

CROSSOVER ENLARGEMENT FOR AN R1100S

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Ben Barkow

Toronto

Horsepower is a very important spec for the Marketing Department and so the aggrandizement of advertized HP casts a long shadow over many engineering decisions. But really it is the curve of torque across the full spectrum of rpm's that is where your eyeball should fall.

Torque is related to the amount of combustible mix ignited each revolution in the cylinders and that's based on volumetric efficiency of filling the cylinders. HP is kind of just a figment of torque because it is calculated as the torque in proportion to the number of times a minute that ignition occurs. For a given torque, the higher the revs, the higher the HP. Thus for a given torque, the faster the engine is turning, the more HP you can advertize and the better the Marketing Department feels about the model.

On the other hand, other things equal, riders (and esp. plain old street and touring riders) like bikes that have power at lower, less jarring revs. They like best engines that are, you'll pardon me, more Harley-like. But profit-craving companies like BMW are favorable to that kind of friendly drivability so long as it doesn't compromise the wishes of the Marketing Department in advertising high HP. Inevitably there is a clash between pumping our big torque at lower, street-rider revs versus high-rpm racer-boy revs.

Which side are you on in your own riding needs?

The R1100S engine was tuned to make lots of HP at high revs yet it struggles to put out the torque at middle and low revs, below say, 4000 rpm. How to increase power at lower revs?

Adding a few thou to the valve lash helps in that direction as Lentini suggested. Adding some spark advance by rotating the Hall Effect assembly may help across the band (again, Lentini's suggestion)¹. But I was surprised to find an anomaly in the front crossover pipe that can help too, as others have previously noticed.

Because a boxer engine fires every 360 degrees, it makes sense to share the intake and outflow systems because the pulse from one cylinder doesn't interact with the next pulse from the other cylinder. For exhaust, adding front and rear crossover pipes helps in that way. Crossovers are added to reduce flow resistance in the exhaust. They are especially cogent for boxers with long dual exhaust systems and the more crossover and sharing the better at every speed, up to some point where further benefits diminish.

Ever ask why BMW designers introduced front crossovers to the boxers? Not for looks as nothing is more wonderfully dramatic than the curved sweep of the exhaust pipes

¹ Adding spark advance is tricky because it cuts into the safety band for detonation.

reaching forward from the heads. It is a pain to have the crossover pipe in that lousy location, being exposed to all the dirt on the road, getting in the way of engine work, adding to the pains of removing the head or headers, and sitting where some designers might want space for the mechanisms of steering.

Adding the crossover is kind of no-brainer, providing you are prepared to meet the downside of added weight, cost, and complexity. However, as discussed below, resonant scavenging, if any is present, can be disrupted.

The traditional logic is that the front crossover helps low speed torque. Indeed, the R1100S has notably large exhaust pipes and massive crossover pipes (about 40-mm ID). But did you know that the front crossover pipe has a baffle all but sealing the passage? This 40-mm baffle has a meager 10-mm (3/8 in) hole to allow gases to crossover! Weird.

More conjecturally, I'd guess in the course of fine-tuning, BMW found they could use resonant scavenging to get some added boost (or to counter-act some shortcoming) of the top end. But cross-overs short-circuit resonant scavenging. More precisely, the cross-over introduces a second path length and a different path length, like an organ pipe, operates at a different frequency. So BMW in their wisdom found a middle course, leaving the cross-over but cutting it down in magnitude by introducing a baffle with a small 10-mm hole.

I think they thought that the small hole would be helpful at low rpms, but too small to be a factor at high engine speeds.

Any other reason for the crossover cross-section is so tiny can only be guessed. Possibly some tuning gremlin of the exhaust system — no doubt interfering with power at upper revs — suddenly materialized when the cross-over was in its natural state of being unobstructed.

Soooo, I drilled, reamed, filed, ground, and otherwise Dremeled. “PhoenixTexoma,” whose experiment is discussed below, wrote me about a better idea for a tool:

“... for you or any others thinking of enlarging the crossover hole. I got a conical grinder with a 3" long female shaft that bolts onto a bench grinder 3/8" arbor. You can enlarge a hole up to 1.5" with it. Plenty long to reach into the crossover. The grinders are \$5 each from McMaster Carr. Took about 30 seconds to get the crossover hole to 1" on my spare header pipe.”

I made the 10-mm hole to around 28+ mm (just over an inch) and that's about 7 times the area and likely somewhat more in effective cross-section increase.

