SUPERIOR TO STOCK: AFTERMARKET ENGINE BLOCKS, CYLINDER SLEEVES, MAIN CAPS

OLD ENGINE BLOCKS once worked pretty well for racing, but those that did dropped out of production decades ago, and were already disappearing from the scrapyards by the time today's entry-level drivers were born. The OEMs still make blocks, of course, but for a whole range of reasons—mostly to shave weight—they literally don't leave much room for modification. So today more than ever, and for the foreseeable future, racing relies on, and will continue to require dedicated aftermarket engine blocks.

It's not just because of displacement constraints. "The constant increase in horsepower requires ongoing development and adaptation," observed Gary Allison of Donovan Engineering, Torrance, California. That includes "beefing up stressed areas with more material, improving material and casting procedures, rethinking the removal of material, and updating machine programming and tooling procedures."

"Today's aftermarket manufacturers use the envelope provided by the OEM design," noted Kevin Feeney of RHS, Memphis, Tennessee, "but beyond that they have a clean sheet of paper to incorporate the features and benefits they feel the market wants. Strength is the first area addressed. OE blocks are designed for the power level of the stock engine, while maintaining a lightweight engine package for fuel economy. Aftermarket blocks address cylinder wall thickness, deck thickness, and other structural reinforcements to provide the strength required for the higher horsepower levels encountered in racing—especially with the use of power adders."

"When you buy a new engine block," added Rick Wilkinson of Alan Johnson Performance Engineering (AJPE), Santa Maria, California, "you are choosing the foundation for your new engine combination. [And] with the advances in today's CAD software and CNC machinery, the options are endless."

Improving On Stock

It's important to remember that those old-generation engine blocks, with all that extra iron for boring and machining, were never engineered for racing, either. "Every block has design flaws, or characteristics which need to be removed or eliminated," said Bill Mitchell Jr. of Bill Mitchell Products (BMP), Ronkonkoma, New York. "We go after strength first; that's the most important feature we can provide. We continue to improve the strength of all of our blocks, based on the failures we've seen in blocks from other manufacturers. We've not had a broken

Advances in CAD software, CNC machining and more are creating virtually unlimited possibilities in an increasingly diverse marketplace.

block or warranty issue in the past five years." Aftermarket designs also seek to improve rigidity, lubrication, and, of course, "dimensional improvements for larger displacements."

"When designing an aftermarket block," added Jack McInnis of World Products, Louisville, Kentucky, "we typically look at two general criteria relative to the OE design. One consideration is features: What do racers and engine builders like about the OE design, and what would be on their wish list for a redesigned unit? How are they modifying the stock blocks, and how are the stock castings limiting their ability to make those kinds of modifications?" The second consideration is the failure modes of the OE design: "How do we best address those weaknesses to create a stronger, more reliable block?"

Given those criteria, "upgrading the material to higher-strength alloys, and adding material in critical areas in order to increase strength and rigidity are among the first things we do. Revising the oiling system for improved high-rpm lubrication is another, as is improving main cap design." And, of course, providing room for increased displacement: "This usually involves thicker, siamesed cylinder walls to accommodate larger bore diameters, and can also mean lengthened cylinder barrels and/or increased deck heights. There are also certain applications where reduced deck heights are desirable, so building some versatility into the castings is a good thing," said McInnis.

To that already considerable list, McInnis added provisions for additional

& BEARINGS

By John F. Katz

Aftermarket engine block and cylinder sleeve manufacturers that over the past few years have made substantial investments in CAD/CAM software and state-of-the-art CNC machining centers are now able to produce far more configurations, and in much less time. For example, one sleeve manufacturer said his company can create a new custom sleeve in as few as five days.

features such as larger-diameter camshafts, perhaps relocated higher in the block; upgraded and/or relocated lifters; extra head bolts; "and other features to take advantage of available performance-enhancing components."

Feeney cited "revised oiling, due to the higher demands created by increased rpm and higher horsepower. Rigidity is important, also because of elevated horsepower and increased cylinder pressure, and with the addition

As race engines continue to produce higher horsepower numbers, race parts engineers face corresponding challenges. When it comes to engine blocks, designers must consider beefing up stressed areas with more material; improving material and casting procedures; rethinking the removal of certain material; and updating machine programming and tooling procedures, according to one manufacturer.

of power adders this becomes an even higher priority. Design changes may be incorporated into the block, and in some cases new fastener strategies are adopted to improve head gasket retention."

