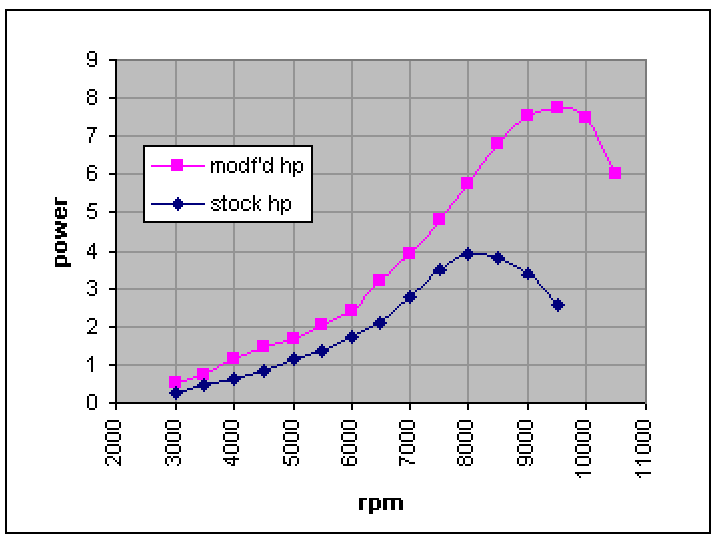
CVT Clutch Tuning Basics - Part 1: Background and Basics

Of the many modifications that are routinely performed, clutch tuning is probably the most misunderstood. It's thought by many to be a matter of hit and miss, or more supremely a black art of sorts. This article will attempt to dispel some of these misunderstandings and offer some insight into the how's and why's of mini quad clutch adjustment. The principles described here apply to all of the Asian mini-quads as well as some of the Japanese minis as well such as the LT80.

Before jumping into how to do it, it's necessary to understand what the clutch does and why it was designed that way to begin with. The automatic CVT, or continuously variable transmission, is a cousin of your typical multi-speed, constant-mesh, gear-driven manual gearbox. Whereas the manual trans requires proper selection of the gear ratio to maintain power, the automatic trans does the thinking for the rider.

Of course, for novice riders the auto trans is a huge advantage in simplifying the riding experience. No worrying about stalling the engine, or keeping it in the right gear- it's all done magically by the CVT. However, unlike the CVT's other cousin, the automotive style automatic transmission, the CVT is designed very cleverly to continuously vary the transmission gear ratio to do one thing only- hold the engine speed constant.



This concept is key, and the crux to the whole tuning exercise. If you were to examine the power curve of a typical 2-cycle engine it would rise, and then fall very quickly near its power peak- hence the notorious reputation of the 2-stroke as a "pipey" variety compared to the more docile and predictable 4-stroke.

The question becomes- if you were limited to operating your engine at only one rpm, what would it be? The rpm at which peak power occurs, of course, and therein lies the beauty of the CVT transmission- it's ability to hold the engine there. The job of the clutch tuner is to identify that point and dial it in.

When modifying your engine you've more than likely shifted that peak power rpm. The original equipment manufacturer (OEM) has probably optimized his gearing to coincide with the stock machine’s peak power rpm. Without readjusting the clutching to realign the controlled rpm with the new power peak, full advantage of the engine mod may not be realized. In the example above, the stock clutch would be adjusted to hold the engine at 8000 rpm from the factory.

If the clutch wasn't readjusted to run at 9500 rpm, only a 50% improvement would be gained since there's only another 1.7 hp available at 8000 rpm. Not too shabby, but if the clutch was properly adjusted then max power available to the quad would be nearly 100% higher, or double!

Not to worry, most performance shops will sell you their products with either recommendations for a particular clutch setup, or provide the clutch hardware as part of their kit. They've no doubt ran their own hardware and through their own extensive testing have determined that a certain set of rollers and spring result in the best performance.

