International Forum on Aeroelasticity and Structural Dynamics
IFASD 2024
17-21 June 2024, The Hague, The Netherlands

AEROELASTIC CHALLENGES IN THE CLEAN AVIATION HYBRID-ELECTRIC REGIONAL AIRCRAFT

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Keywords: Clean Aviation, Hybrid-Electric Regional Architecture, Distributed Propulsion

Abstract: Air vehicles operating in inter-urban regional connections could take benefit of adopting hybrid-electric propulsion technologies and associated complementary solutions for reducing the environmental footprint of aviation, towards climate neutrality. Airbus Defence and Space is partner of a consortium which, as part of the Clean Aviation Strategic Research and Innovation Agenda (SRIA), is responsible of the engineering solution of a short-range (500-1000 km) Hybrid-Electric Regional Aircraft, one of the new aircraft architectures that will thrust the aviation towards 2050 climate neutrality.

This paper summarises the aircraft architecture solution and the aeroelastic challenges/technologies that will be developed during the different phases of the project. Some of the technologies developed for supporting the design of the HERA aircraft are:

> 1. The Hybrid-Electric Regional Architecture (HERA) aircraft will include distributed propeller-type propulsion with inertia and aerodynamic impacts on wing component that shall be considered thru high-fidelity simulations. These simulations are performed using a Fluid-Structure Interaction (FSI) procedure based on MSC.Nastran coupled with different High-Fidelity aerodynamics solvers. A graphical workbench DYNFSI is being developed to increase robustness and enhance the user experience when calculating 1-way or 2-way unsteady aerodynamics.
>
> 2.The rigid-body response of the aircraft will be improved by introducing the Integrated Flexible Aircraft Model (IFAM), with improved coupling between flight mechanics and aeroelastic formulation, all integrated in the industrial procedure of Airbus Defence and Space (using DYNRESP software) to calculate Dynamic Loads.

The Structural Dynamics and Aeroelasticity in the HERA project are described with emphasis on the previous two points and future activities (LCOs/flutter suppression activities, wind-tunnel tests, digitalization of methods and tools, etc.)

1 INTRODUCTION TO CLEAN AVIATION

1.1 The context for a Clean Aviation partnership

Decarbonizing the aviation sector is a critical challenge and opportunity in the global fight against climate change which will require concerted efforts from governments, industry and technological innovators, alongside substantial investment in research and infrastructure to scale up sustainable solutions. This transformation will involve the adoption of sustainable aviation fuels (SAFs), advancements in electric and hybrid propulsion technologies, improvements in operational efficiency, and, eventually, zero carbon connectivity.

In this context, the Clean Aviation Joint Undertaking has been established as the European Union's leading research and innovation programme for transforming aviation towards a sustainable and climate neutral future. Constituted as a public-private partnership between the European Union (represented by the European Commission) and the European aviation sector (represented by the founding members and the associated members), Clean Aviation will develop disruptive new aircraft technologies to support the European Green Deal, and climate neutrality by 2050 [1].

Clean Aviation is supported by the European Commission's Horizon Europe research and innovation funding programme. In particular, the Climate, Energy & Mobility cluster will support Europe's green transition based on competitive industrial and service value chains in the energy and mobility sector.

1.2 Objectives

The Clean Aviation Joint Undertaking will contribute to the delivery of Europe's climate neutrality by 2050, by pioneering new solutions in the aeronautics disciplines through zero- and low-emission technologies which include hybrid-electric solutions for regional and short-range flights and ultra-efficient aircraft designs utilising thermal engines suited for the adoption of sustainable aviation fuels (SAF) covering the larger and more energy intense medium and long-range sectors.

The Clean Aviation trajectory defines two clear horizons towards climate neutrality by 2050:

- 2030: demonstrating and introducing low-emissions aircraft concepts exploiting the research results of Clean Aviation, making accelerated use of sustainable fuels and optimised 'green' operations, so these innovations can be offered to airlines and operators by 2030 for an entry-into-service in the 2030-2035 timeframe;

- 2050: climate-neutral aviation, by exploiting future technologies matured beyond the Clean Aviation phase coupled with full deployment of sustainable aviation fuels and alternative energy carriers.