Even the water jacket may require some attention. "At RHS, this is as high a priority as increased strength and CID capability. A larger engine developing more horsepower produces more heat, so it needs an upgraded cooling system," Feeney said.

And then there's serviceability: A racing engine is rebuilt far more frequently than one that runs on the street. "For

example," said Feeney, "the GM LS comes with integrally cast cylinder liners, which are a very cost-effective weight-reduction feature for General Motors—that makes servicing labor-intensive for aftermarket engine builders. Our LS block uses press-in liners for ease of replacement—and to provide the engine builder with additional material for larger bore sizes. Of course, increasing cubic-inch capability is a trend that continues across all engine platforms."

Perhaps the ultimate expression of that trend is the new wave of custom blocks with wider-than-stock center-to-center bore dimensions. "The standard small-block Chevy, with its 4.400-inch bore spacing, allows a maximum cylinder bore of 4.165," noted Jeff Brotherton of Brodix, Mena, Arkansas, "where the 4.500 spacing of our aluminum block allows the engine builder to use up to a 4.250 bore."

Block Stories

To help us understand the process even better, a few manufacturers recalled for us how some specific products have evolved. "Racers need reliable performance," said Allison. "When we introduced the Donovan 350 aluminum block, based on the iron small block Chevrolet, we improved the main cap design from a two-bolt to a four-stud configuration. As horsepower demands grew, the outer studs were angled into the pan rail—first 10 degrees, then 15, and now 20. And we raised the cam to improve rotating assembly angles." Oiling was another issue. "The original 350 block design gave priority to the cam. Changing to priority oiling of the mains simplified plumbing and strengthened the main web."

Donovan also offers cast aluminum Chevy big blocks, in 454 to 800 CID. "Our first change from the OEM 427 was a 3/4-inch wider pan rail with bigger main caps," he added. "Then the cam was raised .391 inch—the length of one link of the timing chain. Today we offer 19 different configurations, all with the original, OE motor mount locations."

To illustrate changes in material, Allison cited the Donovan 417 Hemi.

ENGINE BLOCKS, CYLINDER SLEEVES, MAIN CAPS & BEARINGS

"The original sand casting was a sodium-modified 356, heat-treated to T6 standard. Today our 417 is cast from strontium-modified 356B, hipped, and given a special heat-treat. And since 2011—in honor of its 40th birthday—we've offered it in billet 6061 as well," he said.

More recently, World Products has redesigned its Man O' War cast-iron Ford small block. "The material was upgraded to a 40,000 psi iron alloy," said McInnis, "and the thickness of the main webs and bulkheads was increased, with .080 inch added to the front bulkhead and .030 to the center three. Additionally, the standard half-inch main cap fasteners were changed to 7/16-inch units from ARP. While going to a smaller-diameter fastener may seem counter-intuitive, it actually adds strength because it leaves more material in the bulkheads. And while bulkheads are a common failure point in OE blocks, fasteners typically are not."

Wilkinson said, "Aftermarket manufacturers react to their customers' wants and needs. Our AJPE billet Hemi block has evolved considerably from the original 426 Hemi that Chrysler debuted in 1964. Both design and material have changed so that this engine platform can withstand the cylinder pressure and engine speed of today's nitro-methane and alcohol engines—and still maintain the same bore spacing and deck height of the 1964 OEM original." (Author's note: The twin-carburetor, 12.5:1 drag race Hemi was rated 425 hp by the factory in 1964.)

BMP's new, all-aluminum 409 "W" block is now available. Developed in conjunction with Lamar Walden Automotive, the BMP 409 accepts the more common internal parts designed for the Mark IV big block Chevrolet, including crankshaft, rods, oil pump, oil pan, harmonic balancer, and timing chain cover.

The Aluminum Advantage

Of course, many aftermarket blocks are manufactured from aluminum, which is not only lighter than iron but easier to machine. Aluminum does, however,

continued on page 64

continued from page 54

present some challenges. "Aluminum is not quite as tough as cast iron," noted Brotherton, "and so requires more thickness and valley bracing. Tolerances also change because of aluminum. Oiling advances in dry sump systems have led us to change oil hole sizes. Our goal at Brodix has always been to continue to refine each part of our products, and in our engine block program, we have worked very hard in the areas of durability and oiling. We also have improved cylinder sealing with additional honing of the sleeves, which is the most important aspect of increasing horsepower."

