MEASUREMENTS AND RECORDING OF LOADING SPECTRUM OF GLASS-FIBER SAILPLANE WING USING THE STRAIN GAUGES

by Piotr Lamers

M.Sc Poland

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I. Measurement idea

The conservative method of designing the loading spectra for wing operational conditions[1] depends on the intermediate measurement. The accelerations at the glider c.g. and wing c.g. have been measured, and on this basis the wing load and structure stresses have been evaluated[3]. The data obtained have not adequately yielded the real values experienced by the spar and its fittings during the measurement, as regards the bending moment and in consequence the stress. The above error, especially when the quick variation of dynamic values is concerned, appears during the take-offs and landings. In the present investigation, the wing excitation has been measured instead of the response.

The nature of the method discussed depends on the direct measurement of loadings by means of strain-gauges at the structure station concerned. The basic problem arises from the very poor experience in the measuring methods applied for the composite material[2]. It was necessary to collect data on the strain-gauge glueing method as well as the measurement errors, due to the eventual plastic deformation or the strain-gauge creeping. It seemed to be possible, imposing the constraints of the relative extension or of the bending moment value, to deal with the composite-laminated material as the elastic one.

To record the bending moment at the spar root, a signal was taken from a strain-gauge working in full-bridge system and

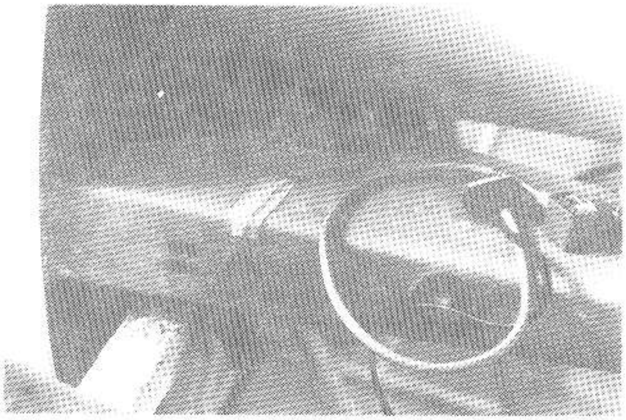


PHOTO 1.

glued on the spar root, spaced in respect to the fitting on about 2/3 of spar root length. (Photos 1 and 2.)

The test was performed on a club-class glider SZD 51-1 "Junior." The measurements were taken in various operation conditions, namely:

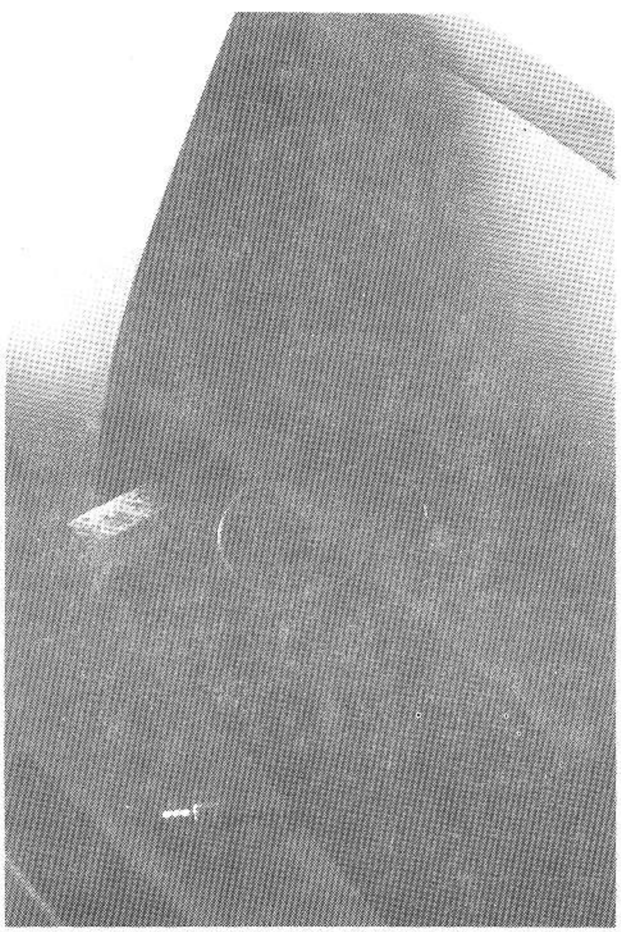
- take-off and landing ground runs on the grass airfield,
- as above but on concrete runways,
- as above but on field landing,
- winch launching,
- acrobatic and towed flights,
- taxiing on the grass airfield.

