

## **Choosing Valvetrain Components: Lifters, Pushrods, Springs & Rockers**

By Larry Carley

The type of parts you ultimately choose will depend on the application (heavy duty, marine, street performance, etc.) and any rules that restrict the type of camshaft, lifters or other valvetrain components that are allowed.

But don't overlook your customer's budget. Affordability often limits your choices if a customer just doesn't have the bucks to build an ultimate engine.

Durability is another concern, especially with endurance racing where the engine is expected to last a certain number of laps without any valvetrain failures.

The thought process that you go through when planning the valvetrain components for an engine build is usually based on your past experience. Unless you're pushing the envelope or experimenting with something new, you tend to stick with the same brands and types of parts you've used successfully in previous engines. There's no need to fix it if it isn't broken, right? That's the safe approach.

But what if you're building an engine for an extremely competitive class where a few extra horsepower may make the difference between winning and losing? In such cases, you may have no other choice but to try some different valvetrain components to see if there's any ground to be gained.

### **Valvetrain Stability**

If there's one thing most of the engine builders we have talked to over the years agree upon, it is the importance of valvetrain stability. The more stable the valvetrain, the more predictable and consistent the engine's power output will be.

Pushrods can flex quite a bit at higher engine speeds, like a pole vaulter's pole. As the lifter rises on the cam lobe and pushes the pushrod up against the rocker, the pushrod can deflect. How much it deflects depends on the load (valve spring pressure) and the stiffness of the pushrod. As the valve reaches maximum lift, the deflection in the pushrod snaps back like a spring and gives the valve a little extra push.

This can actually cause the valve to open further than it would otherwise, increasing valve lift a bit more than expected. Under controlled conditions this can actually provide a little extra power. But in many cases, pushrod deflection creates harmonics in the valvetrain that disrupts valve timing and control causing a loss of power. It also increases the risk of the pushrod bending or breaking.

The fix here is to beef up the pushrods as much as possible. Weight on the lifter side of the rocker arms has much less effect on the valvetrain than weight on the valve side of the rockers. So although larger diameter and/or thicker wall pushrods add some weight to the valvetrain, the increase in rigidity and reliability is more than offset by any weight penalty.

Standard sized 5/16" and 3/8" diameter pushrods can be replaced with larger and stiffer 7/16", 1/2", 9/16" and even 5/8" pushrods where clearances allow. Most of the circle track racers are limited to a maximum pushrod diameter of 7/16", but many drag race engine builders say they are now using the larger 1/2" to 5/8" diameter pushrods in their motors. Most are using straight tube pushrods, but others are using tapered pushrods to get increased strength and stiffness in the critical lower area where loads are greatest.

For performance applications, many engine builders tell us they prefer to use one-piece pushrods rather than three-piece pushrods where the ends are welded on. The ends on a one-piece pushrod are CNC machined to conform to the recessed cups in the rocker arm and lifter. The hardened ball on the end of a stock three-piece pushrod or even a chrome moly pushrod can sometimes break off under extreme racing conditions.

But there are alternatives to going with a more expensive one-piece pushrod. One such alternative is a pushrod where a radius that matches the diameter of the ball has been cut into the ends of the tubing. When the ball is welded on, the increased contact area makes for a stronger bond that reduces the risk of the ball breaking loose.

Valvetrain stability also depends on the rocker system and valve springs. Shaft mounted rockers are much more rigid and stronger than stud or pedestal mounted rockers, and don't require a bulky stud girdle for reinforcement. But shaft mounted rocker systems are expensive and may not be allowed by the rules.

The advantage of a shaft rocker setup is that the shaft holds the rockers in better alignment, eliminating the need for a separate guide plate for the pushrods. This reduces flex in the valvetrain at higher speeds for better valve control. The shaft can also supply oil pressure directly to the rockers to improve lubrication and reduce friction.

The position of the shaft may also lower the pivot point of the rockers slightly with respect to the valves and pushrods. The improved geometry of shaft-mounted rockers reduces friction between the tips of the arms and top of the valves, and is typically good for an extra 15 to 20 horsepower with no other changes.

Choosing rockers with a higher lift ratio can add horsepower with little or no loss in low rpm torque, idle quality or vacuum. By opening and closing the valves at a faster rate, the engine flows more air for the same number of degrees of valve duration. High lift rocker arms also reduce the amount of lifter travel needed to open the valves, which reduces friction and the inertia of the lifters and pushrods that must be overcome by the valve springs to close the valves.

On the other hand, you also have to make sure the valve springs can handle higher ratio rockers so the coils don't bind and bottom out. You also need to check clearances between the top of the valve guides and the underside of the spring retainers to make sure there's enough space to handle the extra motion.

### **Actuating The Valvetrain**

The type of lifters you choose for an engine will depend on the application and camshaft. When the rules allow it, most engine builders tell us they prefer roller cams, either solid or hydraulic. Roller lifters have much less friction than flat tappet lifters, and they don't have the lubrication, cam break-in and wear issues that flat tappet lifters can have with low zinc oils. A roller cam also allows more radical lobe profiles and faster valve opening and closing rates for more area under the curve (valve opening) to make more horsepower and torque.

