10-07-2007, 04:08 PM #1 (permalink)

DavidVizard-GFN OFF
Pit Crew

Join Date: Apr 2007
Posts: 840

#3 Turbulance and Combustion Dynamics

#3 Turbulence and Combustion Dynamics

OK, lets be frank here. It is OK to start an article with OK especially if a) you have little idea what the rules concerning English grammar are and b) there is no editor looking over your shoulder. But to get going here let's take a look at where we left off in part two of this subject. This, in yellow, is as follows.

So why am I highlighting these negative results? Simple – I want to emphasis that the subject we are dealing with here is far from simple. I had no idea why power went down then and here we are 30 years later and I am still shy of an answer. In this instance the results were about 180 degrees apposed to all the other tests I have been involved with. This Avenger engine liked to have the piston stop 0.120 (120 thousandths) short of the head face (0.080 down the hole and a 0.040 head gasket) for best results. For just about every other engine I have done tests on like this that piston to quench source *gap is about the worst in terms of low detonation resistance and poor combustion. It really begs the question as to whether or not we can give an engine too much quench action. It is this factor, and crevice volumes such as the ring land volume that we will look at in the next installment.*

We can, from the forgoing, draw, with some degree of certainty, a tentative conclusion. Namely that applying a universal rule can, just once in a while, turn around and bite your rear end. Just to keep my feet on the ground I have a little policy that all lessons learned – no matter how certain or obvious they may seem, should be regularly reappraised for anomalies that may actually reveal something that was overlooked or misinterpreted.

If the big fuel droplet deal with the Mini Cooper engines intrigued you here's another somewhat mystifying case concerning – once again – a Mini engine. After a successful season with a 1293 cc Mini Cooper S hill-climber (finished second in championship and only narrowly missed first spot due to going of on honeymoon and missing a round) a customer asked if I would build him a blown, bored and stroked version of this engine. I did just that – capacity was stretched to 1442 cc and a large Shorrock supercharger installed. Just so that we did not have to use an intercooler as there was no room for such, the boost was limited to about 12 psi. Dyno testing was to be on a chassis dyno. The successful engine from the previous year made just on 100 hp at the front wheels. After a break in period and a change of oil and plugs to a race grade type the engine was given its first wrestling match with the dyno. This resulted in only 85 hp in spite of the 12 pounds of boost going into this big 'A' Series engine. This was scary – the customer was standing right there watching and here we were with a car that sounded for all the world like it could break the unlimited land speed record yet it was way down on even a conservative estimate of what it should make.

As it happened Mike Lane, GFN's F1 correspondent, had helped out a lot on this build and was on hand during the dyno testing. Mike had built one of his slick close ratio 'knife-through-butter' shifting gearboxes for this car. Between us we waded into a search for all the likely causes of great noise – no power. Ignition timing, valve lash, ignition box etc. (had an early two spark transistor ignition box designed by the guy who was scientific advisor to the war ministry – the guy had an IQ that was about off the scale and our box was about like a lightening bolt generator) were all diligently checked for function and ruled OK. At several points along the way we made dyno runs but with the same results – about 85 hp. Finally we got all the way down to pulling the front end off the engine to check cam timing. It was right where we thought it should be. During reassembly some inadvertent throttle pumping flooded the motor. With the engine virtually cold it may not have fired up to well on these super cold grade plugs. If they were also wet it certainly wasn't going to be that happy from a cold start. So the Champion race plugs were pulled and an equivalent heat range of Autolite race plugs installed.

