# THE DESIGN AND FABRICATION OF TOP SECRET – LA MOUETTE'S RIGID HANG GLIDER

**Zaidi Mohammad Zain**
**Faculty of Mechanical Engineering**
**Universiti Teknologi MARA**
**40450 Shah Alam, Malaysia**

## Abstract

*A rigid hang glider TOP SECRET was designed and developed by La Mouette, Dijon, France. Rigid hang gliders are gliders that have a rigid board of attack made of composites and have rigid ribs. The skin is usually made of MYLAR or DACRON. This paper discussed the current types of rigid hang gliders, their performance and configuration. The choice of 2D airfoil and their analysis using computational methods are also included. 3D wing optimization was done using Weissinger Extended Lifting Line Theory to find the best linear twist angle from root to the tip of the wing. Ergonomics consideration for the design was highlighted. Ground and flight tests for development and certification are discussed. There is market for rigid hang gliders and more research and development will lead to better, safer and cheaper gliders.*

## 1. Introduction

Rigid hang gliders are the new innovation in hang glider design. On the market now, the more renowned names are PEGASUS, EXXTACY and SWIFT. La Mouette decided to join the fray by designing the TOP SECRET. This hang glider wing can also be used on trikes (microlight). Even now, La Mouette is developing the TOP SECRET to be the wing for the new COSMOS trikes. The design and fabrication of TOP SECRET is documented here to help spur more research and development in the field of sport and fun aviation. Looking back to the past, we see that hang gliders designed and flown by Otto Lilienthal pave the way to powered flight. With new materials and advances in analysis, we can make flying cheaper, safer and more accessible to the common folks.

## 2. Design and fabrication of TOP SECRET

### 2.1 Currently available rigid hang gliders

The more popular rigid hang gliders on the market now are EXTACCY, PEGASUS, MILLENNIUM and SWIFT. All are rigid hang gliders with composite board of attack cantilever beam except SWIFT, which is an all-composite rigid wing. Listed below are their characteristics of PEGASUS, EXTACCY and SWIFT. [1]

| | Pegasus | Extaccy | Swift |
|---|---|---|---|
| Weight | 39.5kg | 42.5 kg | 63 kg |
| Span | 11m | 12.26m | 11.89m |
| Area | 15.2 $m^2$ | 14.8$m^2$ | 12.52$m^2$ |
| Sweptback | $20^0$ | $16^0$ | n.a. |
| Vne | n.a. | 120 km/hr | 120 km/hr |
| Vstall | n.a. | 28 km/hr | 40 km/hr |
| Vz min. | 0.75 m/s | 0.75 m/s | 0.65 m/s |
| Finesse | 16 | 17 | 25 |

Table 1. Data on rigid hang gliders

Using the above figures as a benchmark tool, TOP SECRET was designed to be better. Market analysis by La Mouette has shown the potential of this new type of hang gliders. They are to

address the higher end hang glider market. The higher end market has proven to be the most profitable for La Mouette as shown by the success of TOPLESS, which is among the first hang glider without kingpost and upper bracing wires.

## 2.2 Description of TOP SECRET

TOP SECRET is a foot launched hang glider with a rigid composite "D-shaped" leading edge. It has carbon composite foldable ribs, which are attached to the rigid leading edge. The left and right wing are hinged together so that they can easily be folded for easy carriage. The sailcloth is fixed on the leading edge by Velcro straps. At the trailing edge, they are attached to the end of the ribs using straps. The sails came in 2 pieces for each wing. The top and bottom surface rest on the ribs solely by the tension between the attach points at the leading edge and trailing edge. For the first prototype, MYLAR is used to make the sail. However DACRON can also be used.

TOP SECRET has an aspect ratio of 7.96 and a span of 11 meters. It also has a sweepback of $20^0$ at the leading edge. The D-shaped leading edge is made of carbon composite material DYNEEMA. At present the keel is made from Aluminium Alloy AU4G. It consists of tubes and sheet metals. The trapeze bar is also made of Aluminium Alloys. Roll control is by spoilers. The spoilers consist of a flat composite plate. An envelope shroud for the spoiler is stitched on the top surface of the sailcloth. The flat plate fits inside the pouch and is activated by a system of cables and pulleys linked to the control bar. Flaps are also provided. It also consists of a flat composite plate enclosed in an envelope stitched to the sailcloth. It can be activated by a cable system linked to the control bar. The control bar is of a standard triangular shape and the pilot is suspended from the keel in the classical prone position of normal hang gliders. Control is by weight shift and also spoilers. The flaps and spoilers have a system of springs to return them to their original position.[2]

## 2.3 Fabrication of TOP SECRET

Listed below are the modular parts of TOP SECRET and their method of construction.

