Powered Hang Gliding

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Introduction

More than a hundred years have now passed since the first powered flight by the Wright brothers. The passion and curiosity of flight still remains as new as the first flight itself. Humans still long to fly. Aircraft have evolved greatly. We have gone around the world, built supersonic aircraft, set numerous records. But the pursuit still continues.

In this article, we will follow a different story. This is about hang gliding. More appropriately, his is about powered hang gliding.

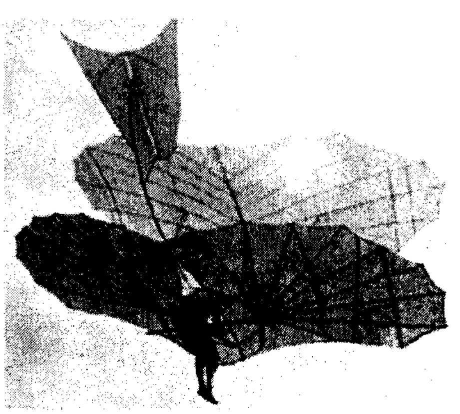
Powered Hang Gliders (PHGs) are also called trikes. Among the powered aircraft, A380s are the beasts while PHGs are the real beauties. This article explores the beauty of these little beauties.

History

While the Wright brothers are credited with the first powered flight of a heavier than air vehicle that could take off and land from level ground, it was the German aviator, Otto Lilienthal, the first one to master the aerodynamics of hang gliders. In fact, the experiments of Lilienthal helped Wright brothers a great deal in understanding the basics of flight. Lilienthal himself built eighteen different hang glider models over a period of five years and test flew them. Figure 1 shows a typical flight by Lilienthal. This particular machine has a bi-plane configuration. [1]

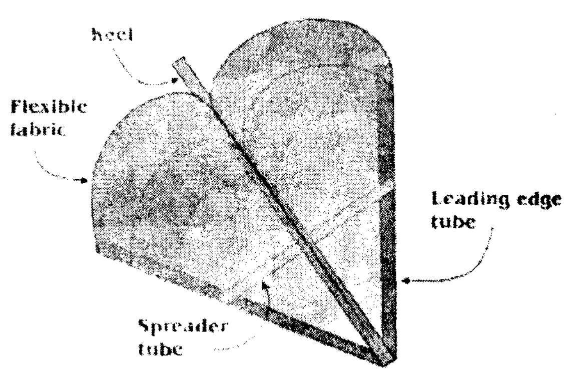
Otto Lilienthal said, "It is easy to invent a flying machine. More difficult to build one. But to make it fly is everything." Lilienthal spent most of his life to make a hang glider fly. He nurtured the idea of flying truly like birds. Today, hang gliding is a sizeable industry.

Lilienthal's idea was to build a big enough wing that could glide in the wind from which man could



Lilienthal flying one of his hang-gliders
(Source: http://invention.psychology.msstate.edu)

Figure 1



Structure of a Rogallo wing

Figure 2

literally "hang" to experience flight. To control the wing flight, Lilienthal thought of shifting the weight of the person hanging so as to change the attitude of the wing in flight. This was remarkable indeed. However, it required skill and strength, both mental and physical.

For Lilienthal, the only means of developing a flying machine was through practical flying experiments. This is quite understandable given the fact that there was hardly any insight into the theory of motion of air [1]. For instance, the first breakthrough in fluid dynamics came in 1904 when Ludwig Prandtl discovered boundary layers. Engineers like Lilienthal mainly drew upon their practical experience. Even today, many of the developments have taken place in total absence of a theory. Theories often come later. Hang glider wing design is no exception. After Lilienthal there was a long pause in the development of hang gliders. After nearly half a century, Francis Regallo entered the scene.

Francis Rogallo was an engineer working with the National Advisory Committee for Aeronautics (NACA), a predecessor of NASA. He was engaged in kite-parachute studies. During the early fifties, Rogallo came up with the idea of a flexible delta wing that is extremely simple in concept and design (See figure 2) [2].

This wing consisted of two half-cone sections with their apex meeting at one point. In flight, this wing assumes the desired conical shape due to air pressure. This wing had excellent aerodynamic characteristics. The design was extremely forgiving and offered good controllability at very low speeds. NASA was originally interested in using this wing for space module recovery missions. It is a different story that this design was never actually adopted for NASA missions. On the other hand, it paved way for hang gliding activity on a scale much larger than Lilienthal could ever have imagined.