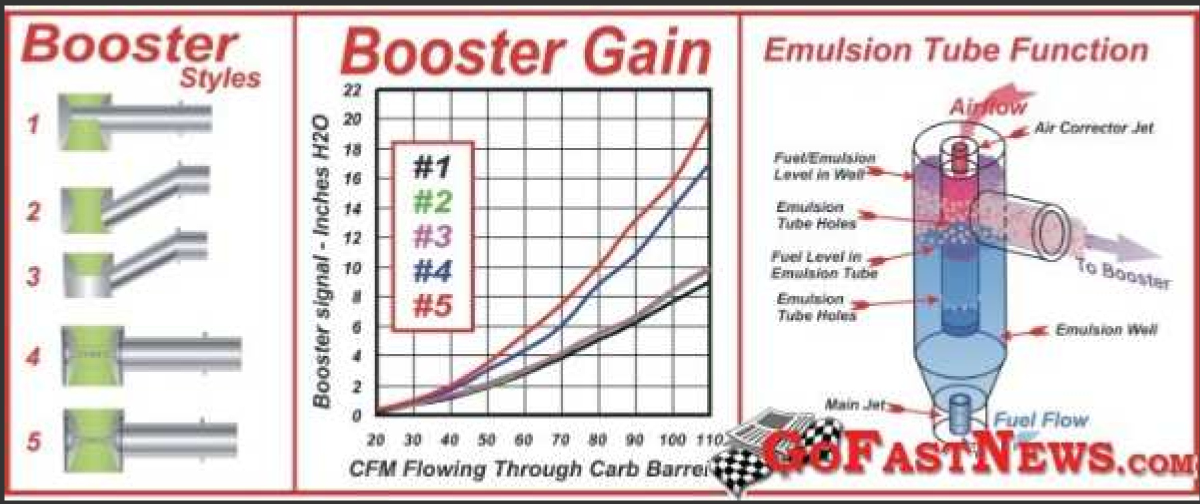
When fired up the motor sounded no less and no more wicked than before but the dyno numbers were – at 142 hp - nothing short of a techno shock. Although a pleasant surprise it was very much a case of 'what is the world is going on here?' This was such a surprise that the Champions were re-installed and re-tested. Same killer sound – just 85 hp! Now I have to tell you that in just about every other Mini application Champion plugs were as good as or better than anything we could find but here was an anomaly. This engine apparently did not like anything with Champion written on it. Anyway with no further ado we went on to finely tune the big carb on the engine and get the timing right on the money. After being tuned on for about 3 hours this engine ended up pumping out just over 170 hp at the wheels. I had hoped for about 185 but that's dyno testing for you. It's like having an eye glass to clearly focus on reality. This may not always be as gratifying as fantasy but regardless of positive or negative results you do get to learn a lot more of what it takes to win races.

Atomization Optimization.

I realize that I had mentioned looking at crevice volumes at the start of this part of our investigation but before going there let's take another look at atomization. First it is easy to jump to the conclusion that the better the atomization is the better the power output will be. If only it were this easy! In reality it is far more accurate (but still not 100% true) to say that as the fuel is better atomized (and/or vaporized) the better the Brake Specific Fuel Consumption (BSFC) will be. This number should not, as is so often the case even with pro engine builders, be confused with the mixture. It is only roughly connected to the mixture. It is in no way a measurement of mixture ratio, only a consequence of such. To get a better understanding of this read Dusty's upcoming story on the in's and out's of BSFC.

At this point the question is 'can the fuel be atomized and vaporized too much?'. Let me set the scene. It's about 1977 and I am just starting testing some of the trick carbs built by Tucson's premier carb builder/designer Dave Braswell. The year before at the 76 SEMA show I got to talk with Holley's then chief engineer Mike Urich. In our conversation I was amazed to find that, as far as Mike knew, Holley had done no official research on the effects of booster design on fuel atomization. I mentioned this somewhat surprising tidbit of info to Dave Braswell and he immediately volunteered assistance and carbs to do some testing on what we perceived as a typical street tuned small block Chevy. Here is how things unfolded.

The tests involved two carbs, each about 750-800 cfm. One had high gain fine fuel spray dog leg style boosters and the other typical low gain courser spraying straight leg boosters.



