LIGHT PLANES PROPELLER'S DESIGN: COMPUTER PROGRAMS AND FLIGHT TESTS FOR THRUST AND NOISE INVESTIGATION

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SUMMARY

In this work we relate about one of the several flight and ground tests performed on an ultralight by our department to achieve more information about that kind of flying machines and to realize a practical laboratory on the field for our aeronautical students.

INTRODUCTION

Around the world, in spite of the general crisis of minor aviation, there is a great diffusion of projects and amateur constructions of light planes and ultralights.
As obvious consequence, also in Italy and in the student's world there is a request for taking an interest in this field.
So our Department, since 1986 is working on ultralight and light plane, both manufacturing an ULM to be used as a flying workbench both developing a whole electromechanical system to perform flight tests with or even without a pilot on board.
Among the several group of tests performed on our prototype, a specific one was carried on to investigate about two important propeller's performances: thrust and noise. The first one is mandatory for the efficiency of any plane, the second one is of growing interest to rebut some critics of people unfavourable on the light planes and ULMs operated from small grass airfields near inhabited areas.

TARGET OF THE NOISE MEASUREMENT FOR LIGHT PLANES

In fact, one of the most important critics against the ultra-lights and light planes is their noise bothering people resting during week-ends and holidays. In many Italian countries there were some angry dispute to try to forbid people not only flying near inhabited areas, but also landing and taking off from nearby private airfields.
Therefore, one of the target of this work is to collect scientific data to demonstrate that airplanes and ultralights are less noisy than other human usual hobbies. In particular we have selected to measure the noise in comparison with one of the most common equipment in the country houses: the lawn-mower.

TARGET OF THE THRUST MEASUREMENT FOR LIGHT PLANES

Correlated with the propeller's noise but not of minor interest is the effective thrust of a specific propeller coupled with a particular engine.

In fact the light planes are often equipped with wood or plastic propellers manufactured by craftsmen or little firms after simple practical tests. So we tried to give a mathematical tool to designe and to verify propellers suitable for low speed, and successively to give proof of the computer programs by means of flying tests on the same samples. The second target of our work is therefore that of easy acquiring propeller's performances during several flight conditions.

THE COMPUTER PROGRAMS

At first we tried to get from books and literature some data concerning propellers to be used with low speed planes. But all the information were regarding high powers and high Reynold's numbers. So we decided to write two computer program: one to design a propeller to be used on our ultralight, the second one to verify the performances given for commercial propellers. Then the results achieved from the computer program have been correlated with data collected during flight tests.

The first computer program, named P.E.A.L. (i.e. Progettazione Eliche per Aviazione Leggera), was compiled in Fortran for small personal computer, referring to a mathematical method [1] modified to take into consideration both induced velocity as threedimensional air flow.

Input data are: flight velocity, flight altitude, propeller rpm, effective shaft power, propeller maximum diameter and number of blades.

The computer program works on a specific aerodinamic profile, the CLARK-Y 14, selected for its wide diffusion among propeller's builders due to its easy geometrical line. To get it working on a different profile, you have only to change aerodinamic tabulated data.

The results are given as in fig. 1 were you can find an angle β and a cord *c* related with a percentage of propeller radius *r*.

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ARCHIVIO DATI ELICA

Quota di volo =     0. m
Velocità di volo =  22.2 m/s
Giri elica = 2100. giri/min
Potenza disponibile all'albero = 60. cv
N° pale = 2
Diametro elica = 1.8 m