II. Measuring system components

Philips foil strain-gauges of 120 ohm resistance and 30 mm base were used. Two gauges on each spar side were glued on the specially prepared surface. The gauges were joined in the full bridge system by means of gluing with the same composition, as used in spar production.

The strain-gauges were supplied by the integrated constant voltage of +5V supplier of high output-voltage stability. The current passing through the strain-gauges is about 40mA which assures the correct thermal stability. The sensivity of the bridge was related to the loading value, and ranges about 5 mV/n, where "n" is the wing load factor.

The value n=1 concerns the wing loading during the free flight in smooth air and airspeeds of 90 to 120 km/h when the acceleration is 1g. The bridge voltage was doubled on the measuring amplifier working in the constant-current differential mode. The amplifier output was connected to the input of measuring tape recorder channel No. 3. The channels 2, 5 and 6 concern the marker, acceleration and airspeed recordings respectively. The entry voltage range of the recorder is ± 50mV enabling the measurement range of $\triangle n=10$. The practicable measurement range is $-2g$ to $+5g$, namely $n=-2$ to $n=+5$. The accelerations were measured by mean of potentio-metric gauge of SFIM type with the range of $\pm 12g$.



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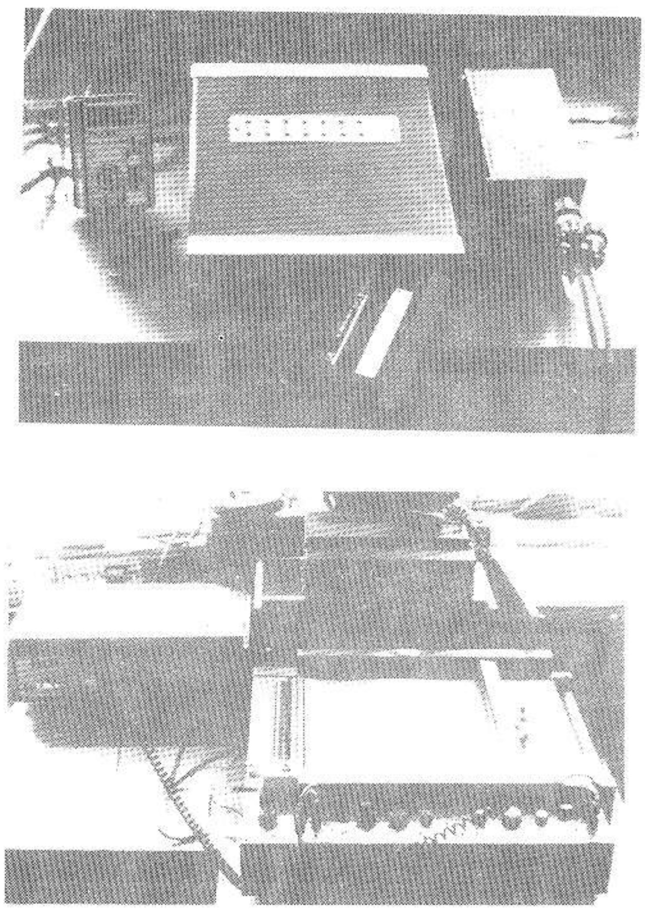


PHOTO 3.

For the measurement, the registering system SRD (photo 3) was used. It comprises the 8-channel cassette tape recorder working with FM mode, type FIS and stationary reader CS8.

III. Calibration and measurement error

The calibration of the measuring system was performed as follows: The signal of tensometric bridge was recorded for various values of the force applied on the wing tip namely: 50,100, . . . ,150, . . . ,500 N. Taking into account the wing span and its weight, the bending moments at the relevant spar station wave calculated. In this way, the scale was derived as the measure of recorded load value. Particularly interesting results were obtained for take-off and landing ground runs, being conditions having a considerable part in operational fatigue sources.

