WIND TUNNEL EXPERIMENTS ON THE MODEL OF YUGOSLAV "WORLD CLASS" GLIDER

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Abstract

Limited experimental results of wind tunnel tests for the Yugoslav "World Class" glider are presented. The experimental work was accomplished in the wind tunnel of Aeronautical Institute of Belgrade. The obtained results show good agreement with the theoretical results. In particular, the values of maximum lift coefficient as well as the slope of lift coefficient vs. angle of attack curves agree quite well with the theoretical results. The lift-to-drag ratio and speed polar within a wide range of velocities show better results than the calculated results. The effect of airbrakes was also investigated and the experimental data show better results than the theoretical ones. The experimental data obtained for a range of low angle of attack shows a larger discrepancy in comparison with the theoretical data. The probable causes are boundary layer and 3D effects along with the impossibility of measuring small values of desired parameters.

Introduction

Our country, Yugoslavia, is one of the rare countries with a long tradition in aerial sports. Besides, we have the lengthy tradition in designing of all kinds of flying apparatus including the gliders, of course. More than 60 gliders of different types were designed and realized, so far.

Among the other gliders, as primary ones and low- and high-performance, the training class gliders had an important place in the process of glider designing in Yugoslavia. Particular attention has been paid to designing the gliders of the first line, that is, of the primary and training gliders having in mind their role in the first solo flights and in realization of the first training flights for the beginners. Some of the well-known Yugoslav training class gliders are as following: Jackdaw, Hawk, Lightning, Trainer, Dolphin-3, and so on. Many of our nationally and internationally recognized soaring glider pilots have started their career by flying the above mentioned gliders. Unfortunately, that tradition has been interrupted for about 20 years. Hopefully, it is now coming back with the design of new training glider of the "World Class" named, CORUNDUM, so far. 'This design has been participated on the FAI-ICIC competition and it was chosen, with another 10, for further evaluation, among 44 designs from different countries. Unfortunately, because of the political/economic situation in Yugoslavia at that time, the design has not been realized on time and it could not attend the final evaluation performed in Germany.

In the mean time, the experimental work on the model of the glider was performed at the Aeronautical Institute in Belgrade. As far as we know, for the first time in our country. such a model of the glider was tested in the wind tunnel before the actual realization of the prototype. In earlier projects the confirmation of the glider's conception, their aerodynamic characteristics, performances as well as the stability and control qualities were checked entirely during the flight tests. The defects discovered during these tests, sometimes, could not been eliminated completely and hence, many times during the operation the unwanted problems occurred introducing dangerous and unsafe elements for the flight continuation.

The main goal of the wind tunnel experiments on the model of the glider was to prove suitability and correctness of the chosen conception as well as the other relevant parameters Necessary To Fulfill The FAI-IGC Competition Requirements (CR).

THEORETICAL RESULTS

The basic conception of the glider is a classical one, as it is shown on Figure 1. Using the available software packages the design was optimized and geometrical dimensions, shape and airfoil were determined such that the CR were satisfied. The basic requirements that have to be fulfilled were as follows:

- maximum (L/D) ratio $(C_L/C_D)_{max} > 30$
- minimum sink $(w)_{min} < 0.75$ m/sec.
- stalling speed $V_{min} < 65$ km/h.

Some further requirements were set up by the Competition Board but at the present they are not relevant for the material discussed in this paper. Therefore, they will not be considered.

The wing is composed from central cantilever and the two tapered outer panels connected with simple attach fittings and with the fuselage. The airfoils are from the FX family. Namely, for the cantilever section FX 6 1-1 84 is chosen, at the beginning of tapered section FX 61-184 and at the end FX 60-126. Those airfoils are characterized with the high value of maximum lift coefficient and good stall characteristics. The major drawback of these airfoils is relatively high momentum coefficient causing the introduction of larger elevator angle of equilibrium and larger equilibrium drag coefficient.

