REDESIGN AND CONSTRUCTION OF A HIGH PERFORMANCE SINGLE ENGINE AEROPLANE

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ABSTRACT

The purpose of this work was to make the best of all the time spent by the author at university and of the infra-structure available to the student at the University of São Paulo to develope a project that would improve his knowledge of aeronautical engineering. The plans of an american project of a high performance single engined twin-seated light aircraft were used as a basis for the project.This paper describes the various problems encountered in the design and their resolution in terms of the redesign and construction of a prototype aircraft.

INTRODUCTION

Because light aircraft certification rules[1] have been so hard to follow, experimental category aircraft has increased its popularity. Because of this, homebuilders have had to cope with new technologies such as composites, engines and aerodynamics in order to improve performance and safety. Some of the proposed designs for efficient and low cost light aircraft have been presented by Universities with Aeronautical and Mechanical Engineering courses. The Sao Carlos School of Engineering of the University of Sao Paulo has in its Mechanical Departament a group of Aircraft Design in which the main purpose is to support and develop new technologies, techniques and aerodynamics for student projects. This paper will present one of these projects developed at the University which is basically the redesign and construction of a prototype aircraft. The most important feature of this project was the use of similar Brazilian material to that originally proposed, such as wood[2,3,4] and fiberglass[9] . Some modifications were carried out in the original project in order to improve general performance. The main modifications were on the primary structure, landing gear system, fuel tanks, engine and its mount. A total of 7000 hours of work has already been spent on this project and the aircraft in now ready to perform initial flight tests.

THE CHOSEN AEROPLANE

An american project with hybrid contruction in wood and fiberglass was selected, which had the following characteristics:

Name: KR-2
Wing Span: 6.30 m
Lenght: 4.50 m
Height: 1.30 m
Empty weight: 220 Kg
Gross weight: 450 Kg
Cruise speed: 290 Km/h
Stall speed: 72 Km/h
Seats: 2

As soon as the prototype construction began, it became evident that the project had several deficiencies or problems, besides this, it was very difficult to obtain all the required material in Brazil. At the end of the construction, the aeroplane was very different from its original project and it showed a very high degree of nationalization.

MAIN PROBLEMS AND THEIR SOLUTIONS

Primary Structure Of The Aeroplane.

The first problem that was found refered the material for the construction of the of the primary structure of the aeroplane, because that originally required was designated as the american wood Spruce. The solution found for this was the use of brazilian Freijó, a kind of wood that has been studied in depth ,for aeronautical use, by IPT (Institute of Technological Researches, São Paulo) and was easily acquired.

Freijó, however, is a heavier wood than Spruce, it has an average tensile strength of 1000 Kgf/cm3 against 900 kgf/cm3 of the Spruce and an average compression strength of 480 kgf/cm3 against 420 kgf/cm3 of the american wood.

At a first sight there seems only to be advantages in the use of Freijó, but this wood has a tensile strength perpendicular to the wood fiber that is lower than that of Spruce.

This characteristic could mainly weaken the areas of strength concentration, such the areas at which metal part fittings are normally attached. The problem was solved, however, by gluing aeronautical plywood in these areas, with the plywood fibers perpendicular to the wood fibers.

This solution was enough to be used on almost every part of the aeroplane except for the spar fitting, where bidirectional fiberglass was also used with the plywood.

When the wooden part of the aeroplane was ready, the most laborious part of the construction began, the making of the fiberglass parts. The fiberglass covers the whole surface of the airplane, and is a part of its structure.

All the wing and tail torsion forces are supported by a fiberglass skin which works with foam. As the fiberglass skin has high mechanical strength and low buckling resistence, the skin is laminated on a layer of foam which gives it stability.

The composite material (fiberglass + Foam + Resin) originally used in the project was American; however in Brazil we have similar material. For the fiberglass skin, several combinations of fiber and resin were tested. The best combination found is fiberglass cloth CJ-19, manufactured by a brazilian company called Reforplás, and epoxi resin DER-331, manufactured by Dow Chemical.

This combination proved to be as resistent as the american material, but there still was the problem of buckling resistence that was solved by the use of rigid polystirene foam, with a density of 35 kg/m3 manufactured by Dow Chemical with the commercial name of Styrofoam.

Several foams were tested and the PVC foam was choosen as the best, but unfortunately, the most expensive. So, instead, Styrofoam was chosen to be used in the project.

This foam is usually used as thermal insulating for low temperatures, and is easy to machine, when burning it produces less toxic gas than polyuretane foam, originally recomended in the project.

However the most difficult problem to solve was the degradation of the composite material, because even the most recent researches on this subject give no conclusive results about the curve of mechanical degradation with time for this kind of material.

The solution found was to use the same safety factor used in some fiberglass gliders available in the region of São Carlos. For this, a safe factor of 3 was used, which would guarantee a structural safe life (time) of about 20 years, when correctly protected from the UV rays of the sun.

Aerodynamic aspects

The next step on this work was to optimize the aeroplane for cruise speed, taking care to minimize any drag generators (points).

