Pedalling through the sky on your bicycle – ‘how wonderful would that be?’ I questioned myself at an age of fourteen. Since there were no flying bicycles around, or human powered aircraft (HPA) as they are named, the only option was to design and build one myself. Two years I spent designing and learning the basics about aerodynamics by myself. Construction took three years, and when I was nineteen years old, on August 9th, 2009, I made the first human powered flight in the Netherlands. This article explains why human powered flight is difficult and how I developed my own HPA.

**BRIEF HISTORY OF HUMAN POWERED FLIGHT**
Throughout history, people have tried to get airborne using muscle power alone. Some prolonged glides were made around 1930 and true straight flights around 1960. In 1977 the first fully controllable HPA was build, Gossamer Condor, and its successor Gossamer Albatross flew the English Channel in 1979. In 1988, Daedalus 88 set the current world records for distance and duration, 115km and 3h54m.

**POWER**
Available power is everything in human powered flight, because a human has so very little of it. Even the Wright brothers’ first flight was made using an engine 25 times more powerful than the average human (power output for a couple of minutes).

This hints to another problem when talking about human power output; it is not the same for any duration, one can deliver a high power output for a short duration, but for longer durations this maximum output drops considerably (Wilkie, 1960, see figure 1).

My HPA was designed to fly for a few minutes maximum, just to give me the experience of flying using muscle power. As can be read from the graph made by Wilkie, the maximum power output of the average human for two or three minutes is about 300Watt. That amounts at bicycling about 30 to 40km/h sitting upright on a standard, upright bicycle (no racing bicycles). Designing an HPA which can fly with 300W of power is no easy task. Compare: even an average microwave or vacuum cleaner uses a couple of times more power!

**DESIGNING AN HPA**
The design process is highly iterative and it is easy to ‘spiral out of bounds’, when parameters like wingspan, aspect ratio, mass, airfoil characteristics, etc. are not chosen well. Aircraft mass has a large influence. Since engine power scales with the airspeed to the third power, minimizing airspeed is very beneficial. However, to support the mass of aircraft and pilot (about 120 kg for my HPA) at such low speeds, a large wing with a large span is needed. As a result, the structural weight goes up...

Finally I found a flyable solution: wingspan 26.0m, wing area 41.6m², airspeed 7.0m/s. The maximum take off weight (MTOW) equals 120kg, of which maximum 70kg is allocated for the pilot. The wing has a rectangular plan form, which is not the most aerodynamically efficient plan form but it would speed up the building process. I made a great effort to design an aircraft which could be built with rather simple tools in not too much time, and made trade-offs of efficiency against simplicity. Another example: using composite tubes instead of metal tubes or wood for the
‘skeleton’ of the HPA would have saved quite some mass and eliminated quite some rigging wires. The required tube dimensions are not standard available, and not easy to manufacture yourself either. Analysis showed that a wire-braced aluminium structure would be feasible too, so I chose that option.

The propeller has a diameter of 3.6m, the pitch calculated using some simple assumptions from Blade Element Theory. Sizing the empennage was rather difficult, since flight dynamics is not that easy. Comparing existing HPA, I managed to roughly size the tail surfaces. In the end the rudder proved not very effective, since the large wing span creates a large inertia around the yaw axis. The elevator proved to be effective, the aircraft responds rather quickly. There are no ailerons since I had no intention to make turns, any heading corrections needed to stay above the runway would be flown using the rudder.

Flight dynamics of an HPA are very different from ordinary aircraft, since normally one can neglect the mass of the air affected by the wing or other large surfaces during a manoeuvre. For an HPA, the affected air mass is of the same order of magnitude as the total flying mass, creating some difficult dynamic situations.

As a note on the building process, it was a real challenge sometimes to transform the lines and numbers on the computer screen to good structural components. Some of the details which are very obvious now had to be designed and built from scratch, which is also part of the fun of course. The aircraft is so large, that it had to be built in parts because it had to be transported to the airport. Still, the wing panels are so large that at least two people are needed to move them around, while these panels weigh only a few kg.

**FIRST HPA FLIGHTS IN THE NETHERLANDS**

HPA are very fragile, and my HPA is no exception. They fly so slowly, even a slight gust could stall the aircraft or exceed the design load factor. Therefore, HPA have to fly in absolute calm and good weather conditions: no wind, no rain. The evening of August 9th, 2009 had such weather. I called the people who would help to assemble the aircraft, and we worked hard to get the HPA ready at 8pm when the runway of Kempen Airport in Bredel, my hometown, was close for general air traffic. After 8pm I boarded my HPA at the end of the runway.

During that evening, I managed to get airborne twice, but chain tensioner problems prevented pedalling shortly after take-off. Still, these were the first human-powered test runs and flights ever made in the Netherlands.

During winter I fixed some minor damage to the tail and installed an improved chain tensioner. No big changes were made because of limited time.

A year later on July 18th, 2010, weather conditions were favourable again. The first few trials I did not take off. After some waiting to get my breath back a few short hops were made, between 15m to 30m each. The power requirement proved to be certainly within human range, but it also proved to be very high for me. Hence, just before total darkness set in shortly after 10pm, I gave all the power I had, fully concentrating on pedalling and nothing else. If anybody still had doubts if the craft could really remain airborne, this flight proved it could. I pedalled very hard, and once airborne I immediately levelled out to prevent stalling. The whole HPA wiggled slightly due to my furious pedalling; really giving me the feeling of flying, the runway seemed much deeper below me as was really the case. I flew for almost 70m, at an altitude of around 1 to 1.5m. When I landed, I was totally exhausted. But what a wonderful experience it was!

At this stage, I consider ‘Project Vliegiets’ to be successful but I do not intend to make any more flights with this HPA, the first in the Netherlands. The power requirement is higher than expected; too high for me to make any long flights, but keep in mind that this aircraft was designed at the age of sixteen, and it has proven to be structurally and aerodynamically sound.

If I ever have the opportunity, I would like to build a second, better HPA using the experience of my first HPA and the knowledge gained at TU Delft – after these first flights I can only dream of more.

**WEBSITE**

www.projectvliegiets.nl

**References**


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