Brodix blocks are 100 percent machined in-house, and the company's manufacturing program also makes options available. Sprint car and late model bellhousing configurations are offered, in addition to the standard Chevrolet pattern. Standard (4.840) bore-space big blocks can be finished in deck heights ranging from 9.800 to 11.625. Lifter-bore choices cover .842, .845, .903, and .937. "We make our small blocks with 350 or 400 mains," Brotherton added—and either way, billet main caps are standard—"and babbitt cam bearings from standard to 60 mm."

Main Caps

When designing these new products, consideration must be given to the original cylinder block design and the integration of other parts, such as main girdle support systems, said Samantha Michalewski of PRW Industries, Perris, California. "Many of the OEM blocks were weak in the main journal web structure area. Trying to convert an original two-bolt block to a four-bolt main cap design is not always beneficial." She cited Ford 302 blocks as an example, which suffer from a weak cast iron support structure for main journals. "For that reason, PRW does not offer a four-bolt 'conversion' main cap for these applications. Instead, we suggest our standard two-bolt steel main cap, combined with a steel main girdle designed to fit accordingly, as the best answer.

"In our experience, engine builders have specific personal preference related to engine bearing selection," she added. "At PRW, we try to focus on maintaining the best machining standards in order to meet the fitment demands of engine bearing manufacturers. All steel main caps require align boring and minor fitment refinements to the individual cylinder blocks."

While OE engine blocks may provide a basis for design, aftermarket engine block companies expand on that foundation to incorporate race-specific features and benefits. And, one contact noted, strength is often the first area to be addressed. Photo courtesy of RHS.

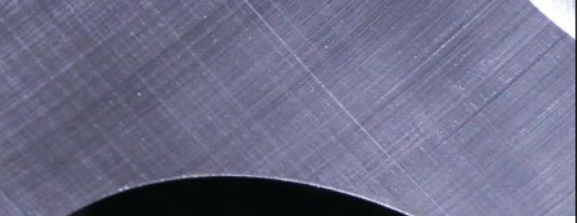
Michalewski noted there are several opinions about the "best" alloy steel for main cap applications. She said PRW customers are satisfied with 1045 steel because it offers adequate strength and excellent machining qualities, and meets high quality standards.

The newest PRW designs include main caps for the Ford FE and an accompanying main girdle. "We are expanding our Performance Quotient premium line main girdle offering to include the Stoker Series," she added.

Tailored Sleeves

The architecture of modern OE engines is also increasing demand for aftermarket cylinder sleeves. In fact, racers and other enthusiasts who choose any late-model stock block will find custom sleeving a prerequisite for any significant displacement increase.

John Catapang of Darton International in Carlsbad, California, pointed out how the trend at the OEM level continues not only toward smaller displacements, but also toward physically smaller engines, with factory bore sizes as large as the stock architecture of the block permits.



(From the OEM's viewpoint, the engine has been made as small and light as it possibly can and still accommodate the desired bore.)

And, of course, the great majority of these new down-sized blocks are aluminum. Gray iron liners may be cast integrally with the block, or the bore may be plasma-sprayed with iron, or coated with Nikasil (i.e. nickel-silicon-carbon). Additionally, advances in head gasket design are allowing tighter center-to-center bore spacing. "BMW is down to four mm of metal between bores," noted Steve Demirjian of Race Engine Development (RED), Oceanside, California—while at the same time, "the demand for stronger cylinder walls is increasing because of advances in supercharging and turbocharging. Racers are now sending over 1000 horsepower to the drive wheels from a two-liter, four-cylinder engine."

"Bore spacing is decreasing, and it's not going to stop," confirmed Dave Metchkoff of LA Sleeve in Santa Fe Springs, California. "And we don't necessarily think that's a bad thing. Castings have advanced, and the OEMs are bringing a better product to the consumer. And those better materials make our cylinder sleeve kits a viable option. Those thinner block castings have forced us to improve our sleeve material—thinner, but equally as strong as the thicker sleeves of the past."

Catapang agreed that boring the newest blocks out beyond their stock displacement requires substantial sleeves. "Sleeving typically creates a stronger containment envelope than can be provided by aluminum," he explained. "In addition to providing a superior wear surface, Darton sleeves increase cylinder strength by 400 percent—so the performance engine builder can further modify the engine for additional power and torque, assured that the basic structure can stand the punishment."

