A Tutorial on Break in and Needle setting for a model helicopter motor.

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NOTE: This procedure assumes a new, RINGED motor, and does NOT deal with ABC/ABN ringless motors. It's a method that has worked for me for many years. It is one method that works, there may be others.

Initial needle setting:

The best place to start with the needle valve setting is the factory recommended settings found in the motor's manual. These settings are usually lean enough so that the motor will actually start and run, but rich enough so that you won't fry the motor on the initial run.

Background I've learned from those Plank Days:

If you have ever run a model airplane engine on a test stand, or had the opportunity to run one installed on a plane, you've been able to play with the needle valves and see what they do without cooking the motor, or chopping parts of your body off by rotating blades.

A control-line motor has two speeds. Off and On, there is no throttle. It's from these that I learned early-on about high speed needle adjustment. Start one of these, then play with the needle valve. You can make it very rich, and what you get is a motor that runs erratically, one that spits a lot of raw fuel out the exhaust, and quite often, raw fuel also gets blown out of the venturi. But it runs. It sputters, blubbers, coughs and spits, but it does run.

The needle valve in these motors has a long taper that fits inside a fixed diameter brass tube called the spray-bar. As the needle valve is screwed into the spray-bar, the taper begins to cut down on the amount of fuel that can go through the brass tube. The taper of the needle valve is very long and gradual, the threads on the needle valve are fairly fine, allowing a very control of the amount of fuel allowed into the spray-bar. Whatever fuel gets through this needle valve is drawn into the carburetor, down the venturi, and into the motor where it makes things go. Screw the needle in, you decrease the amount of fuel in the fuel-air mixture, you go lean. Screw the needle out, you increase the amount of fuel in the fuel-air mixture, you go rich.

As you begin to lean out the needle valve, the motor speed increases a bit, the amount of raw fuel coming out of the exhaust and venturi begins to diminish, and the coughing, sputtering, and erratic behavior begins to "get better".

When too rich, the motor is not always firing on each down stroke because the fuel isn't completely being burned, it's almost running as a four-stroke at this point. That explains the excess glop in the exhaust, the fuel coming out of the venturi, and the erratic operation.

Continue to lean out the needle, you will find there is a distinct needle position where the motor seems to be switching between two modes of operation. It actually changes the way it sounds. You can hear it alternating between a four-stroke cycle, and a two-stroke cycle. The sound alternates between a "low" note, and a "higher" note. The amount of raw fuel coming out of the exhaust is greatly diminished, and very little is still coming out of the venturi.

(If you're hovering a heli with the motor's needle set here, you'll be one of those complaining that the gyro is having a difficult time holding the tail, or complaining that the tail is twitching all over the place. The reason being, at this needle setting, when the motor is in the four-stroke cycle part of running, it isn't

developing a lot of power. But when it switches over to the two-stroke mode, it does begin to develop power. Power is being delivered to the drive train in bursts, and the gyro is doing all it can to handle the situation).

The motor generally stays very cool when run at this particular needle setting. You can put your finger on the cylinder head all day long and won't get burned, just a bit warm.

As you continue to lean out the high speed needle, the motor begins to operate solely in two-stroke mode, what it was designed to do. The RPM increases, the power output increases, the amount of raw fuel going out the exhaust continues to decrease, almost no raw fuel escapes out the venturi, and the operating temperature of the motor begins to rise.

If you continue to lean out the high speed needle, you will hear the RPM increase, and you can hear the motor's note change as it comes onto its power curve. There is a distinct sound the motor makes as it gets close to its optimum needle setting. Operating temperatures continue to rise to the point where it's almost instantly uncomfortable to touch the cylinder head.

As you lean out the main needle even further, you reach a point where the RPM actually begins to decrease (sometimes very rapidly), power output drops dramatically, and the heat generated is tremendous. It's THAT point where you have gone too lean with the main needle and get into the gray area that can fry your motor.

In general, adjust the high speed needle just to the point where you detect the RPM dropping off, and then back off, or richen the main needle three or four clicks to obtain the optimum needle setting, just a bit on the rich side of peak power development.

