

Development of a multipurpose test rig and validation of an innovative rotorcraft vertical tail - TAILTEST

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Abstract. TAILTEST 9th call of the CS2 project started in the 2019 year is aimed at the development of a multipurpose test rig for validation of an innovative rotorcraft vertical tail. It is conducted in Czech Aerospace Research Centre (VZLU) as coordinator cooperating with the Greek Athena Research centre (Athena RC) as a participant. The project was initiated by Fokker Aerostructure Company and as part of the project chain is contributing to conceptual aircraft type of Next Generation Civil Tiltrotor with the reduction of fuel consumption and CO₂ emissions by lowering the structural weight of a rotorcraft tail through the application of thermoplastics. The paper summarized project objectives, concept and approach and main objectives of technical work packages.

1 Introduction

In the frame of the 9th call of the programme Clean Sky II was submitted and successfully accepted project TAILTEST. The current proposal addresses topic JTI-CS2-2018-CFP09-AIR-02-74 "Development of a multipurpose test rig and validation of an innovative rotorcraft vertical tail" [1]. As the project name indicates this project is directly aimed at the physical development of a multipurpose test rig for validation of an innovative rotorcraft vertical tail for purpose of its certification. The project has started in the 2019 year and is conducted in the Czech Aerospace Research Centre (VZLU) as coordinator cooperating with the Greek Athena Research centre (Athena RC) as a participant. See Figure 1. This project was initiated by Fokker Aerostructure Company and as part of the project chain is contributing to conceptual aircraft type of Next Generation Civil Tiltrotor with the reduction of fuel consumption and CO₂ emissions by lowering the structural weight of a rotorcraft tail through the application of thermoplastics. The problematics of project solutions has a usual structure of work packages that can make it possible for project management to guide, control and evaluate all processes. Here are concentrate also all coordination activities including the prompt periodical reporting. The creation of the certification strategy both for strength reliability of tail and damage tolerant bonding joints are included.

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This paper describes the content and solution proposal at the moment of project launch. That means the project solution has made great progress from this time and it will be the object of another VZLU's contribution.



Figure 1: Geographical distribution of TAILTEST partners

1.1 Project objectives

The main objectives of the current proposal, aligned to the respective topic description, are:

- To perform structural tests and FE models validation to support the certification process of an innovative rotorcraft vertical tail.
- To develop, apply and validate advanced numerical models for the simulation of debonding propagation in adhesively bonded or welded structural joints.

To achieve the mentioned main objectives, several intermediate steps have been identified:

- To design and manufacture an innovative multipurpose test rig to be used for testing a full-scale rotorcraft fin, as well as parts of the fin structure like the spar-to-skin joints.
- To perform structural tests on a rotorcraft vertical tail, up to ultimate load for at least the representative load cases
- To perform structural analysis of the fin utilizing the Finite Element Method (FEM) and validate developed numerical models by correlating displacement and strain measurements acquired during the structural tests with the respective numerical results.
- To develop and validate advanced numerical models for the simulation of debonding propagation in composite structural joints.
- To perform mechanical tests to obtain the material properties required for the application of the above mentioned advanced numerical models for the debonding prediction.

2 Concept and Approach

Current airworthiness requirements specify to prove the durability of composite structure based on damage tolerance philosophy [2,3]. These requirements are experimentally discussed in [4] in detail. Today's certification guidelines according to AC 20-107B [3] are limiting the certification of composite bonded joints within the standard means of compliance to the following possible approaches for civil aircraft applications: "For any bonded joint, the failure of which would result in catastrophic loss of the airplane, the limit load capacity must be substantiated by one of the following methods:

- (i). The maximum disbonds of each bonded joint consistent with the capability to withstand the „specific” loads must be determined by analysis, tests, or both. Disbonds of each bonded joint greater than this must be prevented by design features, or
- (ii). Proof testing must be conducted on each production article that will apply the critical limit design load to each critical bonded joint, or
- (iii). Repeatable and reliable non-destructive inspection techniques must be established that ensure the strength of each joint.”

Today, no suitable NDI method to fulfil the AC 20-107B requirement; (iii) of a secured measurement of the failure strength of a joint is in place. Moreover, it is not affordable to establish a full single part testing of each bonded joint within an industrial environment of commercial aircraft manufacturing according to requirement; (ii). Therefore, the only requirement; (i) is practically taken into account for the sizing and certification of bonded joints.

The state of the art to certify a structural composite joint is to follow approach; (i) by the usage of additional bolts which have to be capable to carry the relevant loads taking into account a global failure of the bondline. This boundary condition and the corresponding technical concept of additional bolts are limiting the benefits of the application of composite bonded joints in terms of weight, cost and performance.

