Valvetrain

Types of Valve Lifters

Source: www.grapeaperacing.com

Hydraulic

Hydraulic lifters take up the slack in the valvetrain for quiet operation. The first thing that comes to mind when high rpm is mentioned is hydraulic lifter pump up. But what is pump up? The valving of a hydraulic lifter allows to lifter to take up the slack much faster than it can bleed off. Pump up is when hydraulic lifters are on the verge of floating; they either loose contact from the cam profile or cause the valves to bounce off the seats when closed. In either case, the same thing happens, the lifter takes up the slack and holds the valve off of the seat. This usually happens because the driver simply revs the motor past the rpm range of the cam or the springs are not matched for the application. This is not the lifters fault; they are working perfectly and just taking up slack that shouldn't be there. Due to the bleed down, maximum lift is not quite reached and some of the duration is bled off at the end of the lift curve.

When hydraulic lifters are matched with the cam and springs, I've seen them go as high as 7500 rpm without pumping up. Since many people refuse to install the recommended springs, they get less than optimum results.

I would not use a stock type lifter with the wire ring holding it together in any performance engine. If you like to adjust the valves with the motor running, the lifters will take up the slack when you loosen the rocker. They can only take up the slack until the plunger is seated against the retainer. This can cause the wire ring to pop off and end up in the oil pan (I have found several of those little rings when tearing down an engine). Also if the engine ever runs into valve float or lifter pump up, the wire rings can come off. Most aftermarket lifters use a true lock or e-ring style clip that is much stronger and more reliable.

Variable Duration Hydraulics

Also known as rapid bleed lifters. These lifters can offer advantages for a street motor. At low rpm they leak down quickly and shorten the duration and peak lift at the valve. It is easy to assume that they simply reduce the duration at the valve, but there is more to it than that.

The opening points of the valves remain the same; any duration reduction comes off the end of the lift curve. So if these lifters reduce the valve duration by 10°, the valve will open at the same time and close 10° sooner. If rapid bleed lifters are used on both intake and exhaust, it not only makes the cam act smaller, but also advanced.

Most small-block Chevy cams give the best power curve when installed about 4° advanced. By retarding the cam some, the peak hp might go up slightly, but the power band gets narrower and the car could end up being slower. Variable duration lifters can help this, but if the cam is already 4° advanced and the variable duration lifter makes the valve timing even more advanced, it would be like a smaller cam running something like 9° advanced. 9° is most likely a little too advanced. A good solution is to run the cam straight up (or 2-4° more retarded than optimum with regular lifters), which would build better top-end hp, and the variable duration lifters will cause valve timing to be more advanced at lower rpm, so the engine will not be as peaky.

You can also run rapid leak down lifters on the exhaust side only. This would only advance the exhaust valve. If you had a cam that had a narrow lobe separation to build top-end power, and need some more bottom-end to use a lower stall converter, advancing the exhaust at low rpm would widen the lobe separation and reduce overlap. This would give more vacuum and more low-end torque.

Many modern cam profiles are very aggressive, pushing lifter opening and closing velocities to the limit. If this is the case, a fast bleeding lifter may not be a good idea. The faster bleed rates increase the closing velocities, which could cause the valve to bounce on the seats. Whether or not they will work for you is best decided by the cam manufacturer. You should always consult the manufacturer before you install a rapid bleed lifter.

Solid

Solid lifters are common in high rpm engines. One advantage is that they can be made lighter than hydraulics. The lighter the lifter, the less of a chance it will loose contact with the cam and the less power it will take to move it.

Solid lifters also follow the cam profile more closely, since they don't bleed off any lift or duration, but some lifter collapse can help low-end power and widen the power band (see variable duration lifters).

When (or if) the valves do bounce off their seats, the solids will not take up any slack and hold the valve open (although the valves should not bounce).

A down side to solids is the noise. Many people try to tighten the valve lash to reduce the noise, but this rarely works. At the point where the lifter contacts the cam, it is a pretty much a constant velocity part of the ramp ramp. So if there is .005" or .025" the angle will be the same and the cam will hit the lifter just as hard. Newer designs have quieted down street performance profiles by making a lower lift rate until the lifter is seated firmly on the cam. In an all out race engine, if more noise makes more power, the engine will be louder. All in all, solids are just easier to get working in an all out racing motor.

Roller

Available in hydraulic and solid, rollers offer many advantages over flat lifters. Roller lifters have less friction, and can follow much more aggressive cam profiles without the lifter digging into the cam. Even with a mild cam profile, rollers can give the motor a wider power band. They can lift the valve more for a given duration, which gives more area under the lift curve.