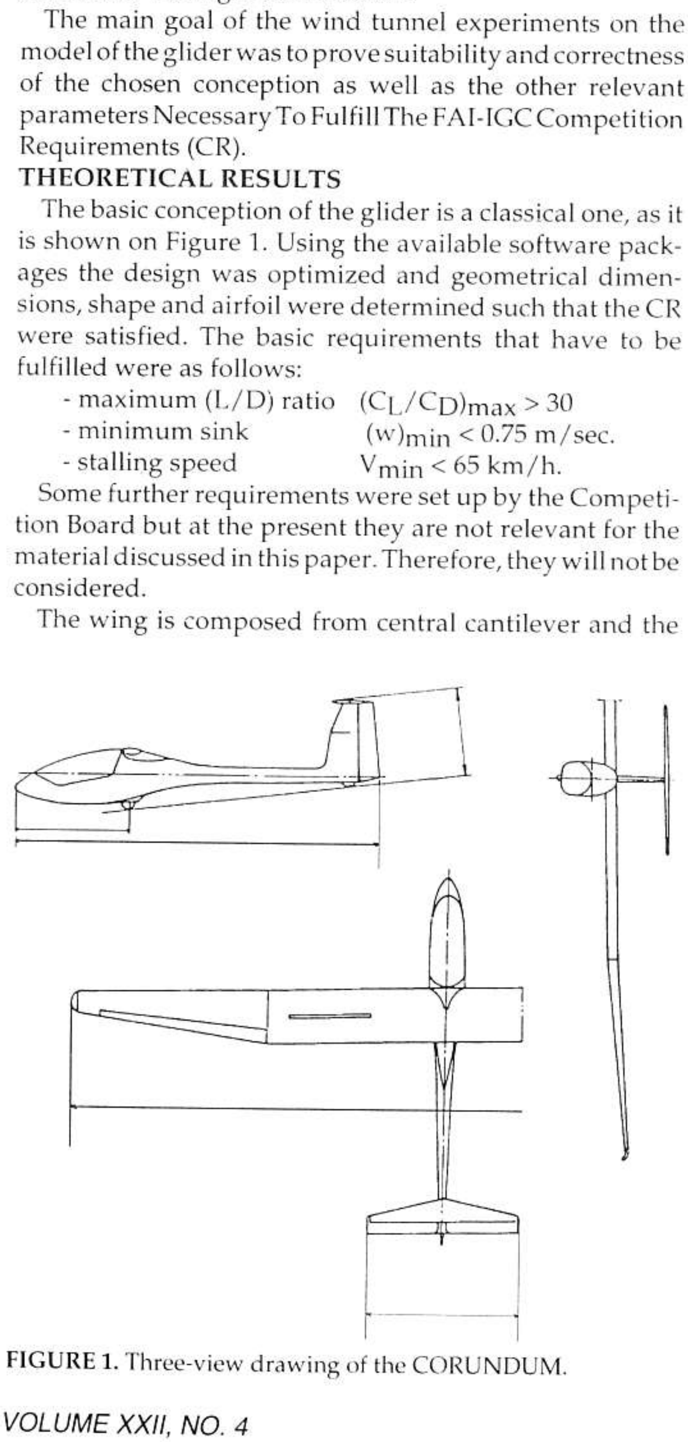

FIGURE 1. Three-view drawing of the CORUNDUM.

Nomenclature

Symbols

C_Z , C_L - lift coefficient
C_X C_D - drag coefficient
α - angle of attack
w - sink velocity

Suffix

t_i, t_k - theoretical
ex - experimental
j - glider
ab - airbrakes

By using the three parameters and varying them, the wing optimization was performed as follows: First, by analyzing the characteristics of different airfoils and planforms, second, by analyzing the influence of the aspect ratio, and third, by analyzing the influence of rigging angle of incidence of the wing (with respect to the appropriately shaped fuselage) on the glider performances. The other aerodynamic surfaces were optimized in a similar way keeping in mind that the performances, stability and controllability must be in the limits proposed by the Requirements. Particular care was taken to determine accurate values of maximum lift coefficient and corresponding angle of attack of the glider, during the optimization process.

The fuselage optimization was performed with the aim to fulfill the following requirements: good ergonomics in the cockpit space, good visibility, minimization of aerodynamic drag with achievement of the corresponding strength, stiffness and stability of the structure with the minimum mass.

The methods used in the calculations were partially based on the statistical data obtained in numerous experiments; besides, the use of the semi-theoretical methods with appropriate existing software packages was accomplished.

