AN ALTERNATE APPROACH TO COST EFFECTIVE SOARING

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Summary

With the ever increasing cost of soaring, an alternative has to be developed if soaring is going to survive. People enjoy the beauty and fascination of soaring but have been frustrated by the expense of the sport.

For traditional soaring, the homebuilders' movement appears to offer a means to cost effective flying. We consider cost effective to be inclusive of low initial financial investment, construction in a minimum amount of time, and performance approaching or equal to that of current production gliders.

To approach these requirements, the development of a high-performance glider using advanced non-woven composite fabrics in a cost effective manner is considered and discussed.

Introduction

Soaring is in a stage of transition. It has attained a high level of popularity that is however being eroded by its spiraling cost. According to the Soaring Society of America nearly half its membership do not fly because of its cost. Yearly membership in the SSA has increased 3–5 percent a year from WW II to 1979. But by 1981 membership had fallen 2.5 percent over the previous year.

What has been found to be a cause for this loss and minimal growth over the years has been cost and the inability of individuals to obtain personal ownership of a sailplane, which for many catalyzes interest and activity. But with cost stifling the achievement of personal ownership, interest declines and activity eventually stops.

In the United States the lending institutions have done little to support soaring and sport aviation. Much of the lending institutions' rationale for not providing funds for soaring was based on outdated information about gliders and considered high risk. Even when attempts were made to correct this, the Ultralight movement was in its early stages of development and conventional sailplanes were placed in the same category as hang gliders, and considered high risk again. Though some lending institutions are now realizing the difference between a hang glider and a conventional sailplane, the economic conditions that are occurring prevent them from financing unconventional high cost products.

There have been alternatives to personal ownership. Clubs, partnership rental from commercial operators, have proven a means to soar but have not maintained the interest on a large scale.

A viable alternative to this problem is for a person to build his own sailplane. Homebuilding offers the advantage of controlled cost outlays as the project progresses. It is an excellent learning experience with the added benefit of acquiring and improving one's craftsmanship.

But homebuilding an aircraft holds many problems in itself. According to the Experimental Aircraft Association, only ten percent of all home-built aircraft are ever completed. Interest in building, once started, lasts only ten months, then a steady decline in interest occurs. Fuelling this decline is the fact that the average completion time on an aircraft is three to five years.

In 1980 the SSA and the newly formed Sailplane Homebuilders Association announced a homebuild sailplane design contest. From sixty original entrants, only two completed their project in time for the fly off. But out of this contest came a very interesting study by Ilan Kroo of Stanford University. Of interest to us was the cost performance curve. The average price that an individual was willing to pay for a sailplane was between $ 4,500 and $ 6,500. Above this price the ability to afford falls off rapidly.

Dick Johnson reported to SOARING on average required performance for extended soaring flight. With an L/D of 36:1 and 2 ft/sec sink rate, one's ability to soar on extended flights is enhanced on average soaring days.

From these various factors we established criteria for a homebuilt sailplane.

1. Performance should not be compromised from the point that this is a homebuilt aircraft.
2. Exotic styles and non-conventional construction techniques should be avoided.
3. Time factor for completion is based upon the assumption that an average of eight hours a week is spent on construction for a forty week period of time.
4. Construction is devised in such a way that no special jigs or tooling are required, and a moderate skill level in basic hand tools is all that is needed.
5. Cost containment methods should be implemented from the start of the design and carried out through all phases of fabrication.

Design

The design of the Freedom in the Spirit sailplane has evolved over the years to its current form as a multifunction aircraft. Care has been taken with the fuselage and wing to incorporate as many parts between all the aircraft. The multitaper wing is designed in such a manner as to offer four wing spans by simply combining the various tapered sections to the desired span (Fig. 1). The 15 meter and 24.5 meter wings approach the optimum taper ratios that are desired.