Another advantage is the ability to handle greater spring forces. A flat tappet cam is treading on thin ice when over the nose forces are 350+ lbs., but rollers can handle more than 700 lbs. of force. To be on the safe side, rollers should have more spring force than an equivalent flat tappet design. Rollers do not like to float and can fail quickly if they do.

A race roller profile can maximize valve-opening velocity, but the increased side loads on the lifter bores can wear them out quickly in a street engine. In an all out drag car, race rollers can last many years, but a street car needs a less aggressive profile to last, so use a street roller on the street.

One other advantage of a roller cam is that as long an the lifters are not damaged they can be reused on a different roller cam, so if you plan a lot of cam changes, you wont need new lifters every time. Crane Cams (among others) offer roller lifters with spring loaded link bars. These bars lift the lifters clear of the cam when the pushrods are removed, so cam changes can be done without removing the intake manifold. Roller cams must be ground from a steel blank rather than cast iron, so a bronze distributor gear must be used to prevent camshaft gear wear (and a bronze tipped fuel pump push rod if it's used). Some cam companies are using a press on iron gear (the rear cam journal is part of the gear also) so the bronze gear is not required. An iron cam gear on an iron distributor gear will out last a steel cam gear with a bronze distributor gear. If you try and run a iron distributor gear on a steel cam, it will wear out the cam gear destroying an expensive roller cam. The bronze gear is softer and will wear out, but is easy and cheaper to change than a cam.

One more thing to consider is that the cam lobes on a roller cam are not tapered, so the cam will need other means to hold it against the thrust face of the block. To solve this you must use a cam button.

One disadvantage is the opening acceleration is more limited in a roller lifter then it's flat tappet counterpart, so when short duration cams are used, the flat tappet can have an advantage. On mild to radical cams the advantages goes towards the roller, which offers about a 20% increase in maximum velocity over a flat tappet cam. As a general rule of thumb, rollers offer little advantage for the cost at 0.050” lift durations under about 225° for most engines. If the cam you are looking for is small, you can get more power spending the money elsewhere.

Lifter Diameter

The most popular lifter diameters are 0.842" (Chevy), 0.875" (Ford), 0.904" (AMC), and 0.970" (aftermarket mushroom type). The larger the lifter diameter, the higher the opening velocity can be.

It is common to bore the lifter bores of a small-block Chevy to 0.875" to repair any machining errors on the factory block. It also allows the maximum lifter velocity to go from 0.00714" per degree to 0.00742" per degree, so a cam with the same seat-to-seat timing can have more area under the curve. A 0.904" AMC lifter can move 0.00767" per degree and the 0.970" mushroom lifter can travel 0.00825" per degree. Increased diameter is only an advantage of the profile is ground to take advantage of it.

Oil Aeration

To use hydraulic (regular or fast bleed), you must pay attention to the oil system. Windage can be a big problem in higher revving motors, and if that motor uses hydraulic lifters, the problem can hurt power even more than you think.

When oil is thrown around by the rotating assembly, it can foam up. Foaming oil contains air, and air compresses. If this oil is used in hydraulic lifters, the motor will be very inconsistent in power output due to the lifters compressing and reducing lift and duration. If you intend to use hydraulics in a high revving motor, consider a deeper sump pan and some sort of windage tray to minimize oil aeration.

Source: www.grapeaperacing.com

Types of Rocker Arms

Source: www.grapeaperacing.com

Stamped Steel

Most engine manufactures use stamped steel rockers because they are simple and reliable. When using a high lift cam, you must check that the slot in the rocker is long enough to clear the stud. If you intend to install used rockers, check the point where the rocker contacts the valve for wear. There will almost always be a ridge. Any ridge must be removed, if it isn't, it could put side loads on the valve and increase guide wear as well as be noisy. If the step is severe, you will need to replace the rocker, do not try to grind too much; the case hardening is only about .020" on most rockers. If you intend to rev the engine higher than the factory spec, have more than .450" valve lift or use springs with more than 250 lbs. over the nose force, then a grooved pivot ball is a must.

Some company's offer stamped steel rockers with roller tips to help reduce valve guide wear, but they do little else. Any power gains will come from reduced friction, and most of the friction is at the pivot point. The geometry should be checked when any part of the valvetrain is changed.

Aluminum Roller Rockers

These rockers seem bulky, but they are actually very good when it comes to a mass to stiffness ratio. Roller rockers require less oil and have less friction, so the oil is not heated as much. Aluminum roller rockers are a good choice for most street performance engines and some drag race engines, as long as spring forces don't go out of sight. The have about the same reciprocating mass as a stamped steel rocker.