In Figures 3, 4, 5, 6 and 7 the results of theoretical analysis and calculations are shown.

Wind Tunnel And Model Description

The experiments were performed in the Low Speed Wind Tunnel of the Aeronautical Institute in Belgrade. The wind tunnel is of the closed circuit type with the semi-open elliptic test section of the cross section of the size: 1.8m x 1.2m. and 2 m. in length. The model was mounted on the three legs and measurements were performed using the six

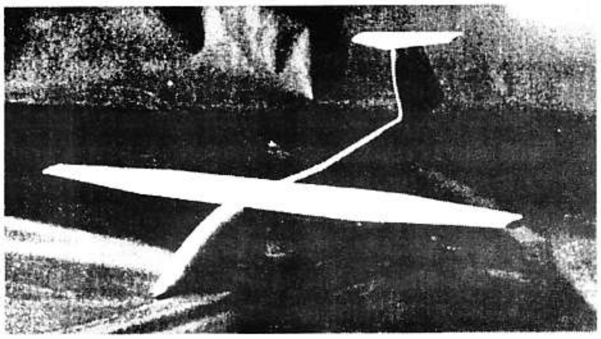

FIGURE 2. Glider model.

component external balance TEM Model 348. The NEFF 500 data acquisition system (64 channels, 50 kHz sampling rate) and VAX 8250 data reduction computer was used to obtain the final results in the form of tables, or charts, or computer data base.

The test conditions cover the range of angle of attack from -6 to +25 degrees, the yawing angle from +5 to -5 degrees and the three speeds 35, 45, and 65 m/sec.

The model in the scale of 1:11 is shown on Figure 2. It was made by machining, on a NC machine from solid Aluminum blocks. It was made without movable surfaces but with the possibility to build-up the air brakes. After fabrication and before the experimental runs the glider contours were measured and the new theoretical results, now based on the actual model, were obtained in order to compare them with the experimental ones.

Experimental Results

In Figure 3 the theoretical and experimental results of the lift coefficient vs. angle of attack are presented. The maximum lift coefficient in both cases is almost the same. The slope of the lift curve shows increasing tendency for the higher angles of attack, that is, for the higher lift coefficient (above the value of 0.5). The zero lift coefficient angle of attack obtained by the experiments is slightly higher than the theoretical one. The experimental results show that the designed wing preserves the characteristics of the basic airfoil, FX 61-186, at the higher angles of attack. Therefore, in these regimes of flight no abrupt lift losses would appear which is very important for this type of glider.

The theoretical and measured drag polars of the glider are shown on Figure 4. Comparing the obtained results, theoretical and experimental, it can be concluded that for higher angles of attack, the measured data show better characteristics than the theoretical one. For smaller lift

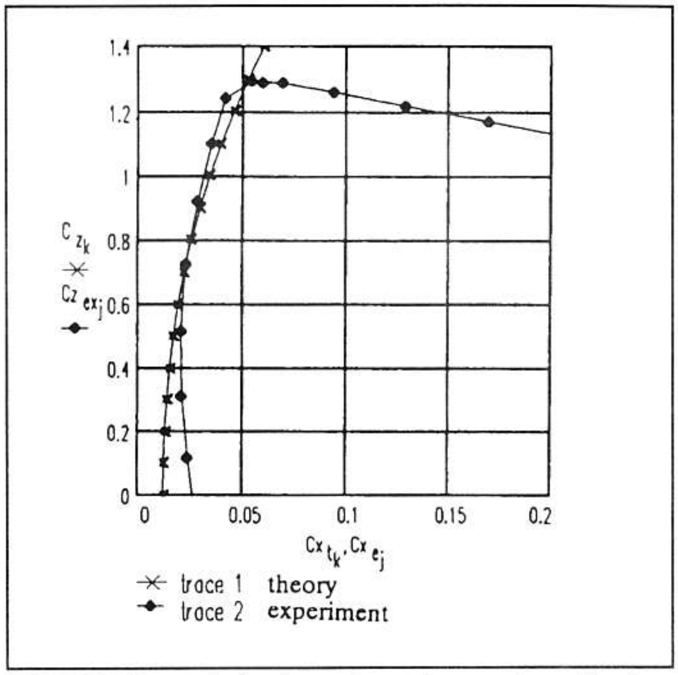

FIGURE 4. Theoretical and experimental comparison of the drag polars.

