DOI: 10.2478/fas-2019-0003
FATIGUE OF AIRCRAFT STRUCTURES
Volume 2019: Issue 11, pp. 19-27

EXAMINATION OF HONEYCOMB CORE COMPLIANCE IN SANDWICH STRUCTURE

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ABSTRACT

The objective of the research presented in this paper was to determine the honeycomb core compliance of a sandwich structure of the horizontal stabilizer of the MiG-29 fighter jet in the static compression test. The study of the specimen was conducted based on the ASTM C365/C365M standard. The article presents the results of experimentally determined dependencies and strength parameters, i.e. the force-displacement dependence, the compressive modulus and the honeycomb core deformations.

Keywords: honeycomb core, horizontal stabilizer, MiG-29 fighter jet, static compression test, compliance.

INTRODUCTION

One of the research topics in the field of operation of aircraft is determining their service life with the possibility of its extension. The service life provides the possibility of safe and efficient operation of an aircraft. During the operation of an aircraft, its individual structural components are exposed to numerous damages, e.g. external impact on the vertical and horizontal stabilizers. Some of these damages may need to be removed. Therefore, the Air Force Institute of Technology (AFIT) develops technologies for repairing honeycomb metal and composite structures e.g. for the MiG-29 fighter jet.

In order to develop a numerical methodology for strength analyzes as well as perform necessary calculations for the repair of components structures of the MiG-29 fighter jet it is obligatory to carry out laboratory tests. The results of these tests are used for experimental verification and scaling of numerical models to ensure the reliability and efficiency of simulation analyzes [1]. One of the investigated elements of the MiG-29 fighter jet structure is the horizontal stabilizer [2].

This paper presents the research on static compression of specimens taken from the sandwich structure of the horizontal stabilizer of the MiG-29 fighter jet that had been operated for approx. 10 000 hours [3]. Because of the variable thickness of the honeycomb core, literal application of ASTM C365/C365M standard was not enough to determine its compliance. For this purpose, it was necessary to make additional tests and calculations presented bellow.

TEST METHOD

Specimens

This paper presents the research on static compression of specimens taken from the sandwich structure of the horizontal stabilizer of the MiG-29 fighter jet. The MiG-29 aircraft was operated for approx. 10 000 hours [3].

The tested specimens were mechanically cut from the horizontal stabilizer of the MiG-29 fighter jet. They consist of a honeycomb core made of aluminum alloy 5049 and of metal covers made of aluminum alloy 1190 about 0.8 mm thick. Leveling pads made of plastic were prepared to compensate for the curvature of the honeycomb core. The dimensions of the specimens were about 70x80x80 mm. Three specimens were tested. The view of the specimen before the test is shown in Fig. 1.

