What's Driving Evolution In RACING CAMSHAFTS

By John F. Katz

JUST AS THE SHAPE of the cam guides the motion of the valvetrain, the engineering of the valvetrain influences the shape of the cam. It's a cyclical process—evolution driven by feedback—and in today's fast-paced racing environment, the mutations can come fast and furious. "We are continually developing new profiles for roller-lifter, flat-lifter and overhead-cam engines," reported John Partridge of Bullet Racing Cams, Olive Branch, Mississippi. "We are generating new profiles almost every day—because the demands of racing are changing almost every day.

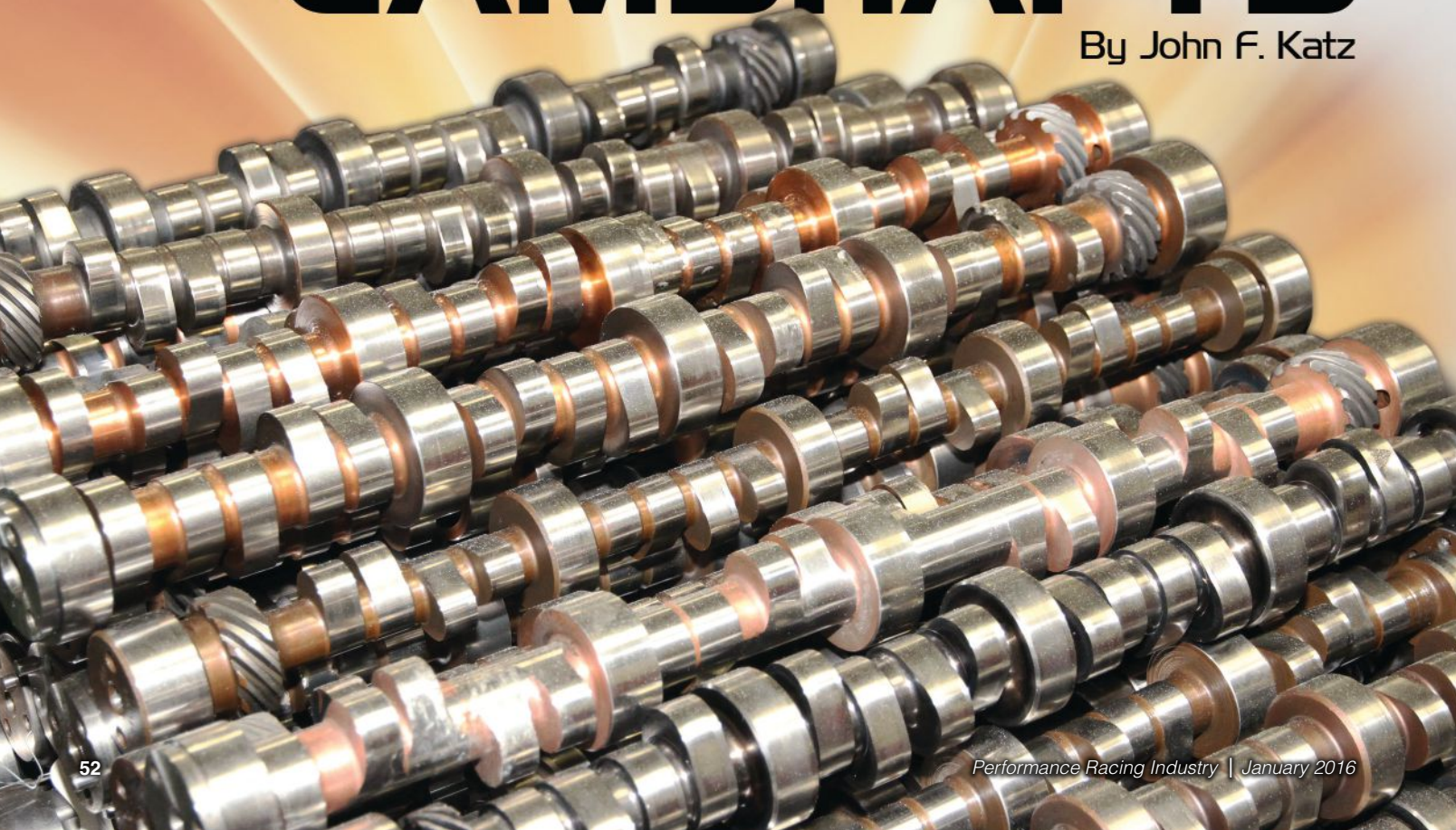
"Journal size is increasing almost daily," Partridge added, "along with lifter size and wheel requirements. Additionally, we are working with different materials—S7 tool steel, for example, for which there is increased demand even in the sportsman classes. Tool steel has greater load-bearing capabilities due to the stronger substructure of the lobe, allowing for higher spring pressure and valvetrain loads."