Considering this timeline, three key thrusts for the Research and Innovation efforts have been identified that will drive the energy efficiency and the emissions reductions of future aircraft [1]:

- Hybrid electric and full electric architectures: Driving research into novel (hybrid) electrical power architectures and their integration; and maturing technologies towards the demonstration of novel configurations, on-board energy concepts and flight control.

- Ultra-efficient aircraft architectures: To address the short, medium and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient thermal propulsion systems and providing disruptive improvements in fuel efficiency. This will be essential for the transition to low/zero emission energy sources (synthetic fuels, non-drop in fuels such as hydrogen), which will be more energy intensive to produce, more expensive, and only available in limited quantities.

- Disruptive technologies to enable hydrogen-powered aircraft: to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero carbon fuel, in particular liquid hydrogen.

The target performance levels across the aircraft categories selected for demonstration in Clean Aviation are shown in Table 1.

Table 1: Clean Aviation aircraft category targets [1]

Aircraft Class	Key Technologies and architectures to be validated at A/C level	Earliest Entry-Into-Service Feasibility	Fuel burn reduction (technology warning)	Emission reduction (net, i.e., including fuel effect)	Current share of air transport system emissions
Regional aircraft	Hybrid-Electric, distributed propulsion coupled with highly efficient aircraft configuration	~ 2035	- 50 %	- 90 %	- 5 %
Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, high bypass (possibly open rotor)	~ 2035	- 30 %	- 86 %	- 50 %

Airbus Defence and Space is a partner of the Hybrid-Electric Regional Architecture (HERA) consortium which, as part of Clean Aviation, is responsible of the development of a hybrid-electric regional aircraft platform to contribute to these ambitious targets. This paper is aimed to provide an overview of the aircraft architecture solution, the aeroelastic challenges and technologies that will be developed during the different phases of the project.

2 THE HYBRID-ELECTRIC REGIONAL AIRCRAFT

2.1 Introduction to the Hybrid-Electrical Regional Architecture (HERA) project

The Hybrid-Electrical Regional Architecture (HERA) project will identify and trade-off the concept of a regional aircraft and its key architectures. The final ambition is to be the first to pursue the hybrid-electric regional aircraft, supported also by full use of SAF and, eventually, hydrogen burning if feasible for the regional scale, as a realistic and operative aircraft at real size, having a realistic payload of interest for operators and passengers, fulfilling the certification rules, and proposing solutions to operate it. The HERA project is coordinated by the Italian aircraft manufacturer Leonardo [2].

The main characteristics of the hybrid-electric regional aircraft platform are:

- Size of approximately 50-100 seats.
- Regional and short-range distances (typically 500 km)
- Operative by mid-2030.
- Hybrid-electric propulsion based on batteries or fuel cells as energy sources supported by SAF or hydrogen burning for the thermal source.

The key targets for the project are:

- 50% fuel burn reduction, technology-based, measured as fuel kg per Available Seat Kilometre (ASK), or energy (MJ) per ASK as applicable, on a typical mission.
- 90% emission reduction (net - i.e., including fuel effect).
- Payload Index (PI) 60% of 2020 state-of-the-art aircraft verifying the first two targets.

2.2 Hybrid-electric propulsion technology

Electrification is a key feature for aviation sustainability. Until recently, the restrictions of required power, size and weight did not suggest electrical propulsion as feasible for aviation. Advancements in electrical systems and power storage make it now a realistic option by hybridization of thermal and electrical sources. Electrification of regional aircraft propulsion is widely considered as the earliest candidate to reduce emissions more than incremental evolution of thermal engines.

The ambition is to deliver a relevant share of propulsive power from electric sources thus reducing the thermal engine size, then allowing a sensible reduction of emission by mid-2030 for the regional segment. A regional aircraft, given typical size, range and mission will enjoy a hybrid-electric propulsion with a thermal engine burning 100% SAF and possibly hydrogen coupled to an electrical propulsion based on fuel cells and/or batteries. The final choice will depend on several factors including the integration and operative features of each power source, such as weight, energy source power density and volume, safety consideration, effects on aircraft performance, flexibility of usage, productivity index and sustainability. Finally, power share among batteries, fuel cell and thermal engine will depend on aircraft size and typical mission: the bigger the size and longer the flight hydrogen burning will mostly prevail; the lower the size and shorter the flight electrical power sources are a better choice for energy efficiency and environmental impact [2].

