TWIN TURBO 385 BUILD UP

VALVETRAIN

Source: www.grapeaperacing.com

CAM SELECTION

For the most part I like solid rollers for race engines, but this engine is different. This engine will only need to rev to about 6000 rpm and it will be street driven so a hydraulic roller was a better choice. I figure I may go through the traps as high as 6500 rpm, so I used an AFR hydra-rev kit. The rev kit puts spring pressure on the lifter body, so it will not add any seat force to the valves or increase the lifter bleed rate. It just controls the extra weight of the hydraulic roller lifters to get higher rpm before losing control of the valvetrain.

This is what the Air Flow Research hydra-rev kit looks like installed.

The cam I am currently using is the third one in this engine. The first was a cam I already had that was ground to favor nitrous, but since turbochargers and nitrous have similar cam requirements, I figured I'd give it a try. It worked very well. It had a 114 degree LSA, which is good for a turbocharged engine providing exhaust backpressure is not too high. The downfall of that cam was the long duration exhaust lobes. I started thinking about a shorter exhaust duration when I got a noticeable power increase by swapping out the 1.6 rockers for 1.5's on the exhaust only.

For the second cam, I had a single pattern cam ground from the same intake lobes of the first cam. The engine didn't' seem to run any different than the fist cam with the 1.5 rockers on the exhaust valves. It did give a little better throttle response, but was for the most part a disappointment.

The third time I did a lot of research. I got all the flow bench data on my heads and manifold, and got the compressor maps from my turbos. I worked with Comp Cams, who ran several simulations on their computer and we came up with a cam that showed good on every simulation they ran. I was hesitant at first because it was smaller than what I was using and had some out of the ordinary specs. I figured I'd give it a shot and see what happens. The first thing I noticed is that it ran very lean with the same fuel map, which was a good indication I was getting more airflow through the engine. After some tuning, it made a huge difference in power and throttle response. The smallest cam made the most power and least turbo lag so far.

The current cam has a 114 degree LSA. The duration at 0.50" lift is 234º intake and 230º exhaust. Lift with the 1.6 rockers is 0.528" intake and 0.540" exhaust. The exhaust duration is shorter than the intake, yet has a more aggressive profile to get more lift. The cam is installed 6 degrees advanced.

The cam was ground on a steel billet core with a pressed on cast iron rear journal & distributor gear. The iron gear lets me run a cast distributor gear. Steel cam gears require a softer bronze distributor gear or the cam gear will wear because the iron gear is much harder. A bronze gear is a solution because it is softer than the steel cam gear. The distributor gear will wear faster, but that is a lot easier to change and cheaper than a cam. An iron cam gear with an iron distributor gear will outlast a steel cam/bronze gear set up making it a better choice for a street car.

CAM INSTALLATION/DEGREEING

Degreeing in the cam is a very important step to make sure it is installed correctly. To be honest, with quality parts, it is very uncommon for it to be very far off, but you'll never know if you don't check it. Any decent cam will have any advance (or retard) ground in meaning that if you have a multiple keyway or adjustable gear set, you install it at zero. The best way to degree a cam for the best power curve is to degree it in on a dyno. If you can't, install it where the manufacturer recommends, which is usually 4º advanced for most street and smaller race cams. Do not concern yourself with getting it within ½ degree. For the most part you will make the best power somewhere between 3º and 5º advanced for a normally aspirated engines. High rpm engines generally like it a little more retarded. If you don't have a dyno available, nit picking it to the last ½ degree is pointless because you don't know if your efforts gained or lost power.

Degreeing you cam will let you know exactly where the cam is installed. Finding TDC is easy; you simply install a degree wheel close to TDC. Then make a pointer from some thick wire that can be bent to adjust it. You'll need a dial indicator or positive piston stop to stop the piston from reaching TDC. Rotate the crank unitl the #1 piston it firmly against the stop, note the position on the degree wheel. Rotate the crank in the opposite direction until the piston is again seated firmly against the stop and note the position on the wheel. True TDC is ½ way between those 2 points. If you are using a dial indicator, just stop the piston at a set point.

I used a dial indicator as shown to find TDC. When using a dial indicator you want it inline with the wrist pin to avoid any piston rock from skewing the numbers.

Once you adjust your degree wheel to TDC you can measure the cam timing events with a dial indicator on the lifter bodies. My cam has asymmetrical lobes, so I cannot use the usual peak lift method for finding lobe centers. I used the 0.050" lift specs on the cam card. Rotate the crank until the lobe you are checking reaches 0.050" lift and see where the degree wheel is. If it's right at the cam card spec, you're right on. You can use offset bushing to advance or retard a cam to get it to spec, but if you used a quality cam and gear set, you'll find it will most likely be within a ½ degree, providing the block machining was done right. A good belt drive will have an adjustable upper sprocket so adjustments can be made more easily, but at an added cost.