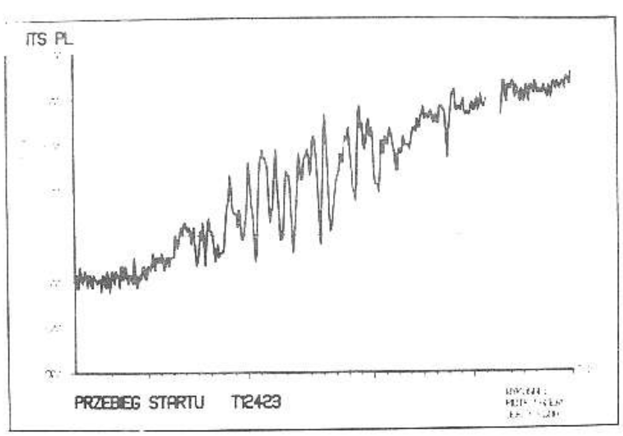
The results are shown (Photos 4,5) concern the airfield at Bielsko-Biala, Poland. These are plotted by the computer.

The vertical axis shows values of force "F" corresponding to the values of recorded stresses. The load level of n=1 corresponds to the bending moment due to the force of about 1000 N applied on the wing tip. The wing weight gives the on-ground loading corresponding to the force of −300 N applied on the wing tip. To find the hysteresis error special test flights were completed. In repeated tests, a static load of +3.5g was simulated. Then the recorded values of n=1 before and after the pull-up maneuvers to +3.5g were compared, as well as the n=3.5g conditions recorded in several flights. Photo 6 shows the diagrams of loadings and accelerations in calibration flights. The loadings for pull-outs and n=1 level before and after the pull-out are visible. The scatter ranged 1.1 percent, so it can be stated that the hysteresis error was 1.1 percent.

Taking into account the other errors due to the accuracy of acceleration gauge and measuring system of about 1 percent, it can be stated that the total error is 2.1 percent for the measuring range of −2g to +5g.

IV. Discussion of measurement results

The calibrated diagrams show that during landing, ground runs on the grass airfield the amplitude of wing spar root loading is equivalent to no more than 1500 to 2000 N of force applied on the wing tip. This corresponds to △n=1.5 to 2. In case of field landing higher amplitudes were found, the highest ones averaging △n=2.4.



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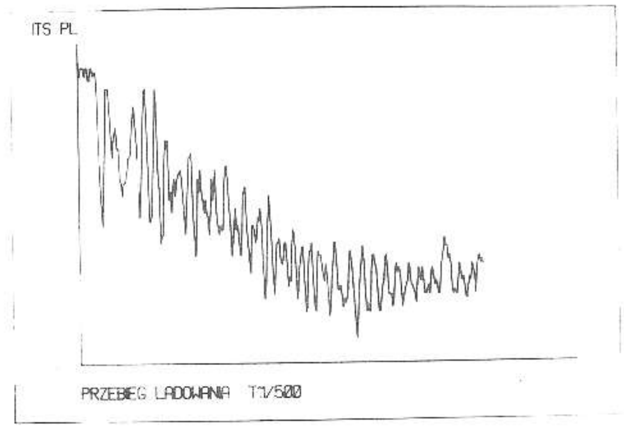

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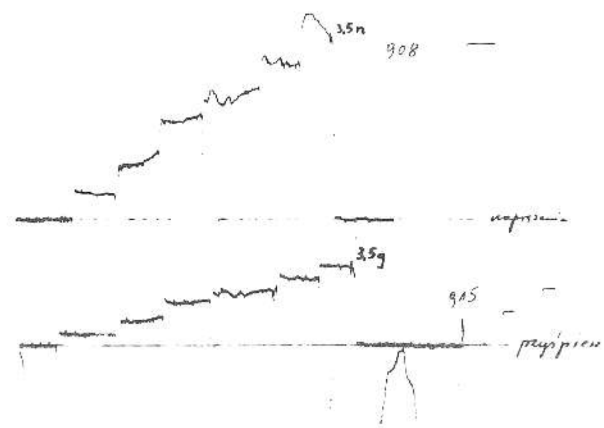