Indeed, tool steel may be the biggest story in camshafts at the moment. But we investigated some other trends as well. Many racing venues still mandate flat tappets, which require specialized cams. Not everyone agrees about how, or even if, bushing-style roller lifters have affected camshaft design; but most concur that larger-diameter lifter wheels have encouraged more adventurous cam profiles. Overhead-cam heads, now standard on Ford V8s, as well as just about all compacts, are exerting some influence, too. Finally, we asked our experts to tell us what their customers ask them about cams—and how they answer.

Tool-steel Tough

As we mentioned above, the big trend of late has been the increased use of tool steel. "That's the biggest change we've seen this year," said Billy Godbold of COMP Cams, Memphis, Tennessee. "More and more of our customers have been moving from SAE 8620 and 5160 cores to tool steel."

"That's the big thing," echoed Duane Boes of Callies Performance Products, Fostoria Ohio. "Tool steel cores are a little more expensive, but considerably more durable. And they



Manufacturers of camshafts for racing applications are continuously developing new profiles for roller-lifter, flat-lifter and overhead-cam engines. In fact, one supplier reported that his company generates new profiles on a regular basis—because the demands of racing change nearly every day. Photo courtesy of COMP Cams.

can be re-profiled several times and still have some durability left. So if someone buys a tool-steel cam and runs it, then decides they'd like to change the separation a little bit, or change the lift, they can do that. Or if it's a cam that they really like, and they run it a long time, and the lifters start tracking the lobes, the heat-treat is deep enough that they can re-profile it and still have a good part."

Not surprisingly, high-end racers were the first to invest in tool-steel camshafts, but Boes said they are now used throughout racing, from World of Outlaws sprint cars to weekend bracket drag racers. "It depends on how comfortable they are with what they are doing," Boes added. "Do they want to stay with the same firing order?" Changing that would require an all-new camshaft. "But if a team has a program that's pretty well settled in, they tend to like tool steel because they don't have to worry about it."

Rollers & Sliders

Boes did remind us of the one segment that tool steel cams will not penetrate: "Flat tappets require a nodular iron cam. So those racers are never going to be interested in tool steel."

"And there are still lots of venues where flat tappet camshafts are required," added Chase Knight of Crane Cams, Daytona Beach, Florida, "especially where there are claimer rules."

And flat tappets, while seemingly unsophisticated, are not without advantages. "Roller lifters are always heavier than a flat or sliding tappet," Godbold noted. "In

Rapid developments abound throughout the category, from new profiles and journal sizes to the growing use of ultra-durable materials.

F1, IndyCar, and the old CART series, all of the tappets slid on the cam face. NASCAR switched to rollers to reduce cost, relative to the DLC coatings the teams were applying to their flat tappets. Roller tappets certainly make it far easier to run high spring loads, and that is why they have been the best choice for NHRA Pro Stock engines turning up to 12,500 rpm. Even the best coating would not hold up well under 1500 pounds of open spring load."

Knight also sees continuing potential for flat or sliding tappets in overhead-cam applications, where "the radius pad found in many heads may well offer performance advantages over a roller, as lobe designers can take advantage of this larger radius to be more creative in their designs. But in a pushrod engine, a flat tappet cannot produce the power band that a roller can."

