Pistons in 2-strokes are under the highest stress of any components in almost any engine, even higher than in a turbocharged 4-stroke. 4-stroke pistons only see combustion load on every other cycle, and are cooled by cold incoming air on the alternate cycle. 4-stroke pistons can also be cooled by oil jets on the underside, as in the new Ski-Doo 4-TEC engine.

Heat, cooling and design
A 2-stroke piston sees a combustion load every time it goes past top dead center, and must transfer a lot of the heat from the crown to its skirts. There the heat is transferred to the liquid-cooled cylinder wall, or cooled by the incoming fresh charge in the crankcase.

An average 2-stroke snowmobile engine must do this 8,000 times per minute, while keeping the heat flow through the piston balanced at a level that ensures survival. In Piston Tech 1.0 (AmSnow Dec. ’08, p. 34) we took a look at improvements in both piston material and cylinder cooling, which has led to the present high power levels achieved in snowmobile engines.

There are two materials presently used: high silicone cast and low silicone forged pistons. Both have advantages. The high silicone cast pistons are harder and expand less under heat loads, but are more brittle and need stronger reinforcement ribs to prevent them from cracking. Lower silicone forged pistons can be made lighter without breaking, but expand more under heat load and must be set up with a couple thousandths of an inch more clearance when cold. Usually there’s an increase in piston noise when the engine is cold, but when fully heated the running clearances are close to the same.

Cylinder cooling has improved from air-cooled engines to fully liquid-cooled cylinders fed from the crankcase to the underside of the exhaust port to keep this area cooler for maximum heat transfer. Nicasil coated cylinders also transfer heat much faster than steel sleeves and Nicasil now is a standard cylinder surface.

Yet, with all the advancements, there are a number of critical areas when it comes to both piston and cylinder design.
that make a big difference in reliability. One area is the ring pack used and the crown's design. There may be a considerable difference in the use cycle the piston goes through. For instance with a motocross bike or snocross sled, the pistons only see short bursts of power, and a lighter piston might benefit acceleration.

On a snowmobile that sees long hauls across lakes there is much heavier heat loading on pistons, and the heat needs to get from the crown to the skirts to keep the ring land from collapsing and pinching the rings. Once the rings are unable to move, hot gases blow by and burn up lubricating oil, leading to a piston seizure.

Many years ago, our firm worked with Olav Aaen at Wiseco to solve a recurring ring land collapse problem on one of their snowmobile pistons. The piston was of a very light and advanced design that had worked well on motocross engines, but with a higher constant snowmobile load, the ring land would collapse and pinch the ring after only 20 minutes on their enduro dynamometer.

The problem turned out to be insufficient material behind the rings for the heat to transfer from the crown to the skirts. As a result the ring land would overheat, the material would soften and the rings would get pinched. This design had worked fine on a motocross bike because the piston had time to cool between the short bursts of acceleration, but under the sled's harder constant load the crown and ring lands overheated.

The Wiseco engineer redesigned the piston using a forging with more material behind the ring land, allowing a wider heat flow path between the crown and skirt. He then ran it for 20 minutes on the enduro cycle and inspected the piston. It looked brand new with no signs of ring land collapse. He then ran the piston for 4 hours, then 20 hours, and there still were no signs of ring land collapse.

With the wider heat flow path, the problem had been solved, and the increased weight required was only 20 grams. If you feel you can get an advantage in your race motor by lightening the piston, be careful and leave the area behind the piston rings alone.

Ring pack design also can be critical to a piston's life. Should you use one or two rings, straight rings or top mounted L-rings? Each ring creates a drag on the cylinder wall as it moves up and down. This friction can be 1-2 hp per cylinder depending on ring design and piston diameter. Using a single top-mounted L-ring vs. 2 straight rings may save you 2 hp per cylinder on a big twin, and competition being what it is, 4 hp can give you a winning edge. This may be fine in a drag race or an on-off snocross run, but may be a problem in cross-country enduro or on a long wide-open run across the lake.

With only one ring there's more blow-by of hot gases, and they tend to wash away or burn up lubrication under the ring, and down the piston skirt. With two rings you not only have twice the sealing against blow-by, the lubricating oil tends to accumulate between the rings, keeping the ring grooves and ring land better lubricated.

A top mounted L-ring has some advantages in controlling port openings, but also has the disadvantage of a much thinner ring land that tends to overheat and burn easier. Another problem with rings mounted close to the top is that the locking pins are more exposed. In one case it actually got so hot it acted as a glow plug and caused pre-ignition at the back of the piston. In other cases the pin loosens up and disappears, allowing the ring to rotate and get caught in the exhaust port, damaging both the piston and cylinder.

