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Racing Oil and Zinc

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You have probably heard that they took all of the zinc out of motor oil, and that you need a zinc additive or a special racing oil to make your cam live. This article discusses the details of anti-wear additives and gives you information to make the best oil choice for your racecar, your tow vehicle, and your family car.

Less Anti-Wear Additives

Although the marketplace recognizes zinc as the anti-wear additive used in motor oil, it is actually phosphorus that is limited. However, since the primary anti-wear additive used in motor oils is a zinc phosphate, when you limit the phosphorus (the phosphate part of the chemical) you limit the zinc.

Here is what has happened, and yes, it is environmentally driven. Years ago, the auto manufacturers gathered some catalytic converters that had failed and scraped glass-like deposits from their catalytic surfaces and analyzed them. The deposits contained phosphorus, which was determined to have come from the motor oil. So, the auto manufacturers imposed a chemical limit on motor oil of 1200 PPM phosphorus.

The tendency to form these deposits is not completely understood, but the volatility of the phosphorus-containing additive and oil consumption are factors. The automakers tried to develop an engine test in the mid '90s to predict an oil's deposit forming tendencies called the Oil Protection of Emissions Systems Test (OPEST). They were not successful due to a lack of repeatability. So after spending a small fortune on a bad test, they simply tightened the chemical limit with the API SJ specifications to 1000 PPM phosphorus. In April 2005, API SM lowered the phosphorus limit to 800 PPM, where it remains with the current API SN specification.

The lubricant and auto industries recognize the importance of zinc phosphate anti-wear additives. Although the rumors floating around say "all the zinc has been taken out of the motor oil," and the amount has been reduced, phosphorus is actually a required additive. Current specifications require at least 600 PPM phosphorus, which means a similar amount of zinc.

As mentioned earlier, phosphorus in motor oil comes from zinc phosphate additives, or more specifically, ZDDP (zinc dialkyl dithiophosphate and/or zinc diaryl dithiophosphate). ZDDP serves three functions. It is an anti-wear additive, it inhibits oxidation, and it inhibits rust.

It is interesting to note that when oil companies and chemical manufacturers announced their API SM products, they claimed that although ZDDP levels were lower, there were other additives in their formulations to compensate. However, their press releases would not name the chemical. A cynical person may speculate that the substitute additives are anti-oxidants, but do not necessarily compensate for the loss of anti-wear protection from the reduction in ZDDP.

ZDDP inhibits wear when metal-to-metal contact occurs (boundary lubrication). Anti-wear additives are not helpful for the bearings, which ride on a film of oil (hydrodynamic lubrication). ZDDP anti-wear additives are activated by heat on a spot basis and use the metal surface as a catalyst to react and form a chemical lubricating film. In an engine, the valvetrain is primarily where boundary lubrication conditions exist, and anti-wear additives are needed.

Design Changes

In recent years, engine design has been evolving from those with sliding cam followers to those with rolling cam followers. Obviously, anti-wear additives play a bigger role when there is a sliding contact than a rolling contact, and therefore rolling cam followers are not as dependent on anti-wear additives for durability as sliding cam followers.

You are probably thinking, "What about the dual overhead cam engines. The cam still slides on the lifter." Correct, but new cars with sliding cam followers are not high risk with new motor oils because valve spring pressures are lower.

Seasoned mechanics tell us that valve springs used to be a struggle to install compared to the valve springs on new cars. The springs of the past were purposely made much stiffer than necessary to compensate for metal fatigue that would reduce spring rates as the springs age. In other words, valve springs were too stiff when new, so that they would be stiff enough after 50,000 miles.

Today's springs do not relax with age like the old

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ones, so there is no need to compensate for diminishing spring rates. Mechanics tell us they can almost compress them with their fingers. Because valve springs are not as stiff, there is less pressure between the cam and lifter in newer engines. Therefore, the level of ZDDP anti-wear additive is less critical in the new engines.

Failures

Each API specification is supposed to be backward compatible. In other words, the API is supposed to protect our older engines when they change the specifications. Backward compatibility is very important when you consider that the average automobile is nearly 11 years old.[1] Although the API and auto manufacturers claim backward compatibility, there are a lot of people with cams in their garbage bins that disagree.