The Overhead Influence

Godbold sees particular potential—and a potential difference in cam profiling—in overhead-cam engines packing multiple valves per cylinder. "Four-valve engines see major improvements in low-lift flow, and need far shorter seat timing for a given flow potential," he explained. "This leads to shorter cam timing and a flatter torque curve"—as opposed to a two-valve engine, where generally some low-end torque must be sacrificed to achieve high-end power. On that note, Comp Cams is expanding its Ford Coyote applications for 2012–2014. "The 2011 engines sometimes have clearance issues with the hydraulic adjuster," Godbold added, "but they can be modified."

"Some of our newest designs are for late model engines such as the SOHC Modular Ford," said Eric Bolander of Erson Camshafts, Louisville, Kentucky, although "we are making these cams primarily on a custom basis, partly because of the way these engines were manufactured, and partly because many of our engine-builder customers are less familiar with overhead-cam designs than they are with traditional pushrod engines. The custom approach ensures that the cams will install and perform as desired with

the specific cylinder heads that our customers are using." Ford made running changes during production, which can make this a challenge.

Knight, however, cautioned us that "customer expectations get a bit complicated when comparing pushrod-OHV engines with the newer families of OHC powerplants. In the 'good old days,' you could bolt a camshaft into a 350 Chevy and pick up 40 horsepower with virtually no other changes. In a modern OHC

Whether they choose stock camshafts or custom offerings, racers and engine builders have multiple options to consider. For example, one manufacturer noted how journal size is increasing "almost daily," along with lifter size and wheel requirements. Manufacturers also are utilizing different materials, including tool steel. Pictured here are camshaft main bearings being ground. Photo courtesy of Callies.

engine, a gain of 8 horsepower from a cam change may be considered a good move, as these engines are already scienced out quite well from the factory."

"Typically, a high-performance camshaft does not deliver the same percentage increase in power in an OHC combination as it would in a pushrod motor," confirmed John Steely of Howards Cams, Oshkosh, Wisconsin. "Usually OHC motors are pretty well optimized from the factory. So a large increase in power requires more parts than just a camshaft—and/or more boost."

Bearings to Bushings

Of course, roller lifters themselves divide into the bushing and bearing types. Each have their advocates, and we found a wide range of opinion regarding the effect of bushed lifters on camshaft design.

"Lifter-wheel bushings can operate under higher loads than needle bearings can generally sustain," said Bolander. "This means we can use very aggressive cam profiles, along with the higher spring pressures they require, and still maintain good valvetrain stability."

Nolan Jamora of Isky Racing Cams in Gardena, California, was even more enthusiastic, stating, "Our patented EZ-Roll technology has allowed us to push the boundaries of camshaft design." He described how needle bearings tend to skew and quiver once per revolution, as they momentarily misalign at lash take-up. "But that's no longer a factor with our proprietary Epsilon-ZX and Zmax NRT bushing materials."

Steely, however, dialed the enthusiasm back a bit. "The biggest benefit seems to be the ability to increase spring pressure without compromising the lifters' life cycle. In race applications, we have not seen much need to change lobe designs. We have seen a lot more street runners with big, aggressive cams switch over to bushed lifters, which allow them to set a tighter lash."

And Godbold was even more circumspect. "Bushing lifters certainly have added durability to the wheel-and-axle assembly in harshly loaded applications; but their effect on cam design is not extreme," he explained. "Cams used with bushed lifters do tend to have a shorter life on the opening side, as the wheel slows down some over the base circle, then catches on the opening ramp—similar to the way airplane tires smoke on landing. Over time we may see that bushing lifters work better with both tighter lash (to provide more oil drag on the wheel along the base circle), and perhaps a slightly convex cam surface (less than 0.0002 inch larger in the lobe center than at the edge). That has been

the focus of our experimentation. We have absolutely seen that our ST4 tool steel reduces this type of wear when compared to either SAE 8620 or S7 tool steel."

At Melling in Jackson, Michigan, "We see no effect at all," said George Richmond. "The cam profile doesn't know if the tappet roller has needle bearings or not. You might notice some difference in the endurance of the engine." Whereas, "the diameter of the tappet wheel has a major influence on the cam profile."