Shown here are the most common style of boosters found in a Holley 4150 series four barrel carb (the BG boosters follow a similar range of patterns). They are shown from #1 to 5 in order of signal strength per cfm of flow. Usually the greater the gain the better the boosters ability to atomize fuel. A point here is that the stepped dog leg (#3) does a significantly better than #2 even though the signal strength is very similar. This is because the step on the underside has an enhanced fuel shearing capability. Atomization however is not dependant solely on the booster design. A high gain booster works more effectively with a larger air corrector bleeding into the emulsion well of the carb (shown right) The more the fuel can be emulsified prior to the booster the better the atomization is likely to be.

The engine was run with three intake manifolds types. The first was the stock exhaust heated and consequently hot running intake. The second was an aftermarket two plane aluminum intake with the heat crossover blocked off. The last was a Victor Jnr intake which of course, being an air gap style intake, was significantly cooler running yet.

On the stock intake, which was also the hottest by far, the tricked up Braswell carb lagged the nearer stock carb with it's bigger fuel droplets, by some 8 hp (nominally a 360 horse engine) but the fine fuel delivered by the trick booster carb produced, by a small margin, the best BSFC both at WOT and part throttle cruise. On the heat blocked after market two-plane the carbs were very close in terms of output but we are still considering a relatively hot running manifold here. The BSFC with the fine fuel droplet booster carb was as much as 8% better especially at part throttle. On the cool running Victor Jnr the finely atomizing booster equipped carb was unbeatable anywhere in the rpm range. It made about 12 hp more and the brake specifics were all better (lower) numbers by a substantial margin.

The left three boosters show the typical form that most boosters follow for a typical down draft US production style carb regardless of brand. The center pair of boosters are 'dog-leg' Holley boosters as viewed from the underside. The one on the right has a step just before the emulsion exit hole. Although it does little to boost the signal this step does atomize the fuel far better. On the left is a BG booster. Many of the BG carbs have this style of remove and replace booster making this type of carb very useful when doing development work.

So what does this tell us? The results indicate that there is an optimum fuel droplet size that balances the need for some vaporization against the need not to evaporate too much fuel and spoil the engines volumetric efficiency. Hot running engines can offset the negatives of big fuel droplets from the boosters but cold ones cannot. Cold intakes need the ratio of the fuels surface area to volume increased (which is just what happens as the fuel droplets get smaller) so that the loss of the heat as a vaporization source is compensated for by increased in the fuel's evaporative surface area.

Let's skip along here a few years. In the early 90's I got involved with booster development with the Carb Shop in California. The plan was to develop a Super Booster that not only gave a big signal but also did not obstruct the flow of the main venturi to any greater extent than a regular high performance booster. If a high gain booster can be used it means that for any given application a bigger carb can be used for more top end before drivability and low speed output suffer. Well the program produced some trick looking high gain boosters which just before Christmas (and unknown to me) found their way into the carb(s) of a front running Cup Car team. On the dyno in the crisp December days just before Christmas in Mooresville NC (For the benefit of those non-NASCAR folk this is the ancestral home of all Cup Car teams) these boosters paid off in the teams Daytona 500 engines to the tune of about 10 hp. So it was with great expectations that the team headed off in early January for the Daytona 500 in Florida.

It was a hotter than usual January that year in an otherwise normally hot Florida. With the new carb the car was well off the pace. In frustration the trick booster carb was replaced with the old one and the car immediately ran on the money. The lesson here is that you can absolutely guarantee that too much of a seemingly good thing is – well not so good. The percentage of fuel atomizing prior to entering the cylinder was such that any gains in better combustion were overridden by the drop in VE caused by the added fuel vaporization taking place within the intake manifold.

So when is a high gain booster any good to a race car engine – maybe rarely if ever as things stood for a typical Cup Car engine of the early 90's but let's move on a little.

About this time (early 90's) I am heavily involved in thermal barriers. It' something I have looked at on and off since Formula Ford days in the late 60's. There we found a temporary 2 hp (it barley lasted a race) by using high temp exhaust paint on the pistons (Sperex I believe). In this case a relatively extensive study was made of the effect of thermal barriers in race intake manifolds.

