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Advanced Robotics System Design
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Hybrid Engine Team

Progress

Our group has expanded on the work done in the past aimed to run the engine autonomously with servo motors to control the choke and throttle. We mounted the two servos on the engine's frame and connected the plastic motor gears to the choke and throttle. We then calibrated the servos. We tested different angles, measured in microseconds, of the servo shafts that would correspond to the choke and throttle closing, without over rotating. Eventually we updated the code that controlled the servos and motor so that the servos would not rotate to a set position, but rather a relative position based on what was happening. For example, the choke servo increments in values of 100 microseconds (either opening more or closing more) and the throttle increments in values of 50 microseconds.

After setting up the servos, we started to run the engine for as long as we could with the new control of the choke and throttle. Even by the end of the previous semester, the engine wouldn't start reliably, due to a variety of problems. We made a number of small adjustments, and the engine now starts and runs consistently. As it stands, we generally encounter a few more minor issues that prevent the hybrid engine from being fully ready to be integrated with the flying drone's frame. Perhaps the most significant of these issues preventing integration is the vibrations the running engine causes and how that will affect the drone in the air, but that is the primary focus of the mechanical design team. Our primary concerns will be covered in the next section.

Looking ahead to the final utility of the hybrid engine system, we have also taken some measurements to better understand necessary future steps. We set up a current sensor, and found 6.7 mV/A. We confirmed this reading with two other claw current sensors. We also used an infrared thermometer to measure the temperature of the engine at various times over the course of an individual run. These temperature measurements actually necessitated the consideration of some underlying problems, covered in the next section.

Issues

One issue we noticed was that after the engine ran for more than 30 seconds, it would slowly start to die. When it was operating at its peak, the system would be pushing 70-75 amps through the water heater load. But after a certain amount of runtime we noticed the current would drop fairly quickly to about 50 amps and then the motor died. Our current hypothesis is that the motor is getting too hot, as it is designed to have airflow from a propellor constantly cooling it. The head temperature reached about 380F which is fairly high, even for a two stroke motor. We will soon be running the motor with a strong fan blowing over the engine and if this increases the runtime then we will have confirmed our hypothesis. Another possible reason for this was fuel starvation, but we found that the carburetor was completely clean and least likely to be causing this issue. Furthermore, the runtime seemed to be shorter on consecutive runs, likely because the engine was already at a relatively high temperature. We are hoping the added cooling will resolve this issue. If this is the case then we will need to implement some sort of cooling mechanism that will work with the system attached to the drone. A big fan will likely not be the most elegant solution. Currently ideas include placing the motor under one of the big rotors on the drone and hope for cooling, or placing a propellor in-line with the coupling mechanism. The latter will cause some parasitic losses of crankshaft power but will ensure that the system stays in operating temperature.

On our last run, 3/22, a few bolts on the coupling mechanism failed and caused the system to vibrate violently, even more so than it already usually does!!! This was a very perplexing issue because it was just the heads of the bolt that sheared off, which isn't where the load should be on these bolts.

As you can see, the loading should be where the gray and black pieces of metal meet (in shear), but when the heads flew out the thread remained inside. In addition to the bolt failures, small pieces of the rubber inserts from the lovejoy coupling have also sheared off during recent tests (as can be seen in the right side of the above picture). We are just beginning to look into this issue as it is very new but it has become top priority because we cannot test with such a wobbly setup. We have discussed the failing of the Lovejoy coupling with Dr. Brooke who advised us to replace the existing, failed coupling as it may have simply aged over time. It has also been suggested that should a replacement coupling fail, it might need to be upgraded to a larger size to handle the stresses of the system.

Next Steps

The current motor we have is a 195Kv 80cc equivalent motor. This motor was designed to run on a 12s system (44.4 V). Since our 2-stroke motor generates peak power at 8000 RPM this is where we would ideally want to run it. This means that the electric motor would generate 8000/195 = 41.02V. This was a concern that Dr. Brooke had mentioned since the drone will run on a 6s battery (22.2 V). Currently we are not sure if this output voltage will sag once a load is put on the system, or if will sag enough to be safe for the rest of the system. Concerns would include overvoltage on the ESCs and the batteries themselves.

One way to solve this issue would just be to run the motor slower than it's peak RPM. However, this would limit how much power we could generate. Another solution is to find a motor with a higher Kv rating, preferable around 300. But since this size/class of motors is designed to run on 44.4V, it is unlikely that a 300Kv motor would be available as this would mean its operating RPM would be around 13,000 and this is fairly high for the large diameter propellers that these motors are designed for. Finally another solution would be to use two smaller electric motors, which would have a higher Kv rating and design a system to have them both generate power from a single engine. This solution would be slightly more complicated than the current system but would give us a lower output voltage with higher current as desired.

There is an ongoing concern regarding the relationship between the loading of the brushless generator and the gas motor dying. In many systems, when an electric motor is being used to generate variable power from a gas motor, an alternator is used. In an alternator, instead of moving magnets inducing currents in coils as in a generator, a coil is used in place of the permanent magnet. Because of this, the power generated (and the load) can therefore be set to any arbitrary value. Right now, there is an obvious problem with the motor needing to be run at a precise speed to generate the desired voltage/current, but the peak torque of the motor occurring at higher speeds. We are just now beginning to dig into the loading issue, but this will likely become a bigger issue as we investigate the engine dying issue.

Automating the system

At present time, the system load is static, and the choke/throttle parameters to keep the engine running are hard coded. Once the battery is added to the load side of the system, we will need to integrate the current sensors with the throttle control in order to be able to properly power the system without over/under charging the battery. At present time, the starter has been manually controlled. A naive approach (ramping the motor's speed for a few seconds in duration) to powering the starter currently exists as a separate Arduino program. In most cases, the timed run of the motor should start the engine. However, given the desire for robustness in the system, it might be better to have some feedback to figure out if the motor has actually started. A transducer mounted to the frame could determine if, after the motor is started, and based on an FFT, if there are components of noise in the ranges generated by running the motor large enough to conclude that the engine is running. Alternatively, if the FFT shows that the motor is likely not running, the starter could continue trying to start it. In our experimentation, air bubbles have sometimes appeared in the gas lines, so having a more robust way to ensure that the motor is running even if air bubbles stop if would be useful. Also, the current output could be measured to determine if the motor is started.