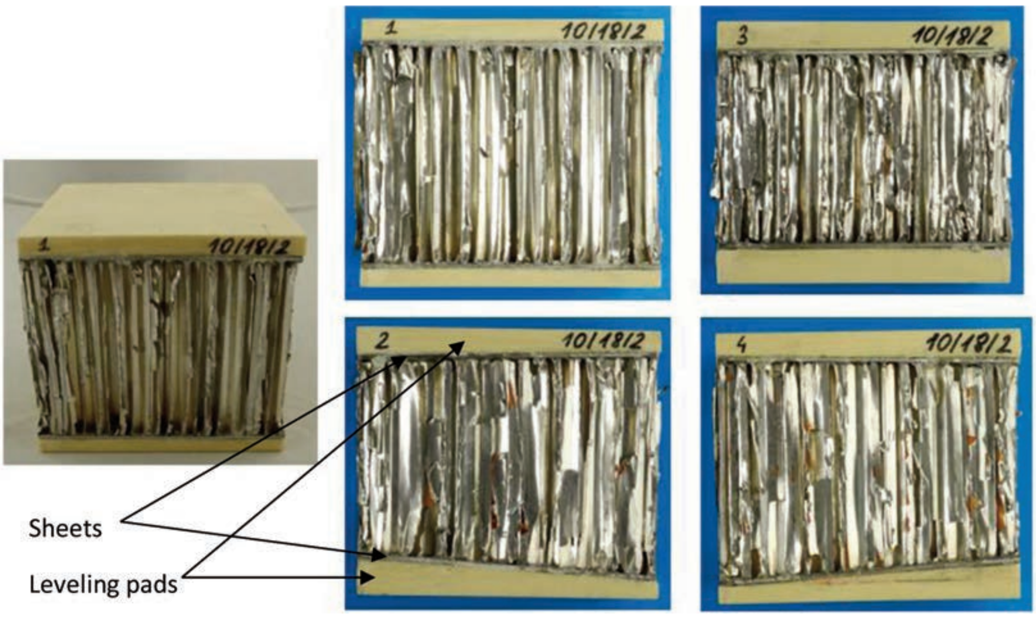


Figure 1. View of the specimen before the test.

The cell geometry and view of the honeycomb core of the sandwich structure for specimens is shown below, (Fig.2).

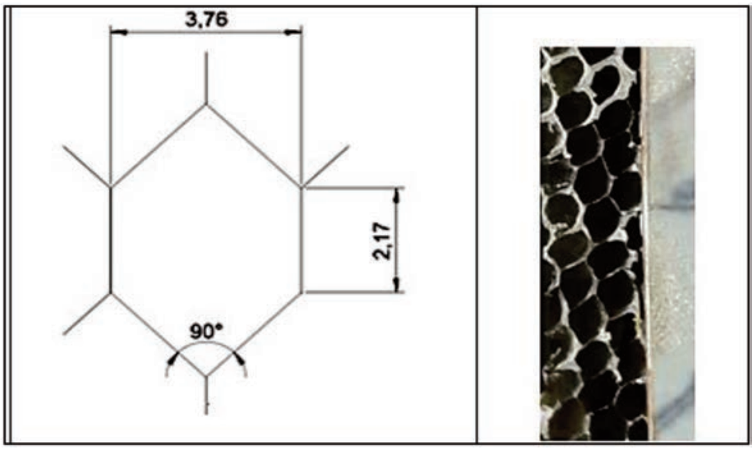


Figure 2. Cell geometry and view of the honeycomb core of the specimen, [4].

As the main goal of the study was to determine the compliance of the honeycomb core of the specimens, the additional compression tests were carried out:
– of pressure plates of the testing machine (type MTS643.41C) used for compression of the specimens;
– of two aluminum alloy sheets (dimensions approx. 0.8x80x80 mm);
– of leveling pads (plastic - dimensions approx. 5x80x80 mm).

Sheets and plastics were made of the same types of materials as used in tested specimens.

The study was conducted at the accredited Laboratory for Materials Strength of the AFIT.

Test Stand Configuration

Compression tests were carried out using the MTS 810.23 testing machine. The pressure plates with flat polished surfaces were mounted on the machine. The top plate was equipped with a ball joint.

Additionally, in order to determine the deformation of the specimens during their compression, black and white markers were bonded to the edges of the pressure plates. The MessPhysik ME46 videoextensometer was used to record the change in distance between these markers.

The testing machine was controlled using the MTS MPT (MultiPurpose TestWare) program. The compression test was carried out at a speed of 0.075 mm/min. The criterion for completing the tests of the specimens was a decrease in force by approx. 70% of maximum force. The criterion for completing the compression tests for pressure plates, sheets and plastics was achieving a compressive force exceeding the maximum compressive force P_{max} among the tested specimens.

The tests procedures for specimens were based on the ASTM C365 / C365M [5].

The test stand with a specimen mounted and pressure plates with the videoextensometer markers are shown in Fig. 3.