For this purpose the cockpit was lowered down to the maximum limit and every edge was streamlined in order not to generate vorticity which would disturb the free air stream.

The engine cowling needed special attention because its drag is a significant part of the total drag. So, the first action was to minimize the cowling area and then the air inlets were designed in such a way that a minimum disturbance in the free air stream would be caused. The outlet has a variable geometry, which permits good cooling during take-off and climb and it can be partially closed in cruise flight, permitting the engine to work at optimum temperature and producing lower cowling drag.

The carburator inlet air provided by a NACA type entrance placed beside the cowling produces a very low inlet drag.

Fuel Tank

As this is a high performance aeroplane, it is important to increase its range in a such a way as to permit a non-stop trip from Brazil to Africa. With this purpose, a fuel tank was built in the front part of the aeroplane which, besides keeping 70 litres of gasoline, also provides a good part of the front structural strength.

The wings also were modified in order to receive a structural integral fuel tank of 60 liters each. So we reached a total of 200 litres fuel capacity distributed in 3 tanks, which will provide a range of more than 16 hours of flight or 5000 Km. As the 200 litres of fuel have a mass that is, aproximately, the same as the aeroplane empty weight, it was necessary to make several studies of weight and balance to maintain the centre of gravity even as the fuel is consumed.

It was also necessary to install a great number of anti- slosh devices in the tank to avoid oscilations during flight.

The aeroplane characteristics with full tank are not very good. Therefore, take-off should be performed on long, paved runaways. During the cruise flight the fuel tanks would be used alternatively in order to keep the aircraft center of gravity within the working range.

Landing Gear

The landing gear system design was one of the biggest problems, because a complete system was imported from the U.S.A.,and it was found to be too short, unsafe and weak.Then, two other different configurations were evaluated.The first one was a telescopic leg with rubber rings installed inside the legs of the landing gear for shock absortion.

The chosen configuration had solid steel bar landing gear legs, made of SAE 8640 quenched and tempered steel.

This steel was not the best one for the purpose, but was the only one avaliable.

This configuration,besides being very light is also quite aerodynamic, because the steel bars are very thin and tapered and cause low drag, if compared to other kinds of landing gear systems.

Engine And Its Mount

The engine used in the aeroplane was a converted VW with 80 hp,dual ignition,with starter and alternator.

The front part of the fuselage and the engine mount were redesigned because this engine is bigger than the original engine recommended in the project. The engine mount was made of SAE 4130 steel tubes, welded by TIG process and oven stress relieved. It was designed acording to FAR-23 rules, and includes very efficient engine vibration dampers, made of nitrilic rubber.

CONCLUSION

The aeroplane, after 7000 hours of building and development is ready and flying. All the redesigned devices work well without problems, but so far it has only a few hours of flight time and the propeller used has a take-off pitch, so we do not yet have information on the cruise speed, but we expect a small increase due to the modifications.

REFERENCES

1. FAR, part 23, FAA 1978
2. A,Brotero. Dados experimentais do freijó. IPT, São Paulo 1945.
3. A,Brotero. Dados para indústria de contraplacado. IPT, São Paulo 1946.
4. Wood Aircraft Inspection and Fabrication, ANC Bulletin,Forest Laboratories, 1943.
5. E,Torenbeek. Syntesis of subsonic airplane design. Delf University, 1982.
6. D,Perry;J,J,Azar. Aircraft Structures. Mc Graw-Hill, 1982.
7. E,F,Bruhm. Analysis and Design of Airplane Structures. 1952.
8. J,Roskan. Airplane Design. University of Kansas,1985.
9. J,Lambie. Composite construction, 1986.
10. Metals Handbooks, ASTM, 1984.
11. S,F,Hoerner. Fluid dynamic lift, 1975.
12. S,F,Hoerner. Fluid dynamic drag, 1965.
13. A,C,Canale. Dinâmica das aeronaves. EESC-USP, 1990.
14. D,Lucato. Estabiliodade e controle. EESC-USP, 1980.

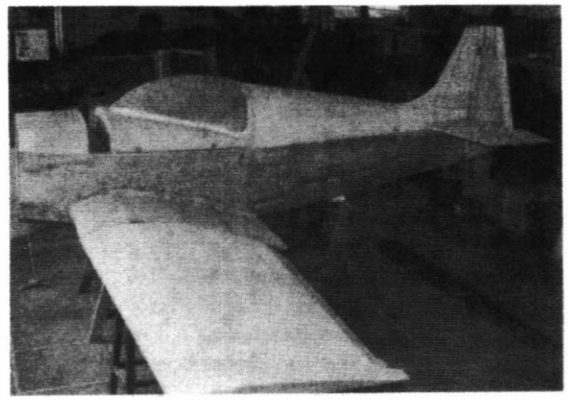

Figure 1 The Aircraft just after covered with fiberglass.

