AeroBest 2025

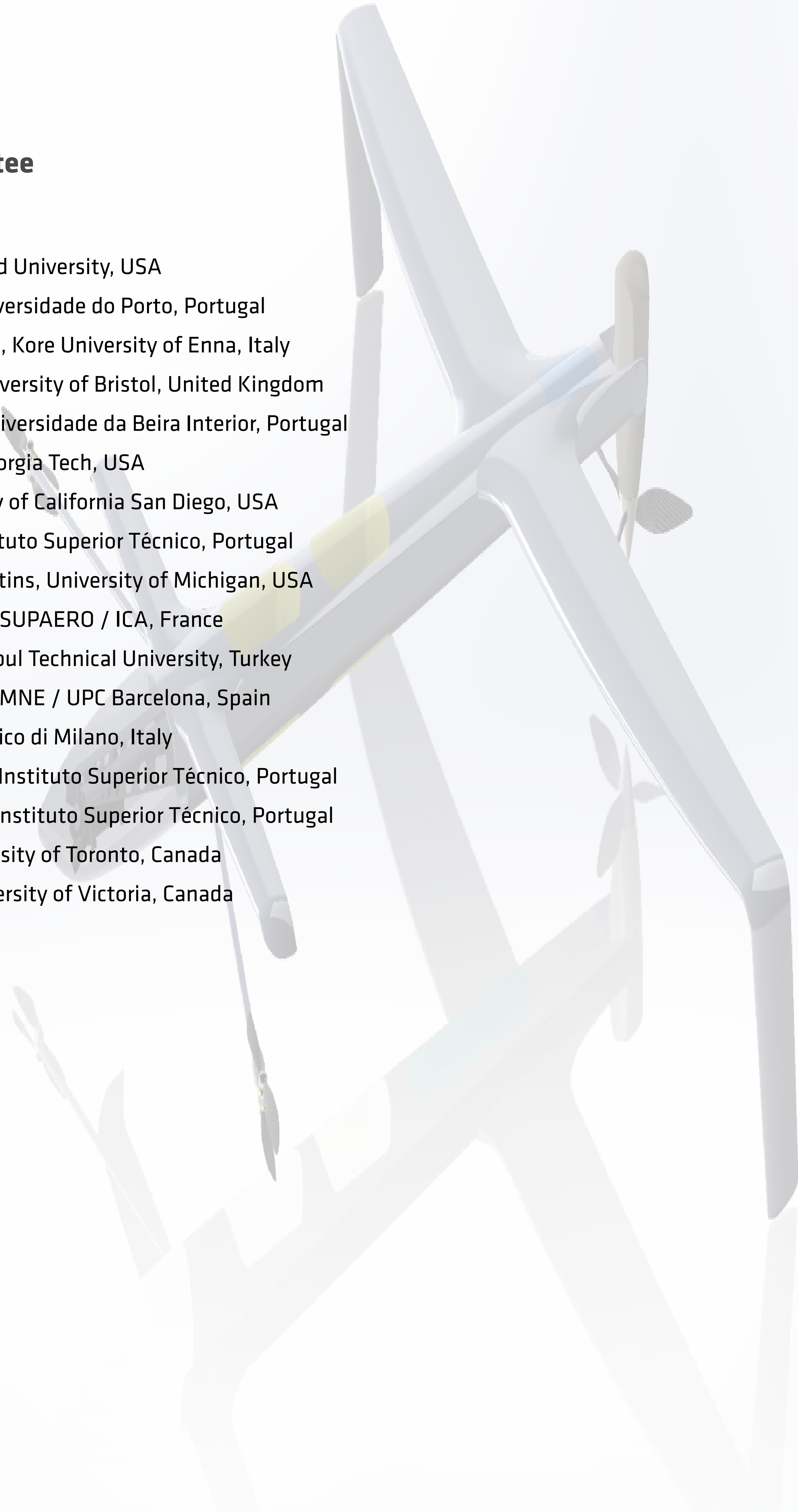
III ECCOMAS Thematic Conference on Multidisciplinary Design Optimization of Aerospace Systems

Programme and Abstracts

22-24 April 2025

André C. Marta & Afzal Suleman (chairs)

Last update: April 3, 2025



Scientific Committee

https://aerobest2025.idmec.tecnico.ulisboa.pt

Programme Overview

(follow hyperlinks to session details)

Tuesday, April 22nd	
8:20 - 8:45	Registration
8:45 - 9:00	Opening Ceremony
9:00 - 10:00	Keynote Lecture I
	Melike Nikbay, Instanbul Technical University
10:00 - 11:00	SESSION 1 - Design Optimization I
11:00 - 11:20	Coffee Break
11:20 - 13:00	SESSION 2 - Design Optimization II
13:00 - 14:00	Lunch
14:00 - 15:40	SESSION 3 - Multi-Disciplinary Optimization I
15:40 - 16:00	Coffee Break
16:00 - 18:00	SESSION 4 - Discipline Analysis Models I

