PUSHRODS & LIFTERS

STANDING UP TO GREATER DEMANDS

Manufacturers address a variety of challenges when designing their newest pushrod and lifter offerings.

LIFTERS are mechanical translators; they transcribe the precision-ground curves of the camshaft into the vertical acceleration required by the valves. The best lifters convey every nuance of the original language, with minimal losses to friction, leakage or extraneous motion. The job of the pushrod, then, is to accurately transmit the vertical motion of the lifter body to the rocker arm. Flexibility is to be avoided, as it also distorts the message. And since this mechanical conversation takes place within the context of racing, all of the pieces involved must be made both light and strong.

"With demand for more horsepower on the rise," noted David Chamberlain of Lunati Cams, Olive Branch, Mississippi, "so is the demand for more aggressive camshafts. And the key to making more power with an aggressive camshaft will always be controlling the valve. That's why it's important to match every component in the valvetrain. We're seeing a trend toward larger lifter bores, which permit a larger wheel on the lifter and more offset on the pushrod seat. Hydraulic lifters are evolving as well, with better materials and tighter clearances for higher spring pressures and rpm's."

"When pushrod issues are resolved," commented John Partridge of Bullet Racing Cams, Olive Branch, Mississippi, "we have been able to reduce the valve duration required for optimum engine performance. This point is sometimes overlooked when camshaft applications are discussed with the customer."

"Pushrod stiffness is still one of the biggest concerns in the valvetrain," echoed Bradley Brown of Comp Cams, Memphis, Tennessee. "It will always be a concern as long as cam designs get more aggressive and engine speeds continue to rise. In fact, I'm not sure a pushrod can ever be stiff enough."

Lift & Flex?

For several years now the industry has focused on maximizing the rigidity of pushrods to keep them from flexing, absorbing motion and energy, and ultimately back-lashing like a spring. We wondered, however, if lifters, too, might flex, if only slightly, under severe valve spring pressure. Several of our contacts adamantly insisted that this was not an issue. But others seemed just as certain that lifter flex could be a real problem.

By John F. Katz

Advances in lifters are widespread in the racing industry, and continuous new products are available in either hydraulic or roller lifters. One manufacturer stressed the importance of checking for proper clearance when mocking up the engine before final assembly to ensure the correct function of the lifters in their bores. Oil viscosity is an important factor as well, he added. "It is a common misconception that a racing engine should always use a heavier weight oil, but the combination of too-thick oil and too-tight clearances can restrict the amount of oil that reaches the top of the engine," he said. Photo courtesy of Trend Performance.

"As stiffer pushrods have tended to deflect less, the burden has shifted to their next-of-kin—the lifters," observed Nolan Jamora of Isky Racing Cams, Gardena, California. "In a needle-bearing roller lifter, the outer bearing race will distort under load, causing an intermittent bunching up and spreading out of the needles." The problem is less acute in a bushing-style lifter such as Isky's EZ-Roll, "because despite the bending or deflecting forces applied to the bearing shell, their load distribution footprint is nearly four times as large."

The struts or legs of a roller lifter may flex as well, but again, according to Jamora, deflection can be minimized by the unified construction ("our Anti-Flex Defense") of Isky's EZ-Roll (bushing) and Red Zone (bearing-style) lifters. Slip-fit or push-fit axles provide easier assembly, but if instead the axle is held in compression at each end, "all diametrical clearances are virtually eliminated, and the axle becomes an integral member of the lifter."

"Lifter flex can be an issue," Partridge agreed. "Roller axles can flex, lifters can spread, and lifter bores can wear out-of-round due to high lifter pressure angles. These high-pressure angles can be caused by many things, but among the worst culprits are the small-base-circle cams used in many stroker applications. The smaller the base circle, the worse the pressure angle becomes. This is unavoidable in some applications, but we advise our customers to use raised-cam blocks in big-stroke applications wherever possible. This allows us to make the base circle correspond to the lift, and to select the cam journal size for the optimum pressure angle—taking some load off of the lifter bores. We also like to see our customers use the largest lifter diameter possible, which provides increased axle length and a bigger wheel diameter as well."

"Absolutely, the lifter body can and does deflect," confirmed Chamberlain, "especially in higher-power engines—while engines with lower speeds and less horsepower are more forgiving. This is why Lunati offers lifters with much fuller body designs for more extreme applications."

Comp Cams shared FEA screen images showing the relative deflection of their Elite (race) and Endurex (street) lifters. "As the pressure angle of the cam to the lifter increases," said Brown, "these stresses increase exponentially. This is why lifter bore clearance and the design of the lifter body are so important."

