SUCK, SQUISH, BANG, BLOW

PART 6: THE RECIPROCATING STUFF

by Mike Kojima PHOTOGRAPHY: MIKE KOJIMA

In this installment, we are going to get into what separates the men from the boys, the racers from the wannabes, the dorks from the geeks... Um, whatever. We will look into the bottom end of the engine, the main rotating assembly, which is very important for the production of big power, but is much ignored and misunderstood by all but the most serious.

As we discussed in our first segment (August 1999), the bottom end consists of the block, crank, rods, pistons, rings, bearings, oil pump and water pump. Its job is to mostly contain the explosive force of the combustion event, changing the outward expanding combustion cloud into smooth rotary motion. For now, we'll just look at the reciprocating parts, the pistons, rings and connecting rods.

Most modifications done to the bottom end fall into two categories: stuff you do to strengthen the block so it can handle the rigors of increased power production, and stuff you can do to increase efficiency and power production for the engine's intended end application. In addition, turbocharged, supercharged and heavy nitrous using engines need some special preparation in the bottom end if they are to live long at high levels of power. Is your curiosity piqued, and are you ready to really kick some butt? Then read on, open your wallet and let's start to get serious.

BUILD IT STRONG TO LAST LONG!

It's my opinion that most Japanese engines are extremely robust when compared to some of the stuff the domestics have been putting out for years. Some engines like Toyota's old-school 2T and 3T engines and also the 3SG, 20R and 22R, Mitsubishi's 4G63 as well as Nissan's SR20DE and L-series engines are notoriously strong. The SR20DE, for example, can easily be turbocharged reliably in its bone-stock form to nearly 2.5 times its stock-rated power without internal modifications. In fact, many of these engines can match that claim, given the proper tuning and set-up. Honda's venerable B-series and H-series engines are also notoriously bulletproof. Even the weaker little brothers of these powerhouses like the Toyota 4AG, the Honda D16 and the Nissan GA16DE are fairly strong with a lot of quality construction in their make-up.

Contrary to how it might sound, this is not import-biased B.S. either. Since the background of my youth was spent blowing up small-block Ford and Chevy engines, the strength and quality of import engines never ceased to amaze me. The small-block Ford, the darling of the 5.0 crowd, in stock form, suffers from rod bolts thinner than Dave Coleman's spindly legs, weak connecting rods, flexy blocks and even more flexy head decks. The Ford 5.0 is also power bound by a poorly flowing cylinder head.

The venerable Chevy small block, the mainstay of domestic performance, although lacking any severely weak areas is only moderately strong when going for big power. When modifying these engines, it was standard operating procedure for me to massage or tweak almost every single piece in the engine from the rod bolts to the timing chain if decent power was to be reliably extracted. I spent many hours polishing rod beams, deburring and chasing holes in blocks with taps and shaving tons of metal in balancing. Lots of money was spent at machine shops having to align bore every engine and resize every rod, as tolerances were so loose. Bolts had to be replaced with studs or high-strength ARP bolts. Cranks and rods had to be shotpeened and nitrided. These domestic engines had many really stupid design features also, like plastic timing chain gears that shed teeth with a harsh word and skinny oil pump drives that would easily snap, leaving you with no oil pressure.

However, since these engines have been produced for more than 40 years and considering their extreme popularity, the performance aftermarket has been able to come up with reasonably priced solutions for every one of these engines' weak points. What is funny is that to produce a very high output and reliable version of one of these engines, you basically pitch 90 percent of it in the trash and replace the parts with trick aftermarket bits. Heads, cranks, rods and even the block all have excellent and needed aftermarket support for the domestic fan.

These engines are still the mainstay of domestic performance and can still make awesome power when prepped correctly, but they are dinosaurs, designed before most of us were conceived of and built on aging and worn tooling amortized before most of us, and even some of our parents were born. That they are still formidable weapons of power in the hands of a skilled tuner more than four decades after their invention is strong testimony to the basic soundness of their design. However, as much as the die-hards will have trouble admitting, their days are numbered except on a grassroots level or where the rules mandate their use. On the streets, there are some new kids in town, powered by imported engines.