Wednesday, April 23rd	
9:00 - 10:00	Keynote Lecture II
	Joaquim Martins, University of Michigan
10:00 - 11:00	SESSION 5 - Design Optimization III
11:00 - 11:20	Coffee Break
11:20 - 13:00	SESSION 6 - Design Optimization IV
13:00 - 14:00	Lunch
14:00 - 15:40	SESSION 7 - Multi-Disciplinary Optimization II
15:40 - 16:00	Coffee Break
16:00 - 18:00	SESSION 8 - Discipline Analysis Models II
20:30 - 22:30	Conference Dinner

Thursday, April 24^{th}	
9:00 - 10:00	Keynote Lecture III Anant Grewal, National Research Council of Canada
10:00 - 11:00	SESSION 9 - Systems Engineering and Integration
11:00 - 11:20	Coffee Break
11:20 - 13:00	SESSION 10 - Aerospace Design and Integrated Systems
13:00 - 14:00	Lunch
14:00 - 15:40	SESSION 11 - Multi-Disciplinary Optimization III
15:40 - 16:00	Coffee Break
16:00 - 17:00	SESSION 12 - Multi-Disciplinary Optimization IV
17:00 - 18:00	Keynote Lecture IV Ögmundur Petersson, Airbus Defence and Space
18:00 - 18:15	Closing Ceremony

Keynote Speakers

Melike Nikbay, Istanbul Technical University

Melike Nikbay is a Professor at the Istanbul Technical University, where she heads the Aerospace Multidisciplinary Design Optimization Laboratory. Her research interests include advanced computational design, multidisciplinary analysis and optimization, multi-fidelity modeling, surrogate modeling, machine learning, uncertainty quantification, aeroelasticity and aeroelastic optimization, fluid-structure interaction, sensitivity analysis (direct and adjoint methods), reliability-based design optimization, robust and stochastic optimization, and sonic boom minimization. Dr. Nikbay is the Chair of the Department of Astronautical Engineering since May 2024, and an Executive Board Member of TÜBİTAK's Space Technologies Research Group since 2024.

Prior to her full-time academic career in 2004, Dr. Nikbay served as R&D Leader at multiple industries, was a visiting researcher at the USAF Wright-Patterson Multidisciplinary Science and Technology Center in Ohio, and led a project at NASA Langley Research Center on "The Impact of Aeroelastic Uncertainty on Low Sonic Boom Aircraft Shaping Optimization" as part of the Commercial Supersonic Aircraft Technology program. Dr. Nikbay earned her B.S. (1996) and M.S. (1998) degrees in Mechanical Engineering from Boğaziçi University, Türkiye. She later obtained a second M.S. in Aerospace Engineering from the University of Colorado Boulder, USA, in 1999. In 2002, she completed her Ph.D. under the mentorship of Prof. Charbel Farhat. Dr. Nikbay has been a representative of Türkiye in the NATO Science and Technology Organization (STO) Applied Vehicle Technology (AVT) Panel since 2008, contributing extensively through various leadership roles. She currently serves as a member of the Scientific Committee of the NATO STO AVT Panel, Director of the AVT-385 Research Lecture Series on "Multi-Fidelity Methods for Multidisciplinary Design Optimization," and co-chair of the AVT-411-RSM program on "Machine Learning and Artificial Intelligence for Military Vehicle Design." Since 2010, Dr. Nikbay has also served as an External Expert Evaluator for the European Commission's Clean Sky and EISMEA programs in aviation. Her achievements include recognition as an AIAA Associate Fellow (2017) and prestigious awards, such as the NATO STO "Young Contributor" Award (2016) and the NATO STO "Panel Excellence" Award (2024).

Lecture on Tuesday, April 22nd, at 9:00

Leveraging Multi-Fidelity Surrogates for Advanced Computational Design and Multidisciplinary Design Optimization in Aerospace Engineering

Joaquim Martins, University of Michigan

Joaquim R. R. A. Martins is the Pauline M. Sherman Collegiate Professor of Aerospace Engineering at the University of Michigan, where he heads the Multidisciplinary Design Optimization Laboratory. His research ranges from developing new MDO techniques to applying those techniques to the design of aircraft and other engineering systems. He is a co-author of "Engineering Design Optimization", a textbook published by Cambridge University Press.

Prof. Martins is a Fellow of the American Institute of Aeronautics and Astronautics and a Fellow of the Royal Aeronautical Society. Before joining the University of Michigan faculty in 2009, he was an Associate Professor at the University of Toronto Institute for Aerospace Studies, where from 2002 he held a Tier II Canada Research Chair in Multidisciplinary Optimization. He received his undergraduate degree in Aeronautical Engineering from Imperial College, London, with a British Aerospace Award. He obtained his M.Sc. and Ph.D. degrees from Stanford University, where he was awarded the Ballhaus prize for best thesis in the Department of Aeronautics and Astronautics. He has received the Best Paper Award in AIAA Conferences five times. He was a member of the AIAA MDO Technical Committee (2006–2018) and was the technical co-chair for the 2008 AIAA Multidisciplinary Analysis and Optimization Conference. He has served as Associate Editor for the AIAA Journal, Optimization and Engineering, and Structural and Multidisciplinary Optimization. He is currently an Associate Editor for the Journal of Aircraft.

