PISTON SEIZURES EXPLAINED

It's a common sight. You see a kart in the pit with the cylinder head off. A group of technical "guess men" are assembled in a circle passing around a seized piston as if touching it can give them greater insight as to the reason for it's failure. Unfortunately, when this whole mess of parts gets dragged down to the shop, the engine builder may not be able to provide much more insight unless he is very familiar with that particular engine's "sources of seizure". It's a lot to ask.

Even among engine builders, there's plenty of confusion about what causes a particular piston to seize. The following information will help to dispel some myths, and shed some light on the understanding of piston seizures. The objective of this article is to make piston seizures a part of your past.

Some fundamentals:

Many people believe that piston seizures occur when engine heat causes the piston to expand larger than the size of the cylinder bore .... This is not true. If you could freeze your engine "in motion" in the middle of a long full throttle pass, and disassemble it for micrometer measurement, you would find the piston skirt to measure at a 0.0000 to 0.0005" or so press fit into the bore. That's right, a slight press fit! The reason that it doesn't seize is because the premix oil has such a terrific film strength that it acts as an unremovable buffer between the piston and the cylinder. That is, the bare metal surface of the piston never actually touches the bare metal surface of the cylinder because the oil stays between them. Many mechanics have experienced this phenomenon while cleaning a freshly bored cylinder. Completely dry without cleaning solvent, the piston moves through the bore with difficulty. After rinsing the piston glides all the way through with no resistance at all. This is because the solvent acts as a film between the piston and cylinder.

A piston seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall. Understanding this, it's not hard to see why oils with exceptionally high film strengths are very desirable. Good quality oils can provide a film that stands up to the most intense heat and the pressure loads of a modern high output engine.

The difference between seizure and scoring:

Seizure and scoring are two different stages of the same problem. When the oil film on a cylinder is momentarily burned or brushed away, the metal surfaces of the piston and the cylinder wall will actually touch. When this happens, there is a sort of scraping that takes place between them. When the oil film is resumed, the marks from this scraping will often remain on the piston and (or) the cylinder wall. This momentary scraping or "scoring" seldom causes any permanent or performance robbing damage. No significant damage takes place because the oil film is resumed before the piston and cylinder have a chance to start exchanging material onto one another.

Scoring is commonly seen on the piston face directly below the piston ring end gaps. The blast of combustion can get between the large end gap of a worn out ring and burn the oil off the piston and cylinder in that area...Hence the surface scoring. In most cases, score marks can simply be sanded off of the piston and cylinder. However when ever you see scoring, it's a good idea to find the source so that it doesn't develop into a full blown seizure.

Seizure is a case of scoring where the oil film does not immediately return. After a few moments of constant scoring, the piston and cylinder will scratch each other hard enough to remove material from each other. This floating material grinds itself into the piston and the cylinder as it continues to grow in size. As this snowballing material grows, it will drive the opposite side of the piston against the cylinder wall with a pressure so terrific that scoring begins to take place. While all this is going on, your engine is still running wonderfully at full throttle.

The death blow comes when the mass of material between the piston and the cylinder wall finds it's way to the piston ring. This nearly molten mixture of aluminum and iron will instantly lock the ring in it's groove. This ring locking, not the piston surface seizure, is what actually causes your engine to quit. When the piston ring becomes locked back in it's groove, it's incapable of providing compression sealing against the cylinder wall. This instant loss of compression, while the engine is at speed, causes a dramatic loss of power. That power loss, along with the added drag of the badly seized piston, makes the engine quit or lock up in a nanosecond. In fact this entire seizure process, from the first scoring scratch to the piston locked solid, takes less than a second at full rpm. That's not even enough time for you to utter the first syllable of your favorite profanity.

THERE ARE MANY CAUSES OR SOURCES OF PISTON SEIZURE.

Each cause has it's own symptoms and it's own visual results. The following is a description of several very common types of seizures, and the most common problem source for each one. It should be understood that diagnosing piston seizures is not done with any precision by even the best engine builders. However this information may allow many of you to make a more educated and accurate guess.