After finding TDC I zeroed the degree wheel, and then used a dial indicator set up like this to find the cam position.

It is very important to check a few cylinders, factory machining is not the most accurate, they go for quantity over quality, and tolerances are too wide for a performance build. I have seen as much as 5º difference between cylinders due to poorly located lifter bore. If you've ever wondered why two identical builds have different power curves, things like this are the cause. The engine builder who pays close attention to all the machine work and corrects all errors WILL get more power from his engines. Correcting all errors is known as blueprinting, which is the most abused term in engine building. Everyone says they have a blueprinted engine, but in reality, very few really do.

So what can you do if your cam and/or lifter bores are not right? Have them fixed. BHJ makes a fixture just for this and any performance engine building shop should have it. The machinist will use the fixture to bore the lifter bores oversize correcting any errors. You can then use the next oversize lifter, or have the bores bushed back to the stock size. Some race classes require stock lifter, so bushing is the only option. When it comes to machine work, you can never be too picky.

For dyno testing we used a dry belt drive so adjustments can be made quickly. Once we knew the best position, I switched to a double roller. The offset bushings to the right are used to dial in cam position.

Since I had access to a dyno and the engine was out of the car at the time, I did dyno test and move the cam around until the power curve was the best. At the time I did not have enough restriction to the 7 psi waste gates so I could not bleed off enough pressure from them to get boost past 12 psi, so all dyno pulls were done at 12 psi without nitrous We pulled from 2º to 8º advanced and did 600 rpm/sec/sec pulls. The engine made the most average hp at 6º advanced with a peak of 857 hp @ 5500 rpm and 865 lb-ft at 4300 rpm. Averages from 3000-6000 rpm were 694hp and 816 lb-ft. My ultimate goad for this build was at least 1000 hp. With 857 at 12 psi, it was looking like a very realistic goal. Once I get the waste gates to 15 psi and throw a 100 hp shot of nitrous at it, 1000 hp should be no problem. Even better was that the engine idles fairly smooth at 900 rpm and pulls 17 inches of vacuum, which is very street friendly.

FIGURING CAM POSITION

Using the 0.050" lift numbers to degree the cam is fine if you want the cam set right were the cam manufacturer wants it, but what if you want to advance it more or less? Or what if you just want to know what position it's in? The cam card will not usually tell you how much how much advance or retard the cam has, so you will need to figure it out yourself.

A cams position is figured in relation to the lobe separation angle. If you have a 112º lobe separation angle, and the cam is installed with a 112º intake centerline, it is straight up. If the intake is installed with a 108 intake centerline, it is 4º advanced. I'll use some random cam specs to show how to figure it all out. Using the 0.050" lift numbers, the intake valve opens at 4º BTDC and closes at 38º ABDC. 4º BTDC + 180º from TDC to BDC + 38º ABDC = 222º intake duration @ 0.050" lift. 1/2 of that is 111º, and since the valve opened 4º BTDC the center line would be 107º ATDC.

On the exhaust side the valve opens 52º BBDC and closes 2º BTDC. 52º BBDC + 178º from BDC to 2º BTDC (it closed before TDC) = 230º exhaust duration @ 0.050" lift. So the exhaust lobe centerline is at 117º BTDC. Now we have the centerline of both lobes, so we can figure out what the lobe separation is. 107º ATDC + 117º BTDC = 224º, you then divide by 2 to get cam degrees. So the cam has a 112º lobe separation angle. We already figured that they we have a 107º intake centerline, so the cam would have 5º of advance.

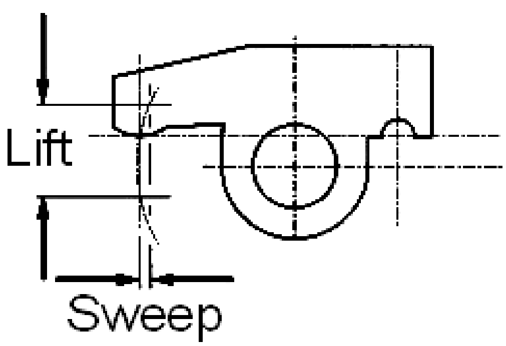
This may not be important to you if you are going by the cam manufacturers recommendations, but if you want to install the cam in a different position, you'll need to know where to put it. For example, if this was a nitrous engine, it would benefit from more advance. Nitrous engines will make more power on the bottle if the camshaft was more like 6-8º advanced.