Cam lobes in older engines are wearing off and lifters are getting torn up.[2,3,4] Even when there is not a catastrophic failure, faster wear rates take place between the cam and lifter on older engines. As the wear progresses, performance drops, fuel efficiency goes down, and emissions go up. Therefore, the environmentally friendly new oils are not so environmentally friendly in the wrong engine.

V-8 engines with flat tappets are particularly susceptible to failure, or maybe it just appears that way because there are more of them, but a lot of failures have been reported.[5,6,7] These engines provided long service life with the old oil formulations they were designed for, but failure rates have increased with today's low-phosphorus passenger car motor oils.

Since additives wear out with use, and the new passenger car oils continue to have some anti-wear additive, some have claimed that changing oil more often is the solution. Although this is perfectly logical, it will not save your cam. The new specifications just do not allow for enough anti-wear additive in flat tappet engines. According to the Engine Rebuilders Association, rebuilders have experienced flat tappet cam failures during engine break-in.[8] They recommend oils with higher zinc phosphate levels for break-in.

In fact, break-in is the most critical time for adequate amounts of zinc phosphate. If you were to look at a brand new lifter under a microscope, the surface would look rough. The pressure, on a per square inch basis, or maybe a per nanometer basis, is extremely high and generates enough heat on those tiny little peaks to weld them to the cam, which then rips them off as it rotates. As metal is transferred back and forth between the cam and lifter, a rough surface is created on each. As the now even rougher surfaces continue to grind against each other, the surfaces wear rapidly and produce an early failure.

However, if you have an enough anti-wear additive in your motor oil, the heat and pressure on those teeny tiny little peaks causes the zinc- phosphate additive to react and form a lubricating film for the parts to slide on, so the cam and lifter do not tear each other up. Usually the cam manufacturer recommends breaking in the cam at elevated RPMs to make sure the lifter rotates for more even wear. As the cam and lifter rub against each other, they kind of polish each other, providing a smoother surface. After this break-in process, the level of anti-wear additives is less critical, but still important.

Keep in mind that, so far, we have been discussing ordinary street engines with sliding cam followers. Higher RPM, cams that ramp up quicker, higher valve lift, and stiffer valve springs, each create additional pressure between the cam and lifter. Since the engine in your race car has all of these conditions combined, the low anti-wear level in ordinary passenger car oils is a recipe for disaster.

Diesel Engine Oils

An inexpensive and readily available upgrade from passenger car oils for racing use is diesel engine oil. The Engine Rebuilders Association recommends diesel engine oil for engines with flat tappet cams because they have higher zinc phosphate levels. Ironically, at the time they announced their recommendation, the diesel engine tests used to qualify oils for API CI-4 were all big rig engines with rolling cam followers.

Since then another diesel specification, API CJ-4, has been released. Again this was an emissions driven spec, and phosphorus has been limited, because it can contribute to plugging diesel exhaust filters. Still it is much better from an anti-wear standpoint because phosphorus is limited to 1200 PPM, 50% higher than the 800 PPM limit imposed on gasoline engine oils used in passenger cars.

Also, there is a CJ-4 test engine with sliding cam followers. After there were over one million small diesel engines with sliding cam followers in pickup trucks on our roads, the API required a test for valvetrain wear with a slider-cam engine called the Cummins ISB. Valve spring rates are higher in this engine than typical gasoline engines, lending credibility for the use of CJ-4 oils in racing gasoline engines.

Now if you decide to use diesel engine oil in your gasoline engine, look for API CJ-4 / SM on the label, indicating performance in diesel engines and gasoline engines. So now you are thinking, "What about the 800 PPM limit for SM?" Well there are some quirks in the rules.[9] The 800 PPM limit only applies to car viscosity grades, such as SAE xW-20 and SAE xW-30. The API assumes that an SAE 15W-40 or 20W-50 is not going to be used in a passenger car. Therefore, there is no catalytic converter and no need to limit phosphorus.

The other quirk is that if the "S" specification (spark ignited engines) follows a "C" specification (compression ignited engines), the chemical limit is removed from the "S" spec. It is assumed that if a "C" specification appears first on the label, such as CJ-4, the oil is intended for diesel engines. Diesel engines do not have catalytic converters (at least not the same type as in cars), so the phosphorus limit is relaxed to the diesel level for oils meeting the performance requirements of the "S" specification. If this explanation makes little sense to you, just realize it is a loophole.