In all fairness, new-tech domestic engines like the Ford modular series, the Duratec V6 found in the Ford Contour, the GM Northstar and even the high-tech (but still pushrod and OHV) Chevy LS-1 use many of the tolerancing, construction and engineering techniques first brought into common use by the Japanese. An interesting note is that the Japanese, Yamaha to be exact, built the Ford Taurus SHO V6. These new domestic designs incorporate steel forgings, powdered metal forged parts, tight-tolerance, high-density casting techniques and select fit parts. Many of these new domestic engines now feature multi-valve heads, overhead cams, bottom-end girdles, cross-bolting and other trick parts that were once only available in the import camps.

When I first took apart a friend's Datsun L18 about 20 years ago, my perception of Japanese engines as cheap, imitation power plants would forever change. This engine had rods that were better than any Chevy Pink or Ford K series rods—bone stock! They were made from stout forgings of quality steel, had big bolts and broached bolt bosses for more strength, stuff right out of the domestic's competition catalogs. The block castings had lots of beef in the main caps and the decks were thick and non-flexing. The castings were precise without a lot of embedded sand or other garbage. The rod's bores were round and so were the main bores—no resizing needed here. The reciprocating parts were internally balanced with a fully counter-weighted, forged steel crank. When I got into Toyota engines a few years later, it was more of the same, resizing the rods was rarely needed and neither was align boring. Parts were sometimes so close in weight that balancing was sometimes not needed. Blocks with more than 100,000 miles usually had the original honing marks still visible in them. This was way better stuff than I was used to dealing with on my beloved Chevys and Fords. My

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love affair with the import engine began and was solidified by these experiences.

To this day, although the domestics are making great strides in engineering and quality parity, import engines, for the most part, still have an edge when it comes to strength and the ability to pump out power without much work to the bottom end.

For mild performance, which includes all bolt-on naturally aspirated mods, low boost (10 psi) turbo or supercharger kits and up to 100 hp of NOS, the bottom end of most import engines can remain totally stock as long as you can avoid detonation. As I have beaten you over the heads repeatedly during this series, detonation is the number one killer of performance engines.

Some exceptionally strong import engines like the Nissan SR20DE, VG30DETT, the Toyota 3SGTE and the Mitsubishi 4G63 can take unheard-of abuse in factory trim and still survive. Up to 20 psi—and sometimes more—turbo boost has been run through these engines in stock form, with the engines pumping nearly 400 hp to the wheels. Of course, this is with exceptionally careful fuel and spark management, as detonation will kill a mega-boosted stock engine almost instantly, but it is all still very possible and even safe, if you know what you are doing. This is equivalent to a stock small-block Chevy or Ford pumping out more than 1,000 hp. Try sticking 20 psi through your Chevy LS1 or Ford modular engine and see what happens. I cannot imagine a stock small block doing that for more than a few seconds.

There are a few popular exceptions to these ultra-strong import engines. The Honda D series, the Toyota 4AG and the Nissan GA16DE have rather weak (for an import) connecting rods. These are relatively weak only when compared with what some of their big brothers can do. They are still fairly strong, as engines go, with the same tough features, just that the internal bits are scaled down a bit. On these engines, the revs should be kept below 7500 rpm and perhaps NOS should be limited to a 50-hp shot or 8 to 10 psi of boost. Granted, this is still pretty strong considering the small size and displacement of these engines, but these limits should be remembered and adhered too for long-term durability.

WHAT IS BLUEPRINTING?

This is a question that I hear time after time. Blueprinting is not some weird magic, nor is it snake oil. Blueprinting is merely the process of shifting the tolerances of the engine to the side of the tolerance that will give you the best power. Blueprinting usually makes a huge difference power-wise in domestic engines, with their large-clearance variations; but the improvement is less drastic in most import engines, because their tolerances are controlled much more tightly from the factory.