The propulsive architecture will require to face relevant technological challenges, such as the new aircraft architecture and configuration, improvements in digital simulations, advanced electrical distribution, thermal management of hybrid-electric systems and its airframe integration, and new power sources.

2.3 Aircraft configuration

Two propulsive configurations for the hybrid-electric regional will be developed as aircraft trade-off configuration, while maintaining the same fuselage and tail-planes, system architectures and the total installed propulsion power [3]:

- Baseline Configuration (UCA): Consists in a twin hybrid electric parallel propulsion configuration. It will be equipped with a novel ultrahigh performance wing using SAF and batteries/H2 fuel tanks and cells for electrification.
- Disruptive Configuration (UCB), equipped with a novel high-performance wing with a distributed propulsion system. Trade-offs are currently being performed in order to select the most optimal distributed propulsion scheme (number of engines, position, with and without tip propeller).

Figure 1. Possible aircraft configuration Use Case A and Use Case B (only for reference purposes, extracted from [2])

The distributed propulsion configuration offers some advantages which can potentially increase the efficiency of new regional aircraft. The high propulsive efficiency of the propeller and the location on the airframe can enhance the overall efficiency of the aircraft. In particular, for tractor propeller located in the wing tip, the interaction of the wing with the slipstream results in a reduction of the wing induced drag if the rotation direction of the propeller is opposite to that of the wingtip vortex [4]. Distributed propulsion is also highly compatible with hybrid-electric propulsion technologies, and improves the event of an engine failure, since the remaining engines can compensate the yawing moment more effectively.

On the other hand, adverse aeroelastic effects due to engine weight near the wing tip is a major drawback of wing-tip engine-mounted configuration. Nevertheless, the emergence of electric propulsion in distributed configuration possible has mitigated these adverse aeroelastic effects, making it possible to be considered as a promising solution.

3 AEROELASTIC TECHNOLOGIES FOR THE HYBRID-ELECTRIC REGIONAL AIRCRAFT

The aeroelastic activities required to support the design, development and certification of the hybrid-electric regional aircraft are common to conventional configurations for propeller-driven regional aircraft, including static aeroelasticity, divergence and control effectiveness analyses, classical and whirl flutter assessment, dynamic flight loads and dynamic ground loads computation and substantiation.

However, the distinctive features of the novel configuration proposed for this aircraft entails some additional challenges which will benefit from the development of specific aeroelastic technologies, such as:

- Characterization of in-flight static aircraft shape, with emphasis in propeller orientation and thrust vectoring optimization.
- High-fidelity unsteady aeroelastic methods to improve the rigid body response accuracy of the aeroelastic model and to capture distributed electric propulsion effects using the aeroservoelastic capabilities of the DYNRESP software.
- Implementation of aircraft vibration monitoring and mitigation/suppression systems.
- The development of innovative ways of working will assist the design of aircraft configurations where aeroelasticity restrictions plays a key role. On this basis, the digitalization of aeroelastic tools increases the adaptability and reduces cycle time, as required to involve aeroelasticity from early conceptual and definition design phases.

3.1 Static aeroelasticity: Flexible wing shape and thrust vectoring optimization

The development of a static aeroelastic model with high-fidelity aerodynamics coupled with the aircraft flexible model is required to characterize the in-flight aircraft deformations. The location of electric engines in outboard wing sections, together with the high-efficiency wing structural concept will result in large displacements in the regions where propulsive elements are installed. Therefore, emphasis must be put on the propellers orientation to reduce the distributed propulsion thrust steady deviations from the nominal orientation and optimize the thrust vectoring. Static aeroelasticity is also important in the redistribution of wing loads due to flexibility and the control surface effectiveness in the presence of distributed electric propulsion.

The aeroelastic model needs to capture accurately the inherent non-linearities of the problem. First, the flexible structural model must capture the geometrical non-linearities associated to large deformations. This can be achieved through nonlinear static analyses (as implemented in MSC.Nastran solution 106), or with post-hoc geometrical corrections to the linear static runs performed with global finite element models (GFEM), which are typically not suitable for nonlinear analyses. Second, high-fidelity aerodynamic codes must be used. In this regard, CODA solver is intended to be one of the standards in the European aeronautical industry in the forthcoming years, which will be validated for treating the particular features of the proposed aircraft configuration from the aeroelasticity standpoint.