The fuselage is a modified Althus NACA profile designed for pilots 7 ft. tall and 275 lb in weight. As with the wings, the fuselage tooling is designed to have interchangeable tail assemblies. Up to station 180 the fuselages are identical, then, depending upon what is needed, a short boom T-tail, long boom T-tail, or a Y-tail with a pusher prop can be incorporated. A proposed two passenger pilot pod has been designed to incorporate these tail assemblies in the same manner.

For our airfoil, we selected the Wortman FX 62-k-13.1 profile section. It has proven characteristics along with not being as sensitive to profile inaccuracies as the newer airfoils. The empennage incorporate the NACA 651-012 profiles. The control system is conventional, incorporating full span "flapperons" with spoilers for glide path control.

Construction

A great deal of research was done to develop a simplified method of construction. Conventional wood and/or aluminium were considered to be too time consuming, and to require a high degree of specialized skill. Foam glass construction, popularized by Rutan in the Varieze, was found to be unsatisfactory because of the lack of consistent reproduction and a moderately high time factor.

At first we set out and developed an inexpensive moulding system that proved to be very time consuming. From this experience we did find a material that can be utilized easily in one-off, mock-up, and prototype building. It is called C-Flex and was developed here in the United States for the Marine industry. It is a self-supporting glass fibre consisting of pultruded rods spaced apart with rovings and held together with a lightweight fabric. It conforms easily to a simple jig and is relatively easy to use and is moderate in price.

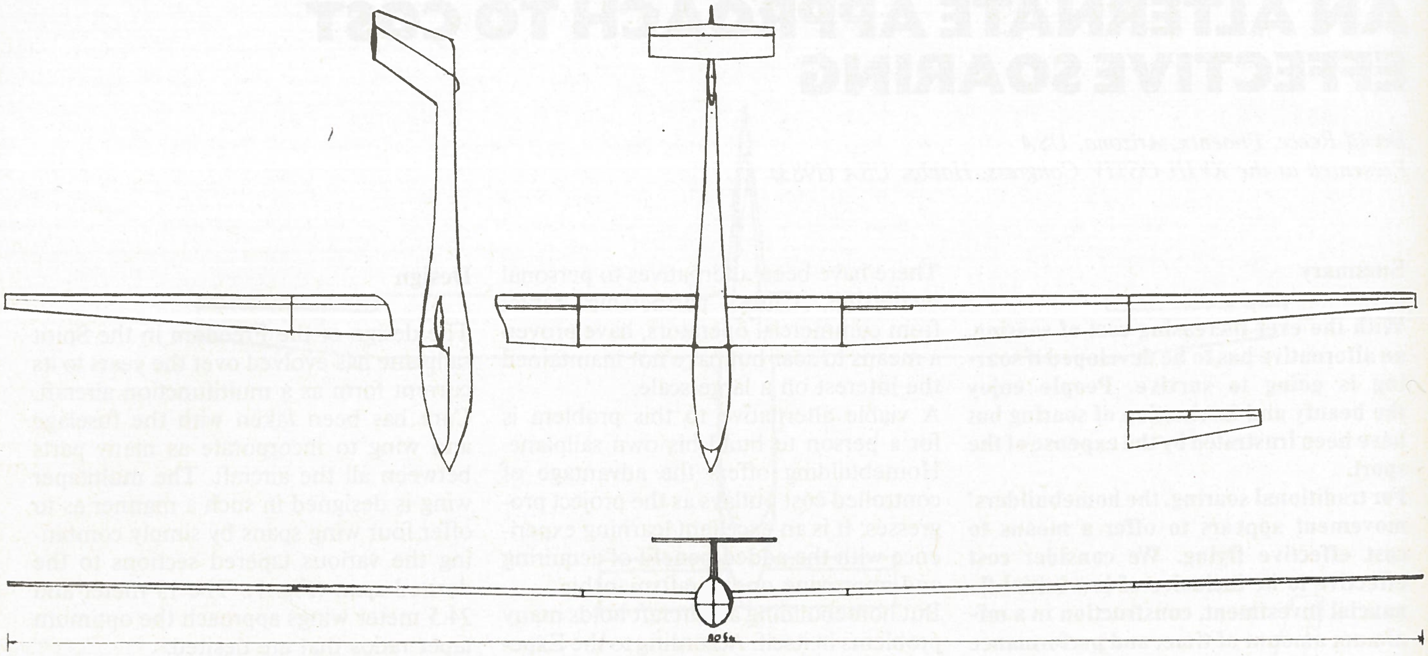

Fig. 1: Multitaper wing to form 2 wingspans.