Many experts feel that the most important aspect of blueprinting is getting the bearing clearances to the loose side of the specs to reduce friction. Most experts also feel that getting the piston-to-cylinder wall and ring end gap clearances to the tight end of the spec in order to maintain good ring seal and reduce blowby is important. Of course, other experienced engine builders will have differing opinions on this, but the important thing is to make sure that the clearances are all equal and controlled.

My personal take on this is that in order to maintain better long-term ring seal and to maintain bearing oil pressure, you always want to try to maintain the minimum clearances on the pistons, the crank and rod bearings of any engine for longer life and less oil sling-off (which can increase windage-losses). On an SCCA showroom

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stock class engine, where no mods at all are allowed, I might run bottom-end bearing clearances a little looser, towards the middle or larger side of the clearance spec but everything else, like the pistons get clearances towards the tighter side of the spec.

Blueprinting bearing clearances on import engines is easy because they feature select fit bearings. These are bearings available in several different thicknesses, so the exact clearance can be maintained for each journal, even if there is variation in the machining from journal to journal. The block, rods and crank are stamped with a code for what bearing size is used for each journal and you can use a chart in the factory service manual to decode the stampings. If you want to tighten or widen clearances, you can go up or down a size.

Because most import cranks are so tough, it is rare that they have to be turned undersize when the engine is rebuilt. This is a common rebuilding practice on domestic engines. If the engine has some miles on it, it is usually enough just to lightly polish the journals and use the next tighter sized bearing on the service manual chart.

Another important aspect to blueprinting is to get all of the piston-to-wall clearances for each cylinder equal. This is done by measuring each piston and having the machine shop match each piston to its bore with the exact same piston-to-wall clearance. Good machine shops can do this easily by honing each bore for a precise fit. Like the bearings, most import engines have select fit pistons with the size used stamped on the block in a code that can be decoded with the factory service manual. If you are replacing the factory pistons, you can specify a piston grade a little bigger and hone the cylinder to get the fit. This gives you the benefit of a nice, fresh bore surface, as you never want to put new rings in a used bore—they will not break in properly and will not seal that way. With aftermarket racing pistons, you do not have this select fit option, so the machine shop must match the bores to the pistons, not a big deal for a high-quality machine shop. The piston-to-wall clearances should all match to within 0.0001 to 0.0002 inches of each other. With aftermarket pistons, you are usually going for a significant overbore anyway to get some more displacement. Most import engines can be bored 0.040-inches or 1 mm oversize with no problem.

Making sure that the combustion chamber volumes of every cylinder are equal is a blueprinting job given to the cylinder head porter. Usually a good head person will try to get all the chamber volumes to be within 0.5 cc of each other so all the cylinders will have pretty close to the same compression ratio.

Every engine should be balanced. By balancing the engine's internal parts, vibratory stress on the engine is greatly reduced. An out-of-balance condition of a few grams can result in an unwanted load of many pounds in the wrong place. If these imbalance loads are added up, they can result in quite a bit more stress on an engine's internals. Balancing means dynamically balancing the crank, equalizing the weights of the pistons and the big and small ends of the connecting rods. This is accomplished by drilling holes or grinding the counterweights of the crank, sanding the rod caps and small end wristpin boss on a belt sander and carefully removing weight from around the pin boss and the underside of the dome on pistons. With pistons, you have to be careful not to make the dome thinner than 0.200 inch or to weaken the pin boss. On domestic engines, I have found the weight of parts to vary by several grams—sometimes more than 10 grams—making balancing very critical.

Blueprinting usually makes a huge difference power-wise in domestic engines; but the improvement is less drastic in most import engines

Lots of metal had to be removed in these cases. On tight-tolerance import engines, the weight variation is usually less than a gram or three. Now you know yet another reason why I love these engines so much.