Finally, the interconnection of the flexible structural model and the high-fidelity unsteady aerodynamic model constitutes a key element to accurately transfer loads and displacements between both models. A specific fluid-structure interpolation module has been developed in Airbus Defence and Space to provide an adaptable tool to complex geometries and multiple A/C platforms, with graphical capabilities to build and validate the model.

3.2 Unsteady aeroelasticity: High-fidelity simulations using DYNRESP

The novel aircraft configurations proposed also have an impact in the unsteady aeroelastic simulations. The high-flexible wing structure combined with electric engine mass and inertia properties in the outboard section is expected to result in first elastic wing modes with low frequency. As a consequence, the rigid body characteristics must be accurately captured to reproduce the aeroelastic response of the aircraft, by improving the classical aeroelastic models based in Doublet-Lattice unsteady aerodynamics. In addition, the distributed electric propulsion effects have an important contribution to wing unsteady aerodynamics which is not captured by classical potential methods.

The advanced aeroservoelastic capabilities of DYNRESP make it suitable for including these complex effects in the aeroelastic analyses.

3.2.1 A short introduction to DYNRESP and the Increased Order Modelling (IOM) method

DYNRESP is a software package originally developed for calculating the dynamic response of aircraft structures to external excitation, with emphasis on dynamic loads for structural design in industrial environments. The code is the result of a fruitful cooperation between Airbus Defence & Space (requirements, beta site, first user) and Karpel Dynamic Consulting (algorithms, theoretical formulation, software development and user interface).

The mathematical modelling of DYNRESP is based on a set of low-frequency natural vibration modes of the structure serving as generalized coordinates. Unsteady aerodynamic force coefficient matrices are combined with the modal properties in an aeroelastic model. The augmentation of a linear or non-linear control system and the addition of input excitation forces yields the aeroservoelastic equation of motion [5].

The calculation of the aeroservoelastic response due to external excitations (such as control surface commands, gusts, etc.) in the presence of nonlinearities is obtained using the Increased Order Method (IOM) [6,7]. The IOM is based on the assumption that the aircraft is mainly linear and that the non-linear effects are concentrated and known, which is a reasonable hypothesis for many applications.

A general block diagram of the IOM calculation scheme is given in Figure 2. First, the linear aeroelastic core of the problem is solved in the frequency domain to obtain:

- The normal modes response to the excitation.
- The response to the excitation at the output towards the non-linear block (YNL)
- The response at YNL to unitary excitations at the inputs from the non-linear block (UNL)

Then, these are transformed to the time domain using Fast Fourier Transforms (FFT) and convolution integrals are used to solve the complete system [8].