To follow directly the directive provided by AC20-107B; (i) the limitation of the maximum disbond to a noncritical size for each structural application is one feasible way within today's certification boundaries. Then the next work should be focused to change the philosophy to slow-growth or fail-safe mainly for critical structural parts. The possible procedures for achieving this aim could be the procedure described in [5-7].

In these consequences one of the aims of the TAILTEST project is to develop a methodology for numerical (virtual) validation of the structure (fin-spar-to-skin) in which the number of bolts will be decreased whereas the capability to withstand the required loads must be kept or/and the crack stopping feature improve today's state of the art additional bolts concept by two means:

- 1) by the understanding of the crack/delamination growth and stopping mechanism in composite bonded or welded joints for primary structure part – the fin with the real load transfer configuration.
- 2) by the development of a novel numerical methodology for decreasing the number of bolts with the aim of weight saving and simultaneously for a crack arresting mechanism due to the bolts.

The overall concept that will be adopted to address TAILTEST's objective is illustrated in Figure 2.

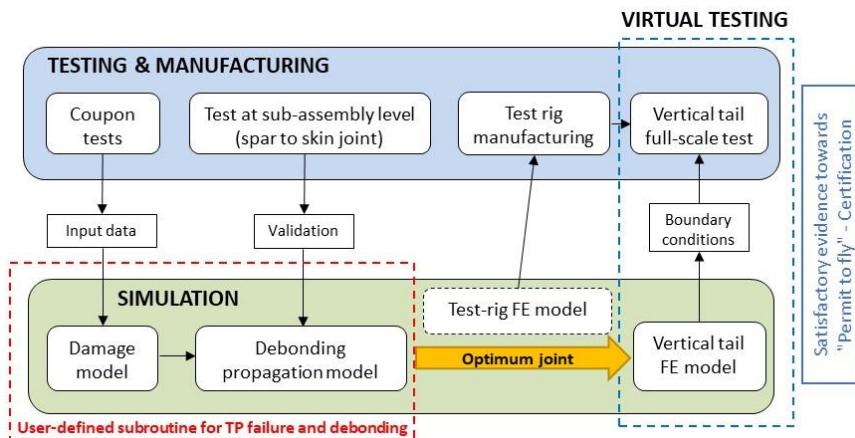


Figure 2: TAILTEST approach flow-chart

3 Main goals of technical work packages

To achieve the project objectives a work programme has been devised comprising of four technical Work Packages (WPs) each one addressing the tasks described in the call text, plus two supporting WPs; one including project management activities and one dealing with communication, exploitation & dissemination of project results. The technical work packages are designated to:

- Design and manufacture of the multipurpose test rig
- Tests execution
- Numerical validation and correlation
- Interface debonding propagation simulation test and analysis of a spar-to-skin joint.

One of the main objectives of the first technical work package is the design and of course manufacturing and assembly of a multipurpose test rig including the test plan development to be used for certification structural tests of a thermoplastic vertical tail fin as well as for testing of representative structural joints.

To meet the above objective a few sub-objectives have been identified:

- Definition by simulation of fin load and joint stiffness requirements.
- Preliminary design of multipurpose test rig focusing on variable joint stiffness and innovative load application capabilities.
- Test rig design optimization based on detailed FE analyses of the complete testing facility, test rig and test articles.
- Test rig manufacturing.
- Verification of joint stiffness.
- Design of sensors network and data acquisition system.

Based on these sub-objectives the real “tasks” were formulated to design a “Versatile test rig of dual utilization”, see Figure 3. In this picture, you can see preliminary assumptions for versatile test rig based on previous experience from experimental engineering. Based on the definition of fin loading and joint stiffness requirements the preliminary design of the test rig focusing on variable joint stiffness and innovative load application capabilities will be optimized through detailed FE analyses of the complete testing facility. Consequently, the test rig will be equipped with a test article and completely instrumented.