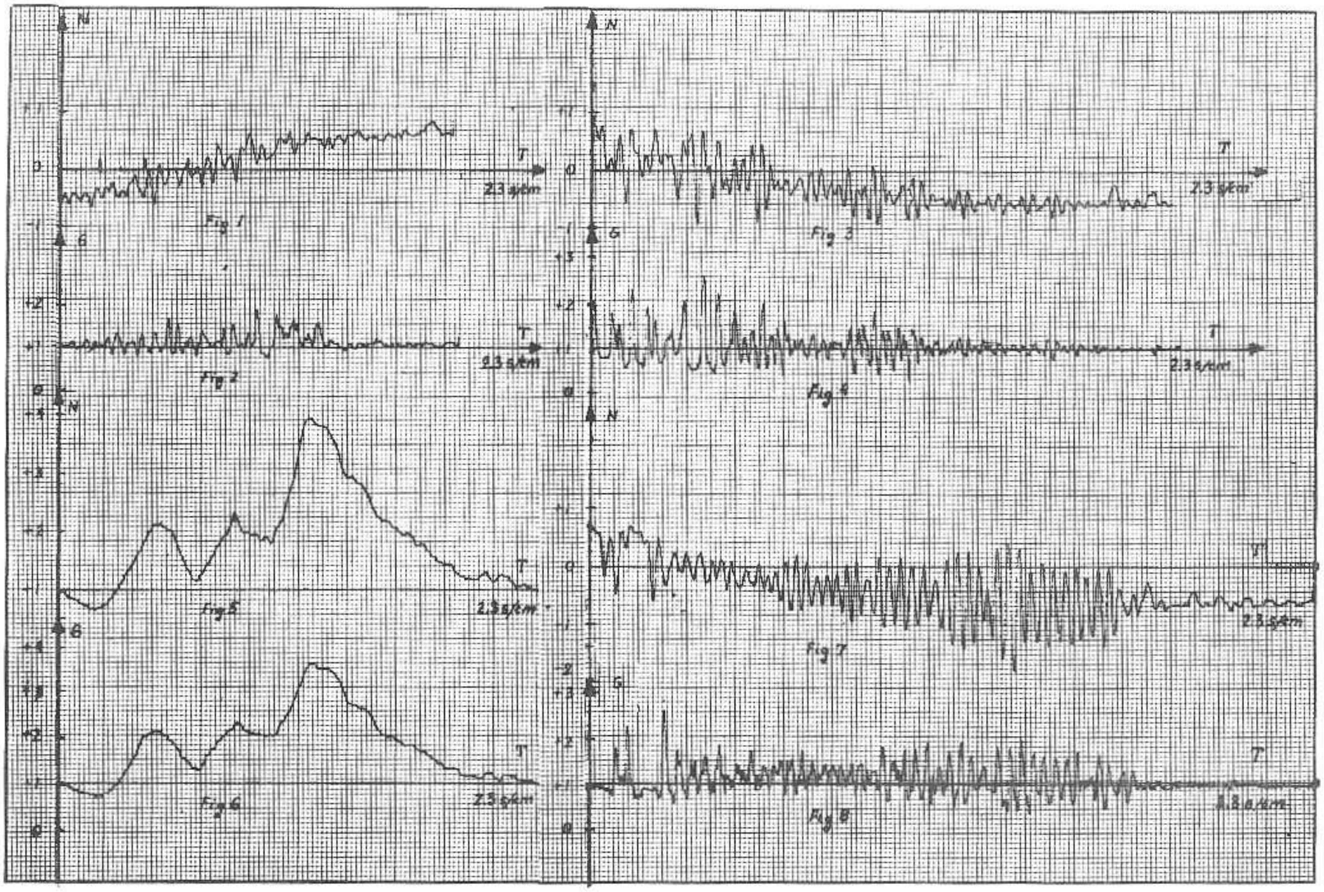
PHOTO 6.