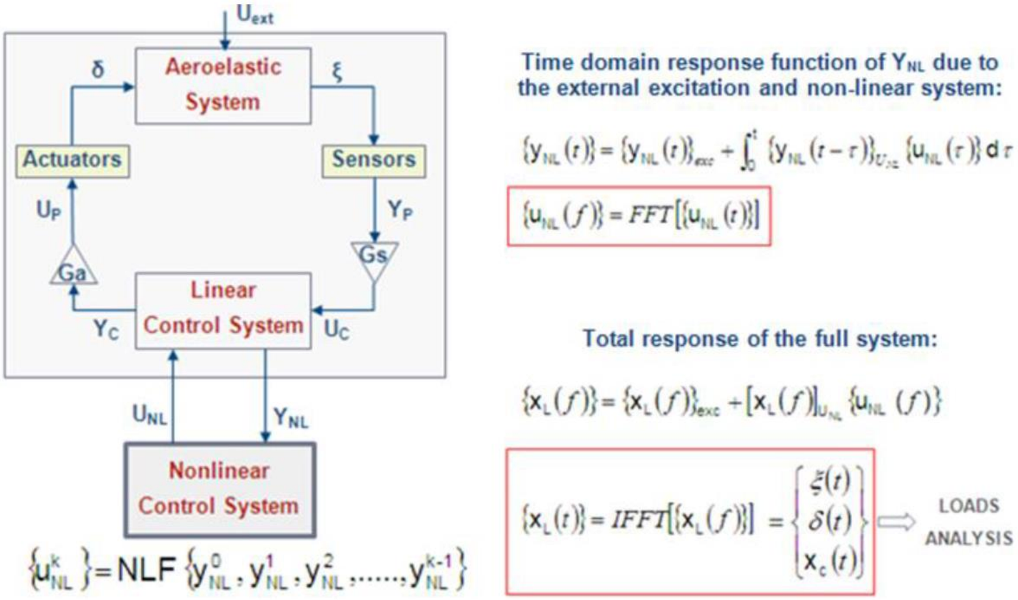


Figure 2. Increased Order Modelling calculation schema (from [8])

This convolution-based formulation has been extensively used by Airbus DS to solve different types of non-linear problems [8]. For example, a non-linear refuelling Boom model implemented in DYNRESP has been used for assessing the non-linear stiffness at the roll-pitch in safe separation assessment manoeuvres [9], to increase the accuracy when predicting the Boom mast flexible deformation [10] and impact forces in automatic refuelling operations [11].

3.2.2 Integrated Flexible Aircraft Model (IFAM)

Due to the modelling challenges introduced previously, it is necessary to apply novel approaches to improve the rigid body response of the aircraft in aeroelastic analyses. To do so, it is important to identify the main requirements of the IFAM model.

Requirements for the IFAM model

IFAM approaches seek to unify flight mechanics, aeroelastic models and, in some cases, steady loads models into a single process that improves the overall load analysis output. This improvement comes from the integration of the different disciplines with a high variety of models, which allows to fill gaps between them. Attention to the underlying assumptions of each model must be taken into account in order to have a consistent IFAM model.

The integration of the different models is tied to the coupling of the dynamic equations of both flight mechanics and aeroelastics models. As first approach, the most relevant coupling term are the external loads. Reference [14] discusses in detail the coupling between both disciplines.

The proposal is to perform the coupling of flight mechanics models and aeroelastics models through the external loads with DYNRESP solver non-linear capabilities. In that sense, the main requirements that apply to this model integration are the following:

- Accurate rigid body motion of the aeroelastic model
- Representative nodal loads that are consistent with the improved rigid body motion. That is, a spatial distribution that is consistent with the modification of global aircraft stability derivatives, such as the inclusion of the drag force spatial distribution over the structure.
- Scalability to massive dynamic load loop computations
- Applicable to all dynamic excitations, including the non-linearity of flight mechanics equations.

Having into consideration the stated topics, it is of relevance to review literature on the topic. Three main references: [12], [13] and [14], will be explored to assess their applicability to Airbus Defence and Space processes.

State of the art on IFAM models

Existing literature in the topic illustrates mathematical methods to improve rigid body modes by means of the following techniques among others:

- **Modification of unsteady Rational Function Approximation (RFA) coefficients according to Flight Mechanics (FM) stability derivatives** [12]:

This method makes use of the following coefficient fitting of the generalised aerodynamic force matrices, such that:

$$Q_h(i\omega) \approx A_{h,0} + pA_{h,1} + p^2A_{h,2} + pD(Ip - R)^{-1}E,$$

where p is the non-dimensional complex Laplace variable. With this approximation, an identification of the terms that appear in the linearised Newton-Euler flight mechanics (FM) equations can be performed to modify $A_{h,i}$ Rigid Body Modes (RBM) partitions to match FM stability derivatives.

This method may accurately capture linear flight mechanics behaviour using the state-space aeroelastic model. In addition, the flight mechanics coupling is two-way, having elastic degrees of freedom influence in the rigid behaviour. However, it is not capable of determining the distribution of the modified generalised aerodynamic loads to the elastic degrees of freedom. Thus, not making it suitable for precise load recovery unless the load distribution data base is modified to be consistent with the modified stability derivatives.

- **System pole replacement** (KS Method) [13]:

By relying in the application of the RFA to obtain a state space representation of the aeroelastic system as shown:

$$\dot{x} = Ax + Bu.$$

Where x is the state space vector containing generalised displacements and velocities, and lag states. And u is the input vector of actuator commands and external forces. Then, the orthogonal coordinates of the system are obtained by solving the eigenvalue problem of matrix A. In that manner, the RBM eigenvalues and eigenvectors can be identified and substituted by the values of FM models.