Add a throttle to the standard control line motor to make an RC motor:

The carburetor of the RC airplane motor allows you to control motor speed from your transmitter. There are various forms of carbs, but essentially they involve a rotating barrel that cuts off the amount of air that can go through the venturi (making things go rich – lots of fuel, not a lot of air).

Simple carburetors such as those on the OS MAX "LA" series of motors, and those found on ENYA motors have a rotating barrel that regulates the amount of air that can go down the venturi. Close the barrel, the mixture gets rich, the motor slows down. But generally, since you've made things really rich, the motor loads up with excess fuel, and won't idle well, or it will have a poor, slobbery-rich transition back to full throttle. These carbs have a small hole drilled into them, called an "air bleed", and there is a small spring-loaded screw that opens or closes the air bleed hole. This small screw is what is used as the low speed adjustment. Open the bleed hole up all the way, the idle is leaned out, close the hole all the way, the idle is richened up.

In the better carbs, the barrel not only simply rotates, but moves in and out as it does so. Inside this sliding barrel is usually an adjustable screw that plugs into the end of the needle valve spray bar. Supertiger uses this design, as do many other motors, including motors such as the OS 32 SX-H, most of the OS better quality plank motors, and many other makes of motors.

In this design, as the throttle is closed down, the venturi is closed off by the rotating barrel, making the mixture go rich. But at the same time, the low-speed needle is now inside the spray-bar and is limiting the amount of fuel coming in. This system provides a metered fuel supply that when properly adjusted, retains the optimum fuel-air ratio for the motor, but controls the motor speed by metering the amount of fuel available for each power stroke.

As the throttle is opened, there is a point where the low-speed needle no longer affects how much fuel is allowed through the spray-bar, and that task becomes the job of the high speed needle by itself. This type

of carburetor is popular, easy to adjust, and depending upon how the designer did things, you can see how the position of the two needles can interact, and affect each other.

Carburetors such as those used in the OS 50 SX-H, Hyper 50, and some of the larger OS motors still have the rotating barrel to control air flow through the venturi, but incorporate a rotating slot driven by a cam to control fuel flow in the idle region. Some have a third needle valve that controls fuel flow at mid throttle. Some have slots cut in the rotating barrel called a "dosifier" (the infamous OS-50 "cat eye" mod was supposed to modify that slot to achieve a better mid-range mixture).

But in the end, the carburetor limits the amount of air available for the fuel-air mixture, or it limits the amount of fuel available, or it uses a combination of the two methods to provide a fuel metering system.

So, what did I learn from messing around with RC plank motors, and that nasty low-speed adjustment?

In planks, we generally got the high speed needle set properly first. After all, you open the throttle as far as it will go, turn the high speed needle until the motor RPM peaks, then back off two or three clicks to stay on the rich side of life. THEN, we'd tackle the idle or low-speed needle.

We'd throttle the motor down, keeping the carb open enough to let the motor idle at a reasonable speed without dying. Then, we'd simply let the motor idle for 30-40 seconds and wait. If the motor gradually slows down and stops, the idle mixture is too rich. It needs to be leaned out a bit. If, on the other hand, the motor gradually increases in RPM and eventually stops, the idle adjustment is too lean and needs to be richened up a bit. The first step to getting the idle needle set is to adjust it so that the motor idles at the desired RPM without speeding up and quitting lean, or without slowing down and quitting rich.

The last step in fine tuning the idle setting is to let the motor sit at idle for a while, then suddenly open the throttle full. Ideally, the motor instantly transitions from idle to full speed without a hitch. Voila, the top end is happy, the idle is happy, let's go fly.

But, if the motor sputters, gurgles, spits, coughs, and slobbers all over the place when we hit full throttle, the idle setting is still too rich. A minor idle-needle adjustment is required, then repeat the process till it works as it should. Go fly and have a great time.

On the other hand, if, when the throttle is suddenly opened wide, the motor hesitates, or suddenly just dies, the idle is too lean. A minor idle-needle adjustment is required, then repeat the process till the motor will sit forever at idle, then respond instantly when full throttle is commanded. Go fly and enjoy.

The above is the secret of tuning a motor. Getting the high speed needle set correctly so that you're near peak power production, but a few clicks on the rich side, and getting the low-speed needle set so that the motor will idle all day long, but transition to full power without hesitation when needed.

