Study, Construction and Flight Tests of the High Performance Sailplane CVT-2 "Veltro"

By Dr. Ing. Piero Morelli

Presented at the 6th OSTIV Congress, St-Yan, France, July 1956

The CVT-2 "Veltro" has been designed as a competition sailplane. It had to be capable not only of good performance in distance and speed flights with favourable meteorological conditions, but possess a reasonable chance of exploiting weak and narrow thermals as well.

The prototype has been built by the "Centro di Volo a Vela del Politecnico di Torino, CVT" (Soaring Experimental Center of the Turin Institute of Technology) in a period of eight months, from November 1953 to June 1954. The first flight was made on 9th July 1954. Test flights were continued in Turin during 1954 and from February to September 1955 in Rome and Guidonia by the Experimental Center of the Italian Air Force. The test flights were then concluded in Turin and the sailplane has been used by the CVT for distance and altitude flights. In one of these, an absolute altitude of 7080 meters (4500 m gain of height) was attained.

The sailplane was designed by Ing. Alberto Morelli who was assisted by his brother, the author of this paper.

Design Criteria

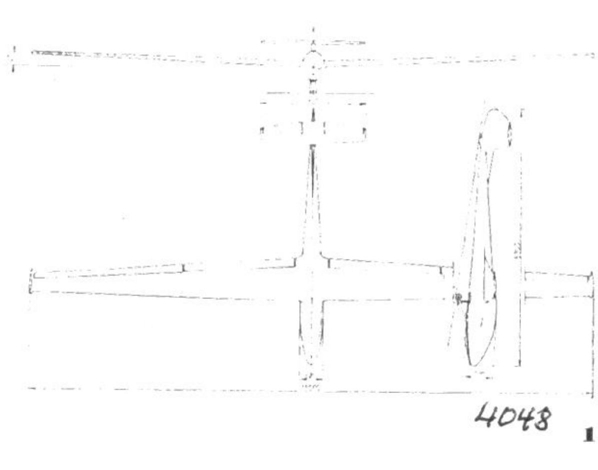
The use of a high wing loading for improving the high speed performance was rejected. Every care was taken to improve the penetration of the machine, by the reduction of parasitic drag, in the following ways:

Laminar wing airfoils: NACA 64_2515 at the root and 64_1512 at the wing tip.

Section thickness was kept within the range 15—12 % in order to maintain laminar flow over a reasonable range of lift coefficient. Calculations based on airfoil wind tunnel data at the proper Reynolds Number (ref. 1), showed that practically the whole wing span works in the laminar "bucket" for a wing C_L range of 0.3—0.7. With a wing loading of 20 kg/m², this corresponds to a speed range of 75—120 km/h, which is practically the useable speed range of the sailplane.

Chordwise location of the minimum pressure point on the airfoil was chosen at 40 %, as a compromise for obtaining an appreciable drag reduction due to laminar flow without incurring a sharp drag rise out of the "bucket" and bad stall characteristics.

We later appreciated that our choice was in perfect agreement with the conclusions of K. G. Wilkinson on the matter of airfoil selection (ref. 2).



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Reduction of fuselage drag: This was achieved through the adoption of an integral canopy and the reduction of fuselage cross sectional area, allowed by the reclining position of the pilot.

This pilot position satisfies the physiological requirements for maximum relaxation and is clearly defined in the following French description (ref. 3):

"Les études entreprises sur le repos par le corps médical montrent que la position provoquant la relaxation totale ou 'moindre action musculaire' se trouve atteinte lorsque les divers segments du corps humain — jambes, cuisses, tronc, bras — forment entre eux des angles de 135°, les pieds situés à l'horizontale correspondant à la meilleure circulation sanguine, la pression intraveineuse se trouvant abaissée, diminuant l'effort du cœur."

We have been asked whether this position affects the reflexes of the pilot or whether it affects his ability to concentrate his attention in flight. We can give a negative reply. None of many pilots who have flown the machine disliked this unusual position: some of them expressed a very favourable opinion. The proper placing of the parachute housing and of the head-rest is important for ensuring a comfortable position.