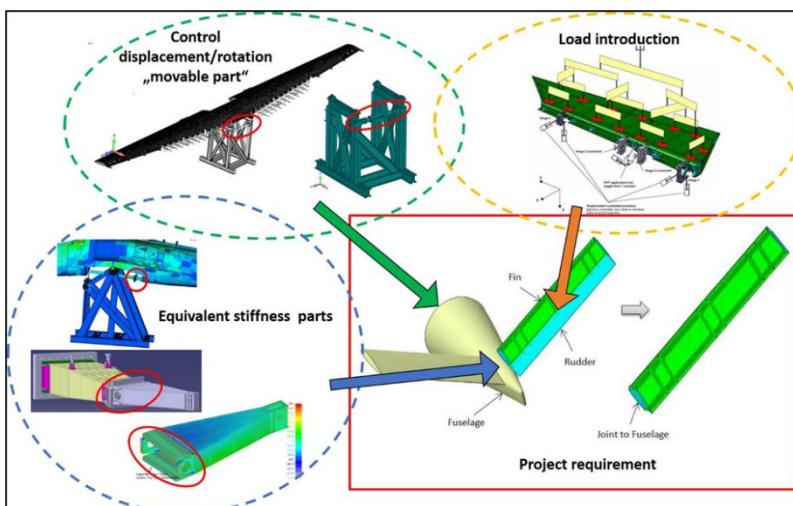


Figure 3: Schematic assumptions for the design of the variable stiffness test rig based on VZLU's previous applications before the start of the project.

There are the following objectives and corresponding tasks identified in the framework of the test execution work package:

- Tests plan development
- Installation of sensors network and measurement equipment.
- Perform structural tests for the rotorcraft vertical tail fin certification according to the test plan.
- Test data acquisition and reporting

VZLU handles with the main assumption that the V-tail will be tested together with the rear part of the fuselage. Only one deck of the V-tail will be part of the tested structure. The second deck will be compensated by dummy when the real stiffness of the second deck will be simulated and experimentally verified. The test article will be instrumented including contactless optical systems utilization. The static tests will be completed up to the ultimate load, see an example in Figure 4. In this picture, you can see the static test of the commuter wing up to the ultimate load, where the wing was fixed in the fuselage dummy that can simulate variable stiffness of main wing-fuselage hinges. In more detail, the tested principle is discussed in [8]. In the case of the TAILTEST project, will be used adequate solution for the test rig. The test will be monitored by cameras and measured data will be remotely monitored and evaluated. The final test report will contain the test setup, test rig and the test articles descriptions, test process, strain gauges and deflection measurements.

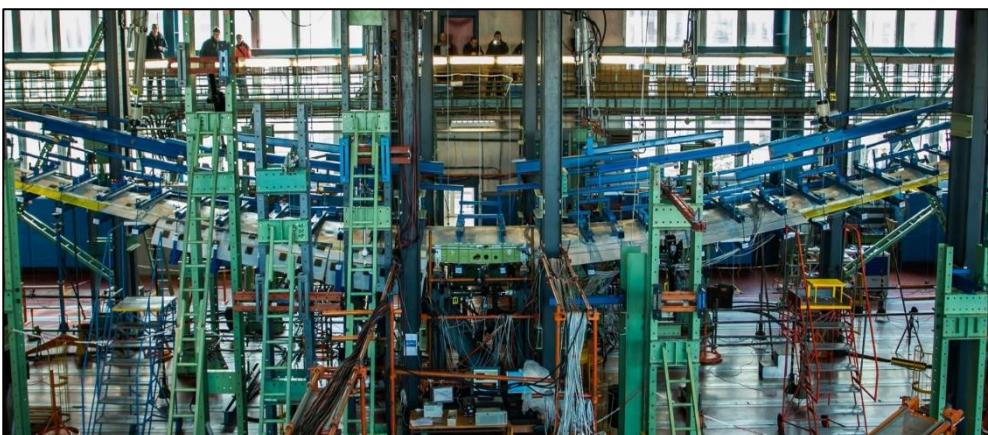


Figure 4: Example of test rig - Wing static test (part of the national project) with a simulation of variable stiffness of fuselage

In the frame of this work package, the novel hybrid sub-scale with welded joints and a limited number of fasteners will represent skin/stringer panel. The panel will be tested separately in compression. Loading will be based either on FE calculations or on full-scale test measurements.

The numerical validation & correlation work package includes project activities related to the numerical simulation of fin behaviour under the applied loading cases and the validation of the respective FE model based on the correlation of numerically calculated strains and displacements with respective experimental measurements.

Interface debonding propagation simulation test and analysis of spar-to-skin joint activities related to the development, calibration and validation of advanced models for debonding prediction are performed. More specifically, advanced models for the prediction of debonding under static and dynamic loading conditions are developed. Experimental tests for the definition of all necessary properties required for the application and calibration of the

debonding models. For the validation of numerical models predicting the debonding damage evolution at a spar-to-skin joint connected by a minimum number of bolts and either bonding or welding. will be developed and static and dynamic structural tests will be performed. Validation will be based on the comparison of numerical predictions and experimental measurements.

References

Online references will be linked to their source, only if possible. To enable this linking extra care should be taken when preparing reference lists.

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