Exhaust port design

Exhaust port design also is critical to piston life. With such a big hole in the wall with very hot edges, it's a real balancing act to make the piston and rings move past it at high speed without getting snagged. If the top and bottom edges are correctly curved, the width of a single port can be as much as 65% of the bore. On racing engines as much as 72% has been used. If the top edge is square you have a potential piston snagging trap.

Not only is a square shape bad for the piston, it also makes for a peaky power curve. With hot exhaust gases streaming out of the ports, sharp edges can get very hot and grow into the cylinder, seizing the piston. Generous radiiuses on the port edges are good insurance against this.

With the edges getting hot, lubrication will not stay on as far as 2mm in from the port's edge. If you have side exhaust ports, the bridges get heated from both sides. If your bridge is 4mm or less wide, you're going to have little lubrication, and the bridge will tend to expand into the cylinder and seize the piston.

If you have a skinny bridge that either seizes the piston or leaves black streaks down the skirt, you can only get some resemblance of life out of it by undercutting it 0.01 to 0.015 with a sanding roll. A popular practice is to drill lubricating holes in the piston by the affected area, but this seems to have little effect on the problem.

We tried a lot of different things to solve this problem in an engine with a severe duty cycle in our road racing car. Despite intricate hole patterns, cross grooves and lubrication slots, nothing worked until we widened the bridge to 10mm and added material behind it to remove the heat. The pistons looked brand new when we tore down the engine after a race.

With 20/20 hindsight this makes sense. If the bridges get heated up 2mm in on each side so no lubricant will stay on, you have no lubrication on a 4mm wide bridge, but with a 10mm wide bridge you have a nice 6mm wide well-lubricated bearing surface for the piston to run on in the center of the bridge. Another plus is that the added material transfers heat on the bridge away and into the cylinder.

In most cases, when the bridge is widened the port is moved further over the transfer port. This means the far edge of the main transfer now sits directly under the bridge and therefore lubricates the piston skirt where it runs across the bridge. This is a win-win situation, and instead of getting two races out of a piston, we ran the combination for two seasons, still without measurable wear.

So what do you do if your bridge is too narrow and causes piston wear or seizures?

If you just run short races like drags or snocross, you can undercut it by 0.015 inches to prevent it from expanding into the bore. Bridges can be widened by welding in the port, but the cylinders have to be re-plated after the cylinder is re-ported.

We have used this procedure with success on big bore kits. With advances in material, piston cooling and exhaust port design, modern high performance 2-stroke engines are now very reliable, despite the extreme heat cycle they go through.

Olav Aaen is a long-time contributor to the snowmobile industry. As a mechanical engineer and president of Aaen Performance, Olav has been heavily involved with snowmobile performance since 1968. Aaen Performance is best known for pioneering performance pipes and introducing the roller clutch to the snowmobile marketplace.
Remove and tune a QRS clutch

Check out these tech tips for Ski-Doo’s new secondary!

Ski-Doo’s new QRS secondary clutch is quite an advancement for the snowmobile industry and it shows that Ski-Doo engineers are “thinking outside the box.” But, such change means we must re-think how we swap out a clutch and clutch components.

The first notable design difference is that you can’t just unbolt the clutch from the jackshaft. That’s because one of the clutch sheaves is cast directly to the jackshaft, and the other is simply slipped over it instead of using the standard clutch hub.

Yet, the new secondary system has two extremely positive attributes. First, it’s a lot lighter. Second, it now has a double-supported movable sheave.

Its light weight was achieved by using a hollow hydroformed tube and fusion welding the gear spline hub to the end, thus having a totally hollow jackshaft. The one movable sheave is now directly bolted to the helix, creating a more supportive movement with less stress on the clutch and bushings. When a movable sheave and the helix are bolted together, the amount of sheave movement back and forth is almost eliminated producing better belt and bushing life, and more precise clutch shifting.