Aluminum is the most popular material to make aftermarket rockers because it is so easy to machine. In an endurance engine that sees high rpm for long periods of time, aluminum rockers can fatigue and fail. Aluminum looses strength with high temperatures.

Stainless Steel Roller Rockers

Stainless rockers have many of the same benefits as aluminum ones. Stainless steel is much heavier than aluminum, but the design makes more of the weight near the pivot point, so the reciprocating mass is only marginally heavier.

Stainless is also much stronger than aluminum and has a higher fatigue resistance, so it is a better choice of a high rpm endurance engine or an all out drag car with extremely high spring forces.

Shaft Mounted Rockers

When some engines, like the small-block Chevy, the pushrods can get in the way of making a high flow port. Many companies use off set rockers to gain clearance at those points. It is hard to get a lot of offset with stud-mounted rocker without getting side loads. Shaft mounted rockers can deal with offset much easier without side loads. Jessel is the leading manufacturer of shaft mounted rocker conversions for popular engines and are commonly found on race engines.

Source: www.grapeaperacing.com

Additional Rocker Arm Information

Source: www.grapeaperacing.com

Rocker Ratio's

If a rocker has a ratio of 1.5:1, it should open the valve 1.5 times the amount of the cam lift. Almost all factory type rocker fall short of their claims. Chevy claims a 1.5:1 rocker ratio on small-blocks, I found that most are 1.44:1 and under.

In a healthy street motor .020" less valve lift could mean a 10 to 15 hp power loss. So make sure that the rockers that you choose are from a reputable company. I've had good luck with Crane Cams, Iskenderian, and Competition Cams.

High Ratio Rockers

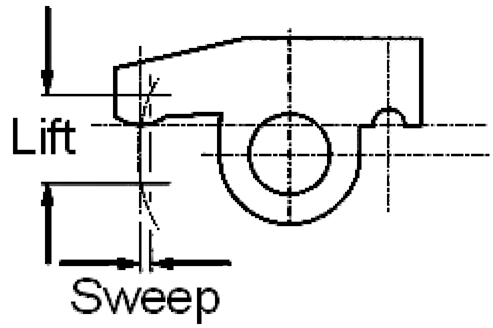
To make a high ratio rocker, the manufacturer simply moves the pushrod cup closer to the pivot point, so you must check that the pushrods have enough clearance where they pass through the head. Most stock engines, especially ones with a dual pattern cam ground with a wide lobe separation, will almost always benefit from higher rocker ratios on the intake side. The exhaust is a different story, It might hurt power, so unless you are sure, only use them on the intakes.

Higher ratio rockers can keep the lifters in control easier also. The lifters are one of the heaviest parts of the valvetrain and one of the first things to cause valve float. By using more rocker ratio, you are also multiplying spring force at the lifter more, helping control it.

A higher ratio rocker also changes the optimum cam timing, if you had an engine that already had a well matched cam with 1.5:1 rockers, and then switched to 1.6:1 rockers, you might have to widen the lobe separation by 1-2°. Changing the ratios will also change the overlap period. If the lobe separation were a few degrees too wide, higher ratio rockers would make the cam better matched to the combo.

Pivot Points

The center pivot point is not on the same plane as the valve contact point. This is done for a good reason. The rocker cannot push on the exact center of the valve tip throughout the entire range of motion; it must travel in an arc. By moving the valve tip contact point higher, most of the side motion occurs at low valve lifts, when spring force is at it's lowest. If you look at the diagram you can see that there is minimal side loading at high valve lifts, the majority of the side-to-side motion is at low lifts. This greatly increases valve guide life.



Proper geometry is very important to limit guide wear. Another plus of making rockers with the pivot point on a lower plane than the pushrod cup and valve tip contact point is that the maximum rocker ratio will not be the same point as minimum movement. That will allow us to get some more power; I'll discuss that in the Optimizing Geometry section.

Source: www.grapeaperacing.com

Optimizing Valvetrain Geometry

Source: www.grapeaperacing.com

Pushrod Length

One thing that most people overlook is the pushrod length. Milling the heads, block, using a thicker or thinner gasket, new valves or even just a valve job can change the required length. Aftermarket heads with longer valves will also change the required length.

Any time any part of the valvetrain is changed, the geometry should be checked. Changing the pushrod length is the easiest way to change the rocker to valve tip contact point, in most cases the pushrod length can be adjusted to compensate for errors and give best power and reliability.