A further reduction of fuselage cross sectional area has been possible through adoption of flexible cable aileron control transmission in the front fuselage. Thus, the six flight control cables pass under the pilot's bed, in a channel that is only 25 mm deep, between the external and internal plywood skin.

The fuselage cross sectional area is 0.39 m² with a ratio of 1 : 32 to the gross wing area. In the front fuselage the section shape is a slight modification of the circular; the aft fuselage is perfectly circular. The fuselage wetted area, referred to as the cross sectional area, is thus a minimum.

Retractable landing skid: described in a separate paper of ing. Alberto Morelli (ref. 4).

High position of the tailplane: this is superimposed to the fin, with reduction of interference drag.

Choice of Span

The choice of wing span has been made with the aim of obtaining the best performance with a prefixed moderate value of the wing loading (around 20 km/m²).

Such a condition, applied to normal sailplanes (i.e. non-laminar, with a normal wing structure, single spar and plywood covering limited to the leading edge) leads to the well established wing span of about 18 meters. This is also the noteworthy result of the theoretical study of B. H. Carmichael (ref. 5), where an analysis is made of the influence of wing span and aspect ratio (on which the empty weight is dependent), on the performance in straight, circling and cross country flight.

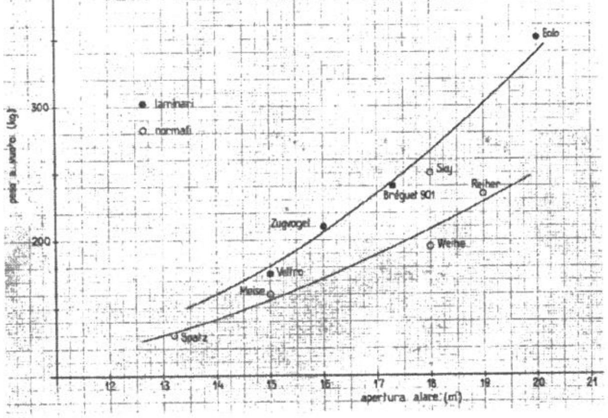


Fig. 1

In the laminar machines, the empty weight is somewhat greater, owing to the necessity for accurate wing profiles, avoiding wing skin waviness and ensuring a smooth wing surface. A thicker plywood covering on a greater part of the wing is generally required and sometimes sandwich structures are adopted; the ribs may often need to be more closely spaced.

In fig. 1 the empty weight (without equipment) of some representative sailplanes, normal and laminar, is presented as a function of span. Such a comparison is, of course, only indicative, owing to the uncertainty in the evaluation of the useful load in some cases, and to the fact that the design data affecting the structural weight, particularly the ultimate load factor, differ considerably for the different sailplanes.

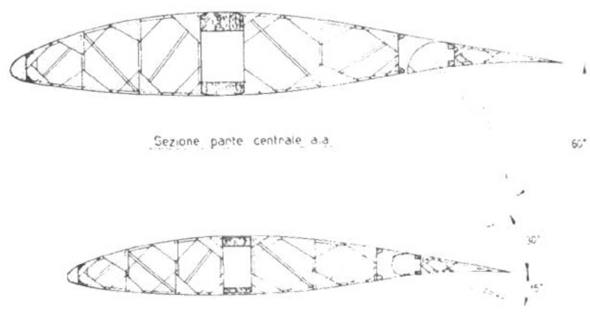


Fig. 2

The first curve (normal sailplanes) does not conform to the relation found by W. Stender (ref. 6), which would be represented by an intermediate curve between the two. We have prefered to trace it according to the data of three sailplanes (Meise, Weihe, Reiher) designed to meet similar structural requirements.

The greater weight of laminar sailplanes is evident from the difference between the two curves. From these weight/span relations results that, if the wing loading is fixed, a definite value of span corresponds to it. For normal sailplanes of moderate wing loading a span of 18 meters seems to be a well established value, from both practical experience and theoretical calculations (ref. 5). For laminar sailplanes, if the same value of the wing loading is wanted, a smaller span is necessary.