Hang glider wing structure

Figure 3 shows the basic structure of a modern hang glider wing frame. These wings are essentially derived from the Rogallo concept. The structure is made up of two leading edge tubes that join at one end giving the wing a delta shape. A keel post runs from the leading edge to the tail. A floating bar made up of two segments is hinged to the leading edge tubes at an intermediate point. A pair of cables attached to the floating bar can be pulled towards the tail to "spread" the wing. Hence the floating bar is also known as the spreader tube. In flight, the floating bar moves up and down making the wing flexible. This flexibility is important from aerodynamic point of view.

Nylon, Dacron and other modern fabric is attached firmly to the leading edge tubes (see figure 4). The

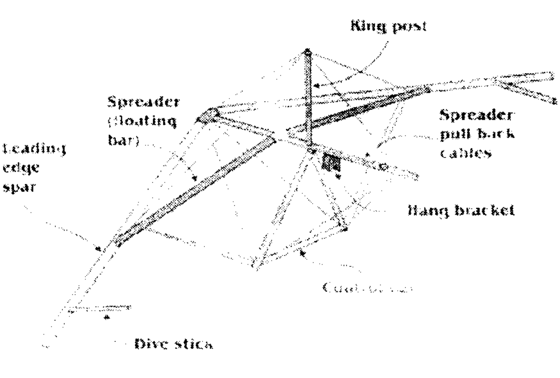


Figure 3

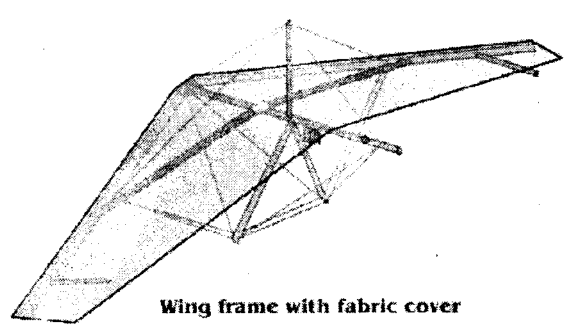


Figure 4

fabric goes into tension when the spreader cables are pulled back. At various points along the fabric, pockets are sewn into which tubular battens of well defined shapes are inserted. These give the airfoil shape. The airfoil section can be a simple curved line or have a double surface (see figure 5). Larger the extent of the double surface, faster is the wing. A typical wing with 30 per cent double surface would have a cruise speed of about 50 to 60 km per hour. Wings with 70 to 80 per cent double surface have cruise speed of about 70 to 80 km per hour.

The trailing edge of the wing is not stiffened allowing the wing to twist. This helps in providing aerodynamic stability. In conventional aircraft, this stability comes from the tail wing. In modern hang glider wings, an additional reflex or reverse camber is imparted to the wing near the centre.

A triangular tubular structure, known as the control frame, is attached rigidly to the wing. The two side tubes are called the down-tubes while the horizontal member is called the control bar. On the keel post a hang bracket is provided to which a harness is attached. With the help of this harness the pilot hangs from wing with his body parallel to the keel post. Control is achieved by moving the moving the control bar and with it the wing.

At the tip of the wings, a stiff tube known as the dive-stick is attached. While this plays no role in normal flight, it is essential for in dive recovery.

Hang gliding offers completely unhindered view and the flight experience is as close as you can get to that of the birds. The gliders are inexpensive costing just as much as an autorickshaw! The disadvantages are the associated logistics. One requires a high point to launch and it is often not possible to return to the same point. Training is not very easy. One needs to be generally well built to be able to carry the wing and run while launching. Injuries are common.

In order to overcome some of the difficulties, the so called trikes were developed. Thus began a new chapter — powered hang gliding.

Trikes

Also known as sky-bikes, trikes are an adaptation of hang gliders. Putting an engine on the gliders was a natural step in the devlopment of trikes. In fact, the trikes, sans engine, built by NASA team to test the Rogallo wings [3] are pretty much as you would see them today. A typical trike is shown in

