodders conception of 4/ days where they would increase the compression and increase the advance to a point and all was cool... but that is a totally different ball game with different rules. They had/have twice as much time to get rid of the heat as we do.

There are no hard fast rules on what timing will work in every situation. You have to develop the timing and timing curve based on what your specific engine design and fuel allow you... all with a goal of achieving max cylinder pressure around the 10-15° point.

So let's develop a curve...

To keep the motor from kicking back, the cranking/idle speed timing should only be advanced 3-6°s. Cranking/idle speed starts at 0 RPM, and can extend to 1200-2500 RPM. This will allow a motor to start easily without kickback, and main a smooth idle without the timing curve varying it to any degree... generally 3° - 6° advance BTDC is all that is necessary. The higher the compression, the less advance necessary...as general rule.

I always felt that the standard factory straight-line timing was a compromise between low and high RPM engine safety and drivability... so what I do to get a starting point, is increase the std timing above the idle area by a factor of 1.5.

Let's say in the method above... that the standard straight-line timing was 20°. Then $1.5 \times 20 = 30^\circ$ timing... from the idle area to roughly 75% of the peak torque RPM. If the motor makes peak torque at 10500, this is about 7875 RPM. So from 0 RPM to about 2500 RPM we have 3-6° advance. At 2500 RPM we ramp straight up to the 30° point, or what ever 1.5 time the standard timing was, and stay at that point till we reach 75% of the peak torque RPM.

Now we get to the slope... that is critical to the engines power and longevity, and it will typically start where the engine starts to pull on the pipe...a range from roughly 75% to 110% of the Peak Torque RPM.

If the motor makes peak torque at 10,500 RPM, this would be roughly 7875-11,550 RPM. The port timing values and pipe design will affect the specific value, but this is a pretty close baseline for most motors.

Generally the resulting timing curve is a straight-line flat slope between these points, although there can be variations to where optimization is found to be needed.... particularly around the peak torque RPM.

The peak torque timing should fall on the slope at around .75 of your original straight-line timing to get in the ball park. In our example, the peak torque timing would be 15°.

The timing slope continues to decline in a more or less straight line to a point about 110% of peak torque RPM. At that point sustaining a retard beyond this region will extend the usable power range by a good margin. This can enable a lower gear ratio and provides a wider power band with no loss of peak torque.

At a point of about 125% of peak torque RPM you are probably at the end of the over-rev region and can start to plug in some advance to act as a Rev limiter if you want. I normally just straight line it out to the right.

This should get you a curve that is close enough to start some serious testing. Without the use of a dyno to help you optimize the curve, then you need to make sure you are jetted correctly and start the on the track testing. Monitor CHT and EGT and take numerous plug chops looking for detonation... primarily around the peak torque RPM. What I do is keep advancing the slope until I start to get a little soft count detonation and then back the curve off by 1-2°'s.

EGT and CHT should follow each other... If the EGT is rising along with CHT you're probably ok. If EGT start to fall under acceleration and CHT continues to rise then that's a sure sign of detonation.

Important point...Now if I know from experience that with my engine design that I can't run the factory advance during the ramp up point and to the 75% point then I back that down to a number that will work in the mid RPM range.

Depending on the variables...I've ran all the way down to 0° advance at peak hp"

This "manual" doesn't match a 100% with my own findings (for example the RZ's like a bit more advance for idling) but it's the best base for your own experiments.