A 15 meter span was chosen for the "Veltro".

The choice of a small span is highly desirable for other reasons, mainly:

1. The greater manoeuvrability of the aircraft. Assuming that moments of inertia vary as the 5th power of linear dimensions and the aerodynamic moments prodticed by the control surfaces as the cube, the angular acceleration in roll will vary inversely as the square of the linear dimensions.
2. The lower cost of the machine.
3. Easier ground handling and transport.

Description

The sailplane is constructed of wood. All parts are plywood covered, except the control surfaces and flap, which are fabric covered.

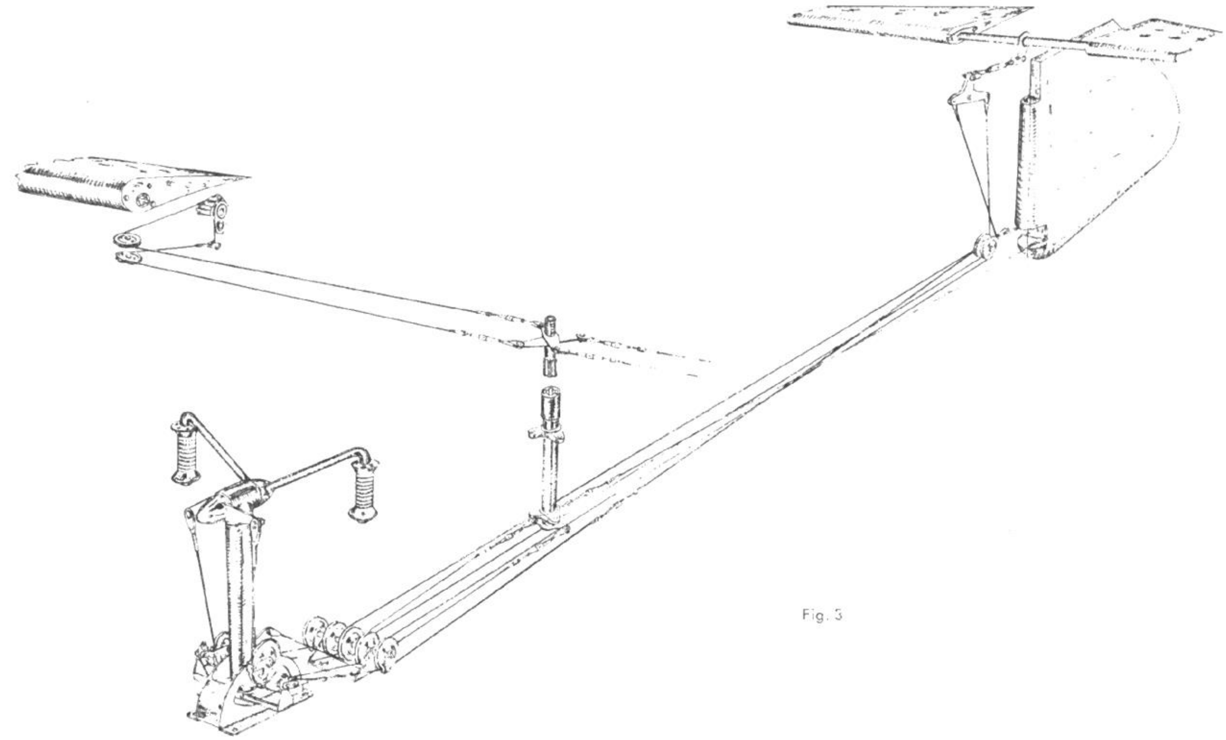


Fig. 3

Wing: The wing is three piece: a 7 meter central part and two outer parts, 4 meters each.

The aileron and flap chord is a constant percentage of the wing chord (0.25 from hinge line to trailing edge). The flap can be employed to improve the low speed characteristics and may be lowered in 5° degree stages. At high deflections (up to 60°) it can be an airbrake for speeds up to 110 km/h.