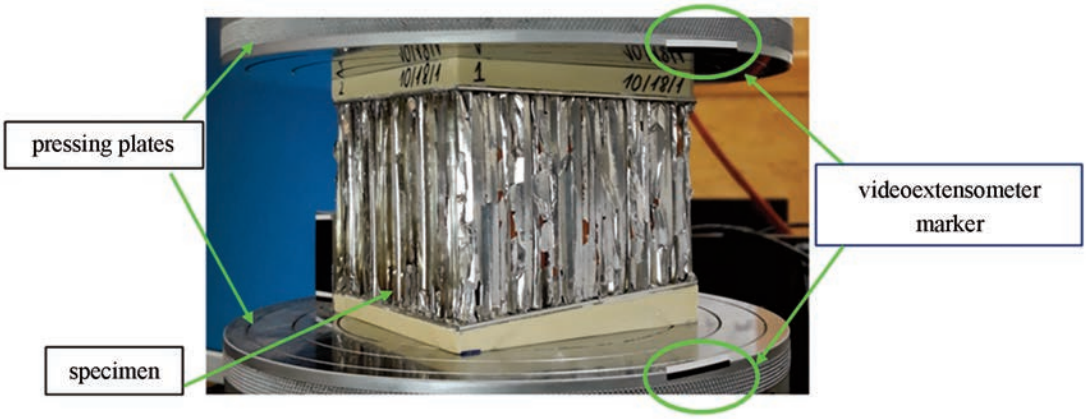
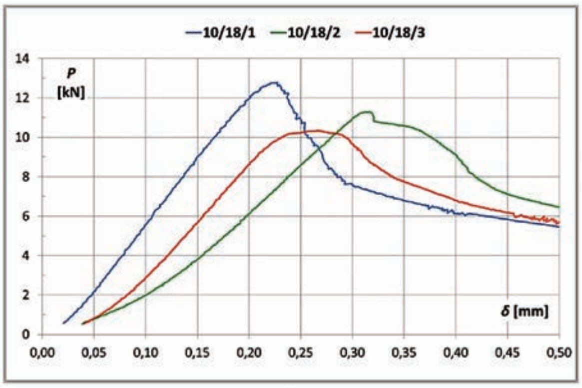


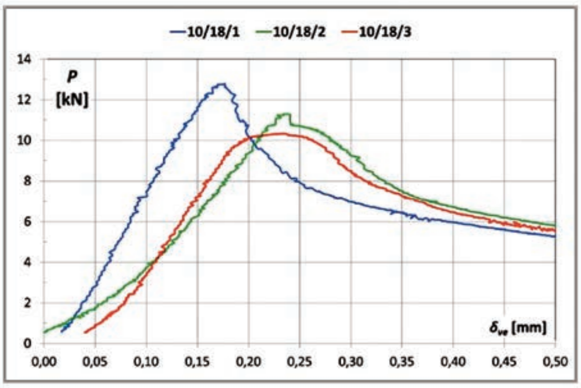
Figure 3. Test stand with a specimen.

TEST RESULTS

Static compression tests of the specimens were carried out. Two types of relationship were recorded: force (*P*) versus displacement of the actuator (δ) and force (*P*) versus displacement registered by the videoextensometer (δ_{ve}), (Fig.4).



a)



b)

Figure 4. Load-displacement curves (a) and load-displacement VE curves (b) for the specimens.

As a result of the compression test, a visible honeycomb core damage was observed – a view of the specimen after the test is presented in Fig. 5.