PISTONS, RINGS, UP AND DOWN THINGS

For extracting big amounts of power like you would if you were building a quick class drag car or even a crazy street car, more severe part replacements are needed for reliability and durability. Stock engines have, for the most part, cast aluminum pistons. Imports usually have high-pressure cast pistons, which are superior to the more common, low-pressure cast used by many domestics. High-pressure castings have a denser grain structure and fewer metallic inclusions to form weak points in their structure. Cast pistons are soft, which wears well with the harder cylinder walls. They also have limited expansion, which allows for tighter piston-to-wall clearances (around 0.0005 to 0.003 inches), which helps emissions by reducing crevice volume, reduces oil consumption, is easier on the rings so they last longer and reduces noise because the pistons don't rattle in the bore, especially when cold.

The disadvantage of cast pistons is that they are relatively fragile, even the tougher high-pressure cast ones. Cast pistons are brittle and tend to crack when they are detonated on or have a lot of load put on them. To avoid these problems, if you are building a high-powered engine—perhaps a high-boost turbo, supercharged or a big nitrous oxide unit—a stronger piston becomes mandatory. In this case, you will want to run a forged piston.

A forged piston is made from an aluminum blank that is smashed into a die at extremely high pressures. This forging process aligns the grain of the metal around the piston for maximum strength. In very simple terms, metal, like wood, has a grain, and also like wood, you want the forces to be with the grain instead of against it. The pressures needed to mash a cold piece of aluminum like plastic also refine the grain, making it tighter and finer, increasing the strength and hardness of the aluminum by cold working it. I will not get into the metallurgy here, as it is beyond the scope of this article, but let me say that forging makes the metal both stronger and more ductile.

Forged pistons come in two different varieties: High silicon and low silicon. High silicon pistons are more brittle, but expand less under heat. They are still much tougher than the stock cast piston, but are not the toughest. High silicon pistons can run a much tighter piston-to-wall clearance, usually about 0.002 to 0.003 inches, than low silicone pistons, which makes them the piston of choice for endurance-type racing and super-hot street cars. The tighter piston-to-wall thickness is easier on rings and cylinder walls, as there are fewer wear-inducing rattles and bangs going on; they are more quiet for this same reason.

Low-silicon pistons are the toughest. Its alloy is more ductile, making it the piston to use for extreme abuse, like drag racing with big-boost engines. Their major drawback is that they expand more under heat, so they must run a greater piston-to-wall clearance of about 0.003 to 0.006 inches. This makes a clattering sound when cold and sometimes even when the engine is hot. An engine with low-silicon pistons often sounds like a diesel, especially when the engine is cold. The wider clearances have long-term wear implications as the cylinder walls and rings get battered as the piston rocks around in its looser bore. That is why low-silicon pistons are often only used for short duration events like drag racing.

Forged pistons must usually be custom ordered; import racing is not yet popular enough for manufacturers to stock pistons for anything except the popular Honda engines. Some well-known piston makers friendly to imports are JE, Aries, Wiseco, Coswoth and Ross.

For guidelines when ordering pistons, keep these things in mind. If you are going turbo or other forced or chemical induction, it is a good idea to run the first compression ring about 0.250 inches below the crown of the piston. This gives your ring land the strength you need to hold up to extreme use. In no place do you want your piston dome to be less than 0.200 inches thick. I believe that the best rings to use are late-model OEM Japanese rings for the correct bore size. Stock rings from late-model Honda, Toyota or Nissan engines are thin to reduce their mass and inertia to help prevent high rpm flutter. Flutter is when the ring floats in its groove, skips and loses sealing when, at high rpm, the piston changes direction at TDC very rapidly. A light ring is less likely to do this. Stock import rings are also low tension to reduce friction and further reduce the likelihood of float. These rings are also chrome faced for long wear with the correct cylinder wall finish.