Using a single 4 barrel carb on a single plane intake the effects of various boosters with the intake were explored both with the intake runners 'raw' and with them thermal barrier coated. The booster that worked best with the raw runners was of the stepped 'dog leg' variety shown in the earlier drawings. When the manifold was coated and used in conjunction with this booster the power figures were within about a horsepower or so – unchanged.

So what's the deal here? With the raw ports and mixture temps measured on #2 runner it was seen, from a carb intake temp of 84 degrees F, a drop to 55 degrees F due to the evaporation of a portion of the fuel. By dividing the plenum front to back and using one end of the engine to drive the other (and no fuel to the front float bowl) it was found that the air at #2 without any fuel picked up (allowing for a few corrections) about 10 degrees of manifold heat (more at low rpm and less at high). With the coated manifold the motored #2 intake runner temp was between 5-8 degrees less so the thermal barrier was doing what it was supposed to – keeping heat out of the intake charge. What was not happening here was the realization of any increased power due to the cooler charge. When the charge temperature was measured on a functioning #2 cylinder the drop in temperature from the carb to head/manifold interface of #2 runner was only barley changed and if everything had been working as before it should have been at least 5 degrees cooler. What this indicated was that the cooler running intake was not allowing as much fuel to vaporize and therefore the added wet fuel arriving at the cylinder was compromising the combustion process. At this point high gain annular discharge boosters along with appropriate (bigger) air correctors were installed. With the same air to fuel ratio the better atomization restored the % of vaporized fuel entering the cylinder. The temperature at the #2 runner with an air fuel mixture passing through dropped to 49 degrees F. The dyno showed some meaningful gains at this point. Essentially the cooler running more finely atomized charge had the effect of jacking the entire torque curve in an upward direction. On a nominally 450 horse engine the torque at 3000 rpm rose by 11 lbs-ft (6.3 hp) and by 7 lbs-ft at 6200 rpm (8.3 hp).

The RS range of Barry Grant carbs, have replaceable sleeves (main venturis) as well as replaceable boosters. This allows the end user to fine tune the carb combination to a degree that should leave little on the table. On the right we have a Holley 950 carb with stepped dog-leg boosters. A carb equipped with such boosters is a good all-round choice as this style of booster is application versatile.

Conclusions to this point.

In this section of our look at 'In Cylinder Combustion and Turbulence' several things have become more evident. First we have not actually arrived at discussing much of anything about what happens to the charge after it is actually in the cylinder. The fact of the matter is that what happens within the cylinder can be greatly influenced by how the intake charge is 'prepared' prior to it's arrival at the cylinder. Also the cases put forward here are one or two from maybe a dozen thermal barrier/booster/mixture preparation tests. All similar in their intent and all showing that the dyno testing rule 'make only one change a time' so often touted by do-it-yourself performance magazines is seriously flawed.

What is creeping in here is the worth of thermal barrier coatings. I have worked with many of the leading companies such as Swain Tech and Polydyne Coatings over the years but, since about 2002, spent a lot of time working with Calico Coatings in Denver NC. They have a great facility and being close I can go and visit to discuss whatever experiments I am into at that time. Without exception, they have been ready to help in such tests and that has allowed me to move along on coating tests at a rate that would have otherwise not been possible.

We have hit the subject of coatings and it is, as we have seen, relevant to our present topic but here it seems appropriate to branch the subject of 'Coatings' off into a separate category (thread). That is where we will go for an in depth look at what coatings can do for us.

The coating features though are still some weeks away - meanwhile if you need Calicoe's phone # it is

704-483-2202

As for the 'In Cylinder' subject we can conclude that for a given fuel, ambient weather conditions and a host of other factors there is a certain ratio of wet to vaporized fuel that will be optimum for best output. Based on everything we have discussed from part 1 of this series to date we can say that keeping the fuel in suitably small droplets, allowing only a given % to vaporize and avoiding, as far as possible, wet flow streams, is a major factor toward increased power from an engine (other than a Mini that is!)