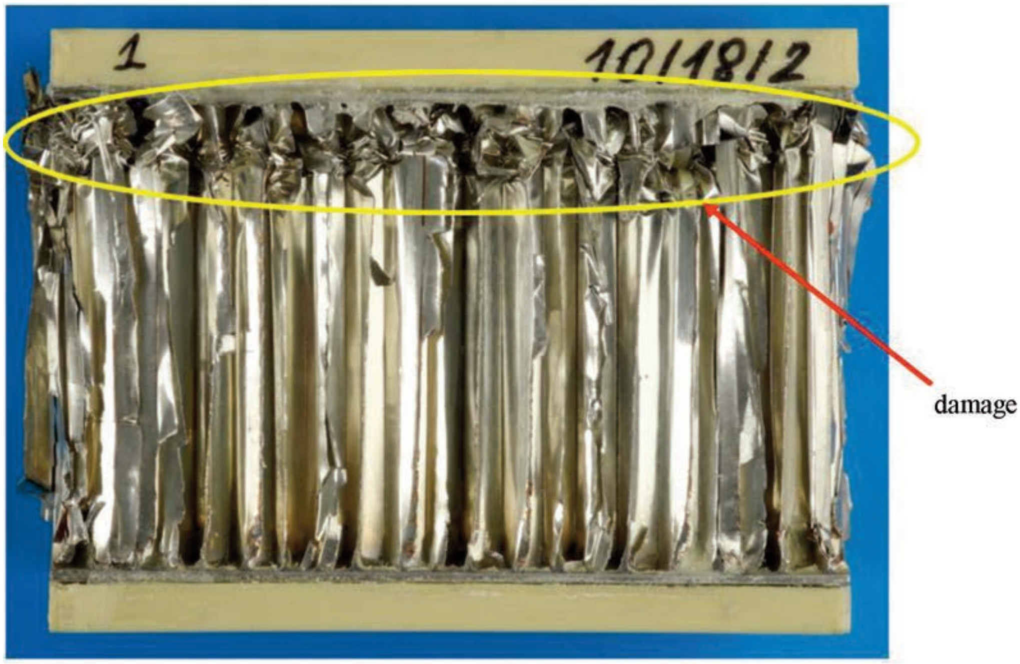


Figure 5. The specimen after the test – side view with damage, [3].

Maximum forces occurring during tests and displacements δ, δ_{ve} corresponding to them were summarized in table (Tab. 1). Displacement δ is higher than the displacements δ_{ve}.

Table 1. Summary of maximum force and displacement δ, δ_{ve}.

Specimen No	Specimen thickness	Maximum force	Displacement at maximum force, δ	VE displacement at maximum force, δ_{ve}
	[mm]	[N]	[mm]	[mm]
10/18/1	73,64	12 785	0,23	0,18
10/18/2	71,79	11 287	0,32	0,26
10/18/3	65,11	10 330	0,27	0,23

For the tested specimens the relationship between force (*P*) and displacement δ and δ_{ve} was transformed into the relationship between stress σ and strain ε and ε_{ve} (taking into account the cross-section of the specimen), Fig. 6. The tangent angle of the linear segment of stress dependence σ on the strain ε and ε_{ve} was determined. The directional coefficient obtained in this way is a measure of the compressive modulus, i.e. *E* and E_{ve}, respectively, (Fig. 7, Fig. 9).

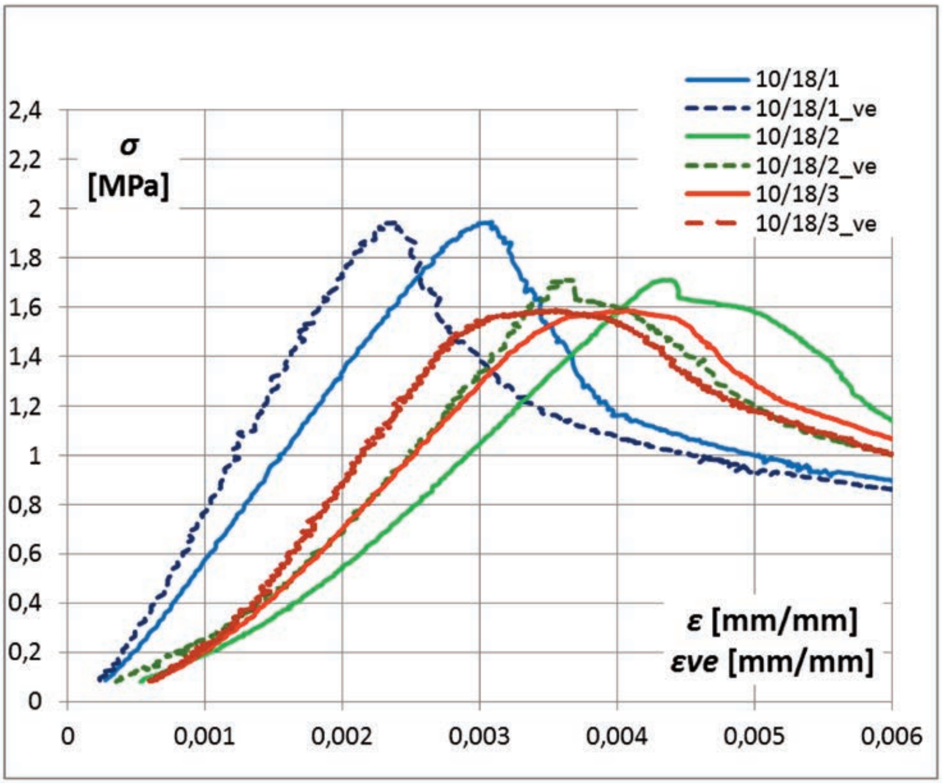
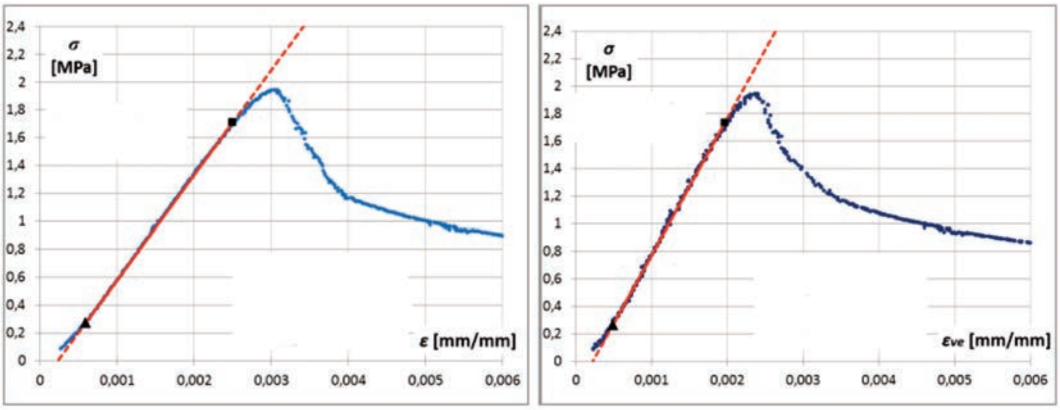


