Energy System of Drones - A review of solutions of extending flight time - DTU Orbit (30/09/2019)

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Drones is a rapid developing technology that has been used for more than 170 years. In this time they have gone from merely military use to an important tool in the daily life. But one problem inhibits how modern drones can be used. They can only be in the air for a limited amount of time before the batteries are drained. This is an issue as batteries are important parts of all electronics sold today, but the current technology cannot follow the development that is seen in other fields. Lithium ion and polymer batteries are at their peak and the marked need battery solutions with a higher energy density. However they are far out in the future. The endurance problem is more profound for multi-rotor and fixed-wing hybrid drones as higher number of DC engines use more energy. Therefore this report tries to find a solution that can solve the endurance issue indirectly for these drone types, but with the possibility to use it for all designs.

In the process other technologies are analyzed as fuel cells, Internal Combustion (IC) engines, solar panels and turbines. After discussing the technologies they are evaluated individually with their pros and cons with respect to the operational environment that drones introduce. The system need to be able to operate at high altitudes, at low and high temperatures, in all weather, it may not introduce vibrations nor produce too much noise.

Solar panels are a clean energy source that have a high lifetime and do not have any direct emissions. This sound perfect, but their disadvantages provide a hurdle that is not possible to overlook. They demand a high surface area and have a weather dependency that makes it difficult to stay in air during cloudy days. It may be possible to use them as a supplement on smaller hybrid fixed-wing drones, but not as a main power system. It is decided that solar panels would not be a sufficient solution.

Next was the jet/turbine system. They pack a lot of power into a small amount of space and keep a high energy density from the liquid fuel. These two advantages are what is wanted from the solution, but with them come issues as complexity, price, noise and a high maintenance level. The P20-SX from JetCat is a small jet turbine which illustrate the problem. It costs 2,500 US dollars, has to go through maintenance every 25 hours, have an exhaust gas/thrust of 580-690 degrees Celsius and it is not possible to reduce the noise with a muffler. All this would introduce too many problems under operation, therefore were turbines left out as a solution.

Further there are fuel cells. They have a disadvantage of a low power to weight ratio and mostly use high pressurized cylinders filled with hydrogen. The cylinder can be seen as a small bomb flying around and can be dangerous to use in public areas, but some solutions are under development that contain solid capsules of hydrogen which is released when needed. Along with this fuel cells have already shown fine results for fixed-wing drones with several hours of flight time. Therefore with respect to development in technology and current proofs of usage fuel cells are seen as a possible solution.

This leaves the IC engines as the last system to be evaluated. This technology is still one of the best sources of energy today, thus there are some issues that need to be addressed before it can be used as a solution here. Piston driven engines introduce vibrations, but it is possible to reduce them with a proper design and engine control. If the IC engine is used as a generator with near constant RPM it is possible to design the crankshaft to counteract the unbalance made by the piston movement. By doing so the vibrations could be diminished. Noise would neither be a problem as a muffler could be designed to match the engine. But a problem that is introduced with constant RPM is that the maximum power output is affected. This effect is further enhanced with lower oxygen in higher altitudes. Therefore to address this it may be forced to use a 2-stroke engine to get more power, but this could introduce a problem with emissions. To solve this alternative fuels as ethanol and methanol are used as a substitution to gasoline.

Further it is important to remember that an IC engine do not produce electrical energy. It need a converter that charge a small battery. This would create a hybrid IC engine system that could be used. Therefore to conclude it is possible that both fuel cells and a hybrid IC engine system could be used as a feasible solution. These hybrid IC engine systems are therefore further used and implemented in a simulation study based on a multi-rotor drone to see how they perform compared to a battery powered drone. The hybrid IC engine is based on assumptions and knowledge from the DTU Roadrunners world record car Dynamo. With these assumptions there are tested three different fuels; gasoline, ethanol and methanol. The fuel cells used in the simulation are 300 bar pressurized direct hydrogen systems based on fuel cells from HES energy systems. Here three sizes are used which produce 200W, 500W and 1000W of power.

From the simulation fuel cells showed fine results in the smaller drones, but lacked power when they reached a larger drone size and had to compete with the hybrid IC engine systems. The fuel cells cannot power multiple DC engines properly which is also seen when there is added payload to the drones. The fuel cells cannot get the drone off the ground within the assumed parameters or are only able to fly for the same amount of time as a battery powered drone. Therefore were all fuel cells discarded and not used further on. Better results were seen from the hybrid IC engines. They all outperformed the battery with a low amount of fuel and were therefore used further in the analyzation.

After the simulation model had been updated with other assumptions, it was clear that the hybrid IC engines are a solution to the problem addressed by the report. By using a fairly low amount of liquid fuels there were achieved a large increase in air time. Even though the gasoline show the largest gain, it is advised to use the CO2-neutral alternatives ethanol and methanol as they have some advantages as fuels including lower emissions. These advantages are not fully seen in the simulation and the difference in air time will in reality be less.