This method may also recover good flight mechanic behaviour through a one-way coupling approach. Moreover, it is capable of introducing non-linear FM time histories as an input to the model. The downside of this model is the same as the previous one: the inability to recover nodal loads as the aerodynamic effects cannot be distributed to the elastic degrees of freedom accordingly.

- **Residualised Method** (RM) approach [14]:

This method makes use of tabulated steady loads databases to include quasi-steady loads. The unsteady aerodynamic DLM model is residualised to exclude steady effects and loads are computed by a two-way coupling of the non-linear Newton-Euler FM equations and the aeroelastic linear system. This framework is focused towards high fidelity load analysis for special investigations, inflight events and other detailed analyses. This approach has similar performance as the KS method; however, it has higher fidelity in load analysis, allowing for consistent nodal load recovery. Nonetheless, the use of RM over KS is really dependent on the existing tool & methods environment [15].

The fidelity, integrability and scalability of these methods is quite different and must be evaluated in order to assess its implementation into standard dynamic loads loop calculations.

In summary, the main issues found in existing IFAM models are: (a) the spatial distribution of rigid body generalised forces that are modified to match FM model behaviour and (b) the integration of the IFAM model in the existing industrial process of massive load loops based on DYNRESP.

Inside the scope of Clean Aviation, the previously presented IFAM approaches will be reviewed, implementing them to the Generic Transport Aircraft (GTA) test case for discrete and continuous gust excitations. Additionally, once the relevant drawbacks are evaluated, new IFAM formulations will be assessed. Mainly, two new concepts will be investigated:

1. CFD-DLM Incremental Strip Loads convoluted by Wagner functions. (ISL)
2. Uncoupled CFD Rigid Body Motion computed aerodynamic load matrices. (CRBM)

Both proposals make use of DYNRESP's capabilities to introduce non-linear behaviour. Moreover, these new approaches will try to solve the problem of distributing modified RBM generalised forces to the elastic degrees of freedom in a simple and integrable manner into current work processes based on DYNRESP.

ISL approach with DYNRESP

The ISL approach is based on corrections coming from steady CFD analyses, tabulated for different flight conditions and attitudes; mainly angle of attack, sideslip, Mach, altitude, etc. The differences from the steady CFD and the DLM at zero frequency will be delayed by Wagner, Küssner and Theodorsen functions depending on the type of simulation and excitation. DYNRESP is key to the assembly of this model as the corrections will be applied at strips of the DLM model. Aerodynamic sensors can be included to obtain the current representative angle of attack of the strip, and a feedback system will return the delayed incremental loads to the corresponding structural nodes.

This approach is not fully accurate, as CFD corrections should be fully unsteady. However, it is assumed that the steady difference, after passing through the appropriate delay filter is adequate in the unsteady domain too. This simplification greatly reduces the computational cost. In addition, this approach has minimum aeroelastic model modification. The only necessary additions to the model include the aerodynamic sensors and force feedback loops. Nonetheless, the major changes are applied outside the aeroelastic model, in the treatment of the strip loads and interpolation in between flight mechanic states.

CRBM approach with DYNRESP

This approach is thought to take advantage of the Fluid Structure Interaction (FSI) capabilities of Airbus Defence and Space structural dynamics and aeroelasticity department. Using DYNFSI framework, the process is easy to implement in the current workflow as only the aerodynamic input data is modified in linear simulations. The method consists in computing frequency dependent CFD for the rigid body modes, and substituting the first 6 RBM columns of the generalised aerodynamic force matrices.

For non-linear simulations, a force feedback loop in DYNRESP can be used to manage the interpolation of CFD databases with the flight mechanic states of the response. Load recovery in this sense might require modifications to take into account non-linear behaviour.

3.2.3 Aeroelastic response considering distributed propulsion effects

Potential-flow based classical approaches for calculating unsteady aerodynamics are also questionable when approaching the type of aircraft configuration proposed. Distributed propeller propulsion will have an impact in the inertia and aerodynamic modelling of the wing component. In particular, high-fidelity simulations are required to capture the unsteady pressure distribution on a wing affected by multi-propeller wakes and the control surface effectiveness of the ailerons, spoilers and flaps as affected by the multi-propeller wakes. In addition, nonlinear effects can be of relevance due to large deformation near the wing tip, where wing-propeller interaction is of relevance.