While a diesel engine oil might be a good upgrade for a hot rod or the pickup used to haul your race car to the track, the best oil for a full-on race car is usually a dedicated racing oil.

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Racing Oils

You need to look a little further than the product label in choosing a racing oil, because too many products are sheep in wolf's clothing. Some lubricant manufacturers have taken the same additive package used for their SAE 5W-30 passenger car oil, made an SAE 20W-50 with it, jacked up the price, and called it racing oil.

Oil companies tend to be conservative in their formulations. It is hard for some of them to offer a product that does not meet the current specifications, and the more anti-wear additive they add, the further they get from what they know and are comfortable with. Understandably so, because having their product linked to catalytic converter failures or any other hardware problem with a low volume specialty product can greatly affect the profits from their high volume passenger car oils. Perhaps that is one of the reasons we see brands at the track that we do not see at the discount store.

Lubricant manufacturers that are serious about serving the racing market display their zinc level in their tech literature. If the zinc content is not above 1200 PPM (0.12%), you may as well consider the diesel oil option. Most true racing oils have between 1200 and 1600 PPM zinc, but some go much higher. These are the products from which you should make your selection.

ZDDP Additives

Another option is to buy a ZDDP additive, which is available in the aftermarket, and add the stuff yourself. However, if you are wanting the best for your car that is not necessarily the best way to go.

Magazine articles, including this one up to this point, make ZDDP sound like a single compound that is all the same. Not even close. There are four major chemical companies that supply crankcase additives (Lubrizol, Infineum, Oronite, and Afton). Any one of them has at least half-a-dozen ZDDP additives. There are primary and secondary zincs, as well as dialkyl and diaryl zincs. The ZDDP compounds are also available in different molecular weights. Such characteristics determine the level of activity, activation temperature, and whether the performance is more oriented toward inhibiting wear or inhibiting oxidation. Some of the less stable ZDDPs can become aggressive toward yellow metals—copper, brass, and bronze. On the other hand, this corrosion of yellow metals can be controlled with other additives, so it comes down to balance. It is safer to use a product fully formulated for the task, than to pump up an inadequate oil with a single additive type that may diminish performance elsewhere. Some supplements have side effects.

Therefore, although an aftermarket additive will definitely help a passenger car oil reduce valvetrain wear, it is unlikely to provide the best balance or performance in the specific oil you are using. It is less risky to buy a product designed to do the job you want it to, rather than try to make your own.

Credentials

If you have a flat tappet cam in your race car, you need more than a thicker version of a passenger car oil. Treat zinc and phosphorus levels like a resume. If you are going to "hire" an oil for your race car, a high zinc level is not necessarily a good reason to give it the job. On the other hand, a low zinc level is a reason to keep looking.

Look for a racing oil that has an adequate amount of zinc and phosphorus. Then look for successful performance on the track. Successful performance is not defined by the company that pays drivers to put stickers on their cars, but by engine durability.

You want the best parts in your racing engine to make power and provide dependability. Take at least as much care in selecting your motor oil as in selecting your other performance parts.

Other Applications

The racing part of the article is over. The remainder is to provide some guidance for your other engines.

Cat Life

Catalytic converters are expensive items that reduce emissions. Nobody wants to shorten their life. Unfortunately, there is very little data available correlating cat life with oils containing higher ZDDP levels.

Scientists believe that the volatility of the ZDDP additive is a major factor in catalytic converter durability, but it does not take a scientist to figure out that oil consumption is a big factor in cat life. Obviously, if the engine is blowing oil out the

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Examples

Within the past month I received three reports that illustrate the need for additional ZDDP as discussed in the adjoining article.