Many good, experienced engine builders disagree with this. A popular aftermarket choice among many engine builders is the Speed Pro gapless piston ring. This has a special second compression ring that has a special way of butting the ends of the ring together so there is no gap. This ring gives excellent static leak-down numbers. I still personally prefer to use the high-tech Japanese stock rings because of their high quality and construction features.

Some interesting features that can be tried with a custom forged piston are gas porting and gas trapping. A gas port is a series of small holes drilled into the dome of the piston down to behind the first compression ring groove. Combustion gas pressure is tapped and used to push the first compression ring hard into the cylinder walls to help improve ring seal, especially at high rpm. This is something that should only be considered for drag racing or other short-duration forms of motorsports because it accelerates ring wear.

Gas trapping is machining another groove

This is an example of a gas trap groove on a forged JE piston. This groove acts like a reservoir between the two compression rings that retains combustion blow-by gas, taking the load off of the number two piston ring and improving ring seal. Engines with high piston speeds, like Hondas, can benefit from this. Also note the circular holes on the top of the number one compression ring land. These direct combustion pressure behind the ring to improve its seal, another method of gas porting.

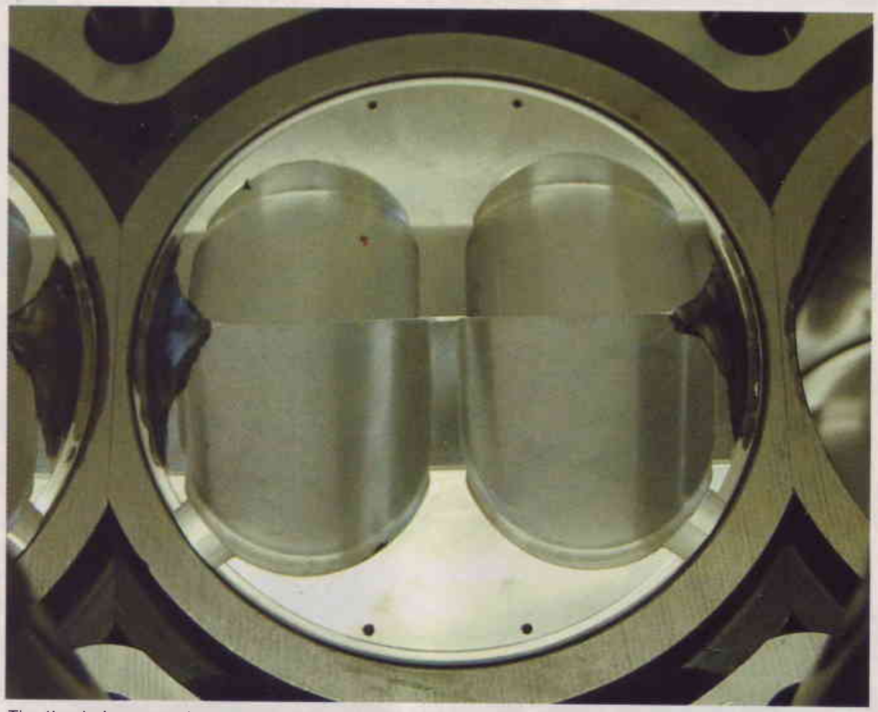
between the first and second compression ring; this groove helps to reduce the gas pressure on the second ring by serving as a reservoir for any gas leaking past the first ring. This improves ring seal at high rpm. This trick comes from Indy and F1 cars as well as motorcycles. Although the only drawback to gas trapping is the extra space it takes up (space that might be needed to maximize the length of the connecting rod, for example), it is still not a common practice on American aftermarket custom pistons, except for possibly Cosworth.

