AEROTAXI ground static test and finite element model validation

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Abstract: *In this presentation, we will concentrate on typical Ground Static Test (GST) and Finite Element (FE) software comparisons. It is necessary to note, that standard GST are obligatory for any new aircraft configuration. We can mention here the investigations of the AeroTAXI™, a small aircraft configuration, using PRODERA® equipment. A Finite Element Model (FEM) of the AeroTAXI™ has been developed in PATRAN/NASTRAN®, partly from a previous ANSYS® model. FEM can be used to investigate potential structural modifications or changes with realistic component corrections. Model validation should be part of every modern engineering analysis and quality assurance procedure.*

Key Words: *finite element analysis, ground static test, strain gauge.*

1. INTRODUCTION

The AeroTAXI™ aircraft is a representative for a new generation of small aircraft configuration conforming JAR-23/CS-23, [1] regulations, based on current developments and trends in aeronautics as given by "Vision 2020" for future development in aeronautics in EU. The AeroTAXI design goals are the following: cost effective design, low time-to-market, increased safety and passenger comfort configuration, with respect to state-of-the art systems and avionics. This design will integrate into a future transportation system based on revolutionary concepts as "Free-flight" and "Highway in the Sky" and customization for CNTAR™ concept developed for the Romanian market at INCAS [2].

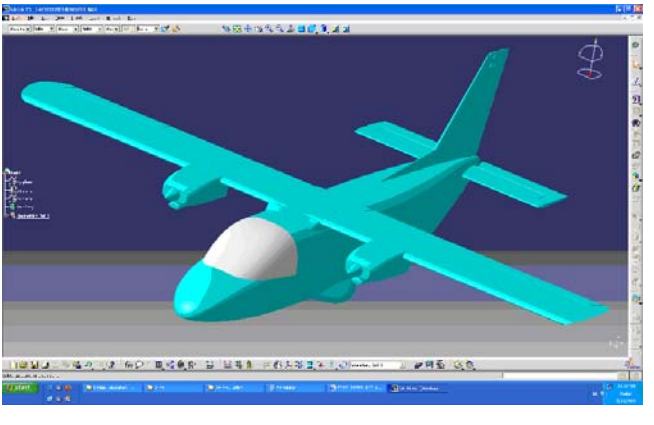

Fig. 1 CATIA representation of AeroTAXI aircraft

External Dimensions

Main Wing Span	15.2 m
Horizontal Stabilizer Span	5 m
Vertical Stabilizer Span	2.645 m
Dorsal Fin Span	0.4366 m
Max Fuselage Width	1.829 m
Max Fuselage Height	1.835 m
Fuselage Length	11.22 m
Tail Height above Ground	1.728 m
Wheel Track	2.7 m
Propeller Diameter	2.2 m

Internal Dimensions

Cabin length	6.215 m
Cabin Max Width	1.757 m
Cabin Max Height	1.783 m

Powerplant

Engine model	Lye TIO-540
Engine Power Rating	350 HP
Number of Engines	2
Total Power Rating	700 HP

Weights and Loadings

Empty Weight	2416 kg
Gross Weight	3000 kg
Payload with Max Fuel	916 kg
Number of Seats	12

Performance

Max Level Speed	119.m/s
Cruise Speed	105.1 m/s
Stall Speed Clean	35.07 m/s
Stall Speed 45 deg. Flaps	29.47 m/s
Max Rate of Climb	7.339 m/s
Max Lift to Drag Ratio	15.57

2. GROUND STATIC TEST ARCHITECTURE

The corresponding details of static test arrangement are shown in Figure 2 through Figure5.