SPINTA = 133.6 Kg   RENDIMENTO =  .659

 10%   RAGGIO =  .093m   ß = 51.0°   CORDA =  .069m
 20%   RAGGIO =  .185m   ß = 32.2°   CORDA =  .103m
 30%   RAGGIO =  .278m   ß = 23.5°   CORDA =  .120m
 40%   RAGGIO =  .370m   ß = 18.8°   CORDA =  .131m
 50%   RAGGIO =  .463m   ß = 15.9°   CORDA =  .139m
 60%   RAGGIO =  .555m   ß = 13.8°   CORDA =  .142m
 70%   RAGGIO =  .648m   ß = 12.4°   CORDA =  .138m
 80%   RAGGIO =  .740m   ß = 11.3°   CORDA =  .124m
 90%   RAGGIO =  .832m   ß = 10.5°   CORDA =  .087m
 95%   RAGGIO =  .879m   ß = 10.1°   CORDA =  .058m
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fig. 1

Then the second computer program called BLADE, also in Fortran for personal computer, is used to verify how much power is necessary to bring that propeller running in given conditions. It evaluates both thrust and absorbed power as functions of propeller radius, than integrating them to give total values at a flight conditions.

THE THRUST TRANSDUCER

After having written the two computer programs, we decided to carry on with practical measurements on the ground and in

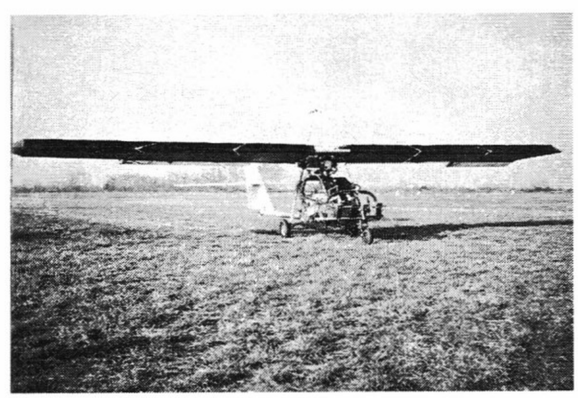

fig. 2

flight. So we manufactured a special load cell to measure directly the force the propeller transmit to the shaft of the airplane. Our ULM (fig. 2) is a three axis with pushing propeller, so we built a tube carrying four strain gages to be interposed lastingly between the propeller hub and the structure (fig. 3).

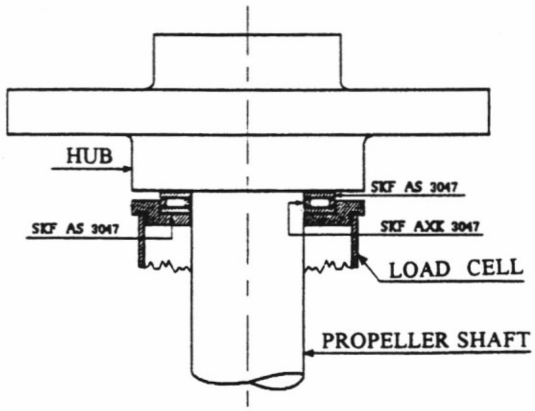

fig. 3

The tube is fixed to the airframe and a spindle bearing transmits the load from the hub to the tube, so the internal shaft coupled to the engine by means of an interposed elastic joint, can transmit only the torque (fig. 4).

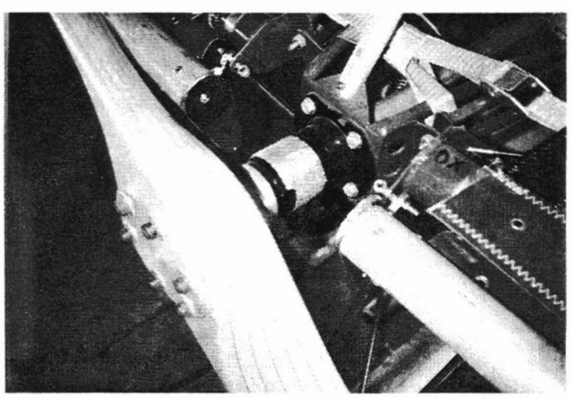

fig. 4

By means of an on board data logger specifically designed [2] we can acquire up to 40 channels of flight data so correlating several aerodinamic measures with structural strain and/or engine performances (fig. 5).
In fig. 6 you can see some graphs as plotted after flight tests to investigate on structural loads on cables [3].