DYNRESP modelling capabilities allow capturing these effects, by using linear models enhanced with specific wing-aileron-propeller interaction models implemented as feedback block loops, or via coupled fluid-structure simulations using high-fidelity CFD unsteady aerodynamics.

3.3 Active control of elastic modes and vibration alleviation systems

There are a number of aeroelastic sources of in-flight vibrations with a potential impact in the configuration proposed, such as unsteady non-linear aerodynamics (propellers wake), concentrated structural non-linearities (control surfaces freeplay) or propellers unbalance. The objective will therefore be to analyse the different sources and identify which of them are compatible to be alleviated or mitigated thru active control, as well as advancing in certification strategies for introducing the LCO-flutter suppression technique.

The development and certification of these type of active control technologies present significant challenges that must be addressed by different engineering disciplines:

- The simulation and design of such alleviation strategies shall be based on reliable models which integrate rigid and elastic modes, accounting for non-linear aerodynamic effects and non-linear flight control laws, as described in the previous section.
- Application of new flight control laws algorithms, with adaptive real time modal identification.
- Development of smart distributed sensors technology minimising sensor delays.
- Development of certification route with airworthiness authorities.

Extending the feasibility of these strategies from the design to the real aircraft needs proper validation of the methodologies thru wind tunnel tests. The validation with wind tunnel tests will assess the feasibility of the studies but also will mitigate risks on the scale aircraft demonstrator. In this sense, Politecnico di Milano (PoliMi) University has a broad experience in general aeroelasticity and aeroelastics-related wind-tunnel tests coming from internal research and European projects, and will be mainly focused on all the aspects related the aeroelastic control systems within the HERA project.

The proposed contribution can be organized in two main phases:

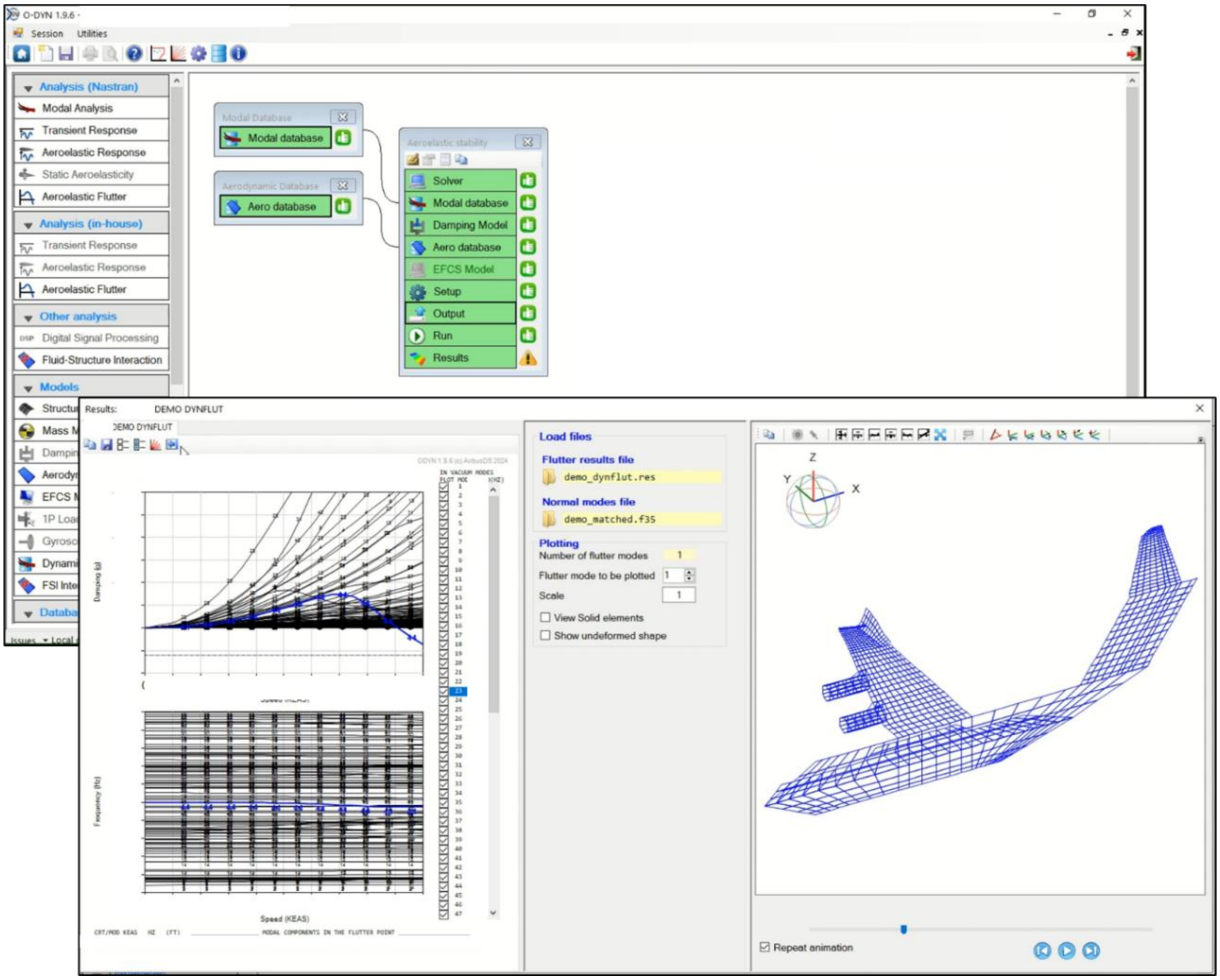
- Phase 1: Validation of active flutter suppression laws provided by the partners on already available wind tunnel test platform
- Phase 2: Design and manufacturing of a new wing/model based on Distributed Electric Propulsion for validation of active flutter suppression laws and aeroelastic control