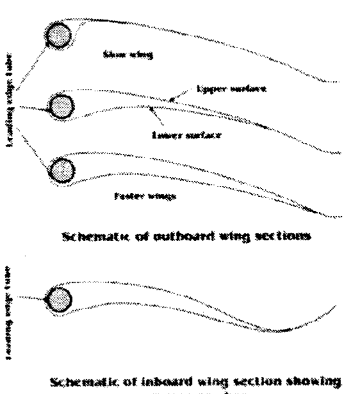


Figure 5

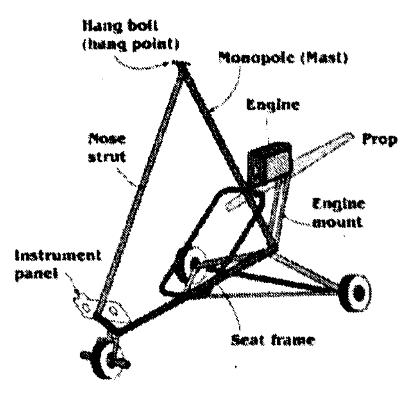


Figure 6

figure 6. The trike has a "chassis" made up of a base tube. A nose wheel in the front and a pair of rear wheels mounted on an axle form the landing gear. The nose wheel is mounted in a fork to enable turning the gliders while on ground. A multipole rigidly fixed to the chassis hangs from the wing at the hang point. A front tube is connected between the multipole and the base tube. A seat frame is joined at one end to the multipole and at the other end to the base tube. One to two seats are fixed in the seat frame. Normally, a tandem seating arrangement is used for training purposes. Side-by-side seating arrangement is rare. The aircraft as a whole typically weighs around 250 Kg. The payload *capacity varies between 150 Kg to 180 Kg.*

An engine is mounted on the engine mount behind the multipole. The engine drives a pusher propeller. Typical engine power requirements vary between 25—30 HP for a single-seat trike to 40—50 HP for a two-seat trike. It is of interest to note that these engines normally run on regular gasoline mixed with two percent motor oil. This offers a major economic benefit over the other types of aircraft.

Introduction of the trike essentially eliminates the need for high points for launching. One can easily operate on level grounds. A very short runway of about 250 m is generally sufficient. The aircraft usually takes-off within 100 m. An open field with short grass or plain hard clay is generally preferred for landing and take-off operations. The primary reason is that in cross-winds, the landing of these crafts can be tricky and dangerous. An open field allows the pilot to land into the wind.

Instruments

Very little instrumentation is required for the basic flying of a trike. In fact, most of the flying is done without the aid of any instrument. Engine RPM and cylinder head temperature indicators are used for monitoring the health of the engine. Altitude and air speed indicator are also often used. For cross country flying, a radio set to keep in touch with airports and a compass are employed. Hand held global positioning systems are becoming increasingly popular in trikes. Since the trike offers unhindered view of the surroundings, these machines are mostly flown with feel for heights and airspeeds.

On the ground, wind-sock is a must. This is a simple conical shaped light cloth construction that orients with the local wind direction. Since trikes should normally be landed in the direction of the wind, the local wind direction information is quite critical. It is interesting to note that chimney smoke from factories acts as a great aid to flyers since they unmistakably mark the wind direction on the ground.

Flying a trike

Learning to fly a trike is probably a little more difficult than learning to drive a car. Just as you do not need to be a mechanic to drive a car, it is not necessary that you be an aerodynamics expert to fly a trike. The trikes are mostly flown by feel. Gauging the height of the aircraft is an important new feel a pilot must develop.

The basic controlling mechanism is the control frame that consists of the triangular structure attached rigidly to the wing. The control bar can be moved relative to the trike in four directions: front, back, left and right. In addition, the propeller RPM can be changed via a throttle. The throttle can be controlled with a foot pedal. This feels very much like the accelerator in a car. Brakes are sometimes not even necessary!

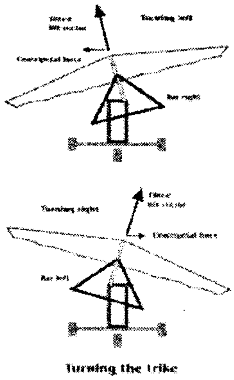


Figure 7

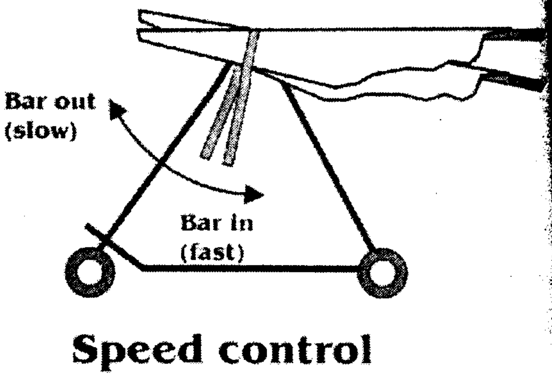


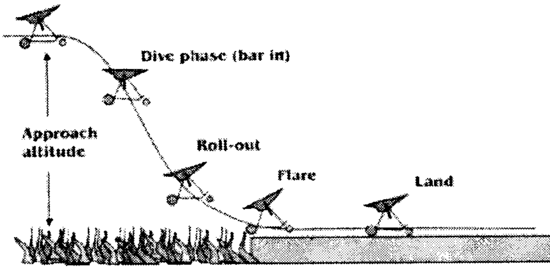
Figure 8

Moving the control bar directly moves the wing. This provides the basic control action. This is known as the weight-shift control. To execute a right turn, for instance, the right wing must be dipped (which will raise the left wing). This is done by the control bar is *pushed to the left* (see figure 7). When the wing banks to the right, the lift vector also tilts that provides the necessary side force to turn the aircraft. In the conventional aircraft, an additional control is necessary for turn — a rudder. The rudder is used to turn the nose of the aircraft in the desired direction. This is called a co-ordinated turn. If this is not done, the aircraft will turn with its nose pointing forward. In the case of trikes, however, the triangular shape of the wing results in wind-cocking, i.e., the nose turns in the desired direction without the aid of the rudder.