Lecture on Wednesday, April 23rd, at 9:00

title to be announced

Anant Grewal, National Research Council of Canada

Anant Grewal has been a Research Officer at NRC's Aerospace Research Centre since 1994, apart from the period from 2000 to 2006 when he worked in industry. In 2015, he was promoted to the grade of Principal Research Officer. From 2012 to 2019, Anant assumed the role of Program Leader of the Working and Travelling on Aircraft program at the NRC. In this capacity he led NRC's research program in the area of the aircraft cabin environment, and cabin human factors, health and safety. He continues as the Air Travel Research Focus Area Leader at NRC.

As a Research Officer, he has been leading collaborative R&D and Technical Services projects in the areas of acoustics, structural dynamics, aeroelasticity, multidisciplinary analysis and optimization and smart structures applications with industrial and government partners. In addition to the NRC, Anant also worked as a Senior Designer at Nortel Networks, and as a Defence Scientist with the Canadian Department of National Defence. Anant is currently also an Adjunct Professor at the Toronto Metropolitan University in the Department of Aerospace Engineering. Anant is currently a member of the American Institute of Aeronautics and Astronautics (AIAA) Structural Dynamics Technical Committee, as well as an Associate Fellow of AIAA.

Lecture on Thursday, April 24th, at 9:00

Multidisciplinary Design and Optimization related to Noise and Vibration: 30 years of research at NRC

Ögmundur Petersson, Airbus Defence and Space

Ögmundur is the eXpert for Airframe Multidisciplinary Design Analysis and Optimization at Airbus Defence and Space in Manching, Germany. He is responsible for the development of the in-house multidisciplinary structural optimisation tool Lagrange and the application of MDO to airframe design tasks in both civil and military aircraft programmes including the A350, for which the team received an award for engineering excellence, and within the FCAS project. He has led the activities of Airbus Defence and Space in numerous national and European research projects on the topic of MDO, most recently within the Clean Aviation Joint Undertaking of the European Commission and Industry.

Ögmundur completed his Bachelor's degree in Mechanical Engineering from the University of Iceland and Master's degree at the Technische Universität München in Germany before joining Airbus Defence and Space where he has since worked in the team for Stress Methods and Optimization within the Airframe Centre of Competence. Current research topics focus mostly on the creation of coupled digital design platforms, leveraging optimisation techniques, existing capabilities in disciplinary analysis and recent advances in sensitivity analysis to enable efficient design of coupled systems.

Lecture on Thrusday, April 24th, at 17:00

Applying MDO to Aircraft Structural Design at Airbus Defence and Space; from Punch Cards to Digital Twins

Conference Sessions

(follow hyperlinks to manuscript details)

Notice to presenters (underlined): 20-minute presentation slots, including Q&A

Tuesday, April 22nd

Session 1 - 10:00-11:00

Design Optimization I Chair: tba				
time	ID	Title	Authors	Affiliation
10:00	52	MULTI-OBJECTIVE AERODYNAMIC DESIGN OPTIMIZATION USING GRADIENT-ENHANCED SURROGATE MODELING	Emre Özkaya, Long Chen and Nicolas R. Gauger	University of Kaiserslautern-Landau (RPTU)
10:20	96	COMPARISON OF CONSTRAINT MANAGEMENT STRATEGIES FOR HIGH DIMENSIONAL BAYESIAN OPTIMISATION USING CLUSTERED ACTIVE SUBSPACES	Maxime Chapron and Michel Bergmann	ONERA, Institut Polytechnique de Paris
10:40	10(	MULTI-FIDELITY BAYESIAN OPTIMIZATION FOR AEROSPACE ENGINEERING DESIGN	Sihmehmet Yildiz and Melike Nikbay	Istanbul Technical University

Session 2 - 11:20-13:00

Design Optimization II Chair: tba				
time	ID	Title	Authors	Affiliation
11:20	47	SHAPE OPTIMIZATION OF AUXETIC UNIT CELLS UNDER DYNAMIC LOADING IN MACROSCOPIC COMPONENTS	Nicolas Grünfelder, Lars Kälber, Navina Waschinsky and Tim Ricken	University of Stuttgart
11:40	58	AERODYNAMIC SHAPE OPTIMIZATION OF RAE-2822 AIRFOIL BY PHYSICS-INFORMED PARAMETRIC MODEL EMBEDDING	Damiano Squillace, Umberto Iemma, Domenico Quagliarella, Matteo Diez and Andrea Serani	Università Roma tre & Italian Aerospace Research Centre & Institute of Marine Engineering
12:00	60	OPTIMAL WING FOR LONG ENDURANCE UAV APPLICATIONS	Abhiyan Paudel, Sharanjeet Kaur, Nikhil Vijay Shende and N. Balakrishnan	Indian Institute of Science & S&I Engineering Solutions
12:20	64	DEFORMATION STRATEGIES IN FUSELAGE AERODYNAMIC SHAPE OPTIMIZATION USING PAYLOAD VOLUME CONSTRAINTS	Luís D. Pinheiro, Nuno M. B. Matos and André C. Marta	Tekever UAS & Universidade de Lisboa
12:40	74	OPTIMIZING UAV WINGLETS: A MULTIOBJECTIVE APPROACH WITH SURROGATE MODELS	M. Almutairi, P. Dunning and A. Maheri	University of Aberdeen