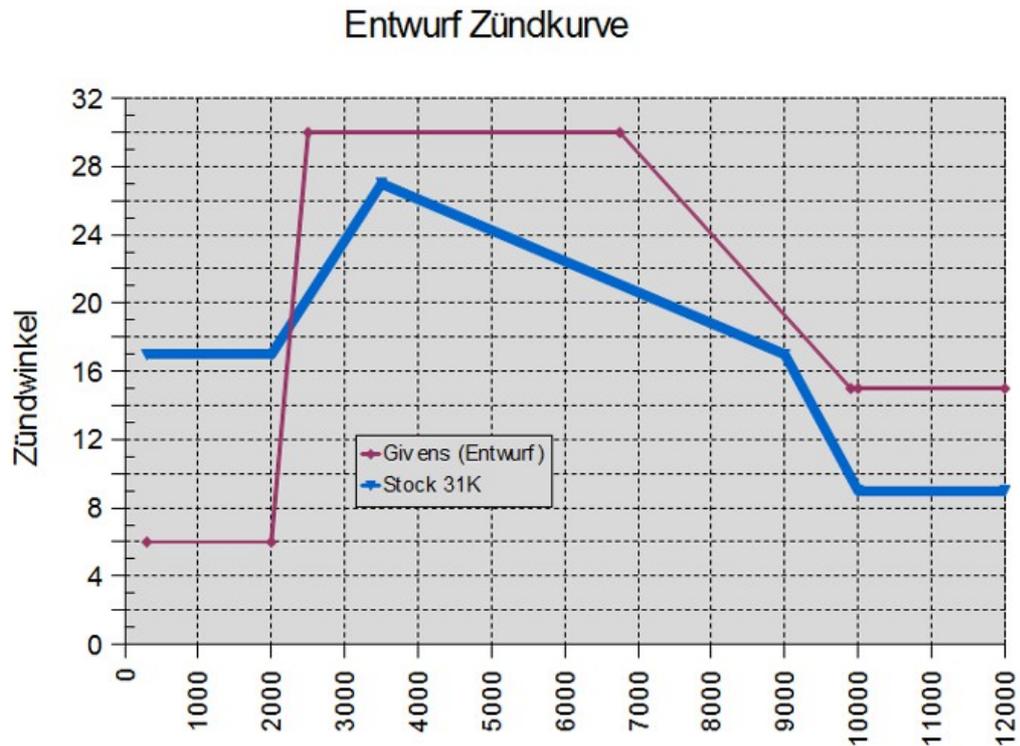


Figure 26 : Draft curve following Bill Givens for RD350YPVS

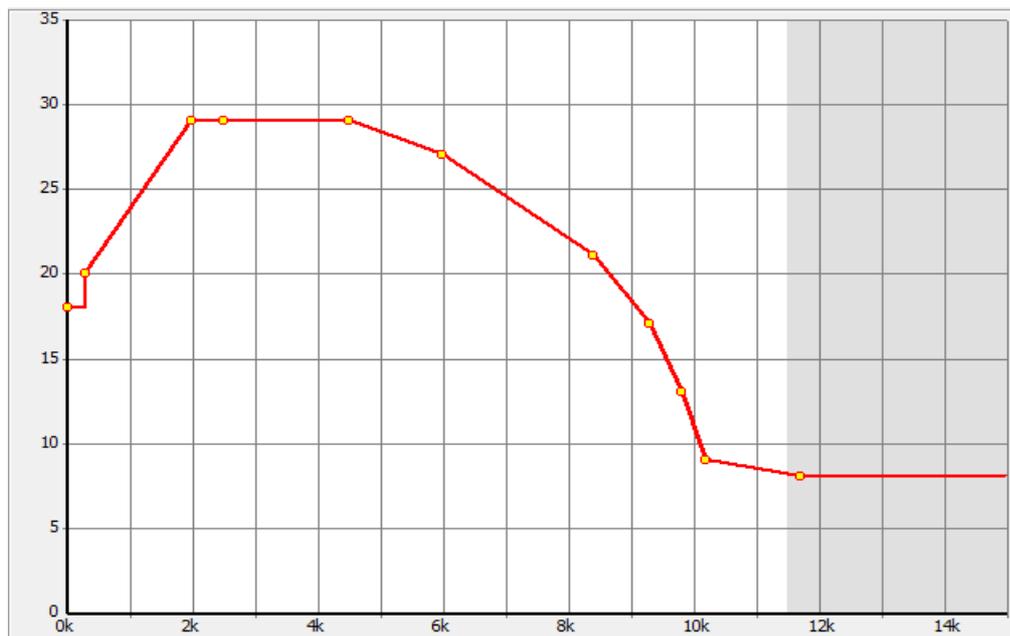


Figure 27 : Ignition advance on my EFI RD with DIY pipes

The second point is the Power Valve actuation rpm.

On the RZ you start to open in the 5-6 k range and target a “fully open” rpm of some few 100 rpm below peak performance.

Try different rpm and curve shapes and pick which engine characteristic you need (straight line = smooth torque curve, S-shape = more 2-stroke kick)

For the pictured pipes this was an S-shape with start at 6k and end around 9.4k.

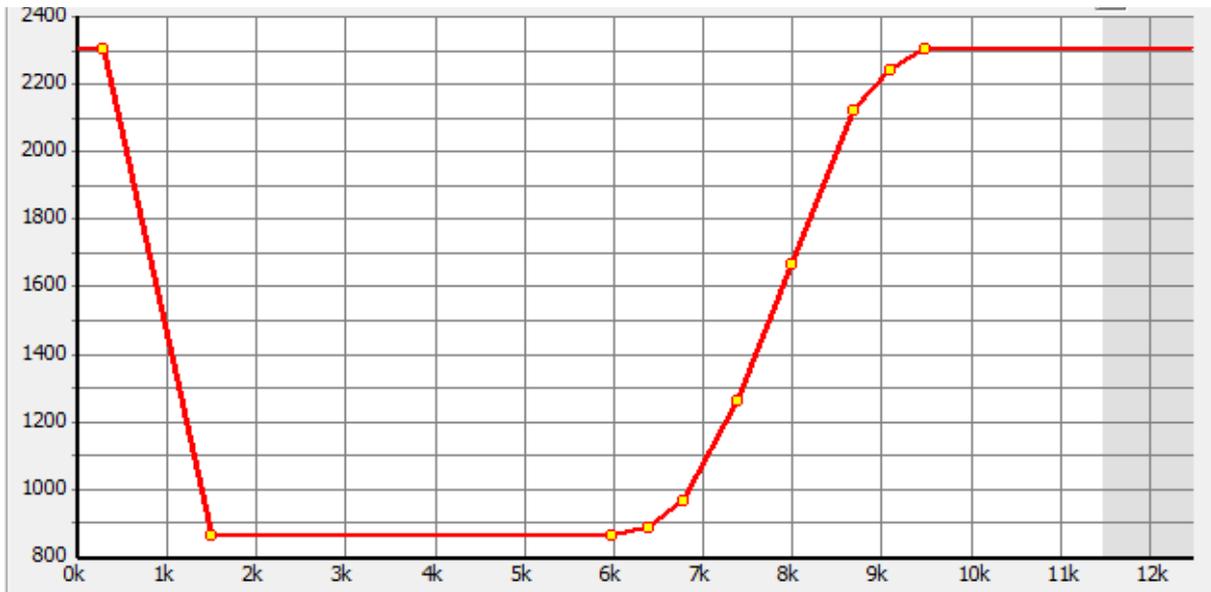


Figure 28 : PV-curve for DIY pipes

As the last point you adjust the carb setup.

If you had the 1WW (F2) pipes, you were on a very rich part-throttle & WOT setting in order to be reliable

Pipes with a bigger stinger diameter usually can bear a leaner mixture without melting your piston and still healthy EGT.

My DIY pipes requires around 2 jet sizes leaner and one notch leaner on the needle.

I have reports that the JLs behave similar; i.e. usually prefer slightly leaner setting.