PAST, PRESENT AND FUTURE OF KITES AND ENERGY GENERATION

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ABSTRACT

Kites have been known to man for thousands of years. Their invention is somewhat of a mystery in itself. Kites have played major roles in art, religion and science. But even after thousands of years, the kite as a flying object has seen a relatively small amount of scientific research. Compared with another popular flying object, the airplane, it seems to have seriously lagged behind in the last 100 years. Using kites for energy generation would seem like a viable way to tap into the energy contained within the winds at high altitude. The Laddermill is a project at the Delft University of Technology, which envisions this very thing. But in the design of the Laddermill, it becomes more and more apparent that the scientific research of kites has lagged behind. This paper will go into the reasons for this, and will attempt to lay down a path through which kites can mature and become a serious player in the energy generation sector.

KEY WORDS
Laddermill, kite, kiteplane, high-altitude, wind-energy

1. Introduction

Imagine a kite, not like we know it today, but a large 50 square meter kite in the shape of a large glider. It is attached to a 20-meter high pole by its leading edge and moves gently with the wind. As the wind picks up, the ground station meteorological sensors tell the flight computer that conditions are favorable for flight. The huge kite, made out of modern fabric materials and obtaining its rigidity through the principle of inflatable structures, detaches from the pole and starts to rapidly ascend. The kite line spools off the base station cable drum, driving a generator. A single operator at the ground station goes over the meteorological data and tells the computer where the kite needs to go. The software moves the control surfaces of the inherently unstable kite to smoothly steer it into the right position.

This vision sounds like science fiction. However, nothing what was described doesn't already exist for airplanes. The advanced materials have been available for years, powerful computers are on virtually everyone's desk and we have been flying inherently unstable aircraft using fly-by-wire technology since the 1970's. Why is it then that the envisioned kite a system does not exist? It does not take a lot of imagination to think of a whole wide range of applications for such a system. Driving generators to create clean energy, using the tug force to propel ships, a high-altitude observation platform or running water pumps in desert areas. The number of applications seem endless. But up until today, kites have seen little research. There are a number of notable exceptions. Some research was done during both the first and second world wars. Today there are a few people involved in the use of kites for industrial purposes like the Laddermill in the Netherlands and Kiteship in Germany. But compared to the amount of research done on airplanes, the research and development on kites has been very limited.

One of the most notable developments of kites came with the advent of Kite-surfing. Pioneers such as Peter Lynn and Robbie Naish have created an industry around kites. But even in this industry, which has become the largest industry, by far, in the field of kites, there is little backing from the scientific community and is therefore forced to use an empirical design approach.

2. The Laddermill

As stated earlier, the energy which is contained within the winds at high altitude (3000ft – 10000ft) is tremendous. It is far greater than the wind at ground level which current windmill technology uses. Figure 1 illustrates the wind speed and dynamic pressure against altitude in kilometers. This higher dynamic pressure allows lifting surfaces, with the same lift coefficient, to generate a much larger force. A force which can be used to generate electricity.

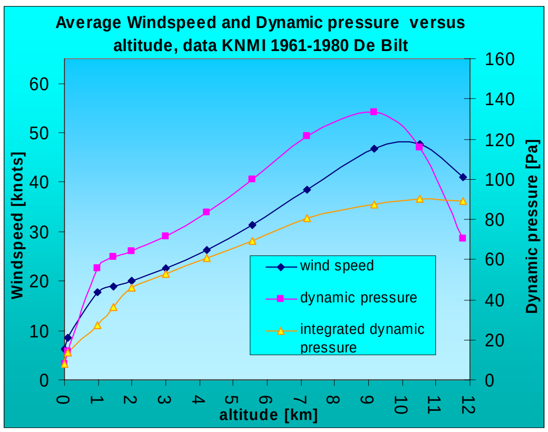


Figure 1: Wind speed and dynamic pressure vs. altitude [9]

In order to "harvest" this enormous energy resource, the laddermill uses large controllable kites to ascend and descend to drive a generator.

A regular kite will fly up without much effort. But when it has to come down, one has to pull on the tether to make it descent. For an aircraft it is the other way around. An aircraft requires big engines to climb, but it can glide down without spending fuel. Laddermill uses kites which combine the climbing capabilities of kites and the gliding capabilities of aircraft. That is why these kinds of kites are called: "Kiteplanes" Figure 2 shows an artist impression of what a Laddermill would look like.