1. D-Shaped board of attack.
   2 pieces, left and right wing constructed using carbon composite materials DYNEEMA. Layers of DYNEEMA were put into wooden molds and epoxy resin applied under vacuum without autoclave. The part was subcontracted to Dyn Aero, Dijon, France. This company produces the MCR-1, an all-composite light aircraft.
2. Foldable ribs.
   The ribs are of rectangular cross section bars made of carbon fiber outer layer and foam core. These are also made at Dyn Aero.
3. Keel and support cables.
   Keel is from standard Aluminium AU4G tubes and plates. Cables are standard stainless steel. All fabrications are done in house at La Mouette.
4. Control Trapeze Bar and cables.
   In house trapeze bar and cables common to other hang gliders manufactured at La Mouette are used throughout.
5. MYLAR or DACRON sailcloth
   The sail was stitched at La Mouette. MYLAR was chosen for the first prototype because it is difficult to stretch and hence can be used as template for the subsequent DACRON sail.
6. Flaps and Spoilers.
   Flat composite boards were fabricated at Dyn Aero using vacuum techniques.
7. Wing attach bar.
   High strength Aluminium Alloy was used to fabricate this part at La Mouette. Their main function is to join the left and right wing and also acts as

pivot to fold the hang glider for storage.

### 2.4 Design Constraints

The TOP SECRET was designed to be lighter than the rest of the rigid hang gliders. The target production version is 38 kg or below. The span was fixed at 11 meters. Any longer would compromise portability especially on small compact cars popular in Europe. Shorter span would affect aerodynamic performance.

For the D-shaped board of attack, carbon stiffener plates were put at certain strategic locations along the span to cater for impact loads. Hang gliders usually take a lot of knocks during assembly at launch sites and during landing. More stiffeners are put near the tip of the wing. Arrangement of carbon composite layers was done carefully to give the necessary all around strength. A lot of testing was done on this structure.

Adhesive choice is also very important. La Mouette worked closely with adhesive manufacturers to ensure quality of adhesion. Tests were done to check the suitability of the adhesive material. We faced a lot of difficulty in bonding the Velcro straps (for the sail to grip) to the D-shaped composite board of attack.

Water droplet tests were also done on the composite ribs to ensure no deterioration of the bonded structure. We were concerned about water vapor inside the wing structure during operations (i.e. flying in humid conditions and also early morning dew).

## 3. Aerodynamic Considerations

### 3.1 Choice of Airfoil

We choose the same airfoil as the PEGASUS. We have the airfoil coordinates but no aerodynamic data. [2]. Aerodynamic data for the 2-D airfoil was obtained using the software XFOIL (by Mark Drela, M.I.T., USA) and EPPLER (by Dr. Richard Eppler). [2] [3]. In the end we chose the results obtained by EPPLER because we are keen to explore the possibilities of choosing other EPPLER profiles such as E344. By choosing the same software to analyze airfoil shapes we can make better and more valid comparison.

In the hang gliding fraternity, what others do is followed very closely. Decisions are made, by comparing the flight characteristics of a new model. Usually, these are obtained at high level competition such as the FAI sanctioned championships. Pilot cum designers have an added advantage because of their intimate knowledge of flight characteristics and engineering background.

### 3.2 3-D Wing Optimization

We decided to use the same airfoil throughout the span. This was to ease construction and to reduce cost. We optimize the linear twist angle along the span. Extended Lifting Line Theory of Weissinger was used to do analysis of the wing. [4]. We vary the downwash at the tip from $0^0$ to $8^0$ while distribution along the span is linear starting with $0^0$ at the root. [2] [5]. The best ratio of Lift/Induced Drag was obtained by the linear twist with $6^0$ downwash at the tip.

The Extended Lifting Line Theory was chosen because we need quick answers as we already have the data on twist angle distribution of other rigid hang gliders. We must also remember that in flight, the sail also tends to undulate because it only rests in tension on the ribs. A lot more theoretical and experimental work needs to be done to come up with an appropriate method of analysis specifically for hang gliders. Our final decision on the twist distribution is based on other considerations as well. Control bar force during maneuver is also of paramount importance. Extensive flights on the PEGASUS and experience in designing the world championship winning TOPLESS (1998) gives a lot of input to the final solution on the twist distribution.

### 3.3 Testing and Homologation

Ground testing was done using a 4WD vehicle. The vehicle has instrumentations to measure the fundamental parameters. [6]. The hang glider was rigged on top of the vehicle using special fixtures. Testing was done at Darois Airport, Dijon. Straight runs at various speeds ranging from 20 km/hr to 150 km/hr can easily be done. Integrity of the structure was checked thoroughly. Any adverse vibration can quickly be detected.