A particular care has been given, as is essential in "laminar designs", to the correct reproduction of airfoil contour and to obtain a smooth wing surface free of waviness. But all costly solutions have been rejected. A close rib spacing has been adopted (14 cm). The ribs are extremely light, being of truss type with the usual gussets so placed that the contour stringers are supported for their whole length (fig. 2). Wing structure is single spar with two secondary spars at 0.05 c and 0.70 c respectively.

The plywood covering is not continuous round the leading edge, but consists of two separate panels. The leading edge is made from balsa wood glued to the front auxiliary spar, accurately shaped to the correct form and surface hardened. This solution has proved adequate and very economical. The balsa leading edge, moreover, provides a very efficient protection of the wing structure in the case of a shock. In the wing central part, the 2 mm thick plywood is not glued to the spar. Thus, the chordwise waviness due to glue contraction has been avoided.

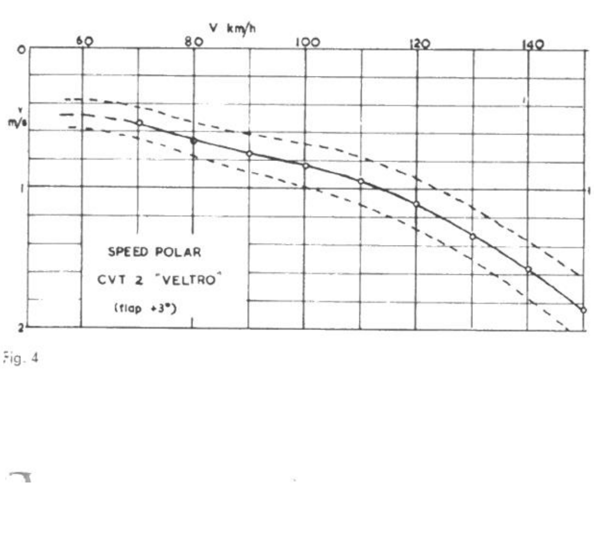


Fig. 4

Fuselage: The structure consists of four stringers of flat rectangular section and plywood covering.

Tail: Similar structure of the wing.

Controls: The controls originally devised were the "ortho-cinétique" type: the rudder control was obtained by a rotation of the wheel about the vertical axis (fig. 3). For the preliminary flight tests a normal stick and pedals were installed, and the original system has not yet been tested in flight, although it has been constructed.

From this control system which, as far as we know, has never been tested on sailplanes, we expect the following advantages:

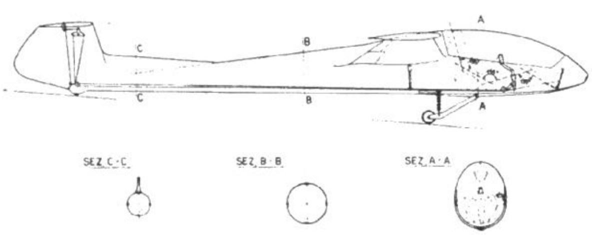
1. A better coordination of the control movements, all being made by the hands, and a more instinctive control. The wheel rotations about the three axis have the same directions as the aircraft rotations about the same axis.
2. The pilot's feet are free. They can be employed for flap control and undercarriage retraction.

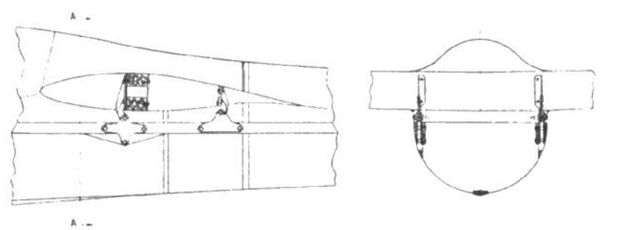
In fig. 3 are also shown: the quick connections of aileron controls between wing and fuselage and between the central and outer wings; the flexible transmissions in the front fuselage, which are collected in one channel and easy to inspect.

Test Flights

The "Veltro" was initially equipped with a single wheel landing gear, retractable sideways into the fuselage. This unusual direction of retraction was adopted to avoid a deviation of the control transmissions and an interruption of the fuselage bottom stringer.