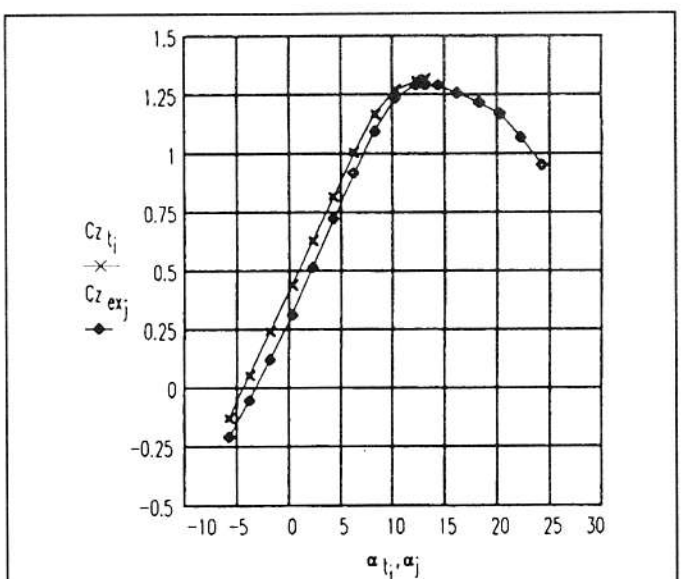

FIGURE 3. Lift coefficient comparison.

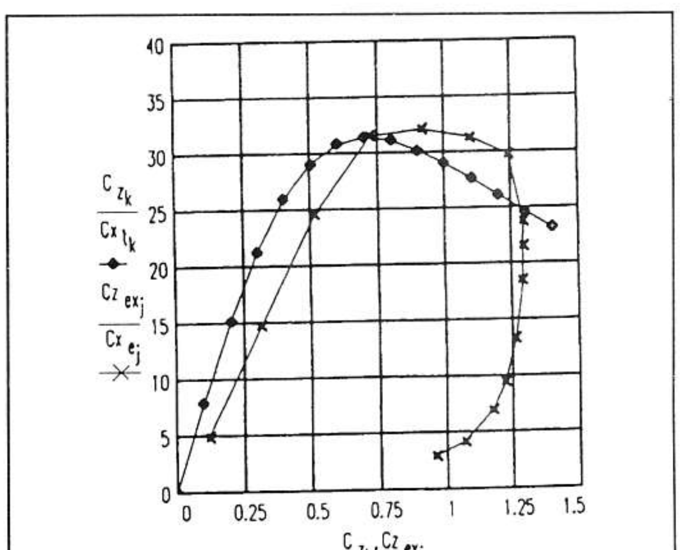

FIGURE 5. Theoretical and experimental comparison of L/D ratio curves.

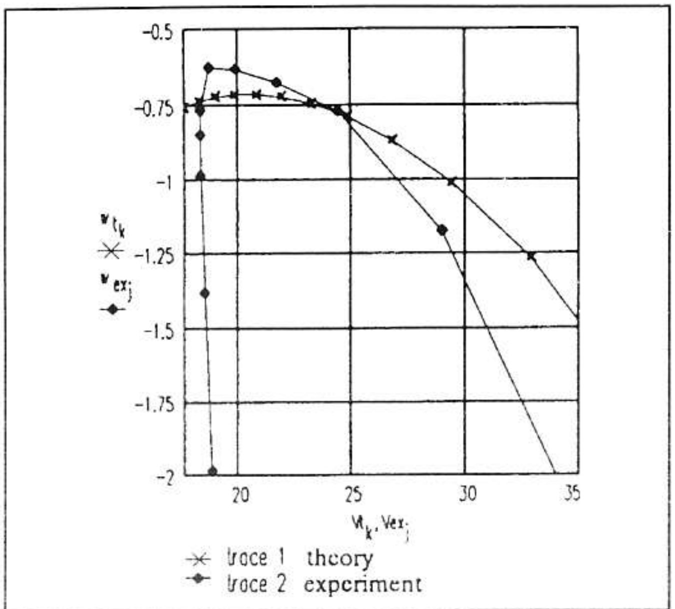

FIGURE 6. Theoretical and experimental speed polars of the glider.

