Bigger, Better And More Sophisticated

PUSHRODS & LIFTERS

By John F. Katz

PUSHRODS have essentially one job to do, and that's to push. You might say the same about lifters, which translate the eccentric turn of the camshaft into a straight-line push up the lifter bore. Of course, all the while the valve spring is pushing back—and the quality of pushrods and lifters is judged mainly on how well they maintain their rigidity and integrity while squeezed between these opposing forces.

Opposing forces—that phrase not only describes the environment in which pushrods and lifters operate, but also the technological and market demands that shape them. On one hand, the high-performance pushrods and lifters currently on the market are better than ever; on the other, well, they have to be.

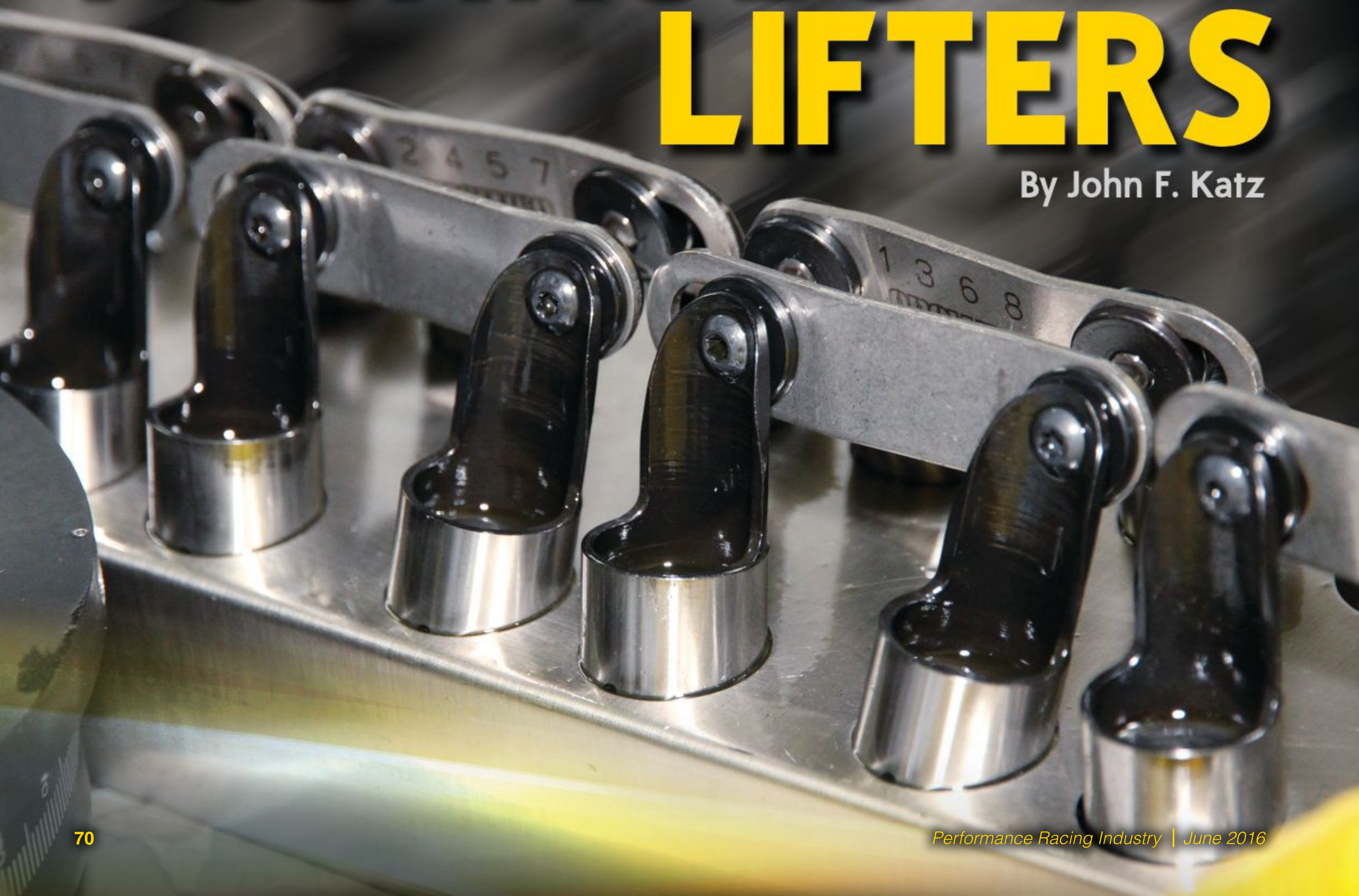
"There are better components available today than even a couple of years ago," reported John Partridge of Bullet Racing Cams, Olive Branch, Mississippi. "The selection of lifter diameters has increased, allowing us to have larger lifter wheel sizes. Pushrods have been less of an issue because of increased wall thicknesses and diameters being more available."