Session 3 - 14:00-15:40

time	ID	Title	Authors	Affiliation
		Multi-Disciplinary Optimization I Chair: tba		
14:00	54	MULTIDISCIPLINARY DESIGN AND OPTIMIZATION OF STRUT-BRACED HYBRID-ELECTRIC AIRCRAFT UNDER MULTI-TRAJECTORY SCENARIOS	Pablo Norczyk Simon and Rauno Cavallaro	Barcelona Supercomputing Centre & Universidad Carlos III de Madrid
14:20	59	GREEN AVIATION MANUFACTURING: ADDRESSING ENVIRONMENTAL IMPACTS WITH MDO METHODOLOGIES	Shantanu Sapre, Joseph Morlier and Christian Gogu	ISAE-SUPAERO & ICA
14:40	63	HIGH-FIDELITY MULTI-DISCIPLINARY OPTIMISATION PROCESSES FOR SOLVING AERO-STRUCTURE PROBLEMS: RECENT DEVELOPMENTS FROM AN INDUSTRIAL PERSPECTIVE	Joel Brezillon, Imane Fadli, Kittinan Thanissaranon and Cian Conlan-Smith	Airbus Operations
15:00	99	MULTIDISCIPLINARY DESIGN OPTIMIZATION OF NONPLANAR LIFTING SYSTEMS FOR UNMANNED COMBAT AERIAL VEHICLES	Hassan Aleisa, Berkay Pirlepeli, Sihmehmet Yildiz, Konstantinos Kontis and Melike Nikbay	University of Glasgow & Istanbul Technical University
15:20	103	AIRCRAFT WING STRUCTURAL SIZING COMPUTATIONAL TOOL TAILORED FOR A COLLABORATIVE MULTIDISCIPLINARY DESIGN FRAMEWORK	Pedro F. Albuquerque, Ana M. P. Silva and André N. Pereira	CEiiA

Session 4 - 16:00-18:00

time	ID	Title	Authors	Affiliation
		Discipline Analysis Models I Chair: tba		
16:00	48	BENCHMARKING SURROGATE MODELS OF VARIABLE FIDELITY FOR THE DRAG COEFFICIENT PREDICTIONS OF AIRFOIL AERODYNAMICS WITH DIFFERENT AIRFOIL PARAMETRIZATION TECHNIQUES	Ivo Zell, Maurice Zimmnau and Eike Stumpf	RWTH Aachen University
16:20	49	ON THE AEROACOUSTIC FEEDBACK LOOP IN SUPERSONIC IMPINGING JETS	António Rebelo, Maxime Fiore and Fernando Lau	Universidade de Lisboa & ISAE-SUPAERO
16:40	50	INVESTIGATING THE INFLUENCE OF A TIP PROPELLER'S VERTICAL OFFSET ON A TRAILING WING'S LIFT AND DRAG DISTRIBUTIONS	Gustavo Padovany da Silva, Shamsheer S. Chauhan, Gustavo L. O. Halila, Joaquim R. R. A. Martins and João Luiz F. Azevedo	Pontifícia Universidade Católica do Paraná & University of Michigan & Instituto de Aeronáutica e Espaço
17:00	51	MISSION-INFORMED SAMPLING STRATEGY FOR AN AERODYNAMIC MULTI-FIDELITY SURROGATE MODEL	Maurice Zimmnau and Eike Stumpf	RWTH Aachen University
17:20	80	HIGH-FIDELITY NUMERICAL INVESTIGATIONS OF FOLDING WINGTIPS ON HIGH ASPECT RATIO WINGS	Pranesh Chandrasekaran, Emre Güler and Melike Nikbay	Istanbul Technical University
17:40	91	SMART WING DYNAMIC STALL	Reza Moosavi	University of Hertfordshire

Wednesday, April 23rd

Session 5 - 10:00-11:00

time	ID	Title	Authors	Affiliation
		Design Optimization III Chair: tba		
10:00	75	A VELOCITY-FIELD LEVEL-SET BASED TOPOLOGY OPTIMIZATION OF STRUCTURES SUBJECTED TO AEROTHERMODYNAMICS LOADS	Apoorva Kanti, Pankil N. Mishra and Abhijit Gogulapati	Indian Institute of Technology Bombay
10:20	77	DESIGN OF ENERGY ABSORBING STRUCTURES UNDER IMPACT LOADING USING TOPOLOGY OPTIMIZATION INCORPORATING PATH-DEPENDENT SENSITIVITY ANALYSIS	Bhanu Pratap Sharma, Pankil Narendra Mishra and Abhijit Gogulapati	Indian Institute of Technology Bombay
10:40	94	COLLABORATIVE TOPOLOGY AND FIBER ORIENTATION OPTIMIZATION SIMPLIFIED VIA MULTI-RESOLUTION ANISOTROPY REPRESENTATION	Shuya Nozawa and Gokhan Serhat	KU Leuven