The figures 1,2,3,4,5,6,7 and 8 shows the stresses and accelerations in various flight conditions respectively:

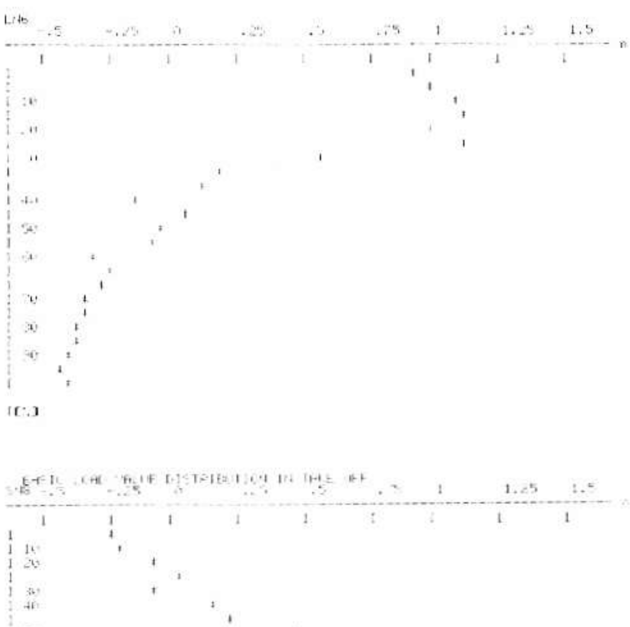
- take-off and landing on the grass airfield,
- aerobatics (2 turns of spinning),
- field landing (meadow in mountains).

The diagrams were obtained directly from the tape recorder, calibrated in load units "n" and acceleration units "g" versus time. The comparison of the dynamic acceleration and related dynamic loadings with the static ones leads to the following conclusions.

The wing response to the excitation in the form of quickly increasing acceleration is weak, when compared with the wing response to the static acceleration (bending line) of the same value. The loading block designed on the basis of stress measurement is more realistic than one designed on the basis of accelerations. Moreover, the acceleration diagrams for take-off or landing have more harmonics than the related load diagrams (wing inertia).



FIGURES 1 THROUGH 8.



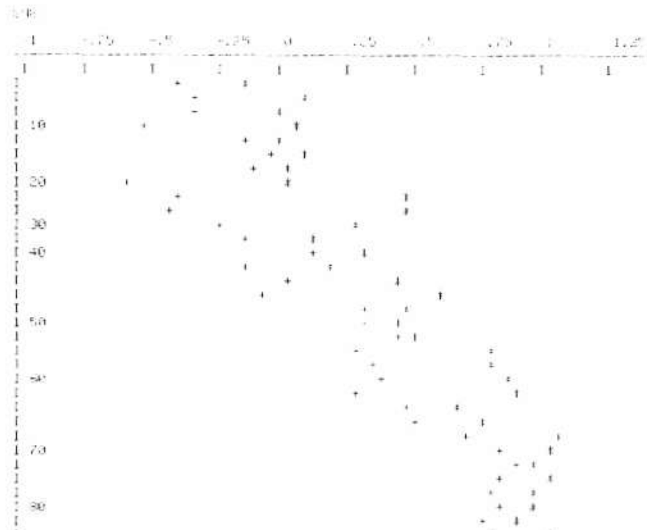


FIGURE 9. Basic load value distribution in landing.

FIGURE 10. Load envelope in take off.