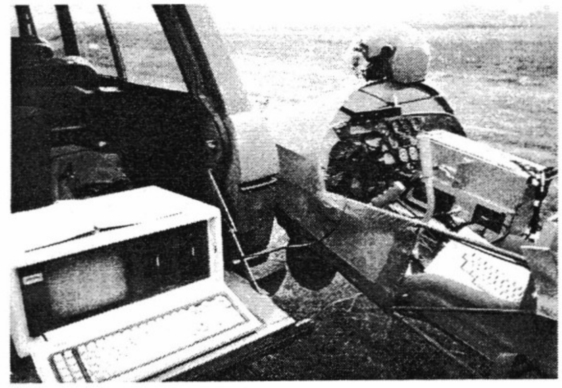

fig. 5

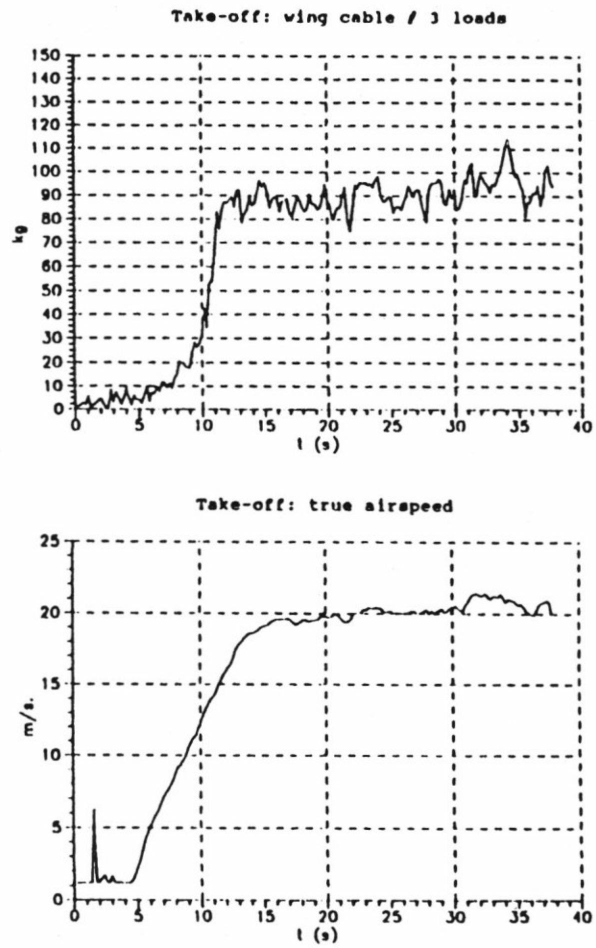

fig. 6

THRUST TEST RESULTS

We carried on three groups of flight tests:
- the first one on a commercial two blades propeller designed for a Rotax engine (55 Hp at 5300 rpm)
- the second one on a commercial three

blades propeller designed for the Arrow engine (the same one mounted on our ULM - 63 Hp at 6500 rpm)
- the third one on a special two blades propeller built accordingly to the data got from P.E.A.L. program and verified with BLADE one.

The photo in fig. 7 shows the propeller built with the data of fig. 1 mounted on our ULM.

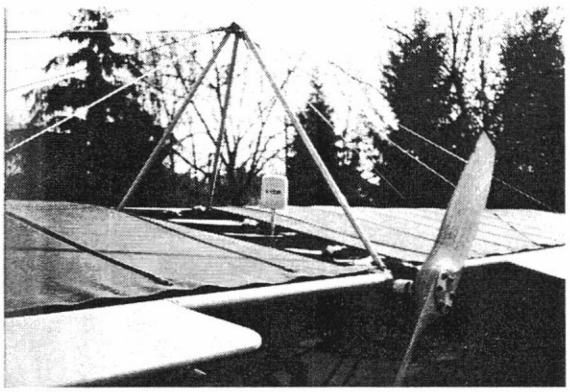

fig. 7

The tests confirmed the theoretical previsions of better performances of the third propeller, as you can see in the graph of fig. 8.