Session 6 - 11:20-13:00

time	ID	Title	Authors	Affiliation
		Design Optimization IV Chair: tba		
11:20	57	CALIBRATION OF TRANSITIONAL MODEL FOR LOW REYNOLDS NUMBER FLOWS AT HIGH ANGLES OF ATTACK USING SURROGATE-BASED OPTIMIZATION FRAMEWORK	Pranesh Chandrasekaran, Dilan Kilic and Melike Nikbay	Istanbul Technical University
11:40	69	STATISTICAL ANALYSIS OF THE ROBUSTNESS OF OPTIMALLY DESIGNED LATTICE STRUCTURES	Geethesh Naiyyalga and Amuthan A. Ramabathiran	Indian Institute of Technology Bombay & California Polytechnic State University
12:00	70	PRECONDITIONING TECHNIQUES FOR GENERAL CONSTRAINED OPTIMIZATION PROBLEMS: APPLICATION TO INDUSTRIAL AEROSPACE COMPONENT DESIGN	Shouvik Bandopadhyay, François Gallard and Simone Coniglio	IRT Antoine de Saint Exupéry
12:20	73	MULTI-PATCH HYBRID OPTIMIZATION OF COMPOSITE WINGS	D. Zamani, A. Pagani, M. Petrolo and E. Carrera	Politecnico di Torino
12:40	87	DEEP LEARNING-BASED FLOW FIELD RECONSTRUCTION FOR M219 CAVITY FLOW	Berkay Pirlepeli, Burak Berkan Bedir and Melike Nikbay	Istanbul Technical University

Session 7 - 14:00-15:40

Multi-Disciplinary Optimization II Chair: tba				
time	ID	Title	Authors	Affiliation
14:00	43	IMPACT OF ADOPTING ACTIVE FLUTTER SUPPRESSION SYSTEMS ON THE OPTIMIZATION OF A TYPICAL LONG-RANGE TRANSPORT AIRCRAFT	Elena Roncolini, Francesco Toffol and Sergio Ricci	Politecnico di Milano
14:20	44	A COMPARISON OF MDO BI-LEVEL FORMULATION VARIANTS WITH MDF ON A HIGH-FIDELITY AEROELASTIC WING TEST CASE	Gilberto Ruiz Jimenez, Nicolas Roussouly, François Gallard, Anne Gazaix, Joël Brezillon, Kittinan Thanissaranon, Vida Brück and Joaquim R.R.A. Martins	IRT Saint-Exupéry & Airbus S.A.S. & University of Michigan
14:40	45	AEROSTRUCTURAL OPTIMIZATION OF HIGH-ASPECT-RATIO WINGS: NAVIGATING COMPLEX TRADE-OFFS	Ousmane Sy, Joseph Morlier and Emmanuel Benard	ISAE-SUPAERO & ICA
15:00	66	EFFICIENT GRADIENT-BASED STRUCTURAL OPTIMISATION WITH MODAL AND BUCKLING CONSTRAINTS ASSISTED BY ALGORITHMIC DIFFERENTIATION	Luca Scalia, Rauno Cavallaro, Andrea Cini, Nicolas R. Gauger and Max Sagebaum	Universidad Carlos III de Madrid & University of Kaiserdlautern-Landau (RPTU)
15:20	71	HIGH ASPECT-RATIO COMPOSITE WING AEROSTRUCTURAL OPTIMISATION OF A SHORT-MEDIUM RANGE AIRCRAFT	Luís M. M. Pacheco, Fabian Volle, Ögmundur Petersson and André C. Marta	Universidade de Lisboa & Airbus Defence and Space & DLR

Session 8 - 16:00-18:00

		Discipline Analysis Models II Chair: tba		
time	ID	Title	Authors	Affiliation
16:00	55	EXPLOITING POST-BUCKLING NONLINEARITIES FOR GUST LOAD REDUCTION IN HIGH ASPECT-RATIO AIRCRAFT WINGS	Pedro Farinha, Francesco Toffol and Chiara Bisagni	Universidade de Lisboa & Politecnico di Milano
16:20	61	SOLVING NONLINEAR PERIODIC AEROELASTIC SYSTEMS USING BOUNDARY VALUE FORMULATION AND CONFORMAL MAPPING	Anshuman Mehta, Pankil N. Mishra and Abhijit Gogulapati	Indian Institute of Technology Bombay
16:40	68	PRELIMINARY NUMERICAL AND EXPERIMENTAL COMPARISON OF TWO TYPES OF PLA BCC LATTICE STRUCTURES MANUFACTURED VIA FDM AND SUBJECTED TO IMPACT TESTING	G. Iacolino, C. Orlando, D. Tumino, G. Catalanotti, E.V. González, G. Mantegna and A. Alaimo	Kore University of Enna & Universitat de Girona
17:00	85	EXTENSION OF THE TWIST-KIRCHHOFF ELEMENTS TO THE BUCKLING ANALYSIS OF PLATES	Hugo A.F.A. Santos and Thomas J.R. Hughes	Instituto Politécnico de Lisboa & University of Texas
17:20	90	INVERSE ESTIMATION METHOD FOR THE CHARACTERISATION OF ELASTIC PROPERTIES OF ANISOTROPIC OPEN-CELL MATERIALS	Huina Mao, Xuefeng Li, Gunnar Tibert and Romain Rumpler	KTH Royal Institute of Technology
17:40	97	OPTIMIZING TRANSITION PROFILES FOR TAILSITTER UAVS: A GRADIENT DESCENT APPROACH	Alexandre Athayde, Alexandra Moutinho and José Raúl Azinheira	Universidade de Lisboa