However, we decided not to use C-Flex in this project because of weight and time. Instead, the decision was made to go with production grade female moulds. Reproduction, quality, and cost containment became controllable. With this decision, we searched for another material which would offer the most cost-effective structure, and selected non-woven S-glass.

Robert Lamson has described in detail the use of S-glass in the Alcor sailplane. It offers outstanding structural characteristics and it is relatively easy to use as compared to graphite or kevlar. Until recently S-glass was not widely available owing to heavy usage in governmental contracts. This has changed in the past few years mainly owing to the increase in exotic composite usage by the sport and pleasure marine industry.

S-2 glass fibre is exclusively in the spar caps. S-500 is a commercially available S-2 unidirectional tape. A special feature of S-500 is that the fibre strands are held in alignment by a single strand of glass that is glued across the top of the rovings. This allows for near perfect fibre orientation and prevents any of the fibres from the crimping that normally occurs when a strand is woven into the rovings.

From a production standpoint, the wing skins have posed a problem of excessive construction time. For proper fibre orientation in a wing skin, the cloth should be unidirectional, such as style 1543, set at 45° and 135° angles. This requires numerous pieces of cloth to be cut and carefully aligned and overlapped to provide the desired fibre orientation. This procedure is time consuming; layups cannot be guaranteed to meet specifications, and have provided inferior structural characteristics.

In the United States a speciality textile manufacturer has developed a cloth that is designed to provide fibre orientation at 45° and 135° as desired. But unlike other biased woven cloths, this fabric

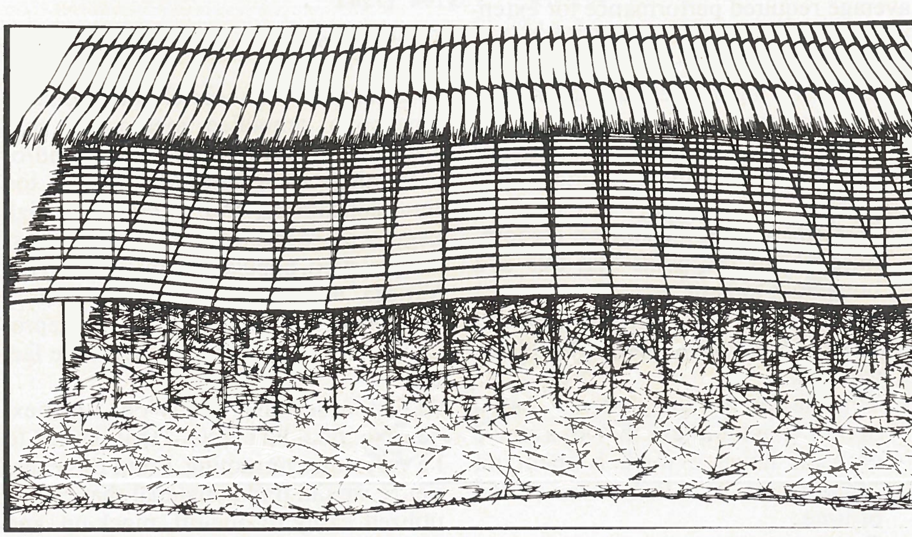

Fig. 2: The non-woven cloth as used in the product Promat. Made from E glass yarn with silane binder and combined with a standard chopped strand mat. The construction of non-woven cloth is the same. Fibre orientation and material combination can be varied to suit ones needs.

is not woven but sewn together (Figure 2). For the double biased 17 oz. cloth the fibres are laid down first at 45° for 8.5 oz. of material, then the fibres are laid down at 135° for 8.5 oz. of material and then it is sewn together. They also provide a triaxial cloth by adding a third layer of material laid down at 0°.