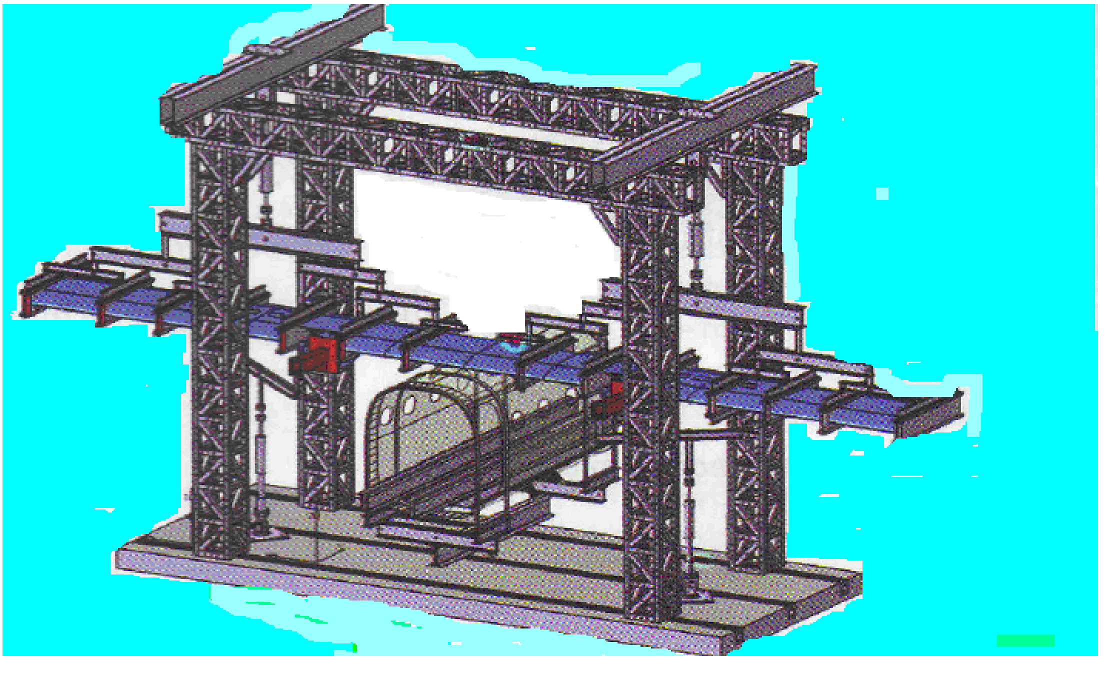

Fig. 2 CATIA representation of GST design

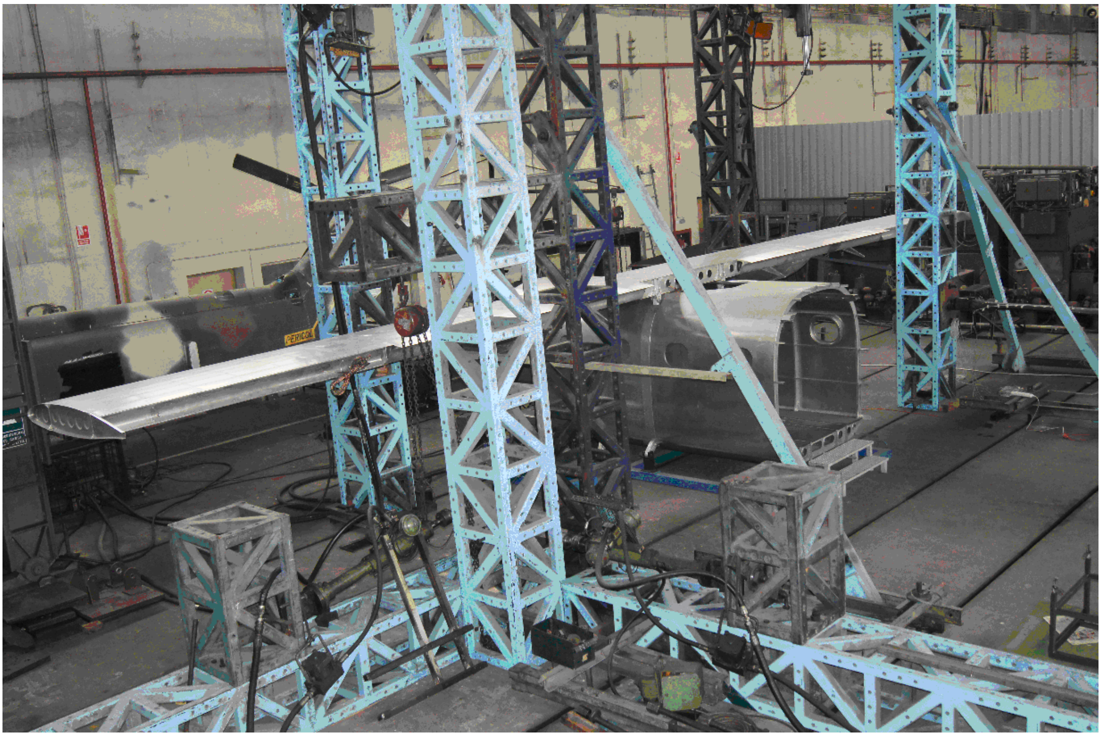

Fig. 3 GST overall view

Fig. 4 GST wing detail view

Fig. 5 GST fuselage detail view

3. CAD-CAE REPRESENTATION

The subsequent details of CAD- CAE representation are shown in Figure 6 through Figure 9.