Thursday, April 24^{th}

Session 9 - 10:00-11:00

Systems Engineering and Integration Chair: tba				
time	ID	Title	Authors	Affiliation
10:00	53	MAGNETIC-ANOMALY POSITIONING FOR GNSS-INDEPENDENT UAV NAVIGATION	D. Pisarski, R. Faraj, L. Jankowski, B. Pop lawski and R. Konowrocki	Polish Academy of Sciences
10:20	95	ASSESSING WIND EFFECTS ON THE OPTIMAL TRAJECTORIES OF EXTENDED FORMATION FLIGHTS IN COMMERCIAL AVIATION	M. Cerezo-Magaña	Universidad Carlos III de Madrid
10:40	101	OBSTACLE AVOIDANCE FOR FIXED-WING AIRCRAFT BY USING CONTROL BARRIER FUNCTIONS	Huriye Nur Toprak and Emre Koyuncu	Istanbul Technical University

Session 10 - 11:20-13:00

Aerospace Design and Integrated Systems Chair: tba				
time	ID	Title	Authors	Affiliation
11:20	56	EXPLORING COUPLING EFFECTS BETWEEN AIRFRAME AND PROPULSION IN PARAMETRIC MODELS FOR ELECTRIC REGIONAL AIRCRAFT WITH RANGE EXTENDER	Didier Brousset-Matheu, Eric Nguyen Van, Sebastien Defoort, Xavier Roboam and Bruno Sareni	DTIS & ONERA & ISAE-SUPAERO & Université de Toulouse
11:40	78	HYDROGEN-POWERED AIRCRAFT DESIGN: A MULTIDISCIPLINARY APPROACH TO MINIMIZE EMISSIONS AND COST	Raúl Quibén Figueroa, Rauno Cavallaro, Andrea Cini1 and Manuel Soler Arnedo	Universidad Carlos III de Madrid
12:00	79	EFFECTS OF TRAILING EDGE MODIFICATIONS ON NEGATIVE LIFT CHARACTERISTICS OF SYMMETRICAL AIRFOILS AT TRANSITIONAL LOW REYNOLDS NUMBERS	Pranesh Chandrasekaran, Emre Güler and Melike Nikbay	Istanbul Technical University
12:20	93	DESIGN OPTIMIZATION OF ELASTOMER MOUNTS TO ASSESS WHIRL FLUTTER PHENOMENON IN A WIND TUNNEL	A. Fereidooni, E. Chen, A. Grewal, V. Wickramasinghe and A. Ben amar	National Research Council Canada
12:40	10[illegible]	AEROELASTIC MODELING AND DESIGN OF A FLEXIBLE BLENDED-WING-BODY (BWB) RESEARCH VEHICLE	Mario Bras, Sid Banerjee and Afzal Suleman	University of Victoria & Bombardier & Universidade de Lisboa

Session 11 - 14:00-15:40

Multi-Disciplinary Optimization III Chair: tba				
time	ID	Title	Authors	Affiliation
14:00	62	FREQUENCY-AWARE SURROGATE MODELING WITH SMT KERNELS FOR ADVANCED DATA FORECASTING	N. Gonel, P. Saves and J. Morlier	ISAE-SUPAERO & ONERA & IFP Energies nouvelles & IRIT & ICA
14:20	67	AN MDAO FRAMEWORK APPROACH EXTENDED TO UNSTEADY MULTIPHYSICS: KEY INGREDIENTS AND EXAMPLES	Florian Roß, Simon Ehrmanntraut, Constantin Höing, Sebastian Gottfried and Arthur Stück	German Aerospace Center (DLR)
14:40	72	DATA-DRIVEN ACCELERATION OF MULTIDISCIPLINARY SIMULATIONS FOR MULTI-QUERY APPLICATIONS IN AEROSPACE ENGINEERING	Susanna Baars and Ulrich Römer	Technische Universität Braunschweig
15:00	76	TOWARD DISTRIBUTED AND SCALABLE MULTIDISCIPLINARY OPTIMIZATION WITH GEMSEO	Jean-Christophe Giret, François Gallard, Antoine Dechaume, Jérôme Fasquel, Jean-François Figué and Anne Gazaix	IRT Saint Exupéry
15:20	82	AEROACOUSTIC SENSITIVITY ANALYSIS OF GEOMETRICAL PARAMETERS FOR OPEN-CAVITY FLOWS	Ramazan Kaba and Melike Nikbay	Turkish Aerospace & Istanbul Technical University

Session 12 - 16:00-17:00

Multi-Disciplinary Optimization IV Chair: André Marta, Instituto Superior Técnico				
time	ID	Title	Authors	Affiliation
16:00	46	DEVELOPMENT OF A SOUNDING ROCKET MULTIDISCIPLINARY PRELIMINARY DESIGN OPTIMISATION FRAMEWORK WITH TRAJECTORY OPTIMISATION	Alexandre M. Palaio, André C. Marta and Paulo J. S. Gil	Força Aérea Portuguesa & Universidade de Lisboa
16:20	88	A STUDY ON THE MULTIDISCIPLINARY DESIGN OPTIMIZATION OF HYBRID-ROCKET PROPULSION	Joana Matos, Frederico Afonso, Girolamo Musso, Iara Figueiras, Alain Souza, Inês Ribeiro, Fernando Lau and Joseph Morlier	Universidade de Lisboa & ICA & ISAE-SUPAERO
16:40	92	MULTI-OBJECTIVE SURROGATE-BASED OPTIMISATION OF ROCKET FIN DESIGN	José Silva, Frederico Afonso and Fernando Lau	Universidade de Lisboa