ROCKER ARMS & PUSHRODS

In dyno testing we got the best curve was with 1.6:1 rockers on both the intake and exhaust sides. I'm Using Crane aluminum roller rockers with a 7/16" stud. Some people may think that a 7/16" stud is over kill for such a small cam, but the exhaust valves must open at very high cylinder pressures. The intake has another problem. Boost pressure is trying to open the valves, taking away from the set pressure. This requires more seat force on the intakes. Your average intake valve has at least 3 square inches of area on the back side. If you were running 15 psi of boost that would take 45 lbs. of seat forced from the intake valves. The lack of seat force will cost power from the intakes bouncing off the seats at higher rpm. It will also cause much earlier valve float. To get full power and rpm potential you need to add seat force to match what boost pressure took away. This is yet another reason why some people make more power than others. These two things are what put higher loads on the rocker studs, so even with a small cam, forced induction engines need more strength in the valvetrain.

Pushrods seem like such a simple component. Selecting the best ones is not so simple. Know is that hardened pushrods must be used with guide plates and that they need to be strong enough to do deflect with high pressing pressures is basic. Figuring out the optimum pushrod length is not so basic. Some people may tell you that it doesn't matter with an adjustable valvetrain; they couldn't be further from the truth. Other people will tell you it's best to have the rocker tip centered on the valve tip at ½ lift, I do not agree with that either.

The two most important aspects to consider when choosing the best pushrod length are longevity and power. As the rocker goes through its range of motion, it sweeps across the valve tip. When it is not centered, it is putting side loads on the valve that wear the guides. The goal is to keep the contact point centered as much as possible, so there is some merit to centering it at ½ lift. We must also consider spring force. Spring force increase as the valve opens. The more spring force there is, the more side loading there is, so it is better to have most of the side loading at low lifts, where spring force it the lowest. The general rule is you want the contact point centered at around 2/3 lift.



You can see from this drawing how little movement there is high valve lifts if the pushrod length is correct. Most of the sweep takes place in the first third of its travel.

Something that not too many people realize is that the rocker ratio is not constant throughout the lift cycle. You can change lift at a given point by changing the pushrod length. Many people adjust pushrod length to get the highest peak lift, which will put the contact point close to centered at 1.2 lift, this is not the best for guide life or power. You want the most valve lift at the highest air flow demand, which is peak piston velocity, not peak lift. Most engines will have peak piston speed at 73-78º ATDC. Since most cams cannot get peak lift until about 106º ATDC, adjusting pushrod length to get the greatest ft at 75 º ATDC will get more power even though you lost a little peak lift. You will also find that it places the pushrod to valve contact point centered on the valve at about 2/3 lift. This in not a coincidence, aftermarket rocker companies know this and design rockers with the pivot point, pushrod cup and tip on different planes for a reason.

Plastic pushrod length checkers are a great tool if you know how to use them.

You can use a pushrod length checker to see what size pushrods you need, but keep in mind these are pres set for a certain amount of lift. This one for SBC is set up for optimum pushrod length for a 0.0600" lift cam. You can still use it, but must do some math to figure out what your cam needs. On a small-block Chevy, any lift more than 0.600" gets multiplied times 0.22 and that is subtracted from the pushrod length. So if the valve is lifted 0.650", you will need to multiply 0.22 with 0.050 and the pushrod will need to be 0.011" shorter than measured. If the valve is lift is less than 0.600", you take a different approach. Subtract your lift from 0.600 and divide it by 3. Then take a feeler gauge of that thickness and put on the valve tip when checking length. If your valve lift is 0.500" the difference would be 0.100", divide it by three to get 0.033", now insert a feeler gauge of that size between the checker and the valve, and the measured length will be correct. Once you adjust the pushrod to the right length, you can then measure it and order the correct length pushrods.

There is one last thing to take into account with hydraulic cams, the lifter preload. Lifter preload pushes the plunger into the lifter body effecting reducing pushrod length. If you have rocker studs with 24 threads per inch and a 1.6" rocker on the rocker studs, ¼ turn of preload would make the optimum pushrod length 0.017" longer. Small details like correct pushrod length can mean an extra 10-15 hp on a 500 hp small-block giving you an edge over close competition.

VALVE SPRINGS

I generally buy a bare set of heads because chances are the valve springs that come with them are not what I want for my cam. It doesn't make much sense to buy a complete set of heads then tear them down to change springs. I almost always port the heads as well, so they'd get torn down even if they had the right springs.

For this cam I went with 1.550" OD dual springs with a damper. A damper is very important to reduce the possibility of spring surge. You can use the specs given with the springs to figure out what heights to install them to get the needed force. You must also know how much boost pressure you intend on running so you can figure out how much seat pressure to add to the intake valves.

Shims like these under the spring cups change the installed height and change the seat force.

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