In some rare cases, the rocker stud might have to be relocated, like when 1.7:1 ratio big-block rockers are used on a small-block Chevy or when a longer valve is used in a stock head (this is usually only a problem when the valve is +.200" or more).

Checking Pushrod Length

A rockers pivot point is lower than the pushrod cup and the valve contact points for a good reason, so the wiping action across the valve tip is the greatest at the lowest spring pressures, this helps reduce guide wear. When higher than stock lifts or any of the modifications listed above are done, the pushrod might be too long. This would cause more side loads at peak lift, which is where spring forces are the greatest.

Imagine a line from the center of the pivot point to the valve tip contact point. As that line passes 90° of the valve stem, the wiping action across the valve tip is minimal. So it makes sense to put that point where the spring forces are highest. For best valve guide life that point should be at about 2/3 of peak lift. If the rocker pivot point is in the correct place, the tip should be in the center of that valve at that point also.

To figure the best length, you must use an adjustable pushrod and adjust it until you get what you need, you can then order a set of pushrods the same size as you adjustable one, you should do this with a solid lifter to avoid any leak down and remember add any hydraulic pre load to the length.

Manley offers an inexpensive pushrod length checkers for most popular engines, these work fine if you know how to use them, and most people don't. For an example, the tool to check length on a small-block Chevy is set to check correct length with 0.600" lift at the valve. If your valve lift is not 0.600" you will need to do some math, or you can just use it as a starting point to adjust your adjustable pushrod. Manley should be able to provide you with the information needed for your application.

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 lifted 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.

The picture shows the Manley pushrod length checker for small-block Chevy engines. The engine here has a cam with 0.510" lift. In order to get the proper length, I need to subtract 0.510 from 0.600 to get 0.090". 0.090 divided by 3 is 0.030.

One last thing to consider on a hydraulic cam is that when you pre load the lifters, the plunger will change the pushrod position. A 3/8" rocker stud has 24 threads per inch. You generally pre load the lifters about 1/2 turn, which will put the pushrod about 0.021" lower. This needs to be considered as well. So I need a 0.021" as well as a 0.030" shim on the valve tip to make my measurement. I simply put 0.051" feeler gauge on the tip of the valve between under the checker. Now I just need to adjust the checker pushrod to just touch the checker, lock it, and pull it out to measure it.

In my case, with the hydraulic roller, the length came out to 7.345" long. It so happens that 7.350" is a popular size, and that's pretty darn close, so that's what's going in. Pushrods generally come in 0.050" increments. It's better to go a bit long that short, so it's better to round up unless you are less than 0.015" short.

Geometry For Best Power

Setting the correct pushrod length will get the most mileage out of the valve guides, but when radical cams are used they might not be the best for power output. What many engine builders don't realize is that the rocker ratio is not constant. The rocker ratio changes through the lift cycle due to the geometry; this gives a chance to change the lift curve slightly.

On most engines, the peak piston velocity will fall somewhere between 73° and 78° after TDC, so the higher you can get the intake valve lifted at that point the easier it will be to fill the cylinder. The cam will not be able to lift the valve to peak lift until more than 100° ATDC, if peak piston speed is at 75° ATDC, this leaves the valve as a major restriction to airflow at that point.

Once you get the pushrod length correct, try adjusting the rod a little longer and shorter. See where the point is that you get maximum lift at 75° ATDC. On most engines this should be pretty close to the correct length. You will also find that when geometry is optimized for performance, the point of maximum rocker ratio will be close to TDC.

After you find the best lift at 75° ATDC go back and recheck your rocker to valve contact point. The geometry for best power will usually be close to what was measured. Small details like this could mean 10 hp on a 500hp race engine, so it pays to check.

I have heard more than once that the proper length pushrod will give the highest peak lift, which is simply not true. You want as much lift as you can get at peak piston speed, which is the point of highest airflow demand. With today’s technology, we just can't get the valves open fast enough. The point of peak airflow demand comes somewhere between 73 and 78° after TDC, but we can't get peak valve lift until more than 100° after TDC. What I'm getting at is that if the piston speed peaks at 75° ATDC and peak valve lift is at 108° ATDC, extra lift will help more at 75° ATDC than it will at 108° ATDC.

Source: www.grapeaperacing.com

Valve Spring Information

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Delivered Force

Spring force is commonly referred to as spring pressure, but this is actually the wrong way to look at it. A pressure is measured in force over an area such as pounds per square inch (psi). Valve springs are measured in the pounds of force applied to hold the valve against the seat or rocker arm so it follows the intended motion.