And with that statement, nearly everyone agreed. "Bigger wheel diameters have more influence on cam design than bearing-less roller wheels," Partridge confirmed, "although bushing-type lifters do have somewhat greater fatigue resistance, and we do take them into account if we know the customer is using them."

Bigger, Wilder…and More Expensive

Meanwhile, the trend we noted last year toward bigger-diameter cores continues unabated. "Larger-journal camshafts are still very much in demand," said Knight, "although some sanctioning bodies have adopted new rules to keep folks from getting carried away. The improved torsional and beam stiffness allow increased power levels with improved stability and durability." Crane, he added, receives new inquiries regarding large-journal cams nearly every day. "And we frequently make them from tool steel, as the superior material provides a cost-effective upgrade."

"Large-diameter cam cores are still trending up," Bolander agreed, "and likely will continue to do so as long as blocks are available to accommodate them. With the larger cam core you can use more lobe lift and less rocker ratio, producing a more stable valvetrain. The primary restriction at this time is the diameter of the lifter and lifter wheel. With the larger cam lobes, wheel speed on the lifter increases—although a larger-diameter lifter wheel will help bring the wheel speed back down."

"At one time 50 mm was big," said Partridge. "Now we sell more 55-mm and 60-mm cams than 50 mm. We have made almost any size you can imagine:

65 mm, 68 mm, 70 mm, 78 mm, 80 mm, and larger. There is a practical limit, but we're not there yet, and might never be due to continual development."

Meanwhile, Godbold noted, NASCAR, at least, has set a legal limit, and it's 60 mm. "Most professional drag race camshafts are 65 mm or larger in effective journal diameter. (Clam-shell bearings are gaining in popularity.) Some builders went from 70 mm to up above 80, but to date, we have not seen any performance benefit above 70. We actually prefer an effective journal size closer to 65 mm, and a follower wheel that's as large as possible (i.e. about .950 inch) for professional drag race applications. For endurance racing and sportsman drag racing, 60 mm is a very good size, with an 0.800 to 0.850 roller wheel. Anything below 60 mm does have some disadvantages above 0.800 inch valve lift."

Inverse-radius cams remain popular as well. "As high-grade components such as bushed roller lifters, large cam core diameters, and heavy-wall pushrods have become more available and affordable," said Bolander. "These 'radical' cams have become more user-friendly, making great power in applications where no one would have considered using them even five years ago."

Howards continues to offer "a number of inverse radius lobes," said Steely. "When used in proper applications, with the appropriate care taken in design, we have seen no durability issues. Some of our competitors make what we like to call 'magazine lobes'—not much good for anything but a dyno pull for a magazine article, as you could not afford to replace the valve springs and other parts it would break on a regular basis."

"Inverse radius grinds are valid," Knight agreed, "especially where rpm's may be limited. They will provide a great broad torque range, possibly at the expense of valvetrain upkeep. Initial cost is increased, as grinding time might be doubled. So, sure, get aggressive, make more power; but be prepared for your component—and maintenance—costs to go up."

"Extreme-action 'inverse radius' or 're-entrant' cam profiles, identifiable by their concave or hollow flanks, look radical," added Jamora, "but their proper place is in more controlled rpm conditions. When this limitation is observed, their high positive acceleration pulse (and 1–2 degree reduction in seat duration) can offer a slight benefit in overall performance. Problems arise when such cams are run at high rpm because the valvetrain becomes difficult to control. They are particularly hard on needle-roller lifter bearings. Valve float also means lifter rebound and impact issues. So if an inverse-radius cam is going to be employed, it is imperative to use needle-free lifters, such as our EZ-Roll, to prevent off-the-charts risk of lifter wheel failures."

"This is something we will be investigating closely over the next few years," said Godbold. "On any camshaft with a base circle less than one inch, there will always be a strong need for inverted-radius cams to accelerate the valves. With larger base circles, you can move the tappet quite rapidly without going inverted. How close to inverted the flank is, or how steep the pressure angle might become, is actually far less important to us than the actual valve acceleration. We could make one cam for a 1.5:1 ratio that was very inverted, then another with a 1.8:1 ratio that was not inverted, but producing the exact same valve motion—and they would behave very similarly."

