Parts Coatings

Taking Engine Performance to the Next Level

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Whether it's more horsepower, better throttle response, or better durability, everybody is looking for an edge when it comes to building a performance engine. Any of these can win races. So what kinds of tricks are winning engine builders using to get an edge over their competitors? Many are using highly specialized coatings to manage heat, reduce friction and prevent engine-damaging metal-to-metal contact.

Coatings have long since evolved from mysterious black art concoctions that sometimes delivered less then optimal results into highly refined surface treatments that provide targeted benefits for a wide variety of engine parts applications.

Dry film lubricants and hard surface coatings can protect critical engine parts such as bearings, piston skirts, piston ring grooves, wrist pins, valve stems, valve springs, rocker arms, pushrods, lifters, timing gears, camshafts and crankshafts from dry starts, oil starvation, scuffing, galling and premature wear. A dry film lubricant provides a layer of protection that reduces friction when there is no oil film between parts. Most of these coatings contain molybdenum disulfide, graphite, tungsten disulfide and/or PTFE (Teflon) in a thermosetting polymer binder (water or solvent based). Some formulas also attract and retain oil to reduce the risk of the protective oil film going away. Some of these coatings are for engine break-in only and quickly wear away while others provide long-term protection and last tens of thousands of miles.

When applied to piston skirts, a dry film lubricant can allow closer piston-to-bore clearances for reduced piston slap and blowby. The added thickness of some coatings can actually restore worn piston skirts back to original tolerances while cushioning the motions of the piston in the bore. Some of these coatings even allow you to install pistons with zero clearance! Of course, that requires good bore geometry with minimal distortion and exact tolerances. Torque plate honing is highly recommended if you are going with ultra-tight piston clearances.

Dry film lubricants are often viewed as "insurance" against a catastrophic engine failure if an engine loses oil pressure momentarily during a race. There's plenty of evidence to back that up. A dry film lubricant on the main and rod bearings provides a sacrificial layer that can prevent metal-to-metal contact and save an expensive racing crank. It can also prevent a rod bearing from seizing, breaking the rod and destroying the motor. Of course, no coating is going to last very long at high RPM if the engine loses oil pressure, but it can provide protection long enough for the driver to realize what's happening and shut the engine off before it totally self-destructs.

Many bearing coatings contain PTFE (Teflon) because of its anti-friction characteristics. The polymer resin may also contain other ingredients (such as microscopic iron particles) to improve wear resistance and durability. One manufacturer who applies a special iron-based dry film coating to their engine bearings says the coating reduces wear 500 percent over an uncoated bearing, and improves fatigue resistance 20 percent. Some manufacturers are also using a different friction-reducing coating made of polyamides on aluminum engine bearings for late model engines with automatic stop/start idle systems. The bearings in these engines see significantly more stop/start cycles, so the solid lubricants that are in the coating help prevent metal-to-metal contact. Metal particles distributed in the polymer matrix also help dissipate heat while improving wear resistance.

Dry film lubricants can also be extremely beneficial when applied to valve springs (especially double and triple springs). Springs generate a lot of friction and heat as the valves and pushed open and close. If the springs get too hot, they will weaken and/or fatigue – and nobody is going to win a race if a valve spring calls it quits or breaks. Putting a long-lasting dry film lubricant coating on the valve springs, friction is reduced allowing the springs to run cooler and last longer. That can provide a significant edge in a long distance endurance race, especially if the engine is revving at high rpm for much of the race.

A properly formulated valve spring coating will also help dissipate heat more evenly across the surface of the spring, reducing hot spots that can lead to spring failure. A heat dissipating, dry film lubricant coating should also allow heat generated by the

springs to transfer more efficiently to the oil flowing over the springs and valvetrain. What you don't want is a coating on the valve springs that acts like an insulator and inhibits heat transfer. That can make the springs run hot and fail.