The results for power output are hard to assess because they are confounded with other changes I made the same January to my 1999 R1100S². But I can readily feel an increase

² Stay tuned for the next revision of this write-up which, weather permitting, will have long-deferred dyno results.

in power in that deficient band below say 3800 rpm. Functionally, I now can use 6th gear at near-legal speeds, something I barely ever did before even with a good tailwind. Also, you know that feeling as you kick the gearbox up, “Geez, I’m sure there’s got to be a higher gear in there somewhere....”

Having achieved good power in the lug-a-long cruising range, I need to add a caution. This comes from my travels with an air-to-fuel ratio gauge. The ECU seems to be in its element when the engine is turning over in excess of 5 grand. When you are riding at those revs, the ECU seeks a lean but powerful A/F and generally, most systems are happy. I suspect this is a fuel-efficient range.

So, the decision is yours: to scoot around with your engine screaming but you are kind’a happy that way or to have the grunt power to go up a gear or two and ride in peace, as I like to.

Different results for Phoenixtexoma

While the results I mention above seem to be characteristic for the few people besides me who have enlarged the baffle hole³, I want to relate the somewhat different outcome for Phoenixtexoma, a skilled and experienced bike modifier, who opened his cross-over baffle to nearly full bore. He found more oomph showing up at the top revs, but not detectable lower down, as I found. In addition to making the baffle hole far larger than mine, his wonderfully crafted bike also has trick cams advancing valve timing by 9 degrees and other changes. Phoenixtexoma also tells me that some high-end German modifiers are aiming for full-bore crossovers.

In light of Phoenixtexoma exemplary mods, the scavenging as initially devised by BMW ended up being of no benefit to a revised bike. Or maybe the scavenging resonant tuning caused a little residual hole in the torque curve at a point in the speed compass that may be quite unwelcome. By removing the baffle as fully as Phoenixtexoma has, he has regained all the advantages of having a cross-over and mostly experienced the help at the top end, at least as compared to his engine behaviour just before.

Scavenging tuning is in my opinion, a bad notion for all but race bikes that need power at the rev peak, because it is tuned to give a boost at one certain frequency... and holes at sub-octaves. Sort of like taking steroids that provide a boost in some respects but the side effects may not be what you want.

Valuable late news.

A super-skilled mechanic and tester with the handle “bacn5” posted the following

³ Or with opposite results, eliminated the crossover flow by removing the pipe or closing the baffle hole.

information on the internet. He sure knows more about these things than I ever will:

“Thanks [Ben], The baffle modification was one of the easiest mods that I could actually feel a noticeable improvement at virtually no cost (it also reduced my 60ft times by about 1.5 tenths. With that being said... it is still a ridiculous design, 10mm is ridiculous and so is the baffle and the large size of the 1100S H-pipe. I believe this was a cost reduction effort- since all the pipes are the same size, you can order larger volumes...

snip

My past experience has indicated that if all other systems are matched properly an H-pipe that is sized approximately 3/4 of the main pipes normally gives the best results. Once the merge collector issue is resolved, if you mark the headers from the exhaust ports back with a grease pen, the H-pipe should be located about where the grease stops burning off, or use a inferred thermometer and look for a dramatic temperature drop.

I believe that an H-pipe works by using the venturi effect at low speeds to help pull exhaust pulses from the opposite bank. This will help increase exhaust velocity at low RPMs which will in turn help pull air into the cylinders on the intake side during valve overlap at low speeds. At high rpms the exhaust velocity is so high that the H pipe is no longer required.

As you probably figured out the H-pipe basically allows you to size the main pipes large for high rpms while maintaining low rpm exhaust velocity's and good throttle response. The current pipe diameter is 45mm; consequently, if everything else is right, the balance tube should be about 34mm (but this is for the entire length of the tube).

If I were going through the trouble of replacing the whole balance tube though, I would start from scratch and try to fit an "X" pipe in place which will work over a broader rpm range than any H-pipe (Dynomax makes a nice universal X-pipe). I would also add a small silencer in each bank up front so that I can run a free flowing muffler in the rear and due to the difference in distance from the engine I would be taking out a broader range of sound.

Something to think about and sorry this is so long.

He also wrote:

The same thinking applies to the header exhaust bulges at the ports, this is a cost reduction compared to the 2 into 1 merge collector you see on the older RT's and other models. If you remove the headers you can see a large cavity in the head that will instantly reduce any good low speed exhaust velocity and scavenging effect. I am in the process of correcting this by building "2 into 1" merge collectors of the appropriate size. When these are ready I will cut off the OE flanges and weld the new ones in place.