"The introduction of higher-strength alloys allows balance between stiffness and weight," added Brad Loden of CV Products, Thomasville, North Carolina. "We use FEA (Finite Element Analysis), factoring material properties and load simulation into our designs, optimizing stiffness with lighter mass." And it's all because "people continue to push power and rpm—while we're trying to achieve maximum durability."

We recently surveyed the industry to determine which factors drive pushrod and lifter engineering—and how valvetrain manufacturers have responded to them.

The Challenges

We began by asking lifter manufacturers to name the greatest challenge they faced in developing designs for today's racing engines. Was it increasingly radical cam profiles, or increasing engine rpm? Higher overall cylinder pressures, or heavier valve springs? Most responded by explaining how all these interact.



While industry experts have long maintained that a pushrod can't be too stout or too stiff, they are quick to point out that lubrication is a critical factor, too, as at least one leading manufacturer cites inadequate oiling as arguably the most likely cause of pushrod failure.

From camshaft profiles to cylinder pressures to lubrication, valvetrain manufacturers are engineering products designed to withstand a host of formidable challenges.

Nolan Jamora of Isky Racing Cams in Gardena, California, pointed to the camshaft as the primary culprit. "Over 50 years ago our 505 Magnum and 550 Super Le Guerra cams would easily run 9000 rpm without a rev kit—with steel valves, 5/16-inch diameter pushrods, and 350 pounds spring force, open. But as cams became more aggressive, using 'accelerated' ramping to capture more area under the lift curve, valve spring loads had to increase to maintain valve control—and, of course, other components, such as pushrods, had to become stiffer. All of this gradually ratcheted up to where we are today. The cam dictates everything we do, valvetrain-wise, and it always has!"

"It's extreme camshaft profiles putting more pressure on roller lifters, and requiring more valve spring pressure to keep the valvetrain in contact," confirmed Don Weber of Engine Pro, Wheat Ridge, Colorado, "all of which creates the need for stronger pushrods that will not flex. The roller rockers must handle more pressure, and bronze bushings are being used instead of needle roller bearings in the most extreme applications."

Partridge added that camshaft profile is particularly challenging "because it involves so many factors itself, including ramp acceleration rate, contact velocity, and ramp clearance (or the lack of it).” All of which certainly “make the design of pushrods and lifters problematic. Every cam profile is maxed out. Roller wheels take a huge load, as do pushrods, because of cam design compounded by valve spring pressure. And cylinder pressure is a big concern, especially on the exhaust side, where it’s driven by compression ratio plus supercharging, turbocharging or nitrous oxide.”

Eric Bolander of Howards Cams in Oshkosh, Wisconsin, noted how, “as the lift requirements on today’s cylinder heads have gone up, the stress levels on rocker arms, valve springs, pushrods and tappets have risen. Lifters have to remain light enough to allow an engine to spin in excess of 8000 rpm, yet be sturdy enough to withstand 1000-pounds-plus of valve spring pushing down on them.”

Billy Godbold of COMP Cams in Memphis, Tennessee, cited “dynamic stability,” or, rather, a lack thereof, as the greatest threat to lifter longevity. “Stable valvetrain systems can deal well with 10,000-pound spring loads. But a 2500-pound shock, where parts crash together, can lead to a bearing failure, wheel failure, or a host of other issues.”

To this growing list of factors challenging lifter and/or pushrod engineering, Kerry Novak of Crower in San Diego, California, added the increasingly radical design of today’s racing cylinder heads. “Because of the rocker offset,” he noted, “the pushrod angle is very severe. Combine that with huge spring pressures and it side-loads the lifter bushing or bearing while playing havoc with the lifter itself.”