Abstracts

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Lisboa, 22-24 April 2025

IMPACT OF ADOPTING ACTIVE FLUTTER SUPPRESSION SYSTEMS ON THE OPTIMIZATION OF A TYPICAL LONG-RANGE TRANSPORT AIRCRAFT

Elena Roncolini, Francesco Toffol and Sergio Ricci

Department of Aerospace Science and Technology
Politecnico di Milano
Via La Masa, 34 – 20156 Milan
elena.roncolini@polimi.it, https://www.aero.polimi.it/it

Abstract *The increasing pressure to reduce the environmental impact of future aircraft is driving the adoption of more innovative aerostructural solutions, such as unconventional configurations and the use of active control systems to ensure high overall efficiency across the entire flight envelope. Implementing high aspect ratio wings to decrease induced drag, which are generally more flexible, requires advanced active control systems to mitigate potential aeroelastic issues. Active Wing Control systems are likely to be integrated with technologies currently utilized in existing fly-by-wire control systems. However, Active Flutter Suppression systems (AFS) are relatively new, although with a long history behind them, and their expected performance and technical feasibility need to be evaluated in terms of safety, robustness, and reliability. Despite this, two aircraft with AWC have been certified under special conditions: the B747-800 and the B787-10, highlighting the necessity for further investigation into the adoption and certification of these systems. Setting aside the intricate certification considerations, a key design question remains: assuming stability can be assured with suitable AFS systems, what potential weight savings could be achieved by designing the structure without the explicit constraint of a minimum flutter velocity requirement? This paper focuses on a generic long-range, twin-aisle transport aircraft and presents comparisons based on optimizing the wing structure with various design constraints, including or excluding the flutter constraint, to draw general conclusions.*

Keywords: Active Flutter Suppression (AFS), aeroelastic optimization

AeroBest 2025
Lisboa, 22–24 April 2025

A COMPARISON OF MDO BI-LEVEL FORMULATION VARIANTS WITH MDF ON A HIGH-FIDELITY AEROELASTIC WING TEST CASE

Gilberto Ruiz Jimenez[1*], Nicolas Roussouly[1], François Gallard[1], Anne Gazaix[1,2], Joël Brezillon[2], Kittinan Thanissaranon[2], Vida Brück[2] and Joaquim R.R.A. Martins[3]

1: IRT Saint-Exupéry
{gilberto.ruiz-j,nicolas.roussouly,francois.gallard,anne.gazaix}@irt-saintexupery.com

2: Airbus S.A.S.
{joel.brezillon,kittinan.thanissaranon,vida.brueck, anne.gazaix}@airbus.com

3: University of Michigan
jrram@umich.edu

Abstract. *In multidisciplinary design optimization (MDO), the selection of the formulation (or architecture) constitutes a critical aspect for industrial applications. While the MDF formulation has been successfully applied to various cases, its usage in a large-scale industrial context using segmented numerical software is limited. Consequently, distributed formulations are actively investigated by industrial actors as better adapted candidates. In particular, several variants of bi-level formulations have been recently developed to address use cases where the number of shared design variables is moderate, the number of coupling variables is large, and when the Jacobians of the disciplines are partially available. The bi-level IRT formulation was originally developed to take advantage of gradient-based disciplinary optimizations within an MDO process. To this end, the disciplinary optimizations are embedded within a system optimization that handles the shared variables using a gradient-free optimizer. Two multidisciplinary analysis (MDA) are utilized before and after the sub-optimizations to satisfy the high-dimensional couplings. However, the separation of the disciplinary optimizations can result in convergence degradation. The bi-level block coordinate descent (BCD) formulation has been proposed as an enhancement, offering more robust mathematical foundations, to overcome this issue by using the BCD algorithm, which iterates on the disciplinary optimizations. This paper presents a comparison of the bi-level IRT and the bi-level BCD formulations with MDF as a reference, on an aeroelastic aircraft wing model, using RANS CFD and computational solid mechanics (CSM) solvers. The MACH framework is selected because it has a state of the art MDF implementation with the coupled adjoint. The comparison highlights the merits and limitations of the bi-level formulations with respect to performance and accuracy. Encouraging results were obtained with the IRT bi-level formulation although a lack of robustness was observed with respect to the initial point of the optimization, the BCD enhancement handles this discrepancy at the expense of computational cost.*

Keywords: Multidisciplinary design optimization, bi-level, multidisciplinary feasible, block coordinate descent, aerostructural optimization

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AEROSTRUCTURAL OPTIMIZATION OF HIGH-ASPECT-RATIO WINGS: NAVIGATING COMPLEX TRADE-OFFS

Ousmane Sy[1,2*], Joseph Morlier[2] Emmanuel Benard [1]