Figure 2: An artist impression of the Laddermill

The principle of the Laddermill is simple. A series of kites is connected to a long tether. The other end of this tether is wound on a drum connected to a generator. While the kites ascend from, for example, 3000ft to 10000ft altitude, they pull the tether off the drum, driving the generator and creating electrical energy. Once the kites reach their maximum altitude, their angle of attack is changed so that they generate very little lift. The tether is retrieved by spinning the drum. Once the kites reach their low altitude floor again, their angle of attack is increased and the process starts over. During retrieval of the cable, some energy will be spent. The difference in the energy created in the upward motion and the energy spent during the downward motion is the amount of energy created during one stroke. Figure 3 shows a schematic representation of the Laddermill.

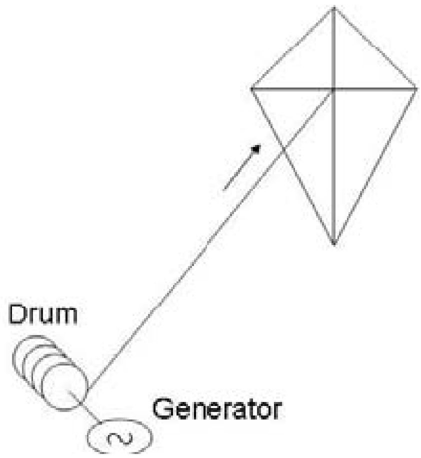


Figure 3: A schematic representation of the Laddermill. [10]

In order to assure a continuous generation of energy, several laddermills can be linked and their strokes timed much like a piston engine.
In order for the laddermill to become a reality. Controllable kites are an essential enabling technology. Kites which are flown like airplanes are a completely new field of science. It is somewhat puzzling that this is a new field, since airplanes have matured a great deal in the last century. We will look at airplanes and kites, side by side, to investigate why aircraft technology has boomed, and kite technology has not (yet!).

3. The early days of kites

As stated earlier, kites have existed for thousands of years. They were first invented in Asia. The first Chinese story of the invention of a kite tells of a wooden one built by Mo Tzu for amusement only. Later tales tell of General Han Hsin, using kites for the measurement of distance to an enemy fortification.

Exactly how kites were invented is a mystery in itself. Peter Lynn wrote in his newsletter of April 2005 [REF 1] an interesting thought on the invention of kites. Lynn states that there is always a gradual path leading up to an invention. A kite is really a delicate balance of aerodynamic forces and turbulent flow. The balance is only stable for a handful of the immensely large combinations. Without a proper understanding of the most basic principles of physics it comes down to blind luck to get the combination right in order for a kite to fly. So how come they were invented at all? Lynn uses the example of a boomerang. Ancient man used throwing sticks to kill their prey. After a while they noticed that a bent stick works better than a straight one. And that it would fly faster if the stick was somewhat flattened. This is a gradual path toward the boomerang we know today. Similar paths can be postulated for other human artifacts such as bows, needles and fishhooks. But no such gradual path exists for kites. It either flies stable, or it crashes hopelessly to the ground in a matter of seconds. The only explanation Lynn can think of involves a particular leaf in Indonesia which, if bridled correctly, has the correct shape and symmetry to fly as a kite.

Kites only became known in the western world in the 13th century when Marco Polo came back from the far-east and described devices made of cloth, big enough to carry a man aloft. Man carrying kites were especially popular in Japan centuries before the invention of airplanes. But in the west, kites were unknown.

In the period from the 15th century to the beginning of the 20th century, kites became more popular. Next to balloons, they were the only flying objects available. Leonardo DaVinci discovered in the 15th century how to span a river using a kite. In 1749, Scottish scientist Alexander Wilson used several kites, attached in a row, to measure and compare air temperatures at different altitudes. Benjamin Franklin used kites to pull boats and carriages and to experiment with electricity. And in 1901, Gugliemo Marconi used a kite to help transmit the first trans-Atlantic wireless telegraph message. Kites had become an important aerial platform for a large number of scientists. But even though kites have been tools in a number of scientific endeavors, it was never really subject of close examination itself.

4. Development of the flying machine

The Wright brothers are often regarded as the first to invent the airplane. Even the Wright brothers themselves would disagree with this notion. They were the first to invent a successful airplane! But as they admitted themselves: “We worked on the shoulders of giants”. The invention of the airplane goes back as far as the work of Leonardo DaVinci. However, in that time, human flight was envisioned to mimic bird flight. Large flapping wings were considered the way to carry a man aloft. The first to ever consider a flying machine in the conventional configuration as we know it today is George Cayley. In 1804, in a stroke of genius, Cayley made a sketch of a hand-thrown glider which departed from the beating wing vision and adopted the fixed-wing design. (Figure 4)

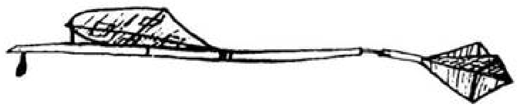


Figure 4, George Cayley's glider [2].