Regular readers are now familiar with Darton's MID system (for Modular Integrated Deck), in which not only the original cylinder bores, but all of the

ENGINE BLOCKS, CYLINDER SLEEVES, MAIN CAPS & BEARINGS

block material between and around them is machined out and replaced with individual, self-supporting wet cylinder sleeves. Demirjian is a co-patent-holder on the MID system, and a new joint product from Darton and RED is a MID kit for Dart's LS Next aluminum block. "We worked with Richard Maskin and Dave Tratechaud at Dart," said Demirjian, "who from the outset designed the dry-sleeved LS Next aluminum block with MID capability."

"An LS Next block with a MID kit will make 2500 horsepower, with longevity, at one-third the cost of a billet block of similar displacement," added Rob Severns of Darton. "Many MID-equipped blocks are being tested now to prove this claim. Our MID kit will provide an alternative to a very expensive billet block."

According to sales literature from Dart Machinery, the maximum bore for the iron LS Next iron block is 4.220; for the aluminum version this is reduced to 4.165. But with the Darton MID kit, an aluminum LS Next block can be bored to the same 4.220 inches as the iron version. Additionally, Darton offers MID kits for the stock LS1/LS6 and LS2/LS3/LS7 blocks, and "will roll out a kit for the traditional Chevy small block in late 2015."

Leaving aside the particular features of the MID system, Demirjian explained why wet liners in general offer significant advantages over their dry counterparts. "A dry liner depends on the block casting to keep it round in service," he said, "so any distortion of the block will also distort the liner." The main advantage of a dry liner is that it is less expensive to manufacture and install.

Meanwhile, Darton's use of Solid Works software for engineering design and CNC programming has allowed "us to be more responsive to our customers' design requests," said Severns. "We can now create a new custom sleeve in as little as five days, where in the past reverse engineering used to take weeks."

"Custom sleeves have always been a staple of LA Sleeve," Metchkoff said. "We've dedicated a feature on our website to provide hope to people

whose projects seem hopeless. We do see swings in demand for custom work; it seems to fluctuate with the national economy." All LA Sleeves are manufactured from the company's "proprietary Moly2000 ductile iron. Ductile iron's metal properties provide greater stability and memory—where memory means the sleeve will return to size better after the motor's been under a boosted load."

Conventional gray iron, in comparison, "is not as stable," said Metchkoff, "and out-of-roundness will result in blow-by." That said, "we are on the verge of announcing a new gray iron alloy which will rival ductile iron's reliability—with a one-third reduction in cost. We're hoping to complete testing by July 2016."

Darton currently offers sleeves in three grades of ductile iron, "depending on the customer's need, price point, and expected durability," Catapang explained. "Our current top grade is used in all of our sleeves for NHRA Top Fuel and Funny Car." These strong centrifugal castings, which are not heat-treated, test at 140,000 psi in tensile strength, and 90,000 in yield, with a hardness of 300 BHN (roughly 32 Rc) and a density of 500 nodules per square millimeter.

Bearing Up

As we mentioned in this space last year, lead-based tri-metal bearings still overwhelmingly dominate the racing aftermarket—but they won't forever. Health and safety regulations banning lead (particularly in Europe) have driven OEMs worldwide to explore lead-free alternatives—mostly "bi-metal" aluminum.

"With each new generation of bi-metal bearings," reported Mark Barkhaus of Speed-Pro Engine Bearings (a division of Federal-Mogul Motorparts) in Southfield, Michigan, "we've seen significant increases in material strength and wear resistance. Today, aluminum bearings are not only standard in the vast majority of passenger-car engines, but also in a rapidly expanding range of performance applications, including the 650-horsepower Corvette LT4 and the 707-horsepower Dodge Hellcat."

However, Bill McKnight of Mahle Aftermarket in Farmington Hills, Michigan, said aluminum bearings aren't yet ready for racing. "While bi-metal aluminum bearings last a long time in OE applications, they are not a good choice for serious horsepower. The hardness that gives them their long life is a detriment when crankshafts begin to flex, rod housing bores start to elongate, and oil film gets extremely thin. In those conditions, we want a bearing surface that is soft and will easily displace—like a tri-metal bearing with a relatively soft Babbitt overlay."

Mike Scott of ACL Bearing in Launceston, Tasmania, Australia, agreed. "Bi-metals tend to have both lower fatigue strength and lower anti-seizure capabilities than the tri-metals they have replaced," he said. "These constraints have required improved engine build quality, and careful control of redline speeds to ensure a reliable operating envelope. Race engine builders operate by definition 'outside the envelope,'" where they need the "toughness, adaptability and strength" of tri-metal systems.