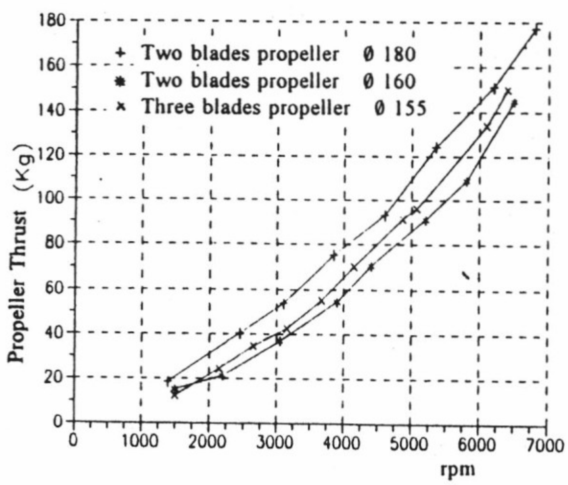

fig. 8

PROCEDURE OF ACOUSTIC DATA ACQUISITION

At the same time, during the field tests to measure the performances of the three propellers, we carried on also some tests to investigate noise problems as indicated in our introduction.

Normally the aircraft exterior noise measurement procedures are intended basically for certification purpose, so in ref. (4) you can find all the terms and analysis techniques correlated with the acoustic problems of the flying machines.

Otherwise neither ULM's manufacturers nor amateurs builders are obliged to certificate their planes. They only need to know if their flying machines are noisy or not.

So we followed only some general test procedures during noise measurement in order to compare similar data collected in similar surroundings.

We used an Integrating Sound Level Meter mod. 700 Larson Davis (fig. 9). It is a por-

fig. 9

table instrument with a built-in frequency weighting network (A-weighting), a memory for storing data, an RS-232 interface to send data to a printer or to a computer. The microphone cartridge (housed at the top of the small vertical cylinder) can be removed thus allowing to use an extensive cable.

We decided to follow the procedure as during light aircraft certification (Annex 6), i.e. to acquire the A-weighted sound-pressure level (with the instrument detector time constant set to "slow"), so we have only had either to read on-line in the field the digital read-out of the instrument or to store that ones in the memory for successive analysis.

After few checks we decided to carry out four groups of tests:

- the first one on four ULMs during take-off with the Sound Meter standing three meters aside the runway near the detachment point.
- the second one on the same ULMs during other take-off with the Sound Meter standing in the center of the runway about twenty meters after the detachment point.
- the third one with the Sound Meter in the same position as before, but when the four ULMs were level flying at an altitude of about fifhteen meters over the runway.
- the fourth one on three type of lawn-mowers: a two-stroke engine of the right-hand neighbour; an electric one of the left-hand neighbour; a four-stroke one working in the center garden where was positioned the Sound Meter.

The four ULMs selected for the test were, besides our one, a Quicksilver GT500 - a Jaguar two place - a Beaver single place. As you can see in the following graphs of respectively fig. 10, 11, 12, 13, there was no great differences between various ULMs but, whereas the noise produced by the ULMs is not exceeding 90 dB in almost any flight conditions (the peak is only in the few second of the flyover), the noise produced by the lawn-mowers (the electric one too) is by far more tedious and annoying because at a high level for a longer period.