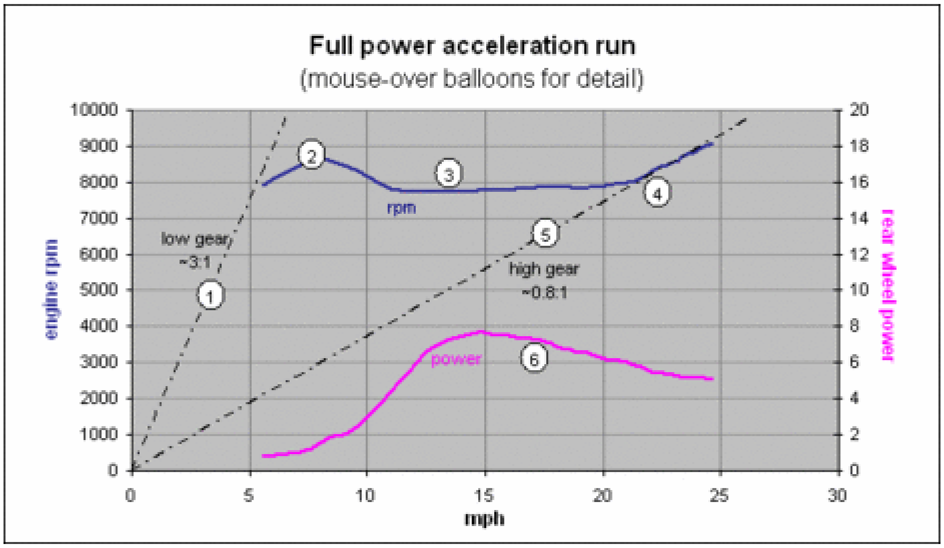
Realize though, that there are subtle (and not so subtle) differences between machines, and the recommended setup should only be considered a starting point.

Move on to next part --> Understanding the Fundamentals

There are two options for clutch optimization- A) a scientific method, or B) a not so scientific method (but also still effective). The way a manufacturer might do it is as follows. First, the engine alone is ran on an engine dynamometer (a means to brake, or provide resistance to the engine) which is connected directly to the crankshaft without transmission. The throttle is held wide open and the dynamometer holds the engine at a low, steady rpm. Slowly, the dyno allows the rpms to increase until the engine reaches redline, all the while measuring power (torque x rpm).

Inspection of the power curve would reveal what rpm peak power occurred. The engine is then reinstalled in the ATV, along with clutch, and fitted to a chassis dynamometer (the "braking" now occurs at the rear wheels rather than at the crankshaft). From a standing start, the throttle is again held fully open and the quad begins to accelerate to top speed.

If the clutch is doing its job optimally, then the rpms will rise, and then hold at the peak power rpm while the clutches adjust the ratio, and then finally continue to rise again once the maximum range of the CVT adjustment has been exceeded. If the shift-speed rpm is off, then an adjustment is made to the roller weights.



This acceleration profile is useful in explaining the overall function of the CVT clutch system. As the throttle is applied from rest, the engine speed quickly rises, spinning the front clutch and variator assembly.

At this stage the belt is resting against the innermost part of the front clutch, and is pushed outward on the rear clutch by the squeezing force of the large torque driver spring. As the rpms rise, the rollers in the front variator are flung outward in their slots and have the effect of squeezing the front sheaves together, thus gripping the belt and starting it to move.

As the belt moves it begins to rotate the rear clutch. The rear clutch begins to spin and accelerates as well. But the quad hasn't started moving yet. Inside of the rear clutch are three brake shoes that are held in place with extension springs. Once sufficient rpm is achieved centrifugal force starts to move the shoes in the rear clutch outward against spring tension of the three little extension springs. The shoes engage on the drive drum and the quad begins to move.

The ATV now begins to accelerate and the rpms briefly over-rev as the shoes seat and settle in to the “shift-speed”. The elegance of the CVT is in this ability to maintain the rpm independent of vehicle speed… When the rpms go above the shift-speed then the increased centrifugal force pushes the variator rollers out farther, squeezing the front sheaves *together* more, thus slightly lowering the ratio of CVT (higher gear), and therefore dragging the engine speed back down.