Material isn't the only issue when designing a bearing for racing. "We have to be very careful not to blindly follow the geometry of OE bi-metal bearings," McKnight cautioned, "when we engineer a corresponding performance part. A good example is the GM LS main set. The stock bearings have very low eccentricity, to prevent oil loss at the parting line. Working with our customers who build circle track engines, we found that the tight eccentricity was causing wear problems. We were able to slightly modify the geometry, make a running change, and make everyone happy."

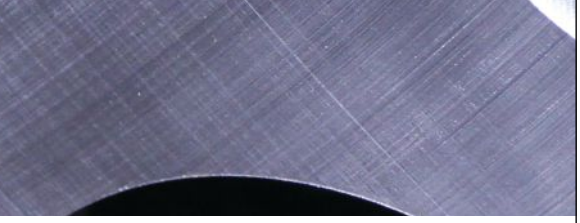
Again, Scott concurred, adding that while bi-metal technology has allowed the OEMs to tighten bearing clearances, for a race engine builder "robust lubrication far outweighs any consideration of noise and vibration."

Still, while ACL continues to improve and develop its Race Series tri-metal bearings for "the full spectrum of performance applications," the company also offers high-performance aluminum-tin-silicon bearings manufactured via "a unique casting method, using ultra-high freezing rates unmatched in the industry. This creates an alloy structure that is super-fine-grained, with excellent dispersion of strengthening additives. The result is a family of alloys that are, for bi-metals, extremely tough."

While bi-metal aluminum engine bearings may offer material strength and wear resistance in passenger cars, the racing industry requires something stronger. As a result, tri-metal bearings appear to be on the radar of some race engine builders. Photo courtesy of ACL.

And Barkhaus believes the inevitable shift to aluminum bearings "will absolutely affect and benefit the performance market, just as any proven technological advance will ultimately replace an older, less-effective solution. Performance engine design was not frozen in time with the introduction of copper-lead bearings 50 years ago." Then and now, performance engine builders and OEMs "continue to explore new ways to make more power, reduce parasitic losses, and increase engine durability. Our award-winning IROX coating has dramatically expanded the performance capabilities of aluminum bearing technology." Although technically a coating, IROX actually replaces the conventional over-plate. "It consists of a polymer resin binder that contains many additives, including hard particles and solid lubricants, that enhance all of the attributes of the bearing. We believe it represents the future of the performance engine bearing market.

"And our latest innovation, our new G-488 bearing material, takes the science of engine bearings to the next level," continued Barkhaus. The Federal-Mogul G-488 bearings feature "a lead-free copper substrate with silicon and nickel, and an intermetallic tin-nickel over-plate



that adapts to the engine's specific load and temperature conditions."

Daido Metal USA in Farmington Hills, Michigan, supplies "higher-strength aluminum bearings with lead-free copper and bismuth overlays," noted Dick Amacher, for "some of the highest specific output production engines in the world." That said, "leaded tri-metal bearings still dominate in all-out racing applications. We prefer lead-indium overlays in a variety of hardnesses, in place of more common lead-tin-copper overlays. For the most highly loaded race engines, such as turbo diesels, we use harder alloys and overlays that are stronger and wear better. Some of these combinations are finding their way into highly boosted gasoline engines as well."

Feeling Groovy

Scott reported "an increasing number of V-type engines in which the OEM has incorporated a less than full oil groove in the upper main bearing. Instead, the oil groove extends over approximately 120 degrees, and tapers out flush to the bearing running surface at each end. This provides additional support for the crankshaft, counteracting piston-and-rod inertial loads close to top dead center." Engine builders, however, have followed this feature "with mixed results. In the end, the length of the oil groove is a compromise between supporting the main journals and providing continuous oil feed. The priority for performance engines is to maintain oil supply to the highly stressed big end." So for now, at least, ACL Race Series bearings will keep their longer-than-stock 240-degree groove. "However, this is a development that we will continue to monitor with interest."

McKnight noted a possibly related trend. "Our pro drag racing customers are buying only lower main shells from us, as they prefer something less than a 180-degree groove in the upper, and make their own parts. The second thing we see is more and more customers running coated engine bearings"—as coatings improve, "and as engines are called to produce more and more power while running the same size bearing."