During a landing the strut was bent due to the small diameter of the wheel (210 mm). It was then replaced by a fixed wheel, and later by the final shock absorbing landing skid.





Collegamento ala-fusoliera

The first flights showed a marked "rudder lock", which was eliminated when a dorsal fin was added on the fuselage (Sept. 1955).

During the test period in Rome and Guidonia many flights were made to measure the performance in straight flight. The method described by P. Bonneau (ref. 7) was adopted, using a SFIM A-20 recording apparatus.

The speed polar derived from the recorded data (fig. 4) is based on a theoretical evaluation of the angle of attack for zero lift of a sailplane ($\alpha C_L = 0$) and the $dC_L/d\alpha$. For this later derivative a reliable theoretical evaluation can be made, whereas the theoretical $\alpha C_L = 0$ is less accurate.

It is interesting to note that variations of $\alpha C_L = 0$ have the effect of shifting the whole polar curve along the v axis, thus affecting considerably the v values at low speed, but relatively little at high speed. Moreover, if a value of v is known at a certain V, through, for instance, a great number of measured losses of altitude in a calm atmosphere, the right polar, among the possible ones corresponding to different values of $\alpha C_L = 0$, is clearly defined.

In our case, a value of $v = 0.55$ m/s at $V = 70$ km/h has been repeatedly measured. The dotted lines in fig. 4 correspond to the possible extreme values $\alpha C_L = 0$, theoretically evaluated ($\pm$ 10 % of the calculated value, corresponding to the full line curve).

It is important to note that the data used in the polar calculations have been recorded in one glide, during which foredetermined speeds have been maintained (for about one minute), in decreasing order, that is starting from 150 km/h, then 140, 130 etc. down to 60 km/h, with one minute interval between two speed values for speed stabilization.

Summary of Dimensions and Weights

Wings: span 15 m, area 12,5 m², aspect ratio 18, wing root chord 1.17 m, wing tip chord 0.50 m, taper ratio 0.43, root/tip airfoils NACA 64-515/512, dihedral angle 2°, Aerod. twist root/tip —4°.

Ailerons: span 4 m, aera 0.67 m², max. deflection up 30°, max. deflection down 15°.

Flaps: slotted type, span 3.05 m, area 1.5 m², mean chord ratio 0.25 constant, max. deflection down 60°.

Fuselage: length 6.50 m, max. width 0.62 m, max. height 0.77 m, max. cross section 0.39 m².

Horizontal tail: span 2.8 m, area of elevator and fixed tail 1.4 m², area of elevator 0.57 m².

Vertical tail: area of fin and rudder 0.67 m², area of rudder 0.45 m², aspect ratio 0.85.

Weight empty, including instruments, excluding radio and oxygen plant 170 kg

Useful load 97 kg

Total weight 267 kg

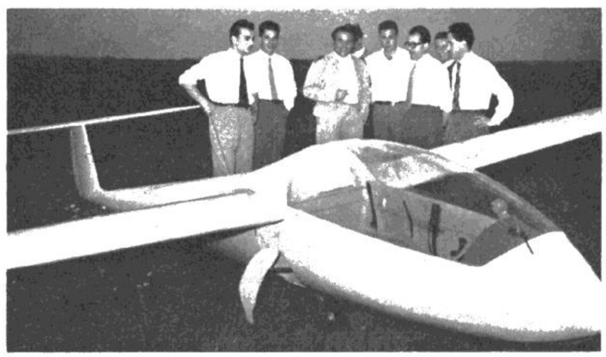
Wing loading 21.6 kg/m²

Ultimate load factor 9

Placard airspeed, smooth conditions 200 km/h, aerotowing speed 150 km/h, max. allowed airspeed with flaps opened at 60°: 130 km/h.

Manufacturers: Centro di Volo a Vela del Politecnico di Torino, Castello del Valentino, Torino, Italy.

Designers: ingg. Alberto and Piero Morelli.



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Separate print from OSTIV Section of the "Swiss Aero Review", January, No. 1/1957