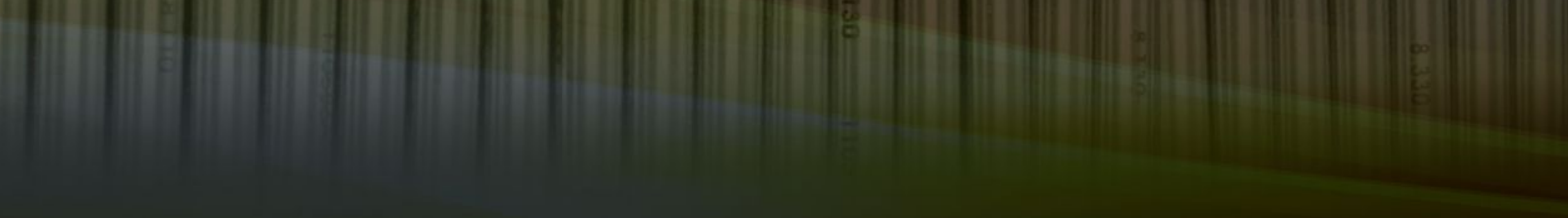
“It’s all of the above,” summarized Allan Bechtloff of Crane Cams, Daytona Beach, Florida. “Racers usually do not make things easier on any engine part. And as we know, if you change one thing to improve performance, two or three other things have to change to make it happen.”

And then, to “all of the concerns listed above,” Loden added, “major challenges concerning lubrication. For example, in the sprint car and late model dirt applications, the clutchless direct-drive systems cause significant rpm fluctuations, which lead to strain on the valvetrain components—especially the lifters.”

Big Rollers

Almost universally, the industry has responded to these challenges with bigger-diameter lifters, accommodating bigger-diameter rollers. “A normal solution with a roller lifter is to go bigger,” Bechtloff suggested. “Increasing the diameter of the body allows for a larger roller wheel, along with more needle bearings and perhaps an enlarged axle, in order to carry more load.”

Novak said, “Bigger diameters, bigger wheels, bigger axles, bigger everything. People are building engines with more



By most accounts, more racers and engine builders are embracing bushed lifters with greater enthusiasm today than in years past. And in fact, "Using bushings instead of needle bearings makes a huge difference in load capacity for our roller lifters," confirmed one top supplier. Photo courtesy of Isky Racing Cams.

than one-inch lift on the camshaft, which is quite large. And then the spring pressures are through the roof"—with 1450 pounds open no longer unusual. "So we've been making .937 lifter bodies for a while, and now we're up to 1.000 inch—and they are just getting bigger. We have turbocharged racers who seem to be trying to destroy everything—and we keep improving our components, to stay one step ahead of them. In blown and turbocharged applications, you have to have very good material, because you're forcing the valve open against exhaust pressure."

Partridge agreed that, in any application, "the largest lifter wheel diameter and the stiffest pushrod we can use work the best. There are lifter diameters available now for every conceivable use that were not available until the last few years." These include .903- and .907-inch diameter drop-in lifters with .850 wheels, for small and big block Fords and Chevrolets. "Chrysler applications are available in .903 diameter with a .815 wheel; and 1.00 and 1.062 diameters with a wheel size of.920."

CV Products now offers keyed .937 and .904 OD lifters through its Xceldyne brand. "The keyway is integrated into the body for less distortion and improved alignment between the keyway and the roller-wheel-to-cam-lobe interface," said Loden, who also pointed to such sophisticated features as "priority oiling, and the proprietary material used for superior strength of the body." Additionally, the pushrod cup is machined integrally with the body, "allowing for excellent stiffness and mass reduction, along with excellent surface finishing and OD tolerances."

"Typically," advised Jack McInnis of Erson Cams, Louisville, Kentucky, "an increase of five mm in the diameter of the cam core should be accompanied by an increase of about .020 inch in the diameter of the lifter wheel, to keep the wheel's speed down to a level where it can survive." Erson now offers one-inch keyed lifters with .910-inch wheels, and .904 lifters with .810 wheels. "If an engine is fitted with a new, larger-diameter and more aggressive camshaft, resulting in higher rpm operation, but the lifters, pushrods and valve springs are not upgraded to suit, valve float becomes a factor and will take a toll on all those components."