Valve spring temperatures can soar dramatically with engine speed, especially in a drag motor, so keeping the springs cool with plenty of oil is very important. But some rebuilders find little advantage to filling the valve covers with oil. Spring oils work just as well and don't increase the risk of oil spillage if a valve cover is knocked loose in a crash.

### **Choosing the Right Valves and Springs**

The type of springs you choose for an engine will depend on the application and other valvetrain components. Heavier valvetrain components, especially on the valve side of the rocker arms, require stiffer springs and higher spring pressures as engine speed goes up. A high revving drag engine will require much stiffer springs than a lower revving oval track engine or a street performance engine.

Choosing lighter valvetrain components such as valves with hollow stems or smaller diameter stems, or titanium valves and titanium valve spring retainers will reduce the amount of spring pressure needed to control the valves. Some steel valve spring retainers are nearly as light as titanium and much less expensive.

For every gram you reduce the weight of the valves and retainers, you can typically add another 35 to 40 rpm to the engine using the same springs. Reducing valve weight also improves valvetrain stability and control. But you don't want to go too light; the biggest mistake many engine builders make is taking too much weight out of the valvetrain. As weight comes out, the risk of breaking something goes up.

Hollow stem stainless steel valves are an affordable alternative to super-light and super expensive titanium valves. Drilling out the upper valve stem can make the valves 20 to 22% lighter than a stainless steel valve with a solid stem. Hollow stem valves are just as durable as conventional valves in naturally aspirated performance engines, but may not be the best choice for a high heat application such as a turbocharged or supercharged engine or one that runs a big dose of nitrous.

Another way to reduce weight is to use beehive springs. The springs taper slightly toward the top so the spring retainer is smaller in diameter and lighter than that on a regular coil spring. Beehive springs save weight and help reduce spring harmonics

Beehive springs are a good choice for street engines and lower class oval track engines that are limited to single valve springs and can increase the engine's rpm potential as much as 1,000 rpm, depending on the cam and other valvetrain components. However, most beehive springs can't handle more than .650" of valve lift, so if an engine you are building needs more valve travel you will have to choose conventional dual or even triple springs.

The amount of spring pressure required to control the valvetrain will depend on the cam, rocker arm lift ratio and engine speed. Dorton says an oval track engine that turns up to 8,500 rpm for 200 laps may need 160 psi of closed valve spring pressure, and around 500 psi of open spring pressure to keep the valvetrain under control. By comparison, a Pro Stock drag motor that's revving to 10,000 rpm for a short burst down the strip may need triple springs with 250 psi or more of closed seat pressure, and up to 1,000 psi of open spring pressure to prevent valve float.

Spring pressure will drop off much faster in a highly stressed engine than one which runs at lower rpms and spring pressures. If a new spring has 160 psi of closed pressure, it should be replaced if it has dropped to 140 psi or less

When springs fail, it usually happens as a result of over-revving the engine or overheating. With most quality brands of aftermarket springs, outright failures are rare. But failures can happen, and the risk goes up depending on where the springs are made and how well the supplier controls quality.

The quality of spring wire from some suppliers has increased significantly in recent years. The best springs are made from "super clean wire" that is a high grade alloy with almost no inclusions or imperfections. When the wire is formed, it is rolled in such a way that any inclusions in its microstructure are pushed to the center of the wire. The center experiences the least stress, so the overall strength and durability of the wire is enhanced. The wire is then scanned with an electrical eddy current to reveal any hidden imperfections before it is made into a valve spring.

Some spring manufacturers are also using special surface finishing procedures to extend spring life. Shot peening has long been used to create compressive residual stresses in the outer layer of the spring wire. Shot peening leaves a matte finish on the springs, while hardening the surface to help the spring handle higher loads and speeds without failing. Nitriding has a similar effect.

By diffusing nitrogen into the surface of the spring, the surface is made harder and stronger. Polishing is another technique that can eliminate small surface imperfections and extend spring life. Springs can also be cryogenically treated to improve their metallurgy and longevity.

## Putting It All Together

Once you've selected the combination of valvetrain components you want to put into an engine, paying attention to detail is absolutely critical during the assembly process. Determining the correct pushrod length prior to ordering the pushrods is important, as is getting the correct installed height so the tips of the rocker arms are centered on the valve stems at half valve lift. Valve lash also needs to take into account the type of heads (aluminum or cast iron) that are used so the valve lash doesn't close up too much when the engine gets hot.

A ballpark amount of lash with solid lifters is about .020" when the engine is hot. Valve lash can change as much as .006" on an engine with aluminum heads when the engine heats up, so you have to compensate for that when the cold lash is set. When you dyno an engine, set the lash cold, then recheck it when it is hot to make sure you have the right amount of lash.

Finally, everything in the valvetrain must be well-lubricated prior to firing up the engine. That means using a high pressure mold assembly lube on the cam lobes with a flat tappet cam, oiling the lifters, pushrods, rocker arms and valve springs, and making sure the engine develops normal oil pressure when it is running.

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