It sounds easy. In a plank, it's child's play, takes a matter of minutes. In a helicopter, it's a nightmare, as you can't tie the chopper to the table and screw in the main needle to the right point, and you can't play around with the idle mixture easily. Helis require a different approach to needle tuning simply because you can't get close enough to them when you need to!

Therein lies the rub. More on needle setting later.

Breaking In Stuff:

It used to be customary to break in a motor using a bench test stand, or if the motor was installed in a plank, we'd fire the motor up with the plane sitting on the ground or a table at the flying field. Breaking in a motor

on a plank or test stand is usually simple, straightforward, and easy to do since you can run the darn thing wide open, at idle, or anywhere in-between, you can put your finger on the exposed cylinder head to judge temperature, and you can just grab the needle valve any old time you want to lean it out or richen it up without getting whacked by anything. The most difficult part about running in a motor on a test stand or plane is keeping your fingers and knuckles out of the back side of the spinning propellor. Breaking-in on a plane is also nice because even with the plane standing still at full power, there is a good deal of cool air moving past the cylinder head, helping to keep things cool.

Once we got the needles set relatively well using the process described above, it is break-in time. This is a relatively easy and painless process in a plane, as you don't have to dodge rotor blades and flybars in the process.

Start the motor, and run it up to full throttle. Use the high speed needle to richen the motor quite a bit so that it runs in that region where it is gurgling back and forth between a four-stroke and a two-stroke mode. Use your finger on the back of the cylinder head to gauge temperature. At this needle setting, the motor should be warm, not hot.

Using the main needle valve, gradually lean the top end out (full throttle) till the motor is producing a good amount of power, but still is rich. Use a finger on the back of the cylinder head to judge temperature. If things start getting too hot, open the high speed needle, get back to that four-stroke/two-stroke mode and let it cool down.

Repeat the process -- gradually leaning out the high speed needle, letting the motor run wide open, gauging cylinder head temperature with your finger, then richening up to get back to the four-stroke/two-stroke mode to cool down. Gradually increase the amount of time that you let the motor run at full throttle, and gradually lean the high speed needle towards the maximum power setting. When things get too hot, richen up the main needle to cool it off.

The repeated heating/cooling cycles is what breaks in the motor. We used to do this for three or four tanks of fuel, eventually getting the high speed needle set at the point where you are getting maximum power, just on the rich side. Go fly and have fun.

During the process, it might be necessary to fine-tune the low-speed needle as you get the high-speed needle set properly. In many carbs, the two needles will interact to some degree and you have to get both right for the motor to run well.

Helicopters are a whole different animal, however. Access to the needle valves is generally somewhat restricted due to the presence of a canopy that extends back over the motor somewhat, just making access to the needle valves inconvenient.

You're also usually trying to adjust the needle valves while kneeling on the ground and perhaps almost standing on your head while trying to get to the needles. This doesn't help. If you're at a flying site with some tables, it's a bit easier to get to the needle valves.

BUT, once you start the motor, you can't really just reach out and grab the needle valves to adjust them because anything above idle has the rotor blades turning. You also can't just grab the cylinder head at will to judge its temperature – partly due to the spinning blades, and partly because in most helis, the head is buried between the side frames, underneath the canopy. The cooling system of most helis isn't the greatest, that's why a heli motor usually has an oversized head with lots of cooling fins. The motor needs all the help it can get to keep from being toast. A different approach is needed to adjust the needles and to break-in the motor.

Initial Steps for a tuning a Helicopter motor:

Set the needle valves to the initial factory settings.

I usually set up the throttle linkages on my helis so that at full throttle, the carburetor barrel is wide open without the servo being stalled. At low throttle and full low-throttle trim, the carburetor barrel is fully closed, without stalling the servo. Mid throttle stick puts the carb at half-open, half closed. The throttle trim on most modern radios does nothing with the throttle stick anywhere but at full low throttle.

If you set up the linkage as described, full low throttle with full low trim will kill the motor. It won't run, it won't start. This is a great way to guarantee that you can shut down the motor from the transmitter.