But before we wind up here there's one more point I want to make. All the temperature measurements of the intake charge temperatures were done at the intake manifold to cylinder head interface. But heated or not the fact of the matter is the intake manifold is not the greatest source of heat input into the charge. A case comes to mind here during the testing of a 2000 cc Cosworth BDA engine about '90. I had reason to turn off the dyno cell lights for a photo of the near white hot exhausts seen during a run on this 280 -281 horse injected engine. Being in the dyno cell with an engine turning 8500 plus rpm can be a little unnerving but as I walked past the deafening intake I realized that I could, down the intake stacks, see the intake valves glowing very dull red. At this point it had not occurred to me just how hot the intake valves could get but consider this. Since the intake valves are of greater area than the exhaust they would, during the combustion cycle at least, pick up more BTU's of heat that the exhaust. And where do they dump a whole load of this heat? You guessed – they put it right into the intake charge. This results in one positive and one negative. First the positive – that is the fuel is further vaporized before entering the cylinder (by how much I have little idea) and second the intake charge is heated - and that is not so good. So I asked myself what would the trade off be between these possibly competing factors. The head was pulled and the intake valves alone were coated. A week later the results were in. First a look down the intake stacks in a darkened cell revealed that the valves were no longer visibly glowing. I fully realize that this is hardly a really scientific way to measure the valve temperature but that was all I had to do the job. The fact they were no longer visibly glowing meant, at a good estimate, they were probably a hundred degrees or so cooler. Secondly power figures at 283-284 hp, were slightly up over those with the uncoated valves.

This is an example of the head I did for Ryan Garcia's giant killing 79 Mitsubishi Lancer. The Calico Coatings applied thermal barriered valves are clearly seen here. What is not so obvious is that this head is my patented Poly Quad design that, with no additional moving parts, emulates a Honda V-Tech variable valve timing.

So what we see here is that with high pressure fuel injection (60 psi in this case) and line-of-sight ports exiting into an open area of a combustion chamber with no chamber wall directly in the path of the entering charge we see an increase in power. The question is are the wet flow dynamics of a typical two valve V8 head such as to deliver similar results or do we need to see greater fuel shredding at the seat and/or greater heat input to vaporize more of the charge by this or other means to get the benefits of cooler intake valves? That, along with crevice volumes (this time for real) is what we will get to next.

David Vizard

Last edited by DavidVizard-GFN; 08-18-2008 at 09:05 AM.

QUOTE

10-07-2007, 05:22 PM #2 (permalink)

Pinhead OFF
Oil Changer

Join Date: Aug 2007
Location: Kansas City
Posts: 265

Excellent set of articles thus far. Thank you very much, Mr. Vizard!!

The part about the red-hot intake valves hit me hard, though. Just to clarify, I'm generally more interested in the subject of lower BSFC's and better fuel efficiency than getting extra horsepower. A guy on the 'net known as Metric Mechanic grooves the face and back side of the intake valves to aid in fuel vaporization. Consequently it also has an effect on the boundary layer that can increase low-lift flow by about 5%, but that doesn't seem to be the predominantly positive factor.

An engine with the "Surface Turbulence" valves installed needs as much as 20% smaller jets (when installing the ST valves, they also reduce the main's by that much). The engine acts like it's running rich if the fuel isn't cut back. I would assume that the increase in surface area on the chamber side of the valve would cause it to pick up more heat from the combustion process, while the grooves on the intake-side of the valve would help the valve dump more of that heat into the incoming air/fuel charge. The required ignition lead is reduced and detonation limits are stretched.

Assuming this is true, could the 20% reduction in fuel be due to a 20% reduction in VE? In other words, the air is a full 20% less dense, and therefore needs the same reduction in fuel. Horsepower goes up, though. I would be forced to assume that this is due to better fuel vaporization and therefore a more efficient burn (causing less ignition lead to be needed and less detonation experienced).