QRS clutch/jackshaft removal

Removing the jackshaft assembly is fairly easy. Here are a few easy steps:

• Step One: Remove the belt, and the belt adjuster. Using your supplied tools from the sled, insert the clutch tool into the center of the belt adjuster and loosen the center nut three turns. Insert the belt adjuster tool and compress the clutch until you are able to remove the belt. After belt removal, completely unscrew the adjuster and remove. Unbolt the gold bearing keeper support just behind the clutch itself.  
• Step Two: Remove the rubber cover on the top side of the chaincase. Unbolt the top gear through the hole and be sure not to drop the bolt and washer.  
• Step Three: You’ll need to push the clutch out through the left side of the sled. Completely push the shaft through the jackshaft bearing support tower. Do this by putting pressure and possibly slightly tapping on the chaincase side of the jackshaft. As you push the clutch out of the chaincase, the top gear, spacer and chain will not be supported anymore and will fall to the bottom of the case. To avoid this, put a screwdriver down the center of the threads and leave it there to hold the components during removal. Ski-Doo has a tool specifically designed to hold these items during removal too. (Part No. 529 036 110, price $28) After removal, you’ll notice the system’s extremely light weight assembly compared to a traditional clutch and jackshaft.

HOLD IT! – You will need to hold the top gear, spacer and chain in place upon removal of the clutch and driveshaft, a screwdriver will usually work just fine.

Clutch helix removal/new install

To remove the helix, a helix compressor tool is required.

• Step One: Insert the tool into the threaded end of the jackshaft and then add the plastic spacer and washer from the tool. Thread the handle onto the tool and screw down to compress the spring.
**QRS clutch/jackshaft install tips**

Installing the full assembly is pretty much a reverse of the removal, but here are a few tips to keep in mind:

- **Tip One:** The most important thing to remember is that when sliding the shaft through the bearing housing and into the chaincase, DO NOT drop the chain, gear and spacer or you'll add a ton of time and difficulty to the process. To make sure you don't drop them as you're installing the shaft, put the screwdriver into the bolt hole and keep it there until the gear splines are lined up and pushed in. Also, when aligning the splines, you may have to rock the shaft back and forth to help alignment. A typical installation requires two people.

- **Tip Two:** You may not be able to push the clutch side bearings all the way into the housing because there is a small amount of press-fit between the bearing and housing. To remedy this, simply install the gear bolt and begin tightening. The bearing will pull itself into the housing. Also, make sure you have no binding during the install. If your bearing starts to bind, apply a small amount of lube inside the housing. This helps smooth the installation.

- **Tip Three:** When installing the bearing keeper and belt adjuster, set your belt tension and lock the center nut three turns.

**QRS tuning**

Ski-Doo's new clutch assembly is a big change, but it still possesses all the tunability of any previous clutches. Helixes and springs are still available for tuning the QRS system. The same springs available for the RER button and RER roller clutches are standard items for the QRS. There are many springs available for self-tuners from Ski-Doo and aftermarket shops, including mine, Straightline Performance.

QRS helixes are full cast helixes with one angle pre-cast into the mold from Ski-Doo. Straightline's QRS helixes are machined from 6061 billet aluminum and are available in most common angles. Typical ski-doo helixes on the stock 08-09 machines are small progressive or straight angle cuts. Ski-doo helix's can range from straight 44, straight 42, and short progressives angles like 42/40 and 44/47.

Clutch tuning is no different than in earlier Ski-Doo models as all the same theories apply.

Compared to stock helices, we see advantages to aftermarket replacements, like Straightline's new 2-piece billet helix. The new 2-piece helix allows the consumer to buy the cover and helix separately saving up to $50 on all following helices. This is a significant amount of money when buying several new helixes to test.

Cast helixes also can have larger tolerances than a fully machined part. Cast parts go through contraction and expansion during production. Hence, the material changes have tolerances to work within and are suitable for production machines.

Straightline's new cover and helix assembly allows the user to buy a cover and then individually buy just the base helices. Using the 2-piece helix, you can just buy a helix angle without a complete helix. The new cover also allows for the use of a torsional spring to produce a torsional load as well as a compression load. During a shift, the spring rate changes at a more precise speed having two loads applied on the helix. Using both forces makes the clutch shifting more repeatable and consistent.

**New CVTs**

Today's continuously variable transmissions with clutches like the QRS still have the same theories as CVTs of the past, but they have improved the percent of horsepower transferred through them with improved geometry, more precise machining and support characteristics. These advantages produce less slippage and belt heat, which means more horsepower to the ground.

With weight loss, EPA guidelines, engine efficiency and other concerns being the focus of much of the current snowmobile technology, there still have been improvements with the CVT system helping to move the machines to the next level.

Is there anything left to be improved? Can it be any lighter?

I get these questions daily, and the answer is yes. With the constant research and development being done, we will soon be asking ourselves again, how did we ever ride those old machines? 🚘

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Jason Houle owns Straightline Performance in Forest Lake, Minn. For more info on this topic, or Straightline's products, visit www.straightlineperformance.com.