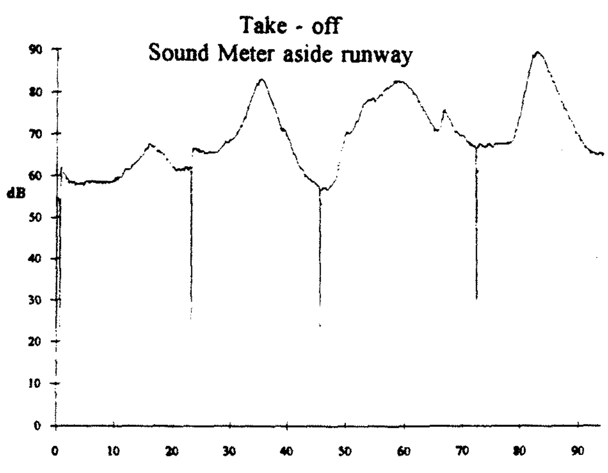

fig. 10

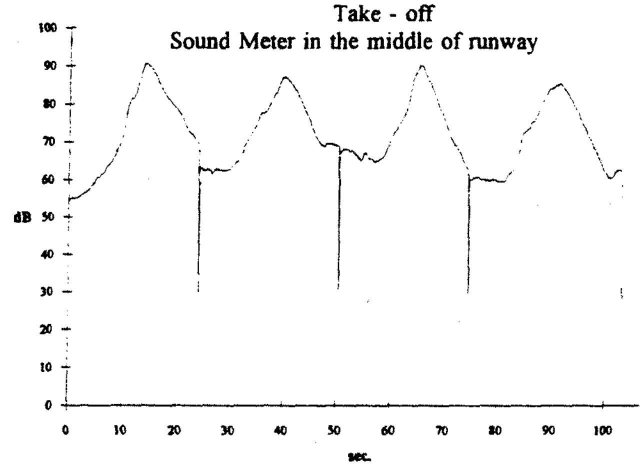

fig. 11

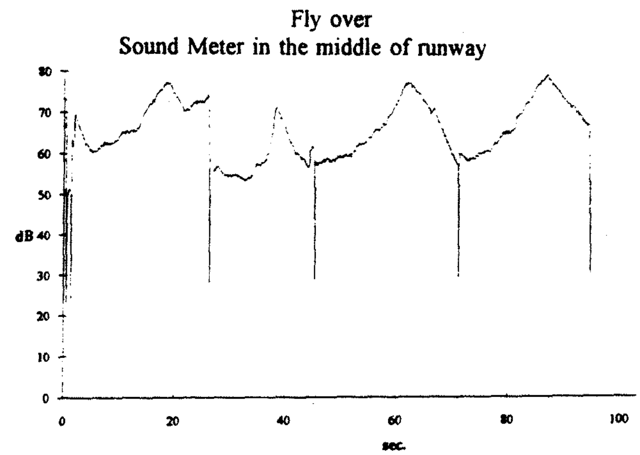

fig. 12

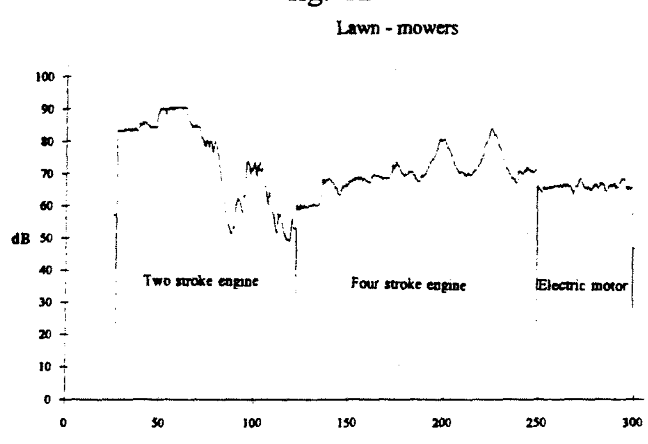

fig. 13

Other tests are now in progress to investigate on some new propeller's configurations designed with P.E.A.L. and BLADE programs for our ULM.

CONCLUSIONS

With these two groups of field tests we think we are dealing with two topics never debated before for ULMs:

- the propeller design for a right coupling with engine and given flight conditions
- the possibility of conducting tests on propeller performances for the purpose to reduce further noise.

The way we have undertook has already yielded good results both with the data collected from the tests either with the new feeling growing among our students towards flying and ground tests.

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