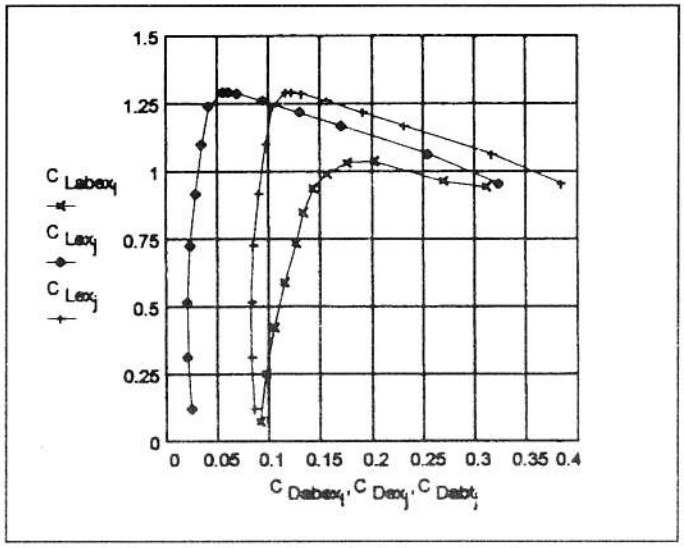

FIGURE 7. Speed polars with and without airbrakes.

coefficient the measured data of the drag coefficient show higher values than the predicted ones obtained by the theoretical approach. The reason for this was not investigated in detail but brief analysis shows that the possible causes are due to several factors. Namely, the external balance used for this experimental work could not measure the small absolute values of the glider's drag at a small angle of attack. Furthermore, three dimensional flow effects were also a cause for the large discrepancy. Finally, but probably not the last cause, is the 3-D boundary layer effect.

Figure 5 presents the theoretical and experimental results of lift/drag ratio. The discrepancy between these results is appreciable (up to 30 %) at small angles of attack. The reasons for such difference are probably the same as listed in the previous statement. In the range of higher angles of attack including the critical one, the experimental results exceed the theoretical ones. The value of maximum L/D ratio experimentally obtained is slightly larger than the theoretical one.

The calculated and experimentally obtained performance, that is the speed polars, of the glider are shown on Figure 6. As it is illustrated on this graph the glider will fulfill the Competition Requirement regarding the minimum rate of sink, in a relatively wide range of the flight speed (about 20 km/h.), that is, below 0.75 m/sec. Furthermore, the other Requirement concerning the minimum flight speed of less than 65 km/h is fulfilled, also. The experimental results obtained for the flight speeds above 100 km/h are not real due to uncertainty of the results measured for the small angles of attack what was noticed before.

Up to the flight speed of 100 km/h the results show the rate of sink below 1.0 m/sec which is very satisfactory for this kind of the glider.

Figure 7 shows results of the theoretical work and experimental tests of the speed polars with and without the air brakes. The air brakes were simulated with small metal pieces attached solely on the upper wing surface. Comparing the theoretical (+) with the experimental (x) results it can be concluded that the effect of the air brakes is much higher than anticipated. That means that the glider will have better rate of deceleration which is very important for the glider that would be used for beginners and the pilots having less flying skills and experience. On the same chart the speed polar of the glider with the "clean" wing is given, also. Using the following relation, Cxabj = Cxexj + 0.0612, the calculation of the wing drag coefficient with the airbrakes comparing to the drag of "clean" wing configuration was obtained.

Concluding Remarks

Considering both theoretical study and experimental tests the following concluding remarks can be stated:

1. Comparison of the obtained results shows that the chosen concept of the glider is appropriate for the purpose given in the Competition Requirements,
2. Analysis of the results obtained give the conclusion that the designed glider will fulfill all of the demands given in the Competition Requirements,
3. The discrepancy observed in the range of small angles of attack are probably due to the inability of external balance to measure small values of drag as well as 3-D effects. Because of that, the improvement of the results obtained for the small angles of attack can be expected in reality, and
4. Clearly, based on obtained results the validity of theoretical study was satisfied by the experimental results and therefore, the designed glider, in our opinion, is just what the IGC desired.