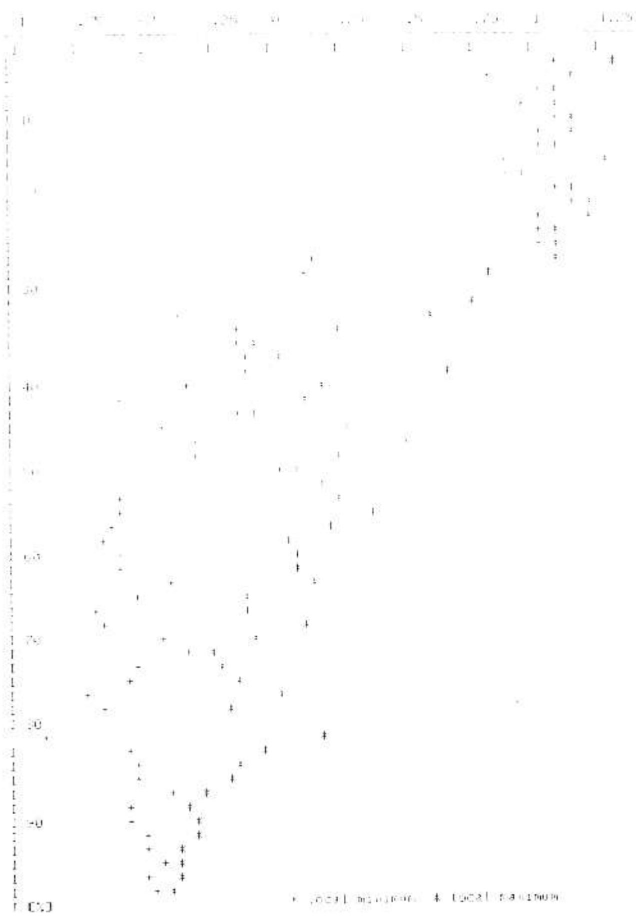


FIGURE 11. Load envelope in landing.

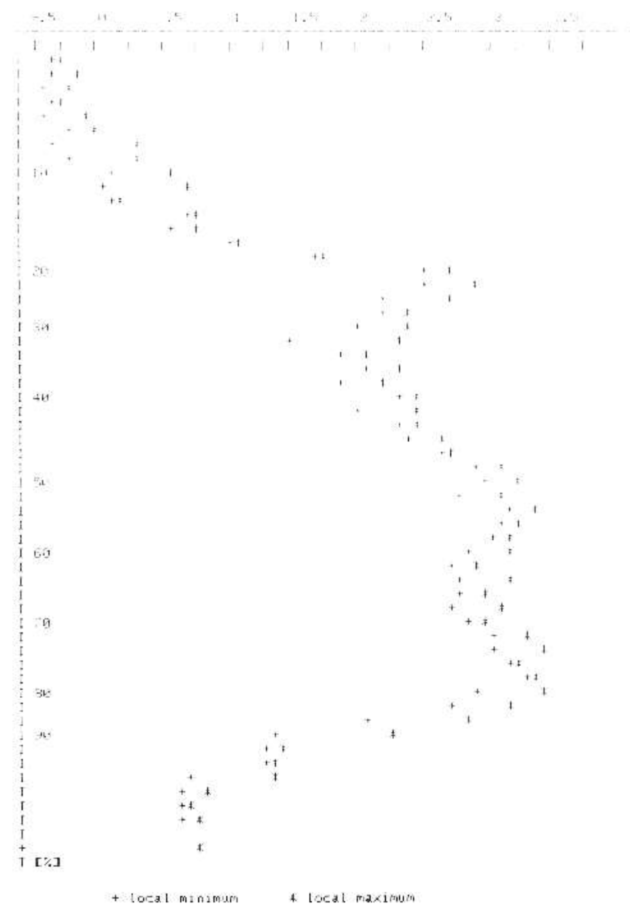


FIGURE 12. Load envelope winch-launching.

Figure 9 shows the average value of loading of take-off and landing, obtained as a result of computer analysis.

Figures 10,11 and 12 show the distribution of maxima and minima. The vertical axis shows the load factor, the horizontal axis, the time fraction of total measurement.

	Maxima	Minima
-2		
	0	0
	0	0
	0	0
	0	0
-1		
	0	0
	0	2
	0	5
	2	6
0		
	6	1
	5	6
	3	2
	5	7
1		
	9	0
	0	0
	0	0
	0	0
2		
	0	0
	0	0
	0	0
	0	0
3		
	0	0
	0	0
	0	0
	0	0
4		
	0	0
	0	0
	0	0
	0	0
5		

FIGURE 13. Loading table.

Figure 13 shows various loading levels, during the landing ground run, numbers of maxima and minima. The above analysis permits designing the loading block for the ground fatigue test of the glider wing.

Further steps of testing the glider wing operational loadings will be undertaken in the near future (spring 1987) and will include the measurements of operational loadings for:

- circling in thermals,
- inter-thermal flights,
- and for towed flights in gusty conditions.

The collected material will permit the further investigation of loadings necessary for programming the fatigue tests and extending the glider lifetime. The test result will contribute to the better operational performances of new designs of gliders.

References

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2. Kossira H., Reinke W. Die Ermittlung von Lastkollektiven fur die Bemessung von Segelflugzeugen, OSTIV Publication XVI.

3. Stafiej W., Wing Loading Spectrum of Glider in Aerobatics Measured on Training Two-seater SZD-9 bis "Bocian". OSTIV Publication XVII.