The two common measurements are seat (or installed height) force, and over the nose (peak lift) force. These two measurements are very important if the valve is to follow the intended motion of the cam profile. If the seat force is too little, the valves can bounce off the seat when closing. If the over the nose force is too little, the lifters can continue to rise after the cam lobe stops pushing it (it just launches off it) until the spring can slow it down and push it back against the cam. This is known as valve float and is very damaging to an engine.

Spring Surge

In order to control the valvetrain, the springs need to deliver enough force to resist the inertia of all the valvetrain parts. If the springs cannot control there own mass, then they certainly can't control the rest of the parts. Spring surge is when the spring vibrates at it's resonate frequency and looses all control. This can happen (and is quite common) at a certain rpm range, especially when the springs are not closely matched to the cam profile

The opening and closing of the valves are one cause of spring surge, but the crankshaft torsional vibrations are another. The crank flex's back and forth with each power stroke, this motion gets transmitted to the cam through the cam drive and right up to the springs.

The frequency that sends a valve spring into surge does not have to be the exact resonate frequency of the spring. A frequency 1/2 or 2 times the frequency can aggravate it also, so building a spring that has the resonate frequency higher than the rpm range of the engine is not always an option, so other means must be taken to dampen the vibrations.

Crankshaft Torsional Dampers

The first step to limit torsional vibrations from the crank is to dampen them with friction. A torsional damper does just that. The most common is an outer inertia ring mounted to an inner hub, with elastomer between them. This is the type that is used on most stock engines. This system works well if it is tuned to the rpm range of the engine.

Another style is a fluid damper. Fluid filled dampers work on the same principle; there is an inner inertia ring that in surrounded by a high viscosity silicone fluid. The silicone does the same thing that rubber does in a stock type damper. The friction between the inertia ring and out shell is absorbed by the fluid and turned into heat. Fluid dampers work in a much wider rpm range than rubber ones and make them a better choice for higher rpm motors. There are a few other more exotic styles of damper, but for this discussion, they are not important, but they mostly rely on friction to dampen the torsional vibrations.

Spring Dampers

Even the best crank damper will still let some vibrations slip through and crank dampers do nothing for the frequency cause by the hitting of the valves opening and closing, so other steps might need to be taken. A flat wound damper can be installed to dampen the frequencies. A spring damper works on the same principle as a crank damper, by reducing vibrations by the use of friction.

Most stock style springs will be a single spring with a damper. Even in a high performance dual spring, a damper can be installed between the two springs. The problem with flat wound dampers is that in high rpm situations they can work there way between spring coils and bind up. Chamfering the edges of the damper can help this, but if you're running a high rpm drag engine, you should check dampers frequently.

Constant Rate Springs

Most stock type springs are of the constant rate type. They have a certain delivered force for a give amount of travel. If a constant rate spring has a 25 lb. Force gain with 0.1" of travel it will gain 50 lbs. of force with 0.2". These type springs have a definite resonate frequency and any spring surge will usually be in a narrow rpm range.

Variable Rate Springs

By making spring windings tighter at one end and making them progressively wider at the other, you can vary the rate at of force. This means when graphing the spring force, the rate to compression will no longer be linear. This style spring can resist surge somewhat due to the fact that there is no definite resonate frequency for the entire spring.

Barrel Wound Springs

Most high performance applications will require a larger diameter spring, but if the spring seat in the head will not allow a larger diameter spring, you can use a barrel wound spring. Also known as beehive springs, these springs are made with smaller ends and wound so the centers are larger diameter. This allows the spring to fit in smaller seats and have the advantages of a larger diameter spring.

Another advantage is that by varying diameter, the rate is not variable and resists spring surge. The biggest down fall is that a damper cannot be used.

Multiple Springs

Running more than one spring can also resist spring surge. On a dual spring set up there will be a smaller spring inside a larger one, each spring having a different resonate frequency. If designed correctly they can be wound in opposite directions and fit snugly enough to have some of the dampening qualities of a flat wound damper. A flat wound damper could be fitted between the two springs for even better dampening. Even better yet, you can use two variable rate springs with a damper and probably never run into a surging problem.

It all depends on how much you have to spend. I have limited experience with triple valve springs, but I can say they that they are expensive and I really don't think the extra benefits are worth it in all but the most radical engines. I good dual spring set up will satisfy almost all situations. Under very high rpm situations, like in pro-stock drag racing a triple spring could be an advantage, but for most street and strip engines that money would make more power elsewhere in the motor.

Source: www.grapeaperacing.com