The piston's dome configuration is also a big factor in finalizing the engine's compression ratio. The compression ratio is a measure of how much the engine compresses the fuel/air mixture on the compression stroke. The ratio is the volume of the cylinder when the engine is at TDC over the volume of the cylinder when the engine is at BDC. A mild, naturally aspirated engine where you have no control over the mapping of the ECU can usually run a compression ratio of 10:1 without any problems on 92-octane pump gas. If you can program the ECU or are running a user-programmable, stand-alone ECU, compression ratios of up to 11.5:1 on 92-octane pump gas are possible. All-out, race-only, naturally aspirated engines that run only on racing fuel, like those used in All Motor 8 class drag racing or road racing, run compression ratios from 13:1 to as high as 15:1.

High compression ratios increase an engine's thermal efficiency greatly and slightly increase the volumetric efficiency. For every point of compression increase, you get approximately 3 to 4 percent more power. This increases power across the board at all rpm ranges. The increase in thermal efficiency from raising the compression ratio also improves the Brake Specific Fuel Consumption or BSFC. This is a measure of an engine's thermal efficiency measured in pounds of fuel per horsepower per hour, if you care. The proportional gain in power falls off sharply at compression ratios above 14:1 and it is almost impossible to get a detonation-free burn at higher compression ratios than this, no matter what the fuel.

High-compression pistons normally have a dome; the dome takes up cylinder volume at TDC to raise the compression ratio. To raise the compression ratio to what you desire, the dome volume must be stated to the piston maker so they can design the appropriate dome. It is a good idea to keep the dome as flat as possible, as too high a dome can hamper flame travel and cause unstable combustion, which can cause detonation or loss of power. The ideal piston configuration is a flat top. This gives best combustion, but the dome is often a necessary evil required to get the desired compression ratio.

Forced induction engines (mainly super and turbocharged, but also including chemically forced induction like nitrous oxide units more than 100 hp) require lower compression to avoid detonation, especially with 92-



The tiny holes around the circumference of the piston on this Honda B18C are gas ports that help aid ring seal at high rpm. Also note the thick-walled STR cylinder sleeves. Outside of the sleeves, you can see the supports that butt up against the block to keep the cylinders from rocking under pressure.

JE pistons has an advanced digitizer scanner where the cylinder head of an engine can be digitized and the dome of the piston can be precisely matched to the combustion chamber. Quench can be built into the piston, no matter what the combustion chamber geometry. This enables the smart engine builder to significantly improve combustion efficiency, even in dated engine designs without a pent-roof combustion chamber.

octane pump gas. Lowering the compression allows for more boost pressure without having to retard the ignition timing too much. Too much spark retard can result in excessive heating of the combustion chamber, valves and turbocharger. At a certain point, due to this heating, retarding the spark can even contribute to detonation. Lowering the engine's compression ratio allows the tuner to have enough spark advance to avoid the vicious circle of retarding the timing to avoid detonation only to have the increased combustion temperature contribute to detonation.

Some famous engine builders like JG Engine Dynamics disagree with this and advocate high compression ratios for race-fuel-only turbo engines (JG uses compression ratios as high as 11:1 on turbo engines). But conventional wisdom is that a low compression of about 8.5:1 or lower is desirable for a healthy turbocharged engine. This is usually achieved best with a dished piston. A dished piston is just that; the compression ratio is lowered by carving a dish into the piston to increase combustion chamber volume at TDC. The configuration of the dish should be such that the top edges of the piston around the circumference of the top—the areas that are not dished—still come into close proximity of the combustion chamber's quench areas. We discussed what quench areas are and do in our last installment on cylinder heads of this series. A dished piston configured like this still allows the quench areas to function correctly. These pistons are called reverse deflector pistons and resist the formation of detonation because of the turbulence induced by the quench areas and end gas elimination from the periphery of the cylinder.

The piston pin is the steel pin that connects the piston to the connecting rod. The very best piston pins are made of a high-strength, wear-resistant tool steel like H11. The strength of H11 allows the pin to be thinner and lighter for the same strength when compared with regular steel pins. Having good piston pins is important because pin failure is always catastrophic, nearly always destroying the whole engine. The best pins are taper walled. Taper walled piston pins are thick in the center where they pass through the rod bushing but taper out at the ends. This puts the metal where it's needed and eliminates a stress riser in the pin as well as minimizing excess weight.