"gear" cross-reference	
when **front** sheaves are **apart-**	when **front** sheaves are **together-**
under-drive, low gear, short ratio, high numerical ratio	*over-drive high gear tall ratio, low numerical ratio*

Think of what happens when you shift a manual trans quad from 1st to 2nd – the rpms *drop*. The converse also applies, when the load increases (like going up a hill) and the rpms drop, the clutching automatically compensates by easing the front sheaves back apart, increasing the ratio (lower gear), until the shift-speed is achieved again. In practice, this happens so quickly, and on such a minute scale, that these adjustments are completely unnoticeable.

sheave's aliases	
front-	**rear-**
drive, primary, variator	driven, secondary, torque-driver

Moral of the story is this: *the variator roller weight is the primary means to adjust shift-speed*. A higher weight will have the effect of squeezing harder at a given rpm, therefore decreasing the ratio (increasing the "gear") and decreasing rpm. Likewise, a lower weight will increase the ratio as well as shift-speed.

Finally, once the adjustment range of the CVT has been exceeded (when the belt is all the way OUT on the front clutch) the quad can continue to accelerate, but no longer at constant rpm. The transmission will essentially act like like a manual gearbox stuck in top gear and the engine will continue to accelerate the quad until it runs out of power, or hits the rev limiter. It's important to understand this since the power of your motor will fall off quickly after the power peak. Since the CPSC has limited youth quads to barely over 15 or 20 mph, they will reach this "rev-out" point fairly early (about 22 mph in the chart).

To reach 30 or 40mph will require modification of the final drive gearing such as new transmission gears, or drive chain sprockets. Otherwise the motor will be spinning at 12,000rpm+, possibly way past its power peak, assuming the rev limiter will even let it.

The rear torque-driver spring also has a very specialized function which is to maintain enough tension on the belt to keep it from slipping. This also is a bit of balancing act because too much belt tension translates to inefficiency. It's kind of like over-tightening the chain on your bicycle- power is wasted by over-stretching the belt. On the other hand, too little tension and the added power of your recent engine modification will vanish as heat generated by belt slipping and won't find its way to the rear tires. The trick is to find the just the right tension without overdoing it.

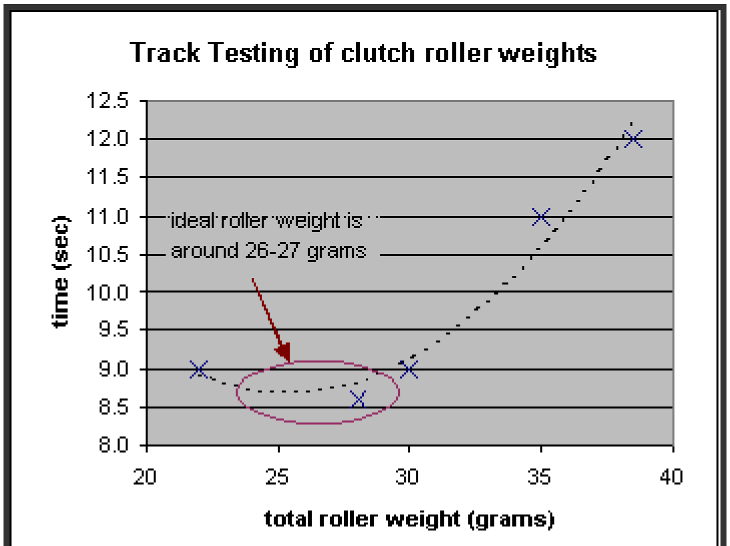
A secondary influence of the torque driver spring is that it has a slight impact on shift speed since the belt tension needs to be reacted against by the front sheaves. The higher belt tension tends to push the belt deeper into the front sheaves making the ratio higher, and revving the motor higher. Therefore, for a given desired rpm you would need to compensate with a higher roller weight to bring the rpms back down. After a torque driver spring change, it's good practice to re-optimize the roller weights.

The three shoe-springs are really the only clutch parts that enjoy the freedom of rider preference. But their role in ratio adjustment is short lived – once the machine has started to move it's all up to the rollers and torque-driver spring. Installing a very tight, stiffly sprung set of springs will provide a higher "stall" speed, effectively raising the rpm during launch. Alternately, a softer set of springs will provide a little easier, smoother engagement. After the shoes have engaged, there's little if any effect of the shoe-springs.