Higher stresses have required tighter quality control as well. "We've been using newer, strong materials with enhanced heat-treating," said Bechtloff. "Surface finishes and coatings are also used to extend the longevity of the parts. All Crane roller lifter bodies are made from heat-treated 8620 alloy steel. Many of the newer camshaft designs are made from tool steel and are through-hardened. These changes are all predicated on the fact that the racer is using higher valve spring tensions and increased rpm."

The Right Equipment

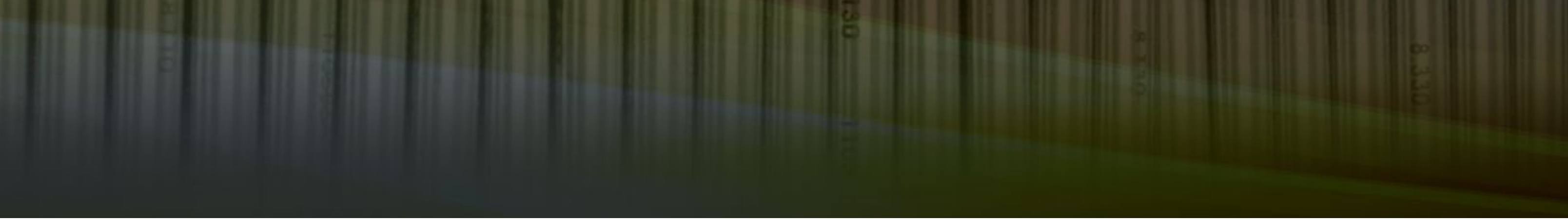
Still, according to Bolander, "the challenges we have been facing" have less to do with the "limitations of the products that are available [than with] making sure that the right combination of parts are being used, and used properly. Hydraulic roller lifters need to match the valve spring pressure required for the valve lift. A small block Chevrolet camshaft with a .480 valve lift and 220/228 duration at .050 doesn't require nearly the amount of spring pressure as one with a .590 lift and a duration of 235/245 at .050." The former needs about 125 pounds with the valves closed, and 300 pounds open; versus 150 and 400 pounds for the latter. "So a lifter that is just adequate for the .480-lift cam will be reduced to clattering wreckage by the valve springs that the .590-lift cam requires."

With solid rollers, too, "it's all about making sure you have the proper lifter for what you are expecting the engine to do," Bolander continued. "As spring pressures start climbing toward quadruple digits, you can't cheap out and run a 'street' or basic 'hot rod' lifter, just because that's all the budget will allow."

"One of the biggest challenges is getting customers to use an appropriate-sized lifter," agreed Rob Remesi of Jesel, Lakewood, New Jersey. "The .842-inch-

Thicker tubing and high-quality material are helping state-of-the-art pushrods "keep pace with the other components that are integral to a valvetrain that functions properly under extreme load conditions," said one performance parts manufacturer. Photo courtesy of Engine Pro.

diameter lifters in a stock Chevrolet small block or big block were fine back in the day when open spring pressures were topping off at 500 pounds. In today's racing engines, with spring pressures easily eclipsing 1000 pounds open, the smallest lifter that we recommend is a .904"—and he'd be happier if you ran something bigger. "You wouldn't run a stock crank or rods in a 1200-hp engine, so why would you run stock-size lifters? And if you are adding nitrous or



turbocharging, which greatly increases the cylinder pressure, then our minimum recommend diameter jumps up to .937. We charge the same price for an .842 tie-bar lifter as we do for a .937 tie-bar lifter, so the only added cost is for having the block prepared."

Remesi still bills Jesel's Roller Guided Cartridge Lifter as "our next evolution in roller-lifter technology. Designed to be used in purpose-built, cast-iron drag race and aluminum-billet blocks, our Roller Guided Cartridge Lifters offer the engine builder options never before available. The 1.000-inch-diameter body houses a 1.220-inch-diameter roller, which is guided by channels machined into the inside diameter of the lifter bushing. The 1.220 roller has a slower rotational speed than a traditional .850 roller, and also reduces the pressure angle against the lifter." The lifter bushing, which has an outside diameter of 1.312, is secured in place by a height-adjustable aluminum collet that is bolted into the lifter valley. "Not only is this lifter stronger than our keyway lifter; in the rare event that it may get damaged, you can simply unbolt the collet, slide out the lifter and bushing assembly, and replace it with a new assembly."