The structural characteristics of the double bias cloth exceed that of two layers of 1543 cloth at 45° and 135° fibre orientation.

Less material is wasted due to cutting, fibre orientation is easily controlled and lay up time is kept to a minimum.

In our design, double bias cloth, utilizing E-glass fibres, is incorporated in the 15m and 18.5m wing. For the 21.5m and 24.5m, S-glass fibres are used. For the fuselage a single layer of triaxial cloth utilizing E-glass fibres is used, along with bulkheads and stringers.

A factor that must be taken into account with composites is the environmental factors they will be subjected to. Thermal shock is one factor to be overcome if long term airframe life is to be realized. Until recently there was not too much that could be done to prevent thermal shock and its potentially destructive effects. About two years ago a specialty plastic cloth came out onto the corrosion-resistant tank market as a replacement material for C-glass. It's called Nexus Veil Cloth. It offers excellent corrosion resistance to a wide range of chemicals but also exhibits the unique ability to withstand thermal shock as an outer veil layer.

We finally examined the resin systems and decided to consider alternatives to the popular epoxy resins currently used (Table 1). We had been using the Shell Epon 815 or the Dow 330 with TETA catalyst as our base resin. They offer good structural strength but contact with human skin is harsh and dermatitis problems arise after a short period of usage. Polyester resins offer ease in handling but not the structural strength required. The newer Vinyl Ester resins offer the desired handling characteristics along with the structural strength of epoxies. They also provide improved environment integrity over epoxy, as well as being marginally less expensive.

Table 1: Resin system comparison vinyl ester vs. epoxy.

Resin	Vinyl Ester	Epoxy
Producer	Dow Chemical	Dow Chemical
Trade Name	DERKANE 510-N Resin	Dow DER 332
Curing Agent	MEKP	TETA
Tensile Strength (psi)	10–11000	9600
Flexure Strength (psi)	18–20000	17000
Flexure Modules ($x10^5$)	5.3	4.74
Ultimate Elongation, %	3–4	4.4
Heat Distortion Temp, C°	121°	107°

From the materials and the use of female moulds, it is now possible to produce the major components for the airframe which in turn can be utilized in a kit for the homebuilder. The critical lay-ups and contours are controlled at the factory and the builder fabricates the internal support structure needed to complete the aircraft. Even with the major shell structures being factory built it is still the responsibility of the builder to complete 51 percent of the aircraft as required by the Federal Aviation Agency. Because of the extensiveness of the shells provided to the builder, the control system, bulkheads, ribs and other structural support systems become the homebuilder's responsibility.

Marketing

The marketability of a product is related to various factors. John McMasters has stated that the aesthetics, of the initial appearance of the glider, is a major marketing factor. If a sailplane appears to have the ability to fly in competition, it is much more desirable to the buyer than a conventional sailplane of equal performance.

As with aesthetic appeal, if the builder perceives he does not have to invest a large amount of labour time and can see the airframe contours early in the building stages, his interest is maintained. Whereas, if he has to fabricate all the components that are needed in conventional construction, he may spend years building and never see the basic contours of the airframe. This leads of frustration and interest usually falls off and the project is abandoned.

From these factors the kit is developed to be aesthetically appealing and devised in such a way that the builder is not overwhelmed by the fact he has to fabricate 51 percent of the aircraft and that he can see the basic airframe profile early in the building.

Conclusion

We consider that a kit sailplane can be produced economically with minimum labour. Performance needs do not have to be compromised if cost containment methods are implemented early in the manufacturing stages. Homebuilder support systems are being devoloped to provide education and assistance to the builder.