Move on to next part --> Making the Adjustments

So, how does the average Joe do it? The reality of the matter is that most guys will replace this highly specialized process with good ol' fashioned track testing. Although seat of the pants feel goes a long way, it can't be relied on for the last 5-10% of refinement. Using a stop watch, a marked-off flat section of track, and a consistent rider you can also dial in your clutch with some trial and error. Make at least three pulls with your machine fully warmed up and use the average time. Pick a section of track that's flat and has few ruts, bumps, etc. The length of track should be just enough to allow the machine to just come off the clutch, where you notice that rpms start to climb again ("rev-out" point). Don't pull to the redline since the machine performance will fall off quickly there. The heavier the rider the better, since it makes the pull longer and minimizes the effects of errors due to timing.

Off the line the rpms should rise quickly and over-rev just slightly. This is due to the rear clutch shoes slipping and finally engaging fully. Any burble or hesitation here should be addressed through jetting, not clutching. Once the rpms settle into a steady whine, they should hold steady until the clutches run out of ratio adjustment, then start rising towards redline. Up to this point, any slipping would sound like the revs being unsteady or climbing. If so, change to a stiffer rear torque driver spring.



Using some graph paper you can plot the time for each roller combination to identify the best setup.

Using a systematic trial and error method, you can then dial in your roller weights. If you notice that the machine really starts to accelerate harder after the rev-out point, that's a perfect indication your clutch rpm setting is too low- go to a lighter roller weight. The reason for this is that the clutch is keeping the motor from reaching the peak power rpm, but after the clutches run out of ratio, the engine finally drives through that "sweet spot". As you keep moving down in roller weights you'll notice your times will improve but begin to flatten out, then start to take a increase again as you pass the power peak rpm. It may be helpful to plot your times against roller weight on some graph paper and draw a curve between your points.

Swapping out your clutch parts can be challenging. First, remove the LH clutch cover. Don't forget to remove the screw in the center of the cover. Some light tapping from the other side of the motor with a hammer and screwdriver against the cover tangs can help to break the gasket seal. Finally, coaxing the cover off the two dowels make take some additional tapping, wiggling, and prying since the steel dowels have a tendency to rust slightly in the aluminum cover.

Removing the front variator is relatively simple if you have an impact wrench. Just spin the nut off the crankshaft and slide off the outer part of the clutch. Next, remove the belt. Last, slip off the inner part of the variator. Make sure all the surfaces are fairly clean and free from burrs or buildup. Click here for an exploded view of the entire clutch system.


Front variator disassembled showing new rollers inside.

New rollers in a variety of sizes are available from most of the mini-quad aftermarket suppliers such as Hetrick Racing and come in sizes ranging from 3.2 grams to 9.2 grams per roller (stock is about 6.5) in ~0.5g increments. These sizes will vary rpms from roughly 8500 rpm to 5000 rpm when using all six rollers. You can, however, only use three rollers, or use three of one size and three of another (alternating) to get just the right rpm. To install, reverse the disassembly process and torque the crank nut to 39Nm by inserting a flathead screwdriver between the teeth of the starter gear and case webbing. The rear clutch is a bit trickier. Remove the small O-ring and nut holding the clutch onto the shaft. Once removed, you'll notice a huge nut on the rear shaft – about 1-5/8" or so. There are two options. One is a socket and impact wrench, but finding one is not common outside of a Caterpillar or Mack service yard. Making a custom spanner wrench is another option.


Rear clutch disassembled showing shoes and springs.

Removing this nut will liberate the large torque-driver compression spring as well as expose the three small shoe-springs. The shoe springs take some finesse to remove and reinstall. Be extra careful to a) not poke a hole in your hand, and b) shoot the spring across the shop. When installing new springs, a heavier spring will delay the engagement rpm (higher stall) and a lighter spring will do the opposite. Some riders prefer a hard hitting clutch which results from a higher rpm stall, while others appreciate the lower rpm/power engagement.

And lastly, to ease the process of parts swapping, don't worry about installing all the cover screws- three or four will be more than enough for testing purposes. However, DO make sure to use the cover. For two reasons: one is obvious- safety, but the other is that the cover has an outboard bearing in the cover that provides critical support to the rear clutch shaft.

Take your time, think about what's going on, take careful notes, and you'll be way ahead of the other guy who didn't.