Dry film lubricants can also be used on the ends of pushrods and/or in the pushrod cups in rocker arms to reduce wear. It can also be applied to stamped steel rocker arms with stud-mounted pivot balls to reduce friction and galling when stiffer valve springs and higher rpms increase the load on these parts.

An extreme pressure dry film lubricant can also reduce friction and wear when applied to lifters, cam lobes and timing gears. The coating improves the wear resistance of these parts and helps prevent cam lobe and lifter damage caused by dry starts or when a new cam is broken in. A coating that also has oil retaining properties will help maintain the oil film between the cam lobes and lifters, which otherwise rely exclusively on splash lubrication.

Getting Hard

Hard surface treatments are another type of coating that can applied to a variety of engine parts to reduce wear, galling, scuffing and damage. Hard surface treatments include metallurgical processes such as nitriding crankshaft journals, anodizing piston ring grooves, skirts and even the entire piston, and applying a hard nickel silicon carbide matrix to cylinder bores to reduce bore wear. All of these require special equipment and procedures to apply the process. Nitriding diffuses nitrogen into the surface of the steel, changing its microstructure and creating a hard surface layer that extends about .010 to .020 inches below the surface. This makes the surface much ore wear resistant without changing the ductility of the metal underneath.

Adding a hard wear-resistant surface layer gives racers an edge by improving the long-term durability of their engine. Parts can handle higher loads without failing, and last longer before they have to be replaced.

Other hard surface treatments include thin film coatings such as titanium nitride, chromium nitride, tungsten carbide and Diamond-Like Carbon (DLC). Most of these coatings are applied using a Physical Vapor Deposition (PVD) process or Plasma Assisted Chemical Vapor Deposition (PACVD). PVD and PACVD coatings are typically applied inside a vacuum chamber at high temperature by ionizing or evaporating the coating material and mixing it with a reactive gas. The vapor then sticks to the part being coated, forming a hard surface layer that reduces friction and improves wear resistance. Parts that are often hard coated with these kinds of processes include wrist pins, valves, lifters, cam followers and other parts.

Heat Management

Combustion temperatures inside an engine can reach 1450 degrees or higher depending on the air/fuel mixture and type of fuel. In boosted engines, the flame temperature is the same, but there's more total heat produced in the combustion chamber because more air and fuel are being burned in the engine. Nitrous oxide (NOx) also increases overall heat but actually has a slight cooling effect on combustion temperatures. Even so, the more highly loaded the engine, the more heat it produces and the more heat the pistons, cylinders and heads have to withstand.

Coatings that can give racers an edge in heat management include thermal barriers and thermal dispersants. Thermal barriers form an insulating layer that reduces heat transfer and reflects heat back towards its source. Thermal dispersants, by comparison, absorb heat and increase heat transfer away from its source.

Aluminum cylinder heads are lightweight and are used on most late model engines as well as most performance engines. Aluminum conducts heat readily and pulls heat away from the combustion chamber. This is good for reducing the risk of pre-ignition and detonation, but it also reduces the thermal efficiency of the engine by allowing heat that would otherwise generate pressure to dissipate into the head and cooling system. Applying a thermal barrier coating to the inside of the combustion chamber and the faces of the valves can slow the loss of heat and increase combustion pressures for more power. It can also help the engine run cooler, which means a smaller, lighter, more aerodynamic radiator may be used to a racer's advantage.

Applying a thermal barrier coating to the tops of pistons can also help keep the heat in the combustion chamber to reduce piston and engine temperatures. A thermal barrier coating also helps protect pistons against thermal damage caused by lean air/fuel ratios, low octane fuels and excessive heat generated by high boost pressures and/or compression ratios. Diesel pistons, in particular, benefit the most with thermal barrier coatings. Reducing heat transfer to the piston body also means you can run tighter piston-to-bore clearances without fear of scuffing a piston (especially if it has also has a dry film lubricant skirt coating).