Four corner seizure: Both sides of the piston will show heavy scoring and seizure marks on each side of the wrist pin hole. The pattern of these four seizure points often appears to be a perfect square, hence the slang term "four corner". The scoring takes

place in this pattern because those areas of the piston casting are the thickest. When the piston is seriously overheated, the thick areas will expand and distort the most. High output kart engines usually experience this type of seizure pattern when a piston has been fitted with too little clearance. Most experienced , and well meaning, kart mechanics would take one look and immediately say that insufficient piston clearance is the cause. However that diagnosis, on watercooled engines, would be wrong about 99% of the time.

Four corner seizures in watercooled engines are almost always a result of the engine creating more heat than the cooling system can exchange away. That is not to say that most cooling systems are under built, but rather that it's easy to make a modification that creates too much internal heat for even the most beefed up cooling systems. Even though a constant feed of cool water is being moved through the cooling system, the cooling system must be capable of exchanging the engine heat away at a rate quicker than the engine is creating it.

The engine factors that have the greatest seizure related effect are operating temperature, excessive compression ratio, ignition advance, high rpm, insufficient fuel octane level, insufficient cooling, or any combination of these. Properly adjusting these same factors will have the greatest effect on total power output. The job of the engine builder is to find the right combination, or "blend", of these factors that will result in strong overall power output at a pace that your cooling system can keep up with. There are many engine builders who have mastered their own combination "blend" that can get you all the power your after without risking a seizure.

A group of mismatched modifications is a first class ticket to "seizure-land". Any inexperienced individual who sets up your engine with over 200 psi of compression and advanced timing, is also guaranteeing your arrival. If your big mouthed racing buddy down the street tells you that he can make any engine "roost".... You should think twice. You could be in for a very expensive lesson.

Lean seizures: The high speed circuit on almost all kart engine carbs are responsible for delivering fuel in the 30%-100% throttle range. If the high speed circuit is lean enough to cause piston seizure, it will also tend to cause a laziness in mid-range throttle response. Dangerously lean high rpm racing motors can sometimes offer acceptable mid-range, however they will accelerate to peak speed very slowly.

The classic lean seizure exhibits heavy scoring and seizure along the entire width of the exhaust port with only light scoring on the opposite piston faces. In lean mixture conditions, the exhaust gas temperatures escalate quickly into the meltdown stage. Those high temperature gases can compromise or completely burn off the oil film on the exhaust piston face as the exhaust port is being covered up. With the oil film weakened or gone, scoring quickly turns into seizure and ring locking.

Air leak seizures: If you could pressure check every engine that showed up at a local racing event, you would find some of them to have an airleak. Because of the varying

degree of these leaks, some will result in seizure, others will only cause poor carbureton or slight overheating. The varying effects of these air leaks makes this a difficult diagnosis.

In any situation where an engine has seized for no apparent reason, the motor should be pressure tested before any other teardown work is performed. If a mechanic does not have the equipment to pressure test your seized engine, it's very unlikely that he will have the finesse to accurately diagnose your problem either. In fact, pressure testing should be a standard finishing procedure for any major engine reassembly work. Race engines should be pressure tested every re-build.

The air leak piston seizure, depending on the severity of the leak, can look like a four corner type or a lean mixture type of scoring pattern. If an engine is operating on the ragged edge of overheating, a small air leak can easily cause the extra overheating that will result in a four corner seizure. On the other hand, a huge air leak will draw in so much additional air that even an over rich engine can experience a lean type seizure at full rpm's.