Godbold noted how "certain engines respond better to a light lifter preload, because it allows a faster recovery from bad harmonics in the valvetrain. Others work better with a heavy preload because oil volume is reduced under the plunger, which increases lifter stiffness. But our Short Travel Hydraulic Roller Lifters let you have the advantages of both light preload and reduced oil volume—for stability with high revs. COMP now offers an XD version of these lifters that features a heavy-duty tool steel pushrod seat. This adds strength and durability in extreme-duty applications such as turbo drag cars with stutter boxes, and offshore powerboats."

Meanwhile, COMP's Sportsman Solid Roller Lifters "are becoming outstandingly popular with racers and engine builders," Godbold added, "providing quality close to a $2000 set" for less than half that price.

Bushings, Bearings & Oil

Particularly because of the side-loading mentioned earlier, lubrication is critical. According to Novak, numerous racers and engine builders try to restrict the amount of oil that reaches the top of the engine. "But we need a minimum amount of oil to flow through our lifters, not only to lubricate them, but to cool the bearings or the bushings."

That's particularly true of bushed rollers (versus the needle-bearing type), which, like a smaller-scale version of the journal bearings on a crankshaft, require oil pressure to operate. "They have to ride on a film of oil," Novak explained. "When someone calls us on the phone, and they've had a failure, we ask them about using oil restrictors. And they'll say, 'Yeah, I use restrictors. Why?' Well, the bushings are riding on a film of oil, and have to have oil pressure." But when bushed lifters are properly lubed, "and we bring them in and take them apart, they look really good."

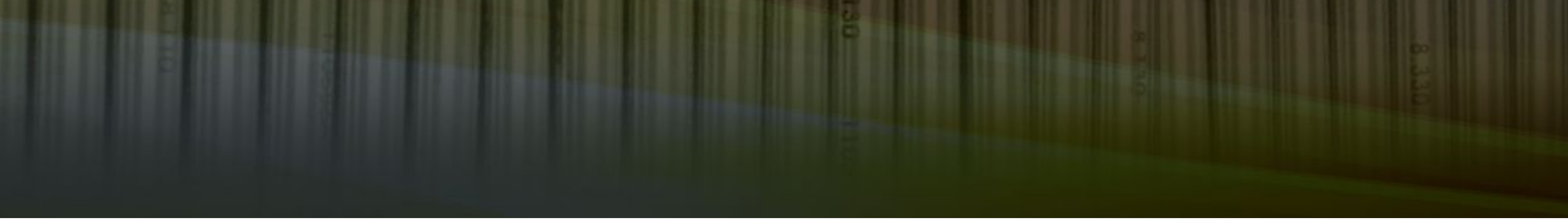
Novak believes some engine builders may be misled by the greater amount of static friction in a bushed lifter—that is, in an engine that isn't running, where the oil pressure is zero. "If you try to turn a bushed-lifter engine over with a breaker bar, it's definitely harder, because there's more friction," he said. One customer used a torque wrench to compare the amount of torque required to rotate a bushed-lifter engine versus a similar engine with needle-bearing lifters. "Of course, it was harder, because there was no oil pressure. But no one has ever called us and said, 'We lost six horsepower because we put bushing lifters in the motor.'"

Godbold also cited the importance of lubrication. "Some bushing lifters seem to wear rapidly as open spring loads approach the 1100- to 1500-pound range, but we believe this may have as much to do with oil delivery"—and with the customer's choice of lubricants—"as with the actual load capacity of the bushing."

"You wouldn't run a stock crank or rods in a 1200-hp engine, so why would you run stock-size lifters?"