Full low throttle with the throttle trim set in its middle position will allow you to start the motor and let it idle all day long (when the thing is broken in, and the needles properly adjusted) without engaging the clutch of the helicopter. This is the position you use for starting and for carrying the heli to the launch point at your local flying site. As it turns out, this is also a great place for the throttle-hold setting, as the clutch is disengaged, the motor idles reliably, and you can put the heli in throttle-hold position to start it and carry it, without worrying about accidentally bumping the throttle stick and having your hands full of a screaming heli that is now smoking its clutch while trying to kill you.

Full low throttle and full high throttle trim will engage the clutch and start to spool up the rotor head. It gives you a chance to stand back, spool things up without fear of lifting off, while allowing you to make sure your cyclics and tail rotor servos are working – a last minute pre-flight control check with things turning on the ground.

You have full control over your motor with the above set up.

Initial start up and initial idle needle adjustment:

Set the throttle stick to full low, set throttle trim to its mid point. Connect the glow-driver, and use your starter to fire up the motor. Set the starter aside and disconnect the glow-driver. The motor should idle at the factory needle setting.

If the motor seems to be running way too slow, advance the throttle trim just a bit. *Use the trim tab to set idle speed and keep the motor running at this point, don't start adjusting the low-speed needle to get a good idle.* If you adjust the low-speed needle at this point, you'll most likely end up with a great low-end setting, but a lean top end needle setting that you can't fix easily.

After the motor has warmed up for about 30 seconds, increase the throttle to the point where the heli is light on its skids, about ready to lift off. Notice how the motor transitions from the idle state up to this throttle setting.

If the motor gurgles, spits, coughs, and slobbers a lot of fuel out the muffler, the idle needle is set too rich. Lean it out a small amount, try again. You are looking for an idle needle setting that allows the motor to idle smoothly, yet make a smooth transition to the near-liftoff point.

If, when you throttle up, the motor hesitates, or just flat out quits, without a lot of excess fuel coming from the exhaust, the idle is too lean and needs to be richened up a bit.

As you make minor adjustments to the low-speed needle, you may need to adjust the throttle trim to maintain a decent idle RPM.

Somewhere along the way, an ingenious fellow invented the “pinch test” to check the setting of the low-speed needle. To use the pinch test, start the motor, run it up to the near-hover point for a few seconds to clear out any excess fuel, then return the throttle back to idle. Let the motor sit at idle for about 30 seconds. Then, use your fingers to pinch the fuel line as it goes into the carburetor hose fitting. With the fuel pinched off and the motor sitting at idle, it should continue to run without speeding up or slowing down for about three to five seconds. At the end of that three to five second period, it should speed up as it goes lean from lack of fuel.

If the motor quits before the three to five second period is up, the idle is too lean and needs to be richened up a bit. If the motor runs beyond the three to five second period before starting to speed up and quit, the idle needle is set too rich and needs to be leaned out a bit.

The above should get the low-speed needle and idle setting close to where it needs to be.

Don’t worry that you will cook the motor by going too lean while sitting at idle. You won’t. First, the RPM is very low, second, temperatures will never get out of hand, to the point where damage occurs. Keep in mind that many people, on that “last flight of the day”, purge their motors and dry them out by simply unplugging the fuel line while the motor is sitting at idle. This allows the motor to slurp up excess fuel, and burn it, but without risking the motor’s innards.

High Speed Needle Adjustment/Breaking In:

When you have the low speed needle set as described above, turn your attention to the high-speed needle.

Bring the heli to a hover. With some luck, you’ll have enough power with the high speed needle at its factory setting to do so, but you’ll lack power and the motor may be switching back and forth between the four-stroke and two-stroke cycles. I’ll usually hover out a tank of fuel at this setting as the beginning of my break-in procedure. The motor won’t get overly hot and you do get some time on the motor.

Lean out the high speed needle a few clicks until the motor is no longer alternating back and forth between a four-stroke cycle and a two-stroke cycle at a hover. You should now be seeing a bit more power out of the motor, and the gyro should not be having much trouble keeping the tail in check. Hover a second tank at this setting. Occasionally land the heli and test the motor backplate temperature with your finger. The backplate should be warm, not overly hot. You should be able to keep your fingers on the backplate for at least 5 seconds as you are running very rich.

