Joint Collaborative Project

between

China Academy of Aerospace Aerodynamics (China) and University of Southampton (UK)

~ PhD Project on Performance Adaptive Aeroelastic Wing ~

1. Abstract

The reason for the joint collaborative project between China Academy of Aerospace Aerodynamics and University of Southampton is twofold. The first reason is to develop innovative computational techniques to design future air vehicles that are optimal at various stages of the flight. The techniques will be developed at the University, and transferred to the Academy progressively throughout the project. The second reason is the already proved expertise of the Academy to perform wind tunnel and flight tests of experimental full-scale prototypes, verifying the predictive capabilities of the new computational techniques.

2 Aim and objectives

2.1 Aim and objectives

The aim of the project is to develop the background methods and tools to allow the design of future air vehicles, overcoming limitations of current methodologies. The technical objectives are to: i) optimise the flight shape at various stages of the flight; ii) optimise the location of control surfaces for control during manoeuvres and gust encounters; and iii) employ a multi-fidelity approach to leverage the appropriate compromise between accuracy and computing costs at the various stages of the design.

2.2 Research content

The goal of the work programme is to research and develop future air vehicles that continuously optimizes the shape for current flight conditions. This approach could maximize lift for take-off, minimise fuel consumption in cruise, or maximize lift and drag for landing. The programme is well aligned with current trends to reduce the impact of aviation on the environment, and increase the performance of autonomous vehicles used for monitoring and detection.

This is in line with the research interests at China Academy of Aerospace Aerodynamics, particularly those addressed at the design and manufacturing of solar-powered unmanned aerial vehicles. Among other references, previous background work may be found in: Wang Y, Li F, Da Ronch A, ‘Flight Testing Adaptive Feedback/Feedforward Controller for Gust Loads Alleviation on a Flexible Aircraft’, AIAA Paper 2016-3100, AIAA Aviation, 2016.

2.3 Key techniques

The research project builds on modern computing techniques, exploiting the flexibility of scripting languages to interfaces arbitrary software tools, and leveraging on high performance computing facilities to launch massively parallel calculations at the edges of the flight envelope. The work will require a certain amount of programming in various scientific languages.

2.4 Innovation

The innovative aspect of the programme lies in the integration of multi-fidelity approaches for structural and aerodynamic modelling to enhance the design of future air vehicles. Today computer codes are limited in the predictive analysis capabilities by the underlying (linear) assumptions. The proposed approach consists of an appropriate combination of methods of varying fidelity, employed at incremental steps to improve the prediction fidelity while narrowing down the search for the optimal aircraft configuration.

2.5 Technology index

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3 Research path and techniques

3.1 Programme roadmap

The work programme consists of several interconnected phases. The first phase corresponds to the conceptual design stage, whereby a beam stick model is used for the representation of the structure and aerodynamic panels are used to model lifting surfaces. The output of the optimisation process is then used during the second stage, which employs higher fidelity methods (through some forms of acceleration techniques) for both the structure and the aerodynamics to verify and improve the design choices made at the first stage. The final stage employs a three-dimensional representation for both the structure and the aerodynamics. Similarly, results of the third stage will be compared to those obtained in previous steps.

3.2 Methods and techniques

As the design maturity increases during the three phases above, the appropriate combination between accuracy and cost of the software tools is identified. It is suggested to employ the following codes.

Design phase	Software tool
First stage (conceptual)	NeoCASS, an open source MatLAB software partly developed by Dr A. Da Ronch, offers a choice of linear and nonlinear beam and plate models for the structure, and a doublet lattice method for the aerodynamics. Coupling with NASTRAN and external aerodynamics is also available.
Second stage (preliminary)	A hybrid aerodynamic method will be used, combining panel aerodynamics (doublet lattice or vortex lattice) with sectional data computed by computational fluid dynamics (SU2 and/or TAU) to improve predictions in nonlinear flow conditions.
Third stage (detailed)	Three dimensional computational fluid dynamics (SU2 and/or TAU) with NASTRAN.

The choice of employing open source codes reflects the need to create a computational platform which can be easily transferred, tested, and integrated at China Academy of Aerospace Aerodynamics.

3.3 Feasibility study and risk mitigation

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3.4 Assessment of the project

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4 Plan and results

4.1 Plan and results

The work plan consists of developing a software that will be used by China Academy of Aerospace Aerodynamics to support the design of current and future aircraft configurations. It is expected that, following a close collaboration between the two institutions, the work performed at the University of Southampton will address a gap in existing methods and tools available at China Academy of Aerospace Aerodynamics. To facilitate the cooperation, the project will employ software tools that are either commercially available but widely used in the aerospace sector (e.g. NASTRAN and MatLAB) or open source (e.g. SU2), or a combination of both.

4.2 Milestones

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4.3 Output format

To provide adequate visibility to the project achievements, results will be disseminated annually at an international conference (AIAA, ICAS, and/or IFASD). At the completion of the project, results will be reported in two international peer-reviewed journals. Furthermore, the project will create a software tool which will be shared with China Academy of Aerospace Aerodynamics and integrated in the system during the student's visits during the summer period.

4.4 Application field

The project is applicable to all areas of aerospace engineering related to aerodynamics, structures, control, and flight mechanics. In particular, the project will develop knowledge and tools that find direct application to both low and high speeds of flight.

4.5 Expectations/benefits from the project

The main outcome of the project is the generation of a software tool. The tool will be employed to design future air vehicle configurations, including high aspect ratio flexible wings and unconventional aircraft designs. Therefore, the main outcome responds to the need to employ a novel software tool for novel aircraft concepts, overcoming limitations of current state of the art methods.

5 Research facilities to support the project

The computational aspects of the proposed project will be performed at the University of Southampton throughout the duration of the project. Activities will also continue beyond the duration of the project until the completion of the PhD programme for the student involved in the project. It is expected that the last six months of the project will be devoted to experimental testing, and this phase will be carried out at China Academy of Aerospace Aerodynamics.

5.1 Research facilities

The University of Southampton has access to Iridis4 which is in the World's Top500 ranking and is the largest high performance computing (HPC) facility in the UK after the national HPC. Dr Da Ronch has free access to Iridis4 and this will be used throughout the duration of the project.

China Academy of Aerospace Aerodynamics has more than twenty wind tunnel facilities, from low subsonic to supersonic flow conditions.

5.2 People involved

China Academy of Aerospace Aerodynamics: Dr Y. Wang

University of Southampton: Dr A. Da Ronch, Mr G. Yang, and an additional PhD student to be confirmed

6 Budget

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6.1 Annual budget

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6.2 Milestones budget

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7 Coordination institution

The proposed project is a joint collaboration between China Academy of Aerospace Aerodynamics and the University of Southampton.

7.1 Key coordination institution

The technical work related to the project will be carried out at the University of Southampton. China Academy of Aerospace Aerodynamics will be responsible to arrange regular project meetings, which will be held every three months via webex, and host the PhD student for one/two months during the summer period. Every six months, the project meeting will be held at the premises of China Academy of Aerospace Aerodynamics.

7.2 Relationship to other projects

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