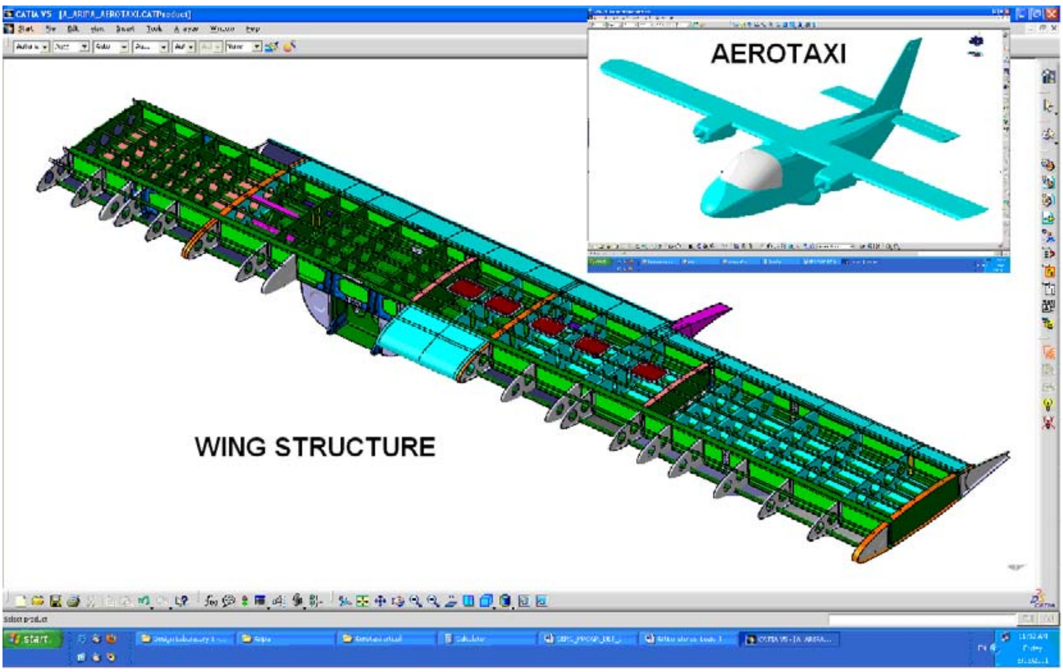

Fig 6 AeroTAXI wing - CAD model

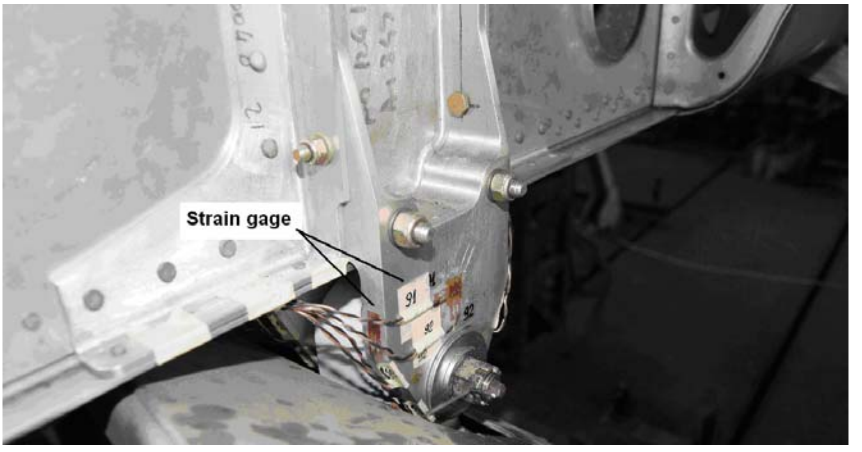

Fig 7 AeroTAXI wing – fuselage junction structure

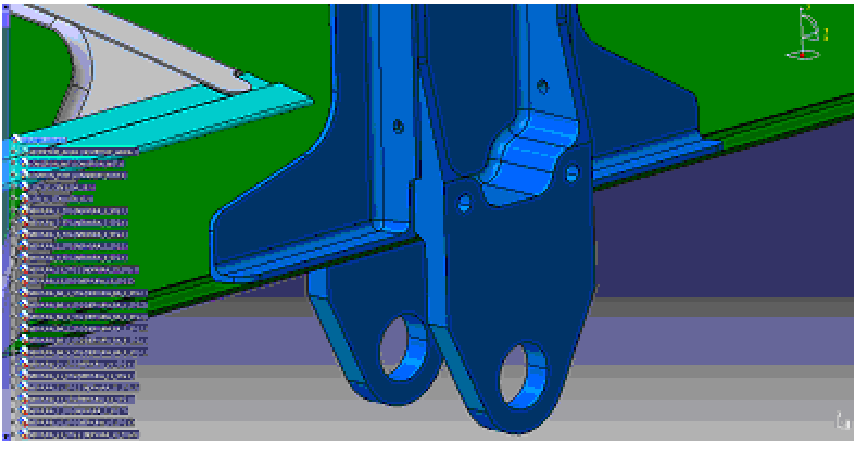

Fig 8 AeroTAXI wing junction - CAD model

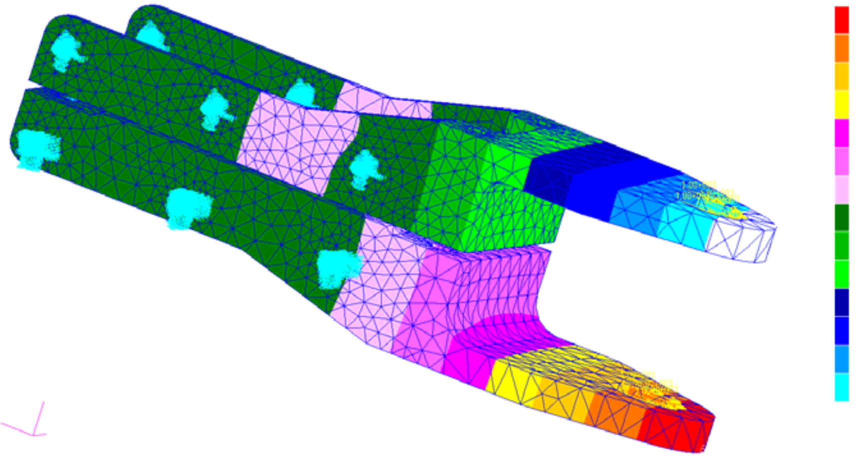

Fig 9 AeroTAXI wing junction – FEM results

4. STRAIN GAUGE MEASUREMENT

Strain is the amount of deformation of a body due to an applied force. More specifically, strain ($\varepsilon = \Delta L / L$) is defined as the fractional change in length, as shown in Figure 10.