Import engines have what is called floating piston pins. Floating pins are ones that ride in bronze bushings in the small end of the connecting rod. Domestic engines use piston pins that have an interference press fit

Here is a JE forged piston with a high, pop-up dome. This dome displaces volume when the piston is at TDC, increasing the compression ratio. High domes like this increase the compression to about 13:1.

to the rod. The easy-spinning floating pins are better at high rpm because they are less likely to fail, due to galling in the piston's pin boss and have less friction than the pressed pins. The issue with floating pins is that they must be securely retained in the piston or they can walk out and destroy the cylinder wall. Floating pins are usually retained in one of three ways.

The first is called a Cosworth clip because Cosworth racing engines were the first to use them. A Cosworth clip is a simple circle of round spring wire that is retained by a circular groove in the piston. The Cosworth clip is easy to use and retains well. A Cosworth clip must be used with a beveled piston pin. The beveled piston pin pushes the clip into its groove tighter with load. A conventional pin can cause a Cosworth clip to pop out with disastrous consequences. Cosworth clips are common on, well, Cosworth pistons and pistons from Japanese tuners. Many stock import engines use clips like this as well. Be careful not to mix up the type of piston pins with these clips.

The next is an internal snap ring. These are just heavy-duty versions of your regular snap rings. They are strong and easy to use with snap-ring pliers. They can be used with flat-ended piston pins. Some pistons use double snap rings for extra security. A caution with snap rings is to make sure the side of the snap ring with the sharp edge faces outward. If the snap ring is placed facing inward, the rounded edge can cause the snap ring to come out. Snap rings are popular with American aftermarket pistons.

Finally there is the spiral lock and double spiral lock. A spiral lock is a circular clip made of many passes of spring steel. Spiral locks are the most secure piston pin retainers. However they are destroyed in the removal process and are a little difficult to assemble, as they must be wound into the groove. Some pistons have the extra-secure, double-spiral lock. Spiral locks are popular on American aftermarket pistons.

Any of these methods is superior to the fixed press-in piston pin.

WHAT ABOUT THE RODS?

Perhaps the most important part of an

This is a JE forged low-compression piston for a turbocharged engine. Note the deep dish in the top of the piston. This dish adds combustion volume when the piston is at TDC, effectively lowering the compression ratio. Also, note the flat area around the dish. This rim comes close to the quench areas in the combustion chamber, allowing the quench areas to work correctly. This is called a reverse deflector dome design.

engine is the connecting rods. The connecting rods have to be strong, because their stress load goes up exponentially with rpm. Because of their largely dynamically imposed loading, rods must be light, as well as strong. Rods also must be bulletproof because their failure will claim the entire engine. Stock import rods are usually very strong compared with their domestic brothers. Import rods are almost always either forged or sinter forged with PIM technology. Domestics cast a lot of their rods. Imports have beefy rod bolts and spot faced shoulders.

Domestic rods often have spindly cap bolts and thin, stress-riser-ridden broached shoulders. Broaching thins the rod in this critical area and causes at least two large stress risers. In case you did not know, sharp edges on parts cause stresses to concentrate there and the part usually breaks in these areas of stress concentration. The perforations in a postage stamp or a sharp fold in a piece of paper are simplified examples of stress risers.