David Popp of Hy-Lift Johnson, Muskegon, Michigan, noted how "offset pushrod seats or greater pushrod angles can create increased side loading of the lifter body. Some lifters have very

little surface area where the body bears against the lifter bore"—for example, the stock configuration in small block Fords and late-model Chrysler Hemis. "Increasing the bearing surface reduces the contact stresses, which can reduce lifter bore wear." Hy-Lift Johnson's new A-2368SE lifters for Ford 302s and 351s, and new A-2335SE lifters for the late-model Hemi "feature a larger lower bearing surface, capable of higher spring loads and rpm's; as well as our Direct Shot lubrication to the roller bearing." Variable-duration versions are also available for increased vacuum and better idle quality when using a performance camshaft.

Jack McInnis of PBM-Erson-World, Louisville, Kentucky, noted how "excessive lifter bore clearance can cause the lifters to rock in their bores, causing wear and damage to the cam. It is important to check for proper clearance when mocking up the engine before final assembly to ensure the correct function of the lifters in their bores. Oil viscosity is an important factor as well. It is a common misconception that a racing engine should always use a heavier weight oil, but the combination of too-thick oil and too-tight clearances can restrict the amount of oil that reaches the top of the engine."

"The proper lifter-to-bore tolerance is crucial to keep the lifter under control," agreed Rob Celendano of CV Products, Thomasville, North Carolina. "A properly prepared block helps minimize this issue."

Rob Remesi of Jesel, Lakewood, New Jersey, advised that "keeping the pushrod cup as low as possible in the lifter greatly reduces the amount the lifter can rock. The closer the pushrod pivot point is to the bottom of the roller, the less leverage there is to rock the body in the bore. Think of it this way: If you're trying to tip something over, the higher you push, the easier it gets."

Not everyone agreed with that approach. Crower Cams of San Diego, California, has updated the design of some of its lifter bodies, "especially for big block Chevrolets," said Kerry Novak, by raising the seat height, so customers don't have to notch the bodies for offset pushrods. "When the pushrod is at an angle, and the seat is way down in the lifter body, you have to cut the body after it's finished. Now you have chips falling down in the seat area, and still the pushrod is rubbing on the body. That's why we're in the process now of moving the seat up, to accommodate the latest cylinder head configurations."

High-performance Hydraulics

Among the industry's long-standing goals has been improved performance from hydraulic lifters—and we found continuing progress on this front. "The main issue you run into with hydraulic lifters,"

said Remesi, "is oil aerating, which collapses the lifter piston."

Popp pointed to "loss of effective valve lift if the spring pressures are great, which causes the piston in a hydraulic roller lifter to collapse inside the lifter body. Our full line of S-type lifters (identified by an S in the part number) feature a tighter piston-to-body clearance—.000080 inch—than most standard lifters. This tighter tolerance prevents the piston from collapsing inside the lifter under high valve spring loads. And because of the smaller amount of piston movement, almost all of the cam's lobe lift is transferred to the pushrod, allowing an increase in maximum rpm."

With demand for more horsepower from race engines on the rise, so is the demand for more aggressive camshafts, reported one valvetrain manufacturer. He explained that the key to making more power with an aggressive camshaft will always be controlling the valve. That's why it's important to match every component in the valvetrain. Photo courtesy of Lunati.

The piston in Comp Cams' short-travel hydraulic lifter travels only .050 inch. "It acts almost exactly like a solid lifter," said Brown, "and is specifically designed to operate in very severe applications. It's a little tricky to adjust, but well worth it." All Comp hydraulic roller lifters feature a patent-pending vent hole in the piston area that allows trapped air to escape—eliminating pump-up issues when the engine is first started.

Bullet Cams, added Partridge, "has improved the material in our lifters. And we offer lifters with varying rates of bleed, both slower and faster than standard." Bullet also offers "hydraulic lifters that function more like a solid lifter. They have only a limited amount of plunge, providing more rpm capability and allowing increased valve spring pressure while remaining a legal hydraulic lifter."

Isky's EZ-Roll Hydro lifters feature RPM Boost—"a short travel, controlled leakage, anti-pump design," said Jamora, "that handles increased valve spring loads for higher rpm. Best of all, they require no modification to the engine oiling system."

Howards Racing Cams of Oshkosh, Wisconsin, offers Direct Lube hydraulic flat-tappet lifters, which are now available for most Ford V8s, as well as small and big block Chevrolets. "We designed these lifters for today's more aggressive cam lobes," said Brian Adix, "where increased oil supply is critical."