At this point, you should have sufficient power from the motor to hover well, and even do simple forward flight and the motor should run reliably. Don’t push the motor and start doing all-out 3D flying yet, just fly. Land occasionally and check the backplate temperature with your finger. The motor should be cool enough that you can hold a finger on the backplate for at least 3 to 5 seconds before it gets to be uncomfortable. Fly the tank out, too.

At this point, you’ve got about three tanks of fuel through the motor, you have the low-speed needle set very close to its final position, and you are developing enough power to fly the heli in a simple, laid back manner without dong a lot of demanding aerobatics.

Continue to lean the main needle out a couple of clicks at-a-time. You’ll see additional power from the motor as you do this. Fly for a minute or two, land, and check the backplate temperature with your finger each time. You should notice it beginning to warm up more and more, but you should still be able to maintain finger contact with the backplate for three to five seconds before you start feeling some heat. Go easy on the motor, some mild aerobatics is not out of the question – simple loops, rolls, some stall turns, stuff that doesn’t tax the motor. Check backplate temperature from time to time, making sure you’re not beginning to roast anything.

After several more tanks of fuel, the next thing I do is to bring the heli to an eyeball-level hover, then romp on full collective pitch so the heli climbs vertically. Initially, with the high-speed needle on the relatively rich side, the climb-out won't be too spectacular, but you will find that the motor is able to pull the heli well without sagging or bogging down.

As the motor gets broken-in more and more, and as you have adjusted the high-speed needle a few clicks leaner, continue to fly around, adding in a few more stressful maneuvers, and landing periodically to check backplate temperatures with your finger. Use this process -- hover – then romp on full throttle and do an extended climb-out to judge how well the motor runs, to judge how well it holds its power, and to judge overall performance until you're satisfied with the motor's performance.

If you start to get too lean on the top end, you'll find that those full-throttle punch outs will find a decrease in climb-out performance. Land immediately, richen the main needle a few clicks, let the motor cool off a few seconds, try again. Eventually, you'll be able to nail the throttle to full and watch your heli simply go vertical for a LONG LONG ways without sagging, or bogging.

The high speed needle should now be very close to its final setting, the idle needle may need to be fine tuned along the way, and you probably have close to ten tanks of fuel through the motor at this point. It's time to just go fly, and make minor needle adjustments along the way. Listen to your motor, learn to feel how the heli responds. If something doesn't feel right, land, and check the backplate temperature. If it's roasting hot to the touch, richen up the top end a few clicks. The motor should be well broken-in, the needles set to where the motor is putting out some serious power, and the finger check on the backplate isn't returning roasted finger-tips.

From here on out, run the same fuel that you've been running, make minor adjustments to the high-speed needle based on the flying conditions of the day, and enjoy your heli. In most cases, you don't need to fiddle with the needles on a daily basis once they are set.

As an aside, if the heli is new, or recently rebuilt and the muffler has been recently installed, make sure the muffler bolts are tight, and remain that way. After flying around and landing, and BEFORE the motor has time to cool way down, tighten the muffler bolts again, using a good quality wrench that fits the cap screws.

Check the muffler bolt tightness a couple more times, always tightening the bolts a bit while the motor and muffler are still hot. This practice insures that the muffler will stay tight until you want to loosen it, you won't need any thread locker, and you won't need to double-nut the muffler bolts.

There is no need to use a gasket, RTV sealant, or other material between the crankcase and the muffler header as long as you keep those two surfaces flat and free from dents and nicks. Gaskets rot, sealant deteriorates, other material eventually fails, causing your motor to run lean and erratically.

Keep a close eye on all fuel tubing, inside the tank, as well as outside. Replace as necessary. Run an in-line filter between the tank and your carb, and make sure it's clean. If it is a two-piece affair that uses a rubber O-ring to seal the halves, check that O-ring often and replace it when it becomes cracked or brittle.

Filter the fuel from the jug as you fill your tanks. Leave your fuel jug tightly capped at all times to keep moisture out. Store the fuel in a cool, dry place, it will not go bad.