Figure 6. Stress-strain curves and stress-strain VE curves for the specimens.



a) **b)**

Figure 7. Stress-strain curve (a) and stress-strain VE curve (b) for the specimen no. 10/18/1.

The results of additional compression tests i.e. compression pressure plates, two aluminum alloy sheets and leveling pads (plastic) are show in Fig. 8.

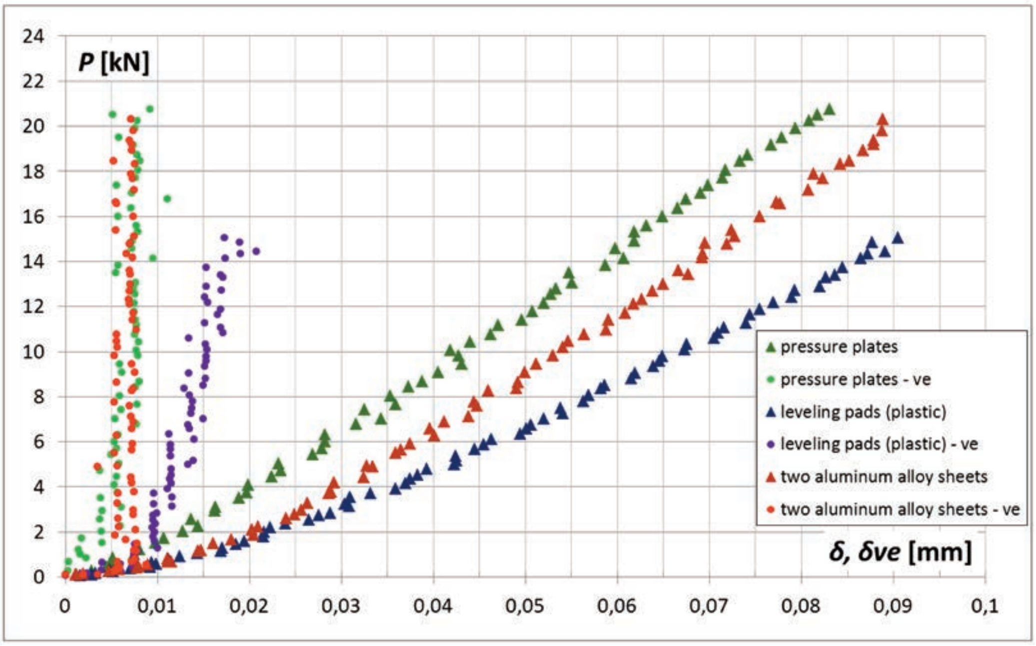


Figure 8. Force-displacement curves and force-displacement VE curves for the pressure plates (a), two aluminum alloy sheets (b), leveling pads (plastic) (c).