There seems to be no question, however, that more racers and engine builders are embracing bushed lifters. "Since competition has forced everyone to push the envelope," Jamora commented, "and no one is of a mind to back down, naturally the weakest link in the valvetrain gets exposed, and that is the needle bearings in roller lifters. The only way to safely cope with the way things have evolved is to replace those outdated needle bearings with Isky's patented EZ-Roll 'needle-free' roller lifters." Now, "to keep pace with upward-trending horsepower and rpm demands in the hydraulic-roller market, we have introduced EZ-Roll Hydro roller lifters," incorporating Isky's patented EZ-Roll technology in a hydraulic lifter. "And they are 100 percent US made, in our own precision manufacturing facility."

Weber agreed that "using bushings instead of needle bearings makes a huge difference in load capacity for our roller lifters." Engine Pro's Ultra Series Bushing Mechanical Roller Lifters offer up to a 40



percent increase in load capacity versus a needle design. So they deliver the needed increased capacity for modern cam profiles and spring rates, he added. They are fully rebuildable, and not for use with oil restrictors.

Engine Pro continues to offer lifters in four other lines, including its Retro Fit Hydraulic that is designed to update a vintage engine to modern hydraulic roller configuration, with fully machined bodies and .700-inch diameter tool steel wheels. Its Pro Series Mechanical is for sportsman-level circle track or drag racing, and features .750-inch-diameter tool steel wheels. The Pro Series Hydraulic also features .750 tool steel wheels centerless ground to .0003 tolerance. And its Ultra Series Mechanical is the company's best conventional needle-bearing lifter, according to Weber, and is machined, heat-treated, centerless ground, and finished in-house to control quality. It features a 9310 axle with wheel options up to .850, and standard or +.300 tall pressure-fed oiling. All are made in the US, using high-quality 8620 tool steel.

Erson is also "increasingly using bushed wheels rather than needle bearings," said McInnis, "as the bushings tend to withstand valve float better. While a bushed lifter can still be damaged, catastrophic failures are rare."

"Bushings have made it possible to increase spring pressure and valvetrain reliability at the same time," Bolander said. Howards Cams offers "our Ultra Max series solid roller lifters, which are bushed; with direct-lube, full-time high-pressure oiling to the axles; and bodies made from case-hardened 8620. The continuous oiling in conjunction with solid roller bushings combine to offer extreme capacity for rpm and high spring pressure."

Novak noted, "Our Crower needle bearings are still fantastic. Some of our dealers have been buying them for years, and they won't change. They'll roll in an oil mist, and for the average racer building the average motor, they're just fine. But when you start hammering them with all the pressures of a high-boost engine and/or high-lift valvetrain, well, it really helps to put a bushing in there instead." Not surprisingly, it's been the "hardcore" racers who have most enthusiastically embraced bushing-style lifters—"the dirt late models, sprint cars, and drag race applications with big spring pressures."

On to the Flatlands

Bolander called our attention to the maintenance requirements of traditional flat tappets. "On the flat-tappet front," he noted, "EDM oil holes help keep the cams alive, but they are not a 'silver bullet' cure for bad lifter bores." In fact, "most flat tappet/flat lobe tragedies are due to worn lifter bores. When the lifter bore starts to wear and enlarge, the lifter gets cocked in the bore, which in turn stops the lifter from rotating. And that's what flattens the cam. It doesn't matter what material the cam or the lifters are made of. If the lifter stops spinning, it's game over."

Jay Verduzco of Speedmaster, Rialto, California, said, "Proper flat-tappet camshaft break-in procedure is more critical than ever before, due to the mandated removal of zinc from most motor oils. The most critical time in the life of a flat-tappet camshaft is the 'mate-in' between the bottoms of the lifters and the cam lobes during the first 20 minutes of break-in."

Verduzco has seen a big change in awareness of this issue and others, including "the lack of, or too much seat pressure." In fact, "roller lifters are really not prone to any major issue if the valve spring pressure is spot-on." Still, Speedmaster asks "each individual customer their intended application for the lifters or pushrods they are purchasing. And we make educated recommendations."