Custom Cams

Another continuing trend is a growing demand for custom-ground camshafts. "In racing," said Richmond, "every advantage you can get over your competitors is critical. This is why custom cam grinds are so popular. You can gain big advantages if you do your homework."

"Demand for custom cams is steadily increasing," Knight agreed. "Everyone wants something tailored for their specific application. Even if the best cam is already in our catalog, folks will insist on something different—as if they'll be looked down upon for choosing the dreaded 'catalog cam.' This applies to all forms of racing, and even street applica-

tions. However, the difference in cost may be doubled (or more) between a mass-produced cam and a custom grind, and this can deter the custom sale."

Somewhat counter-intuitively, heavily restricted circle-track classes have provided some of the most fertile ground for custom grinds. "In fact," said Partridge, "a rules-restricted class is the perfect storm for a custom cam. We can alter any parameter using a given lift, vacuum rule, or camshaft configuration; and we do not charge extra for this service."

"Lots of folks don't understand that there's no magic cam that can cure a combination of poorly chosen components," reported one camshaft manufacturer. To avoid this scenario, another source advised matching the camshaft to the customer's combination, including engine size, cylinder head, and rocker ratio; also to be factored in are the weight of the vehicle, the type of transmission and gearing, and, of course, the type of racing. Photo courtesy of Crane Cams.

"Rule-based restrictions have actually increased the demand for custom grinds," Godbold confirmed. "The tighter you hold the engine specs, the more valuable a slight performance advantage becomes. All of the Pro Stock teams are already ordering cams for next year's rules package, which includes EFI and a lower 10,500 rpm limit. In NHRA Factory Stock, the 6.75-inch lift limit has increased the number of cams the teams are testing; we have 10 different lobe series specifically for the COPO, Drag Pak, and Cobra Jet cars.

"On the LS side," Godbold continued, "custom grinds are becoming more popular in our ESI, ESX and LSG series."

Jamora agreed, adding, "The strongest market for custom cam grinds is and has been for some time the Chevy LS engine platform. Because of their

lighter valvetrains, these engines are capable of high rpm, and so demand for custom cams for both normally aspirated and supercharged/turbocharged applications has grown steadily. We supply multiple engine builders who prefer their own grinds, and a few specialty shops that build high-end motors for street use in Cadillac and Corvettes."

"Our custom camshaft sales are growing every year," added Bolander, "for almost every type of performance application, with circle track and street performance growing the fastest." Erson is also selling more custom cams for the Super Stock and Light Super Stock classes in tractor pulling, reported Bolander.

Supporting Role

Dura-Bond Bearing of Carson City, Nevada, specializes in camshaft bearings for high-performance and/or low-volume applications. New from Dura-Bond are coated bearings for the GM LS blocks (including the Dart LS Next,) and a complete cam bearing set for Chrysler's 5.7-liter Hemi. "Previously, you had to buy a new Hemi block to get a new set of cam bearings," noted Chuck Barnett. "But we've designed a replacement bearing set that will fit an existing block." On the LS engines, the fluoropolymer coating addresses wear caused by marginal lubrication in certain applications.

Materials and manufacturing set Dura-Bond's hydrodynamic cam bearings apart from the stock units they replace. OE cam bearings are manufactured by sintering powdered metal to a flat steel strip, which is subsequently formed into a full-round shell. The process requires expensive tooling, so business economics dictate large production runs. Dura-Bond, on the other hand, spin-casts bearing material into a pre-welded steel tube four or five feet long. "And then we cut the tube to make individual bearings," Barnett explained. "Tooling cost is minimal, so we can run as few as a couple of hundred pieces." The process also allows Dura-Bond to hold tighter tolerances than would be possible for a strip-type product. "We can make an oversized OD to replace a cam bearing

that's spun in its housing. We offer undersized IDs for camshafts that have been ground or polished down in size. We offer bearings .001 under in ID to increase oil pressure in engines that have been rebuilt multiple times." Custom grooves and holes can provide "a whole host of fixes" for various lubrication issues.