3.4 The digitalization of aeroelastic tools: O-DYN

The objective of the Airbus Defence and Space aeroelasticity digitalization initiative is to develop specific software for reducing aircraft design time (and therefore time-to-market) by encapsulating the aeroelastic/dynamic loads codes into a digital framework, reduce the learning curve, assuring digital continuity between the high-fidelity calculations codes, making the process more robust and less prone to human failures, and enhancing the flow aero-loads-stress for optimizing the subsequent structure justification process. All these features are of great benefit when considering novel configurations as the distributed propulsion aircraft, which will require agile aeroelastic analyses and trade-off studies from the initial phases of the project.

As the backbone of this digitalization strategy, O-DYN is the frontend software developed to serve as all-in-one, state-of-the-art, user friendly digital tool suite to handle all structural dynamics and aeroelasticity tasks: model building & validation, stability simulation (flutter, divergence, control reversal, etc.) and response analysis (dynamic ground loads, dynamic flight loads, etc.).

As an example, Figure 3 shows a screenshot of a single classical flutter analysis within ODYN.



Results: DEMO DYNFLUT

Load files

Flutter results file: demo_dynflut.res

Normal modes file: demo_matched.f35

Plotting

Number of flutter modes 1

Flutter mode to be plotted 1

Scale 1

☐ View Solid elements

☐ Show undeformed shape

☑ Repeat animation

Figure 3. Example of O-DYN application to a single-case flutter analysis

4 CONCLUSIONS

The Clean Aviation Joint Undertaking has been established as the European Union's leading research and innovation programme for transforming aviation towards a sustainable and climate neutral future. Hybrid-electric architectures have been identified as one of its key thrusts which will drive the energy efficiency and the emissions reductions of future aircraft. Driving research into novel hybrid-electrical power architectures and their integration is the main purpose of the Hybrid-Electric Regional Architecture (HERA) program, which will develop a regional aircraft platform of approximately 50-100 seats for the regional sector (typically 500 km) and will be operative by mid-2030.

The configurations proposed for such aircraft, including a distributed propulsion concept, will entail many aeroelastic challenges that will drive the development of additional technologies such as high-fidelity unsteady aerodynamic simulations coupled with flexible aircraft model, enhancement of the rigid body response of aeroelastic models, development of vibration mitigation active control systems and digitalization of methods and tools.

ACKNOWLEDGEMENTS

The research performed in this paper has been performed in the framework of the HERA project (Hybrid Electric Regional Architecture) and has received funding from the European Union Horizon Clean Aviation Programme under grant agreement n. 101102007.

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