Interesting to note is that kites had been using a fixed wing approach for centuries. But such a configuration was simply not perceived for human flight. It is a testament to the fact that in the minds of people at that time, kites were something entirely different than birds and flying machines. We will see later on how they grow closer in the minds of the aviation pioneers. Cayley's design was a revolution in the creation of the flying machine. Virtually every design henceforth adopted the fixed wing design.

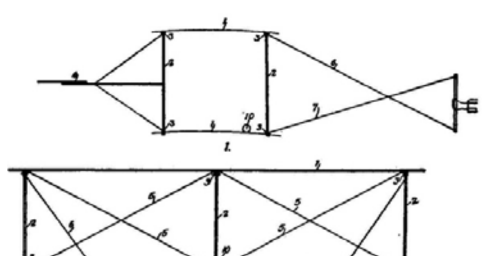
Alexander Mozhaiski, responsible for what is called: "the second powered hop" was one of the first people to realize the value of kites in the design of a flying machine. He was one of the first to experiment with kites in light of the development of human flight. Some of his kites were large enough to lift him off the ground when pulled at high speed by a horse-drawn carriage. From this point on, kites were considered a valuable research tool in understanding the mechanics of powered flight.

Lawrence Hargrave from Australia invented the box-kite in 1893. It was to play a vital role in de development of the flying machine. The box kite provided tremendous lift capabilities and admirable stability. On one occasion in 1894, Hargrave lifted himself more than 5 meters in the air in a mild wind using four box kites in a train configuration. In the following years, Hargrave experimented with powered flight, using box-kite designs and even using box kites to carry the flying machine aloft before trying to fly it freely. But propulsion, or better yet the lack thereof, ensured his failure to realize powered flight.

In 1899 Hargrave visited England with his family to make much-needed contact with likeminded individuals. In England, he wrote a paper on box-kites which was delivered to the Aeronautical Society in London. The head of this society was Percy Pilcher. Pilcher incorporated some of the box-kite designs into his own triplane which he built in 1899.

Samuel F. Cody, Klondike prospector, wild west show-man and aviation pioneer designed the now famous Cody War Kite, a type of box kite which had excellent stability qualities. Patented in 1901, the British war office became interested in using the Cody Kite as a man-lifting device for observation purposes. To convince the war office of his kite, he crossed the English Channel in 1903 using a boat, pulled along by a kite. The Cody War Kite was the first kite to be able to change its angle of attack, effectively powering and de-powering the kite. In another instance in 1903, Cody's kite reached a staggering altitude of 14000ft. It would be another 9 years before an airplane would reach that altitude. Research on the man-lifting Cody Kite was done between 1903 and 1906. Later on, Cody became interested in airplanes and used his kite knowledge to design and build is own aircraft. He eventually died in 1913 in a crash landing in one of his own inventions: the waterplane.

Otto Lilienthal had done extensive flight testing of gliders. The Wright brothers were aware of his exploits. Lilienthal controlled his gliders by shifting his weight and thereby changing the center of gravity. The Wrights quickly concluded that such a form of control would be inadequate for their powered flying machine. Meticulous as they were, they started to investigate the matter and came up with the need for lateral control. Before the Wright brothers, only longitudinal control (pitch) and directional control (yaw) were identified to be useful for controlling a flying machine. The wrights were the first to identify lateral control or roll as a necessary form of control by rotating the lift factor. In July of 1899 the Wright brothers tested their theory on lateral control using a kite. Another instance of where a kite helped the development of the flying machine. Figure 2 shows the kite used by the Wright brothers



Firgure 2, The Wright brother's kite [2].

Up until their first powered flight on December 17^{th} 2003, the Wright brothers continued to test many of their gliders as kites as well.

The Wright brothers' successful flyer was a collection of cutting edge technologies. Even though many of these technologies were in its infancy, the Wrights meticulous persistence forced a breakthrough. Most of the technologies they needed were already invented, much like the envisioned kite system mentioned in the beginning of this article. The challenge was the integration of these technologies.

5. The great divide

With the exception of Otto Lilienthal, none of the aviation pioneers mentioned in the previous section had an academic education. As a matter of fact, all these people were self-educated craftsmen. The designs they made borrowed little from the scientific community in the nineteenth century.

Lord Kelvin, a renounced scientist, stated at the end of the nineteenth century: "I have not the smallest molecule of faith in aerial navigation other than ballooning" This statement reflects the views of the scientific community on the exploits to invent a flying machine. In the nineteenth century, the advances in science were unprecedented. The atmosphere among scientists was that of supremacy. "Almost everything is known", that was the sentiment of that day. Scientists were only concerned with the physics and the mathematics; practical applications such as the flying machine were of no concern to them. This atmosphere of superiority stalled the scientific community into formulating very little new questions. Questions the craftsmen had in abundance. But a great divide existed between the scientists who struggled to understand the physics and the craftsmen who tried to design and build things, and make them work. This greatly hampered the development of the flying machine. A similar situation concerning kites exists today. Most of the craftsmen designing kites today have no college education and have little or no access to the knowledge and facilities of the scientific community.