A thermal barrier coating that also combines some of the attributes of a thermal dispersant coating can help dissipate hot spots across the top of the piston. This too can reduce the risk of pre-ignition, detonation and burning a piston in a highly stressed engine.

Thermal barrier coatings can also be applied to the inside and outside of exhaust headers to keep heat in the exhaust. This increases exhaust velocity for better scavenging and also reduces the amount of heat radiated into the engine compartment by up to 150 degrees F or more!

Thermal barrier coatings can also be applied to the underside of metal intake manifolds and carburetor base plates, throttle housings and on the outside of the fuel bowls to reflect heat. Cooler air is denser than hot air and makes more power. The same logic applies to turbocharger housings. Reflecting heat away from the compressor housing reduces air temperatures for more boost pressure and power. Likewise, keeping heat in the turbo compressor housing allows it to spool up faster to reduce lag.

A thermal dispersant coating that absorbs and dissipates heat can be beneficial on a radiator or turbo intercooler, as well as on the inside and outside of an oil pan or valve covers. A coating that improves heat transfer means lower oil and coolant temperatures, which reduces the risk of oil breakdown or engine overheating. It may also allow the use of a smaller radiator or oil cooler (rules permitting).

Oil shedding coatings are yet another option that can be used on certain parts to give you an advantage over the competition. An oil shedding coating prevents oil from clinging to the surface like water beading up on a windshield treated with a product like Rain-X. An oil shedding coating on the crankshaft throws can reduce aerodynamic drag on the high revving crankcase. The same type of coating in the valley area of the block, on the underside of valve coves and manifold covers, on the underside of pistons, and on the inside of the oil pan can help redirect oil back to the sump more quickly to reduce the risk of oil starvation at high speed. This, in turn, may allow you to run less oil pressure (with less parasitic horsepower loss to drive the pump) without fear of creating lubrication problems.

Coating Advice

With so many highly specialized coatings for different kinds of applications (street, drag, circle track, diesel, etc.),

it's not always obvious which type of coating might be best for a particular engine you are building. Our advice is to take advantage of the expertise that is readily available from the various coating suppliers and ask them which product or process would be best for what you are trying to achieve. They know their products and they know which ones will work best in a given situation.

Although coating materials are readily available from a variety of suppliers, applying coatings is not a simple process of spray and bake. Although some products are relatively easy to apply (like exhaust manifold coatings), most require careful surface preparation to assure good adhesion. Manifolds and headers typically have to be sandblasted or bead blasting to remove all rust, grease and oil before spraying on a coating. The coating must then be cured in an oven at 300 degrees for a certain length of time.

Other coatings such as piston, bearing and valvetrain coatings require much more care in the application. Some may be applied by a simple silkscreen process while others involve chemically etching the surface to assure good adhesion. And with high tech hard coatings it takes special equipment and know-how to apply the process.

The best coating in the world won't do you much good if it is not applied properly and flakes or delaminates from the part you put it on. For that reason, we recommend that you have critical engine parts coated by a company that specializes in this type of service. One supplier we interviewed for this article said some coating processes involve multiple steps with different materials, and that each step in the process is just as important as the next for achieving good results.

Some suppliers who sell coated engine parts have common parts like bearings, pistons and other parts in stock so there's no waiting. Other suppliers only coat parts on a custom basis. You send them the parts, tell them what you want and they apply the coating. Turn around times typically range from several days to a week depending on the job and the time of year.

The cost to do a complete coating package on an engine (bearings, pistons, valve springs, valves, heads, manifolds, etc.) can cost up to $1200 or more depending on what you want. But that same $1200 investment in coating protection may save a $50,000 engine from self-destructing – so from the racer's perspective it's money well spent. It may also give a racer the extra edge he needs to beat out his competition no matter what type of racing he's involved in. Some suppliers even offer "invisible" clear coatings that are difficult to detect for venues that have rules against coatings. Of course, we're not encouraging anybody to cheat, but if there's an edge to be had, somebody will find a way to take advantage of it. ■