- One was a guy from the old school that broke-in his stock rebuilt engine on non-detergent oil. The cam failed during break-in.
- I received a call from a guy in Las Vegas that used passenger car oil meeting the current specifications in his freshly restored 70's era muscle car. The cam failed in less than 300 miles.
- A client with a B-Mod stock car had a buddy ask him, "Why am I on my third cam, and you are still on your first?" This client recently had his engine builder call him over to look at his cam while freshening the engine. The cam had a couple of little pits in it and was still in serviceable condition, but they decided to replace it. They called the cam manufacturer to order the same cam as the now pitted one. The cam manufacturer asked if the client had quit racing for a couple of years. No, he races practically every weekend during the season. The cam manufacturer said that they normally see re-orders 1 to 1½ years apart. This cam had lasted 4½ years.

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exhaust, a lot more phosphorus from the motor oil will come in contact with the catalytic surfaces. It is reasonable to believe that if an engine has been well maintained and does not consume oil, reasonably long cat life can still be achieved with relatively high phosphorus levels.

Now that you know the compromise between phosphorus and cam life, and you know your oil consumption, you decide. Would you rather risk replacing the valvetrain or the catalytic converter?

Pickup Trucks

Nobody drives his or her race car to the track these days. You have a truck, SUV, or something larger to trailer your car there. If its engine has rolling cam followers, anti-wear additives are not critical. If it has sliding cam followers, diesel engine oil makes sense.

Or, you can use the same oil that you use in your race car if you want to consolidate inventory. Be aware that some racing oils have very little detergent, so you may need to keep the drain intervals rather short. Check with the oil's manufacturer for guidance.

Small Engines

Nearly all small 4-cycle engines have sliding cam followers. Lawn mowers, generators, power washers, roto tillers, personal watercraft, and many small industrial machines have sliding cam followers, but few have catalytic converters.

Of course most of the small engines are air cooled, making SAE 30 lubricants appropriate (check your manual). However, you will not find a straight viscosity CJ-4 oil. For small air cooled engines calling for SAE 30, look for a diesel engine oil that also meets an "S" specification, such as API CF SL.

Air-cooled engines tend to operate at higher temperatures than liquid cooled engines. The added bonus in using a diesel engine oil in your air-cooled engine is assurance of high temperature deposit control.

Motorcycle Engines

Using a passenger car oil in a motorcycle has been a mistake for quite a few years, but it has become a bigger mistake as anti-wear levels dropped. The overwhelming majority of motorcycles have sliding cam followers, and most motorcycles have a common oil sump for the engine and transmission. A more robust anti-wear package is needed to protect the valvetrain and drive gears.

Also, modern car oils are not compatible with the wet clutches in motorcycles where the transmission shares the engine oil. There is a fuel economy test for passenger car oils called the Sequence VIB. When the test engine evolved from sliding cam followers (Sequence VIA) to rolling cam followers (Sequence VIB), the friction modifiers used to defeat the test also evolved. This last generation of friction modifiers does not provide the correct coefficient of friction needed for motorcycle clutches.

Although passenger car oils from 20 years ago would probably provide acceptable protection, new passenger car oils are a poor choice for motorcycles. Dedicated motorcycle oils are available, and some diesel engine oils or racing oils provide excellent results. Consult the manufacturers for guidance.

Conclusion

If your engine has sliding cam followers, the passenger car motor oils meeting the current API specifications are not the best choice for protecting your valvetrain. If it is an older or modified engine, the new oils can cause damage. Look to diesel engine oils and racing oils with higher zinc phosphate levels to protect them.

Cen-Pe-Co Recommendations

This article was written a few of years ago for a magazine, but was never published. Questions and misconceptions continue to surface about ZDDP, so we are publishing the article here.

The client in the third example on the previous page is Randa and Dale Burkhead's son, Doug, who uses Cen-Pe-Co Racing Oil. It has 2400 PPM zinc and is recommended for motorsports engines.

Cen-Pe-Co S-3 Oil has nearly 1600 PPM zinc, which is as much as a lot of racing oils, and is recommended for hot rods and classics. It has additional rust inhibitors, making it well suited to vehicles that spend all winter in the garage. This is also the oil we recommend for small engines.

Neither Cen-Pe-Co Super Racing Oil nor Cen-Pe-Co S-3 Oil have the latest generation of friction modifiers used in passenger car oils, so they are appropriate for use in motorcycles.

Cen-Pe-Co has you covered with higher ZDDP levels for hot rods, classics, antiques, small engines, motorcycles, and engines used in a vast array of motorsports.

Reference Notes

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