Detonation seizures: If a modified engine has been prepared with too much compression or spark advance, or if it's run on unacceptably low octane fuel, it will begin to "ping" or detonate. Detonation is a big subject the merits another article of it's own. For now we only need to understand that it causes a terrific amount of internal heat in a very short time, as well as physical damage to the combustion chamber. If you have ever seen the outer diameter of a cylinder head dome that looks as if it's been eaten by termites, you have seen the results of detonation. It packs a physical force that is roughly equivalent to hitting the edge of the piston crown with a full arm swing of a ball peen hammer. In a short amount of time, this detonation pounding will collapse the ring land and lock the ring in place (usually on the hotter running exhaust side of the piston). As soon as the ring is locked, the flames of combustion burn the oil film off of the cylinder wall, and the scoring/ seizure process begins. Because of the exhaust side scoring and the swift overheating caused by detonation, you'll have a 50/50 chance of a four corner seizure or a "lean mixture" appearing seizure. Only an experienced engine builder will be able to accurately diagnose this seizure source.

Cooling system seizures: This cause cuts into the gray area of piston seizure. A clogged cooling system on any machine can cause swift and serious temperature problems. However, no engine will ever experience a seizure purely as a result of inadequate cooling from the stock system. I have seen several karts run an entire trouble free season with a bone stock cooling system. These engines are not a statement of the effectiveness of the stock cooling system, but rather a statement to the benefits of having a professionally prepared high performance combination. The larger line and dual line cooling kits certainly have their merits on high output race engines that will be run at full throttle for extended periods of time. Their ability to more rapidly exchange away engine heat is a great asset on modified engines that are run at full throttle only. However, none of them can exchange away the excess heat created by a poorly prepared engine package. If you are experiencing chronic piston seizures of any

kind, increased cooling may temporarily stave off the problem, however it will almost never cure it.

Piston clearances As mentioned earlier, too little piston clearance is one of the most common " wrong " diagnoses made on seized watercooled engines. Most of today's engines come brand new with cylinder clearances that are .001"-.002" over the recommended factory setup clearance. This extra clearance is an added protection against drivers who don't follow the proper break-in procedure. If the clearance of a bored cylinder has been set at the factory recommended clearance, the close piston clearance by itself will not cause seizure. There is usually an added factor such as excessive compression or an air leak. If a piston if fitted with too little clearance, it will usually experience a four corner type seizure pattern. In most cases the ring will experience little or no damage. If this is the case, it's entirely safe to sand the score marks off the pistons and re-use them in the freshly honed cylinder.

Too much piston clearance can also result in piston scoring and seizure. A piston ring, in an excessively large cylinder bore, will have a very wide end gap not to mention very weak ring tension against the cylinder wall. The flame of combustion can easily burn past this weak ring seal as well as down the end gap opening itself. If this flame burns off a significant amount of the oil film on the cylinder wall, the scoring seizure process begins.

Break in seizures: The most common break in related seizure is usually caused by the ring not the piston. Some new piston rings come with a coating on their outer sealing surfaces. This coating seals to the cylinder wall in just a few operating minutes, which provides better power during the break in period. As the engine is breaking in, the Teflon eventually wears away and lets the hard surface of the ring come in from behind to provide the long term seal. The down side of this coating is that it makes for a dangerously small end gap during the first hours of operation. If the engine is run too hard too soon, the heat will cause the ring to expand in diameter which may drive the ring ends together and drive the ring surface hard against the cylinder wall. A piston ring that is being overheated in this fashion will easily have enough tension against the cylinder wall to scratch off the oil film which will begin the scoring/seizure process. A piston seized in this way will have heavy scoring around the entire diameter of the piston, with the ring usually locked into the groove all the way around as well.

Lubrication related seizures By now it's apparent how important the oil film strength can be. Equally important is the amount of oil that is present in the engine. Most kart engines carry factory recommendations for oil premix ratios between 15:1 and 20:1.

The total amount of time that it takes for a drop of oil to get from the carburetor, to the lower end bearings, to the top end, and out the exhaust port is called "oil migration time". As peak rpms increase, the amount of time that a drop of oil remains inside the engine is drastically shorter. In other words, a 17000 rpm race engine would need a mix ratio of about 20:1 to maintain the same internal lubrication presence that a 12000 rpm engine would have with a 30:1 mix. There are several oil brands that claim that their oil can provide equal lubrication at a leaner mix ratio (40:1 or 50:1) because of a claimed

better lubrication quality. I have never experienced this to be true nor has any oil manufacturer, to my knowledge, proven it to be true. It's like running your truck on two quarts of a special oil instead of four quarts of a standard type oil. The quality cannot make up for the quantity.....Ever.