During the exploration of the flying machine in the nineteenth century, much of the theory needed to design a successful airplane was already known. Bernoulli's law, Navier–Stokes equations (not the solving), Vorticity (generation of lift), principles of friction drag and theory of laminar and turbulent flow had all been extensively explored by the scientific community. But unfortunately, the craftsmen attempting to design and build the first aircraft had no knowledge of this. As a matter of fact, the mature state of fluid dynamics contributed almost nothing to the development of the flying machine.

Nowadays, aeronautical researchers in the academic community, researchers in government laboratories and designers in the aerospace industry all work together closely, optimizing the technology transfer between all parties through conferences and scientific publications. Such a situation is still not in place for kites. As a matter of fact, the community around kites more closely resembles the situation as it was for airplanes at the end of the nineteenth century. With regards to kites, a lot of applicable scientific theory and research tools are already available. Cable mechanics, aero-elastics, computational fluid dynamics and material sciences have reached a very mature state. Yet these powerful tools are rarely used in the development of kites. What happened for the airplane in terms of development trajectory also needs to happen for kites.

5. The turning point

At the end of the nineteenth century, researching flying machines was not a popular endeavor. It was viewed by the public as the exploits of a mad man. Therefore, one of the biggest hurdles in the development of the airplane was not so much the science, but the credibility. Credibility will pull people of different specialties on board to contribute. Credibility creates a situation where the very best of all worlds is directed to a single focal point. The lack of credibility creates isolation and makes existing expertise inaccessible. This was the situation for the airplane during the nineteenth century, and it is the situation for kites today.

The craftsmen working on airplanes grew more and more disillusioned by the lack of interest by the scientific community and grew more frustrated by the fragmented nature of the knowledge they developed. In order to establish credibility, they employed the discipline of peer evaluation and widespread publishing of technical journals. As the number of craftsmen working on flying machines grew, and as the amount of knowledge grew, there was an increasing demand of a centralized organization. The first was the Societe Aerostatique et Meteorologique de France, founded in Paris in 1852. But by far the most important was the Aeronautical Society of Great Britain, founded in London in 1866. With the formation of this society, a formal mechanism for the establishment of technical credibility was in place. Through the Aeronautical Society, many important discoveries such as the effects of aspect ratio and the performance of cambered airfoils were available for all whom were studying human flight. The establishment of the Aeronautical Society was a pivotal moment in the development of the flying machine. Through this establishment, the occupation of aeronautical engineer was first formulated. And even though nowadays, most aeronautical engineers are university educated, their profession was not established by the academic world, but by craftsmen and inventors of the late ninetieth century.

A similar establishment for kites is not in place today. Not even a sub-section within existing scientific societies devoted to kite research exists. As a matter of fact, searching for publications on kites within existing conferences and journals will yield limited results. And even though today, kites actually constitute a multi-million dollar business, within the scientific community there seems little interest to pursue its development. The reason for this is the lack of credibility. Even today, kites are mostly seen as a toy, or at best, a means for adventurous people to pull them along the shoreline on a surfboard. It is hardly seen as a serious and valid research topic even though the mechanics behind a kite can be considered a challenge, its applications seem only limited by imagination and a market for existing applications is already in place. The item which is absent from the equation to make kite research work is credibility, and with it the drive and the will to do it.

6. Conclusions

This paper has outlined the path along which the development of the aircraft progressed and has indicated that in a number of instances, there are great similarities between the development of the aircraft and the development of kites. In a way the airplane, only being in existence for 100 years, has far surpassed the kite, which has been in existed for thousands of years. It was outlined that the situation surrounding the development of the aircraft in the nineteenth century bears striking resemblance to the development of kites today. Furthermore, it was shown that credibility is key and that, in case of the aircraft, credibility was established with the creation of a central institute performing peer-reviews and spreading knowledge through publications and journals.

In order for kites to make the quantum leap that aircraft made over a hundred years ago, credibility needs to be established as well. The belief that kites using our latest technologies are able to be successfully employed in a number of advanced applications such as the generation of energy or the propelling of ships. Establishing this credibility will have to be done through a centralized scientific establishment providing peer-reviewed publications and periodicals. This will eventually get more and more scientists and engineers involved and will drastically further the development of advanced kite systems and their employment in energy generation.

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