When all the ground testing was done, flight tests were conducted at the nearby La Mouette fly zone (a wheat field). The glider was towed by a trike and released at altitude. Comparisons were done directly by flying two gliders of a different make side by side. Video and still pictures were taken to help identify problem spots. This will help to identify what improvements are to be made.[7]

The glider will also be subjected to normal flight tests. Instrumentations to check flight qualities are attached to the control trapeze bar. Two test pilots will do the flight test and they will compare their result during debriefing and also during flight by radio contact. All information is jotted down in the design logbook.

All these are done to prepare the documentation for the DHV (German Certification body for hang gliders). The DHV certification is among the toughest and to be able to sell TOP SECRET in Europe, this certification is a must. In the end safety and quality must be upheld at all times.

## 4. Conclusion

There is a need and market for rigid hang gliders like TOP SECRET. At the moment, price per unit will increase compared with conventional hang gliders. However, the improvement of flight performance will more than compensate this price increase. Moreover the wing will be attractive to the microlight community especially the trike manufacturers. Our experience at La Mouette will hopefully spur more research and development in this area so that better, safer and cheaper hang gliders can be built.

## 5. Acknowledgements.

Thank you to Gerard Thevenot (pilot-ingenieur-owner of La Mouette)and all staff at La Mouette, Jean-Marc Moschetta and the Aerodynamic Staff at SUPAERO, Herve Bezard of ONERA and Dr. Richard Eppler for technical support and excellent guidance. This continuing research was made possible by the financial assistance of the Bureau of Research and Consultancy, Universiti Teknologi MARA (UiTM).

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Figure 1. TOP SECRET

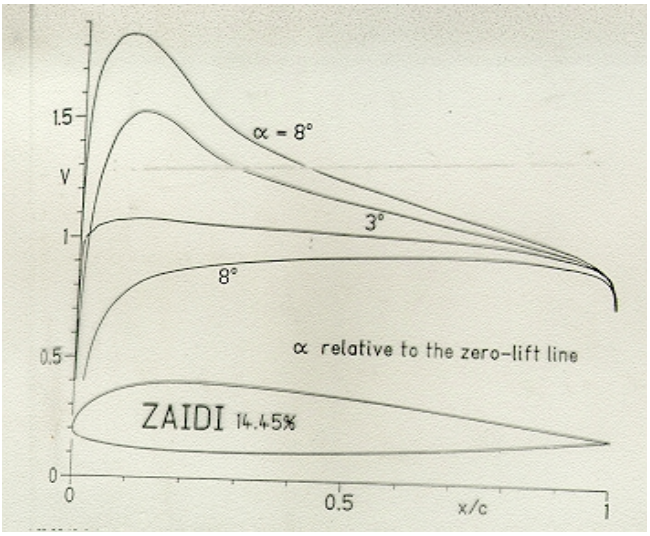


Figure 2. Airfoil Shape

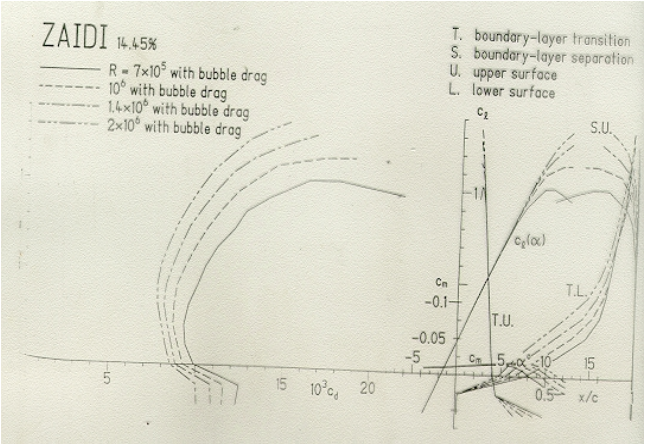


Figure 3. Airfoil Polar by EPPLER

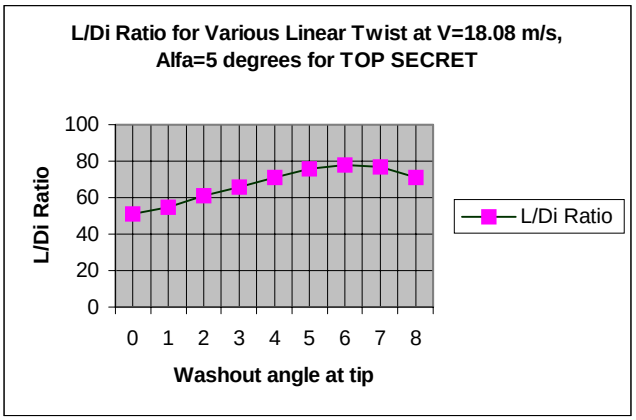


Figure 4. Optimization Result