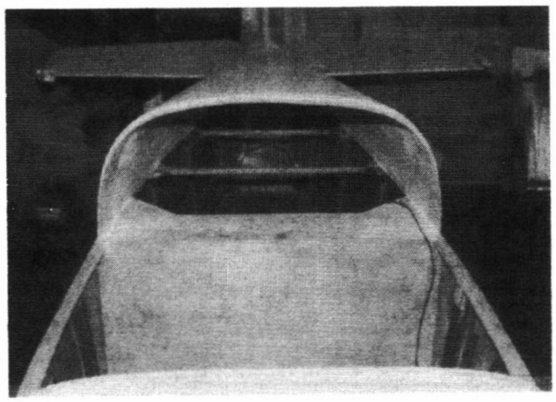

Figure 2 Details of the fuselage tail cone and empenage.

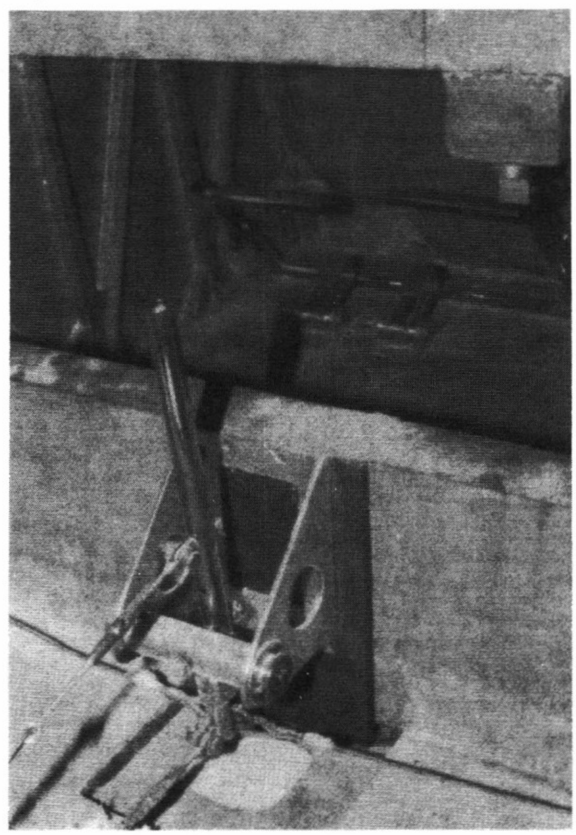

Figure 3 Detail of stick control and rudder pedals.

Figure 4 The landing gear.

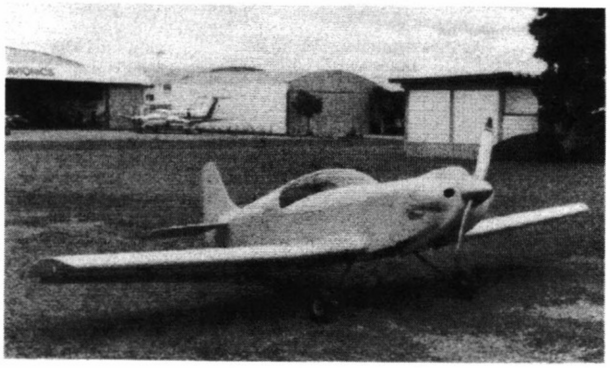

Figure 5 The Aircraft ready for flight tests.

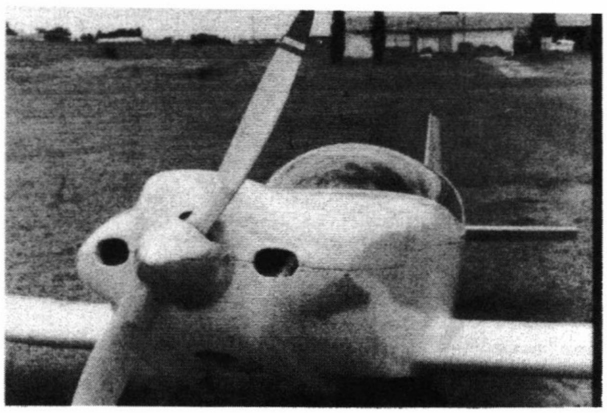

Figure 6 Details of the propeller and engine cooling inlets.

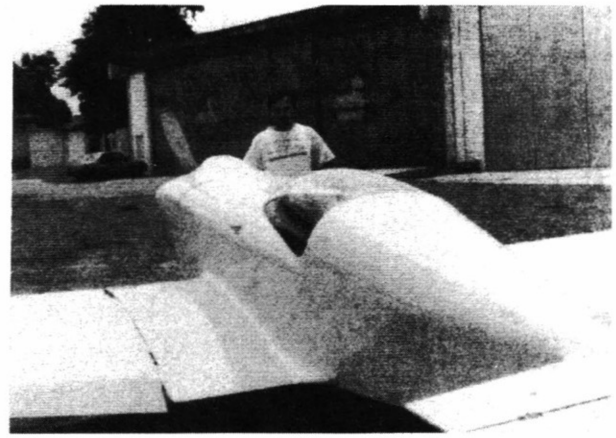

Figure 7 The author and the KR-2