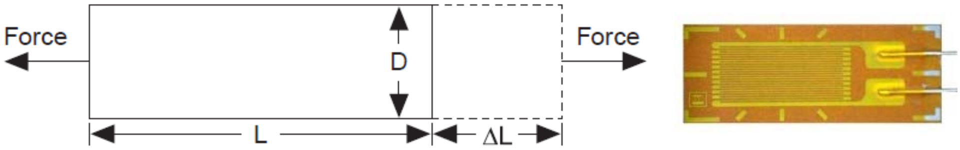

Fig. 10 Definition of strain

Strain can be positive (tensile) or negative (compressive). In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro strain ($\mu\varepsilon$), which is $\varepsilon *10^{-6}$. When a bar is strained with a uniaxial force, as in Fig.10, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio ν of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force), or $\nu = -\varepsilon_T/\varepsilon$. Poisson's Ratio for steel, for example, ranges from 0.25 to 0.3 and for aluminum is around 0.33.

Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance.

Fig. 11 AeroTAXI Wing-Fuselage junction detail

A wire strain gage can effectively measure strain in only one direction. To determine the three independent components of plane strain, three linearly independent strain measures are needed, i.e., three strain gages positioned in a rosette-like layout:

Fig. 12 Rosette strain gages example

The following coordinate transformation equation is used to convert the longitudinal strain from each strain gage into strain expressed in the *x*-*y* coordinates:

$$\varepsilon_{x'} = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\theta + \varepsilon_{xy} \sin 2\theta$$

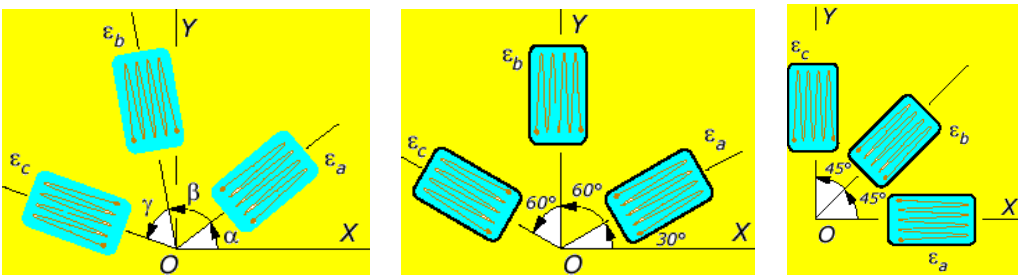

Fig. 13 Rosette strain gages arrangement

Applying this equation to each of the three strains:

$$\begin{cases} \varepsilon_a = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\alpha + \varepsilon_{xy} \sin 2\alpha \\ \varepsilon_b = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2(\alpha + \beta) + \varepsilon_{xy} \sin 2(\alpha + \beta) \\ \varepsilon_c = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2(\alpha + \beta + \gamma) + \varepsilon_{xy} \sin 2(\alpha + \beta + \gamma) \end{cases}$$

5. CONCLUSIONS AND FUTURE WORK

In this paper, we have reviewed some methods for the comparison and quantitative correlation between the static properties predicted by a theoretical model of AeroTAXI and those measured in a static test [4].

First activity is the static testing of the complete aircraft structure built to purpose and which will never fly. This is one of the two structural tests (the other is fatigue) of the complete aircraft provided in this program.

The loads will be applied by means of 2 hydraulic actuators commanded by the most advanced controlling system. The stress in the structure under load will be measured at minimum 100 different locations.

A PATRAN/NASTRAN, [3] finite element model of the AeroTAXI, originally created for design analysis purposes, could be used also for static-experimental comparative analysis.

The main objectives are to demonstrate the structural capability to withstand critical loads for which it has been designed.

The AeroTAXI test program is an example of how a GST is used to qualify an airplane for flight.

Future actions:

- Static tests of the aircraft shall be analyzed to validate and improve the analytical finite element model.
- GST of the airframe with selected configurations shall be used to validate and improve the analytical model.
- The validated analytical model shall be used to examine the configuration effects on the aircraft and the local structures.
- The test results were used to update the AeroTAXI to more accurately represent the airplane.

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