Bold Solids

We found some particularly interesting developments in the field of solid rollers—and of lifter-bore bushings. At the 2013 PRI Trade Show, Jesel demonstrated its new cartridge-style lifter, which features a removable bronze bushing for easy repair and block cleaning. The lifter slides inside the bushing, and an aluminum collar around the bushing fastens to the block with a bolt or stud. "These lifters are intended for high-end race blocks with a solid, un-machined lifter valley," said Remesi. "They are located in a receiver groove in the bushing, instead of using a traditional keyway or tie-bar." A large-diameter (1.220-inch), but more narrow than standard roller reduces wheel speed and friction.

New from Isky are EZ-Roll JR (Just Roll) mechanical roller lifters for naturally aspirated engines with open valve spring pressure of less than 800 pounds.

SportMax mechanical roller lifters from Howards Cams offer "most of the features of our Pro lifters," described Adix, "but are priced with the sportsman in mind. Heat-treated 8620 steel billet bodies are CNC-machined in one process to assure accuracy, and are precision ground for proper fit in OE and +.300-inch-tall aftermarket lifter bores. The axles are tool steel, heat-treated and nitrided, with pressure oiling."

You can count on new product debuts at the annual *Performance Racing Industry* Trade Show. For example, at last year's Trade Show, Jesel demonstrated its new cartridge-style lifter, which features a removable bronze bushing for easy repair and block cleaning. The lifter slides inside the bushing, and an aluminum collar around the bushing fastens to the block with a bolt or stud.

Debbie A. Jackson of Precision Products Performance Center, Arden, North Carolina, noted how new alloys are being used for lifter-bore bushings. "Beryllium copper, Moldstar bronze, and two other proprietary alloys are now superseding Ampco 45 because of their superiority in hardness and lubricity," she told us. "That prevents premature wear to the bores and maintains proper clearances."

"Our main focus has been how to oil the lifter and make the bushing stronger and

able to withstand higher lifts," added Ed Doyle, while noting how CHE Precision of Newbury Park, California, has "developed lifter bore bushings with new oiling techniques, and keyway bushings that have a solid broached ring at the top for more strength and rigidity. We have a new broaching method that does not require us to machine a slot completely through the bushing, so the alignment slot does not spread at the top of the bushing. We have also worked with materials that wear better and do not wallow out when using aggressive cams with high lifts."

Needles or Not?

Howards Cams has joined the growing number of manufacturers who offer bushing-style roller lifters. "We took our severe-application ProMax lifters one step further," said Adix, "by replacing the needle bearings in the roller tip with solid bushings." Engineered for "ultra-high spring pressures and the most aggressive cam lobes," the resulting UltraMax mechanical roller lifters also feature "full-time high-pressure oiling to the axles; lightened, alloy steel bodies with an enhanced finish; heat-treated stainless steel link bars; and case-hardened 8620 rollers."

Isky offers EZ-Roll X plane bearing lifters for naturally aspirated applications with up to 1000 pounds open valve spring pressure, and EZ-Roll Max plane rollers for forced-induction engines. Both feature raceways made from exclusive, proprietary materials such as Epsilon ZX and Zmax, rather than traditional bronze, allowing EZ-Roll lifters to operate with oil restrictors. "Needle bearings offer a short-lived advantage over plane bearings," Jamora claimed, "as initially they offer slightly reduced rolling drag"—worth about one-third of one percent increase in net horsepower. As the needles wear, however, their surface roughness increases, which in turn chews up the bearing race, increasing friction and leading ultimately to catastrophic failure. Oversized lifters, allowing an increased cross section of the outer bearing shell, only "forestall the day of reckoning," as does improving the surface finish on the needles. To duplicate the load distribution footprint of a plane-bearing lifter, said Jamora, a needle-bearing lifter would need a body 1.5 inches in diameter.

Still, needle bearings remain the first choice of a significant percentage of parts manufacturers and engine builders. While nearly all of the purveyors of plane bearings tout some form of positive oiling, lubrication remains a major concern. "All of the lifters we sell use a needle bearing roller assembly," Remesi reported. "The issue we see with bushing-type rollers is the amount of oil needed for proper lubrication. Unlike a rod or main bearing that receives a constant,

pressurized oil flow, lifters receive only a sporadic oil flow at best. And needle bearings need far less lubrication. Our lifter axles, rollers, and needles are machined from high-end materials to extremely tight tolerances, which is the key to a quality needle roller package. While a bushing-design lifter may work in a low-to-moderate-spring-pressure application, you would be hard pressed to find them in any engine with open spring pressures over 1000 pounds."