The Big Push

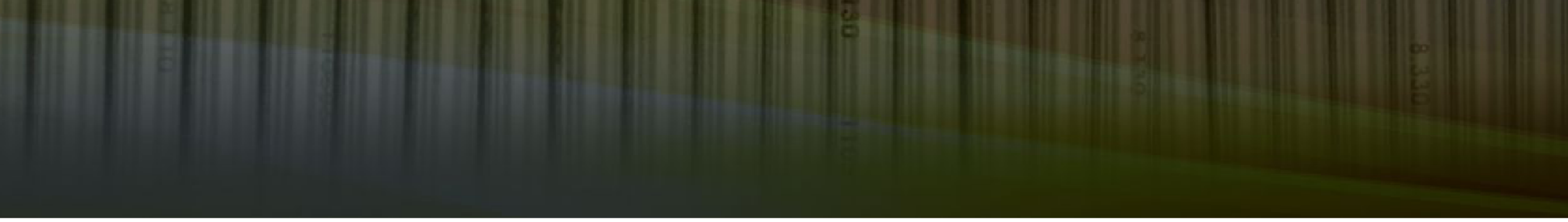
For years, manufacturers have been telling us that a pushrod can't be too stout or too stiff. Lubrication is critical here as well; according to Godbold, inadequate oiling is the most likely cause of pushrod failure. "But then we've seen valve springs fail because a pushrod was not stiff enough for that system, and everything went out of control." And because "the remaining cylinder pressure at exhaust opening goes up with increased horsepower, we like to see beefy pushrods on the exhaust side of a 2500-hp engine—even if the exhaust valve is light, and your Spintron testing without combustion does not seem to warrant it."

Similarly, observed Loden, "When the cam profile is optimal but the spring pressure is excessive, using a pushrod with less-than-adequate stiffness can lead to durability issues." He added that CV Products' X2 line has expanded both its tapered and straight pushrod lineups to include half-inch-diameter units, in addition to the 3/8-, 5/16- and 7/16-inch sizes already offered.

Speedmaster, said Verduzco, is "excited to release a new range of one-piece, chromoly swedge-end pushrods, made from the highest-quality material," and priced only "slightly higher than OEM-style pushrods." In general, he continued, Speedmaster manufactures pushrods to a "one-quality-fits-all ideal; i.e. mid-market priced with the best available quality."

Erson now offers 5/16-inch pushrods with a .120-inch wall, "for small block applications where larger diameter pushrods won't fit," said McInnis.

Weber noted how "thicker tubing, using top-quality chromoly material, allows our pushrods to keep pace with



The endless pursuit of "stronger materials and more precise manufacturing techniques have provided us with the ability to supply reliable lifters to engine builders," according to a leading supplier, "giving them the confidence to add more camshaft lift, greater ramp rates and increased spring rates." Photo courtesy of Jesel.

the other components that are integral to a valvetrain that functions properly under extreme load conditions." Engine Pro offers a variety of thick-wall pushrods, "including our new Nitro Black series," said Weber, which is actually three series. First, the 5116 Series features a 5/16-inch diameter with .116-inch wall thickness. These provide the extra strength required in applications that lack the clearance for larger-diameter pushrods. Next is the 3121S Series, with a 3/8-inch diameter and .120-inch wall thickness. Finally, the 3141S Series has a 3/8-inch diameter with .140-inch wall thickness.

"All of our Nitro Black pushrods are made with 4130 seamless chromoly tubing," Weber continued, "and have a .210 radius on the rocker-arm end for higher-lift applications. They are carbon-nitride hardened to 60–62 Rc, and, like all of our 4130 pushrods, are matched in sets to within plus-or-minus .005 overall length."

Chromoly tube is still the material of choice for custom pushrods, reported Pierre Chango from Smith Brothers Pushrods, Redmond, Oregon, and the trend is a big diameter, thick wall tube for extreme duty engines. "We are always looking at different materials and have done some testing, but haven't found a replacement or better offering than the chromoly tube. We have also been working with different materials and coatings for the pushrod tips to support these high power applications today," he said.

Smith Brothers Pushrods has made design changes to some of its bigger diameter pushrods that require a taper for additional clearance in some applications. Chango noted, "These changes offer the necessary clearance while offering more pushrod strength and reliability."

A Strong Future

Where is the industry headed with these components? According to Jamora, the trend toward "concave, hollow or inverse-radius cams has just about run its course," as people recognize that such designs ultimately limit both rpm and valvetrain control. "Now we are seeing more customers who appreciate properly designed cam lobes that capture high lift area without stepping over the line."