For the specimens, the values of the honeycomb core compressive modulus were determined, i.e. E_r and E_{rve} after taking into account aluminum sheets and plastic covers modules. The list of module values is presented in Fig. 9, [2].

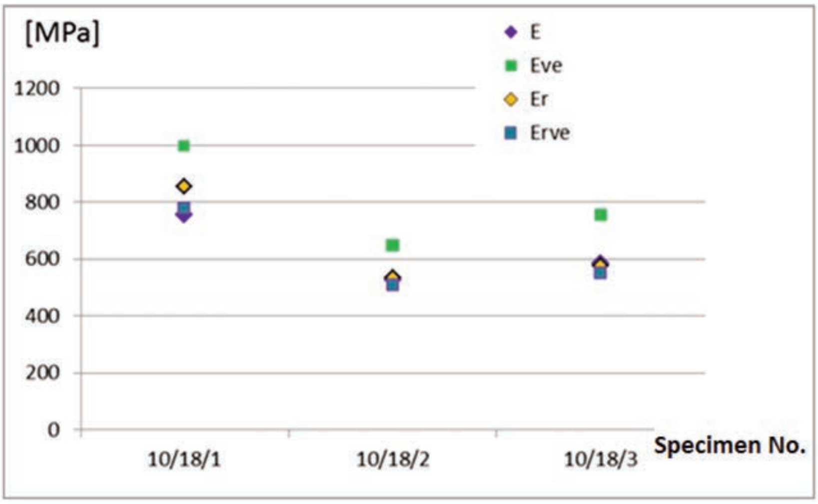


Figure 9. Values of specimen compressive modules E, E_{ve} and honeycomb core compressive modulus E_r, E_{rve} for the specimens.

Table 2. Values of modules from Figure 9.

Specimen No.	E [MPa]	E_{ve} [MPa]	E_r [MPa]	E_{rve} [MPa]
10/18/1	754	998	853	777
10/18/2	528	648	533	509
10/18/3	583	756	577	548

In the Table 2, it can be seen that Specimen 10/18/1 shows for each module variant its highest values among the tested specimens. In addition, this specimen had the largest thickness among the specimens tested.

For tested specimens, the determined strength parameters show a relatively large dispersion. This variation should be taken into account in the numerical calculations of the strength properties of the elements.

CONCLUSIONS

The static compression tests of the specimens taken from the horizontal stabilizer of the MiG-29 fighter jet were carried out. These allowed researchers to accomplish, among other project aims, the honeycomb core compliance calculations.

The stress-strain curves determined from the actuator displacement δ are shifted relative to the stress-strain curves determined from the displacement δ_{ve}, (Fig. 8). It is because strains determined from the actuator displacement δ include the compliance of the measuring chain, i.e. deformations of mechanical connections. What is more, the abovementioned curves also include deformation of aluminum alloy sheets and leveling pads. Therefore, in order to extract the parameters of the investigated core, the additional compression tests of pressure plates, two aluminum alloy sheets and leveling pads (plastic) were carried out. The obtained force-displacement curves are also shifted relative to the force-displacement VE curves.

It is possible to estimate the compliance (as inverse to the honeycomb core compressive modulus) of the honeycomb core of the sandwich structure of the specimens both for the actuator displacement δ and displacement δ_{ve}.

ACKNOWLEDGEMENTS

The work presented was prepared as part of the Air Force Institute of Technology project called “MiG”; performed under the contract with the Polish Ministry of National Defense. The main goal of the project was to develop repair technology for CFRP and sandwich structures of the MiG-29 jet fighter, including verification in flight tests as the last stage. The contract was signed on October 15, 2015.

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