Because of these features on the stock rods, unless you plan some crazy modifications requiring lots of boost, NOS or insane rpm, you can get away with stock rods in your engine. A few popular imports have marginal rods, the most well known are the Honda D series engine found in the popular Civic, the 4AG found in the 1985-1988 GT-S Corolla, MR2 and FX16, and the GA16DE found in 1991-1999 Sentras and 200SXs. Although these rods are still strong enough for most bolt-on mods, their limitations can be reached when going for all-out mega-power. These rods become marginal just past 200 hp and 7500 rpm. This means you should keep it to a 50 shot of nitrous, and under 8 to 10 psi of boost. Note that these conditions will still give you a reasonably fast car! The rods found in B and H series Honda/Acuras, the Nissan SR20, the Toyota 3SG and the Mitsubishi 4G63 are nearly bulletproof for all but the most extremely built engines.

If your rods are to be used in a semi-serious street engine, they can be prepped by polishing the rod beams and shotpeening them. Polishing the beams removes the forging parting line, which is a major stress riser, and shotpeening improves the fatigue strength by about 100 percent. After shotpeening, the rods should be checked to see if they need to be resized and straightened as the force of shotpeening can distort them. The shotpeening process consists of blasting the rod with steel balls of a controlled size at a controlled velocity; it is not sand blasting or bead blasting. Shotpeening cold works the metal's surface and refines the grain, sort of microforging the metal's surface. This compressed outer layer strongly resists the formation of cracks. Small cracks can rapidly grow into larger ones. This is how shotpeening works to greatly improve the number of cycles near the yield point that a part can take before failure. It is not as important to shotpeen your rods as it is in most domestic engines, because many of the strong popular import engines have shotpeened rods from the factory.

The rod bolts can also be replaced with high-strength aftermarket bolts, in many cases from SPS or ARP. They usually won't have the exact drop-in application for your engine, but SPS or ARP will have something close. The stock rods can be reamed slightly larger for the aftermarket bolts. Usually though, the stock bolts are fine. Good enough so that if you feel you need to replace the rod bolts, you really should be looking into racing rods instead.

If you are building an engine for real racing or even a psycho street machine, you may want to consider getting real racing rods. Racing rods are made using superior metals such as the tough, but ductile, 4340 alloy steel. The rods are machined from solid billet, or in the case of Cunningham rods, forged 4340 blanks. Racing rods are usually completely polished to get rid of all stress-riser-generating sharp edges and tooling marks on their surface. Most racing rods are also shotpeened. The rod bolts are high strength, made of stuff like H11 tool steel with more than 200,000 psi of tensile strength. Normally racing rods are made to such close tolerances that they do not need to be balanced.

Racing rods are good for boost levels above 15 psi and more than 8000 rpm. There are basically two types of rod beam configuration, "H" style and "I" style. "H" style rods are generally considered superior by engine nerd-type purists, because they have a bigger section modulus (engineering term for a measure of stiffness relative to cross section) in the direction of the rod's bending load. Carrillo and Eagle rods are good examples of "H" style rods. However, there are a lot of excellent quality "I" style rods. These emulate the external cross section shape of most stock rods. Crower and Cunningham are examples of high quality "I" style rods.

A rod failure always means the total destruction of the engine, so racing rods are never a bad investment for the serious enthusiast. It is very rare for a racing rod to fail, even on the most built engine. Usually the only way one will fail is if a bearing spins, and the rod goes metal to metal on the crank, or if the engine ingests a good chunk of water at high speeds, in which case, the whole engine is usually destroyed.

An interesting note is that, since the tensile load on the rod goes up exponentially

Racing rods are never a bad investment for the serious enthusiast

with the rpm, a screaming 10,500 rpm, 280 hp N/A class engine puts more destructive tensile stress on the rod than a 500 hp turbocharged quick class car chugging at 8500 rpm. The rod can handle the compressive loads that turbo boost provides better than it can take the bolt-stretching spinning that it takes to make power with an all-natural machine. That is one of the reasons stock engines can make a lot of power when boosted, if they are properly tuned.

NEXT TIME...

There is more to the bottom end of your engine than just pistons and rods, so much more that we're going to make you wait until the next installment to learn about the rest of it. See this space next time for all of the dirt on crank and block preparation, head gaskets and important details like oil and water pumps. ■