For its bearing surfaces, Dura-Bond uses SAE 13 Babbitt, which is slightly softer than the copper-lead material favored by OEMs, which is more forgiving of a less-than-perfect alignment. That's a boon to engine builders who don't have line-boring equipment. Dura-Bond also makes bearings for some overhead-cam applications, including the 4.6- and 5.4-liter Modular Ford V8s, as well as some popular imports; but according to Barnett these are intended more for volume engine rebuilders rather than performance applications.

Cam Questions

Finally, we asked our experts to relay the most common cam-related questions posed by their customers. How do they answer? And how do they steer their customers clear of some typical mistakes?

"The most common question," Partridge responded, laughing, "is 'How do I get my 283 Chevy to make 800 horsepower?' Everybody thinks a camshaft can solve all their horsepower problems."

"What's the biggest camshaft I can run?" echoed Ivan Korda of COMP Cams. "Most people who ask this question truly do not understand the camshaft's purpose, or the numbers associated with it. We do our best to educate the customer, to help them understand why a particular camshaft is correct for their application."

"Lots of folks don't understand that there's no magic cam that can cure a combination of poorly chosen components," Knight added.

Partridge explained, "The most common problems arise when customers install a camshaft that's too large in duration or lift, and/or too aggressive in rpm for their existing valvetrain. What we do instead is match the cam to the combo the customer has—including engine size, cylinder head, and rocker ratio; plus the

weight of the vehicle, the type of transmission and gearing, and, of course, the type of racing."

"The biggest mistake that people make in selecting a cam, whether for street or competition, is 'over-camming,'" added Jamora. "Since cams often cost about the same regardless of their lift/duration specs, customers are often influenced

Materials and manufacturing processes are just two of the areas in which camshaft bearings for auto racing differ from their OEM counterparts. For example, smaller product runs allow Dura-Bond to manufacture an oversized OD to replace a cam bearing that's spun in its housing. The company also offers undersized IDs for camshafts that have been ground or polished down in size, as well as bearings .001 under in ID to increase oil pressure in engines that have been rebuilt multiple times.

by friends or other racers to go unnecessarily large. Nothing is worse than an engine that is over-cammed; it runs so lethargically." Another "problem area" is the "increase in cheaply sourced offshore components such as timing sets, which we frequently find are improperly indexed by several degrees."

According to Richmond, the most common mistake is to build the engine first, and then try to select the best camshaft for it. "What they should do is answer all of the cam designer's questions about the application and its intended use, have the cam made, and

then build the rest of the engine with the components that will best complement the camshaft."

"Improper selection, installation and/or maintenance will cause a loss not only of power, but usually is a big hit in the pocketbook," remarked Michael Hughes of Howards Cams. "You have to work closely with your engine builder, who in turn has to work closely with a cam grinder they feel comfortable dealing with. Developing that trust with the customer is most important."

That said, Hughes continued, "In the last few years, customers have asked more relevant questions about the specific materials used in the cam core, and about lifter construction"—in addition to "manifold vacuum, idle quality, power output, and rpm range. We work hard to get the most relevant information from our customers, so we can guide them toward their goal."

"Our customers' questions are important," Knight concluded, "and we do our best to answer each one. Usually, however, we ask the customer more questions than they ask us. If the customer doesn't have the answers, it becomes difficult for us to provide good results. ('What's your compression ratio?' 'I haven't decided yet.' Sometimes, the customer criticizes us for asking too many questions!) It's a well-planned overall combination, sensibly thought out, with reasonable expectations that will provide the greatest satisfaction to the customer. If we're considering mild street performance, or a marine application, then the challenge is to create a profile that will increase performance without reducing reliability or producing excessive valvetrain noise. Compromises can be made in any direction, so it's a matter of understanding the individual customer's goals—and what they may be willing to sacrifice. In racing, there's always a tradeoff between power and reliability: Do you want to change valve springs every weekend, or go a season with only basic maintenance? We can take you in any direction, but you have to be realistic." PRI