"The main advantage of using needle roller bearings is reduced friction," added Popp. "Heat and insufficient lubrication are the main reasons for bearing failure, so we developed a Direct Shot oiling system that introduces a stream of oil directly into the bearing—increasing lubrication and reducing heat." The Hy-Lift Johnson system "is also designed not to allow any debris to enter the oil supply going to the bearing."

Still other manufacturers offer a choice. "Comp Cams recognizes that some engine builders prefer needles and others prefer bushings," said Brown, "so our new Elite lifter is available either way. With both bushing and bearing versions, the axles are super-finished and feature the same material and hardness; and oil passages are designed for maximum flow to either the bushings or the needles."

Bullet Racing Cams also offers both bushing and bearing styles. "One of the main problems with bearing lifters is lack of oil," said Partridge. "Customers want to limit oil to the lifter gallery, to provide more oil to the lower end of the engine. But when limited to 'splash only,' lifter bearings do not get enough oil to remain alive under the loads that are typical today. Larger-diameter wheels with more bearings inside the wheel race do help," but even bushing lifters can also be damaged by a restricted oil supply.

At Crower Cams, said Novak, "Our bushing lifters have really taken off. They've been a fantastic addition to our line of components. They feature high-pressure oiling, which keeps the bushing floating in oil. We have been making them for several years now, and they are starting to come in for rebuilding. We took one set apart after 4000 laps in a dirt late model, checked all of the dimensions, and they were only one or two tenths out-of-round, which is amazing. Some of our customers have said, 'I've been using your needle-bearing lifters forever, I don't want to change.' We're not trying to make them change. We just want them to be aware of what's new, and that they have a choice."

CV Products offers .937-inch-diameter bushing-style roller lifters with wheels that are .100-inch larger than before.

Crane Cams in Daytona Beach, Florida, manufactures needle-bearing rollers, but

continues to test bushing-type lifters. "There are so many bushing materials available now," said Chase Knight. "We've done a lot of experimenting with rollers, including a lot of work on the Spintron, testing for optimal performance." He agreed that the choice of one or the other "depends on the application," and also that oil supply is particularly critical with bushings. Meanwhile, Crane has "invested in a new manufacturing process to make the roundness and diameter of our needle roller bearings more consistent." Crane also offers custom lifters.

Trend Performance Products of Warren, Michigan, is "working on roller-lifter projects for some customers on an individual basis," said Andy Anderson. "Some use needles and some do not. We evaluate each project to determine which is best for the customer."

With plane or needle bearings, McInnis recommends using larger-diameter lifters with larger cam cores. "The benefits of these larger cores include reduced deflection in the camshaft, and allowing ramps and transitions that are less severe, thereby aiding valvetrain stability. Larger cam cores, however, also increase lifter wheel speeds at any given engine rpm. This is due to the greater distance the lifter wheel must travel to follow each revolution of the camshaft. Upgrading to .904 or .937 diameter lifters can help alleviate this condition, as their larger wheel diameters reduce wheel speed.

Rollers into NASCAR

As most of our readers know by now, the NASCAR Cup series will convert to roller lifters for the 2015 season. "Many of the teams have progressed further in development than some of the manufacturers," Jackson observed, "and will be supplying their own roller lifters." So rather than compete against their own customers, Precision Products has chosen not to manufacture a roller lifter for this new market, but will instead supply the various teams with key components. "We are already manufacturing components for this transition." Precision Products will continue to offer its large line of tool-steel flat tappets, "which is expanding into new arenas inside and outside of NASCAR."

All the Angles

Which brings us to pushrods—and the continuing trend to offset the cam and lifter from the rocker arm, forcing the pushrod to operate at an angle. Engine builders have used such offsets to make room for modified ports since (at least) the 1970s—and as Jamora pointed out, this was not a problem until "valve motion via camming and rocker ratios became so radical that valve spring load forces moved into the stratosphere." Analysis of failed roller lifters have indicated that, due to extreme side loading, only half of the

available surface load distribution footprint—the available contact patch on the axle—was actually being used.

"With larger ports and greater offsets between the rockers and the lifters," said Al Perkins of Manton Pushrods, Lake Elsinore, California, "there is less room for the pushrod to go through the head"—and the pushrods that do fit may not be "large enough in diameter to handle the load and/or angle without flexing and causing valvetrain surge. You can't flow air past a fluttering valve."