Following this theory, a "normal" valve wouldn't have as much of a fuel vaporization advantage as the ST valves due to the reduction in surface area (the ST valves can "catch" the fuel better, allowing the fuel to absorb more heat and less being lost into the air itself).

Taking this a step further, a "normal" valve with a thermal barrier would have the advantage of not heating the air, much like the ST valve would be shielded from the air by the fuel. However, the ST valve should vaporize the fuel and therefore hold an advantage.

Waddaya think???

QUOTE

10-07-2007, 11:23 PM #3 (permalink)

MadBill OFF
Garage Sweeper

Join Date: Sep 2007
Posts: 76

A most thought-provoking article David, both the booster and coatings portions!

Re inlet valve temperatures, somehow it never occurred to me that in normal operation they could get so hot, despite having experienced inlets tulliped by detonation, with the mating faces 're-forged' by the head seats to maintain a 45° angle.

An IR pyrometer should be a most useful tool in an engine where the valves are visible to an observer. Face coating Vs. face and underhead, different coatings, etc...

QUOTE

10-20-2007, 09:58 PM #4 (permalink)

1989GTA OFF
Tire Changer

Join Date: Oct 2007
Posts: 114

Hehehe. Can't wait for the next test regarding intake coatings. My car is apart waiting for the answers.

10-24-2007, 02:10 PM #5 (permalink)

1989GTA
Tire Changer
Join Date: Oct 2007
Posts: 114

Hi David

I brought this up in my thread on Intake Manifold Coatings. In the article you mentioned you could see the intake valve glowing red. Having the valve coated seemed to solve that problem of heating up the incomming air.

My question is with a fuel injection system spraying cool fuel to the back of the intake valve would this not help solve the hot intake valve problem and also help atomize the fuel at the same time? Just trying to separtate the carb systems from the FI systems as this is not always done.

QUOTE

11-18-2007, 01:59 PM #6 (permalink)

DavidVizard-GFN
Pit Crew
Join Date: Apr 2007
Posts: 840

Dear 1989 GTA,

I think that making a concrete rule here might be a little preamature. However on every occasion I have done a back to back test (about 5 times) we have found some power. It has not always been there instantly with a carburated engine but it seems consistant with the two injected engines I have tried. As a result I coat the valves as a matter of course if total output is of real concern.
DV

QUOTE

11-18-2007, 06:28 PM #7 (permalink)

1989GTA
Tire Changer
Join Date: Oct 2007
Posts: 114

Thanks David for the reply.

QUOTE

11-20-2007, 02:46 AM #8 (permalink)

hotrod
Garage Sweeper
Join Date: Oct 2007
Posts: 20

intake valve coating

Just out of curiosity, did you always coat both front and back faces of the intake valve on these valve coating tests?

I am thinking you might get best of both worlds by coating the chamber face only but leaving the manifold face clean so it is easily cooled by the fuel, Which would also help evaporate and slightly preheat the fuel so it would more readily evaporate as it entered the lower pressure area inside the chamber on the intake stroke.

Larry

11-24-2007, 01:25 PM #**9** (**permalink**)

big block fiero
Tire Changer

Join Date: Sep 2007
Posts: 145

Remember the engine that ran best only when running by large fuel globs rather then A fine vaporizing mist. could it be that ,that engines valves were glowing and the large droplets were fixing the problem? Is it possible that an engine could make more power if the valves were not coated and the glob theory was used instead? Do we now test engines for valves that we can't see by globularizing (new word) the mixture, look for a gain, then if there was A gain pull the motor down and coat the valves? comments?

11-24-2007, 01:31 PM #**10** (**permalink**)

big block fiero
Tire Changer

Join Date: Sep 2007
Posts: 145

Ooops, I didn't reread this article before my post so it's a little out of context.

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