Seizure by running out of gas: - as many people already know, a larger size needle and seat must often be installed into a carburetor to contend with the increased fuel demands of a moderately modified engine. If a modified engine is operated at full throttle with a stock size needle and seat, it will usually carry full rpm for about 2 or 3 seconds and then shut off as if someone hit the kill button. When the machine comes to a stop, the driver re-starts to see what the problem is. The engine, no longer in fuel deficit caused by the undersized needle and seat, unexpectedly starts right up.

This instant high speed shut off is caused by the carburetor literally running out of gas. It is sometimes possible that during this shut down moment of fuel starvation, the engine is also starved of the oil that is pre-mixed in. This oil starvation may cause subsequent piston scoring or seizure.

At the moment that the fuel starved engine shuts down, combustion and all the heat associated with it "ceases". A karts rear wheel traction continues to move the pistons in the bores at a very high "friction causing" speed,. This same concept applies to any machine that simply runs it's tank dry.

It is possible for a driver, whose carb has an under sized needle and seat, to induce a piston seizure. However this would require a great deal of combined skill and stupidity. Once the driver has established that extended full throttle operation causes his engine to quit, he might make the very poor choice of only applying enough high speed throttle to avoid starving the engine. When he does this, he will be capable of maintaining about 90% throttle which will hold the engine endlessly on the lean thresh hold of fuel starvation. As this driver eventually masters this throttle position, he will be able to maintain a very high rpm with the carb feeding a horrificly lean mixture. Ultimately his finesse will be rewarded by one of the most abrupt and destructive lean mixture seizures that his mechanic has ever seen

FABLES AND UNTRUTHS

Cold seizure: - this is by far the most over used "seizure scape goat". It some how implies that the driver ran his engine in a way that caused the failure. At least 95% of the "so called" cold seized engines have had a very apparent problem elsewhere in the engine that the builder failed to see. Telling a customer that he cold seized the engine is an easy way for a mechanic to immediately reverse the guilt and the responsibility.

If a freshly bored engine or a high performance engine were started from stone cold, and then run hard at high rpm within 30 seconds of the start up, it could very likely experience a true cold seizure. This happens because the aluminum piston would

experience a radically faster rate of expansion in that 30 seconds than the cylinder does. The reason for this difference in expansion rate is two fold.

First and foremost, the internal temperatures that the piston crown is exposed to at full load are on the order of 1500'C-2500'C. The gases passing through the exhaust manifold ports is also in this temperature range. The expansion rate caused by these temperatures is usually not a problem when the water entering the water jacket is preheated. During the first 30 operating seconds, cold incoming water will maintain the water jacket around the cylinder at "stone cold diameter" while the piston is becoming "full temperature diameter". On engines with properly sized pistons, the difference in these diameters becomes much more than even the best oils can withstand. Any engine that has been warmed up for 60 seconds or longer, would be virtually incapable of a "cold seizure"

Hot water seizure: - the hottest water operated in high output race machines is about 92' C. Machines equipped with a single cooling line system show no signs of any piston scoring or seizure. There is evidence however that the warmer water causes engines to lose peak power ability during longer races.

Leaning out: - this is a term for a phenomenon that doesn't really exist. It implies that a carburetor, whose needle/seat and high speed metering screw is properly set, will suddenly begin to meter slightly less fuel to the engine for no apparent reason. This does not happen .... Ever. In most cases what a driver is actually referring to is the way his machine begins to slow down noticeably during a long full throttle pass. In most cases this slowing is the result of a serious overheating problem caused by excessive compression, ignition advance or poor quality gaso