How does one control the speed and altitude? This is quite unlike the car control. When an accelerator is pressed in a car, the car moves faster. But in the case of an aircraft, the additional power pumped into the aircraft engine by increasing the throttle *does not make the aircraft go faster!* On the other hand, it makes the aircraft go higher. This is contrary to the intuition and needs to be learned by practice. Reducing the throttle has the opposite effect of lowering the altitude. Essentially, the additional power goes into increasing the potential energy of the aircraft and not the kinetic energy. The aircraft speed is mainly governed by the so called angle of attack (AOA). This is an angle made by the wing with respect to the oncoming wind. If the wing is rotated such that the nose of the wing goes up (see figures 8), then the AOA increases. This increases the lift coefficient defined as the ratio of the lifting force to the force due to the dynamic pressure of the oncoming wind. The dynamic force of the oncoming wind is half the product of air density, square of the wind velocity and the wing area. The wing area is fixed and so is the air density at a given altitude. In level flight the lift balances the aircraft weight. Therefore, aircraft speed decreases to match the increase in the lift coefficient. The opposite happens when the AOA is decreased. This is one of the peculiarities of aerodynamics.

Trike flyers tend to use a particular type of landing technique that differs from the technique used in conventional aircraft. The landing sequence begins with the alignment of the trike with the runway from a relatively *high point*, see figure 9. It is important to make this high approach. The aircraft then "dives" thereby gaining airspeed. This is accomplished by lowering the throttle and pulling the control bar in. As the trike approaches the ground, the bar is slowly pushed out resulting in a roll-out. The aircraft loses airspeed during roll-out and descends further. Then the bar is pushed out further to "flare" the trike. This results in the trike floating parallel to the runway and with passage of time the speed decreases and the trike lands safely on the ground. Of course, the trike spends just about a second or so in roll-out while the flare is executed in a fraction of a second. Once on the ground, the bar is pulled back in to effect aerodynamic braking.

Take off is perhaps the simplest of all the maneuvers. There are two techniques in vogue — bar in and bar out take-off. In the bar out technique, the control bar is pushed fully against the front tube and full throttle is applied. Within a short distance, the trike becomes airborne. At this point the bar is pulled back just a little. The wing would stall otherwise. If using the bar-in technique, the aircraft is throttled up with the bar in. The bar is gently pushed out as the speed is gained while on the ground. This results in the nose wheel rising and with further throttle, the trike becomes air-borne.



Landing sequence

Figure 9

Concluding Remarks

Aircraft production, operation and maintenance are highly regulated. This is particularly true of military and commercial sector. The trikes, however, do not come directly under such severe regulations. The rules and regulations applied to the trikes are highly simplified. For instance, the trikes do not require a type certificate for production and operation. They are given a simple Permit to Fly instead. It is also not necessary to obtain a pilot's license to fly the trikes. The flight instructor is authorised to grant a person the "license" to fly.

Flight safety is the sole responsibility of the trike pilot. The engine must be maintained as per the guidelines laid down by the manufacturer. It is mandatory to maintain a log book that records each flight details.

Trikes are ideally suited for many applications apart from the mere thrill of flight. Aerial spraying for agricultural purposes, aerial photography and survey come to mind immediately. Hand held GPS are a great aid in aerial survey. In the National Aerospace Laboratories (NAL), trikes have been used to carry out in-flight experiments on wing sections etc. These have proven very useful.

The powered hang gliders were developed in India by NAL jointly with Raman Research Laboratories under AR&DB grant more than a fifteen years ago. These hang gliders are also produced privately by a number of small companies in India.

Acknowledgement

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References

This article is based on personal experiences with flying the Clipper Powered Hang Glider that is operated routinely by NAL, Bangalore. Some of the information has been taken from the following resources:

[1] Practical Experiments for the development of human flight by Otto Lilienthal. James Means' The Aeronautical Annual, pp. 7-20. 1896. (See http://invention.psychology.msstate.edu/i/Lilienthal/library/Lilienthal_Practical_Exp.html for HTML version)
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