"Obviously, extreme offsets can lead to less than optimal valvetrain geometry, affecting overall stability and performance. In some cases, camshafts with relocated lobes can alleviate the condition," said McInnis. "Of course, this also requires moving the lifter locations in the block to correspond with the relocated cam lobes. The effect is to straighten the pushrod angles and reduce the offset required between the lifters and rockers. Erson Cams offers cam cores with this feature, and World Products offers this feature in its blocks."

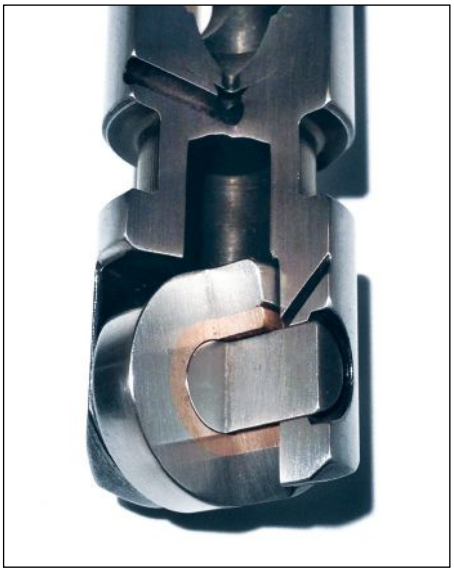
"Keeping the pushrod as straight as possible is one of the keys to a solid valvetrain," Remesi agreed. "Excessive pushrod angle not only side-loads the rocker and lifter, it also reduces net valve lift. One advantage of a keyway lifter is the ability to offset-bore the bushing, and move the lifter over to reduce the pushrod angle. In the case of a big block Chevy with a spread-port head, offsetting the lifter bushing .080 inch, in conjunction with a .150 offset lifter cup, relocates and straightens the lifter end of the pushrod by .230."

The Big Push

"We've worked with several manufacturers to develop pushrods with increased wall thickness within a given diameter," said Partridge. "Our standard 5/16-inch pushrod was .080 inch in wall thickness, but now we're using .120-inch wall for most applications. We continue to examine pushrod integrity, and to test different approaches to improving these parts."

Manton's newest products are 5/16-inch copper-alloy radius cups, "providing a larger loading surface and a very low coefficient of drag," said Perkins. "That means less heat in the valvetrain, for improved power and longevity. Of course, we also offer a .281 ball adjuster in two sizes: 3/8 x 24 and 7/16 x 20, pressure-fed or not, to replace the cup-style adjuster in the rocker. These will accommodate either our new copper-alloy radius cups, or H-13 radius cups, to provide the proper wear characteristics for the application." For big-inch engines, Manton offers three-quarter-inch pushrods.

Erson Cams has released new 5/16-inch pushrods with .125-inch wall thickness.



As stiffer pushrods tend to deflect less, the burden has shifted to the lifters, reported a representative from Isky Racing Cams. He explained, "In a needle-bearing roller lifter, the outer bearing race will distort under load, causing an intermittent bunching up and spreading out of the needles." The problem is less acute in a bushing-style lifter such as Isky's EZ-Roll, because despite the bending or deflecting forces applied to the bearing shell, their load distribution footprint is nearly four times as large, he said. Seen here is the Isky Racing Cams Red-Zone EZ-Roll Max lifter.

"They provide the increased stiffness associated with larger-diameter pushrods," explained McInnis, "but require less clearance, therefore potentially reducing offset requirements as well."

Howards Cams offers .080-inch wall, 5/16- and 3/8-inch swedged end pushrods with a 210 degree tip, providing extra radius clearance in the rocker cup area. These single-piece pushrods are formed from 4130 centerless-ground tubing, case hardened to Rc 60, black-oxide finished, and laser etched with size and part number. "We strongly recommend them for all shaft-style rocker systems," said Adix. Custom lengths are offered, from 6.000 to 13.000 inches in .025-inch increments.

The X2 line of pushrods from CV Products feature one-piece 4130 seamless-wall construction and 5/16-inch tips. "We've refined our pushrod selection," said Celendano, "to keep the latest in lengths and wall thicknesses in stock."

As an alternative to larger diameters, Trend Performance is currently developing better materials for pushrod tips and adjusters. "Increased spring pressures and/or greater rpm's are causing a lot of failures at the rocker end of the pushrod," said Anderson, which are aggravated by some of the new oils now in use. "The geometry and the material used for the adjuster or rocker arm and pushrod tip are becoming more critical. We have several ongoing projects involving different materials and geometries for both adjusters and pushrod ends to help our customers address the issues we have been seeing." PRI