1: Fédération ENAC ISAE-SUPAERO ONERA
Université de Toulouse
31400 Toulouse,France
ousmane.sy2@isae-supaero.fr, emmanuel.benard@isae-supaero.fr

2: ICA, ISAE-SUPAERO, MINES ALBI, UPS, INSA, CNRS
Université de Toulouse
Toulouse, France
joseph.morlier@isae-supaero.fr

Abstract. *A promising innovation path in aircraft design aimed at improving fuel efficiency and reducing emissions is the adoption of concepts featuring increased wing aspect ratios. This study investigates the aerostructural optimization of high aspect ratio (HAR) wings using the uCRM-13.5 benchmark and the OpenAeroStruct framework. The impact of model fidelity, objective metrics, analysis methods, and material selection on optimal wing design is examined. Results showed that neglecting viscous and compressibility effects leads to unrealistic designs, with fuel burn underestimated by up to 45%. Mid-fidelity models, which combine a vortex lattice method-based aerodynamic model with estimations of viscous and compressibility drag, and a 1D beam finite element structural model, achieve results within 6% for fuel burn and 4.85% for wing weight compared to high fidelity models, while reducing computational time by over 97%. Objective metric selection was found to significantly influence the optimum design. Pareto fronts analysis revealed that extreme weighting cause disproportionate trade-offs between fuel burn, structural weight and take-off gross weight (TOGW). For instance, a 0.6% improvement in structural weight led to a 21.28% increase in fuel burn, while a 0.17% improvement in TOGW came with a 2.26% increase in fuel burn. Optimal designs lie between these extremes, balancing direct operating, manufacturing and acquisition costs. Different analysis methods were evaluated across mission ranges. While single- and multi-point approaches performed adequately for long-range missions, they underestimated fuel burn by up to 50% for short missions. The sequential method, which includes the climb phase, offered more accurate fuel predictions at lower computational cost compared to the multi-point method.Material exploration showed that switching from aluminium to composite materials reduced fuel burn and structural weight by 18% and 13%, respectively, for fuel burn-focused design and 31% and 2.24%, respectively, for structural weight focused design. However, this improvement comes at the cost of increased* CO_2 *emissions from material manufacturing.*

Keywords: Aircraft design, High aspect ratio wings, MDO, Aerostructural optimization

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DEVELOPMENT OF A SOUNDING ROCKET MULTIDISCIPLINARY PRELIMINARY DESIGN OPTIMISATION FRAMEWORK WITH TRAJECTORY OPTIMISATION

Palaio, A. M.[1*], Marta, A. C.[2] and Gil, P. J. S.[2]

1: Academia da Força Aérea
Força Aérea Portuguesa
Granja do Marquês , 2715-021, Sintra, Portugal
ampalaio@academiafa.edu.pt, https://academiafa.edu.pt/

2: IDMEC, Instituto Superior Técnico
Universidade de Lisboa
Av. Rovisco Pais 1, 1049-001, Lisboa, Portugal
{andre.marta, paulo.gil}@tecnico.ulisboa.pt, https://mdo.tecnico.ulisboa.pt/

Abstract. *The design of rockets is known to be a complex task, not only due to the harsh operating conditions but also the strong coupling among disciplines. A multidisciplinary optimisation (MDO) framework was developed, aimed at providing preliminary designs of a single-stage solid propellant rocket. The choice of the optimiser algorithm, MDO architecture and discipline models, namely, mass and sizing, flight dynamics, aerodynamics, propulsion, structural and atmospheric, were such that the developed numerical tool has a very low computational cost while being able to meet a set of pre-established mission requirements. The resulting design framework solved a co-design optimisation problem, due to the coupling between the trajectory and rocket sizing optimization processes. The capabilities of the design framework were tested for different sets of design variables and multiple missions, with increasing complexity, for an optimisation problem aimed at minimizing the total mass of the rocket while imposing a minimum altitude constraint, with a prescribed payload capacity. First, studies with up to 10 geometric design variables showed that the latter were capable of achieving the best results, as expected. Then, sensitivity studies of the payload and the minimum altitude confirmed that the rocket sizing is greatly impacted by both. Lastly, comparisons with real rockets, namely, the REXUS 2 and REXUS 10, showed very good agreement, achieving a total mass reduction of 14.5% and 14.9%, respectively. Given the great modularity of the framework, a straightforward extension to other types of rockets, such as multi-stage or liquid-propellant, is expected upon additional development.*

Keywords: MDO, Trajectory, Co-design, Sounding Rocket, Modularity

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SHAPE OPTIMIZATION OF AUXETIC UNIT CELLS UNDER DYNAMIC LOADING IN MACROSCOPIC COMPONENTS

Nicolas Grünfelder[1]*, Lars Kälber[1] , Navina Waschinsky[1] and Tim Ricken[1]

1: Institute of Structural Mechanics and Dynamics in Aerospace Engineering (ISD)
Faculty for Aerospace Engineering and Geodesy
University of Stuttgart
70569
nicolas.gruenfelder@isd.uni-stuttgart.de, https://www.isd.uni-stuttgart.de/

Abstract. *Auxetic metamaterials, characterized by their negative Poisson's ratio, exhibit unique mechanical properties such as enhanced energy dissipation, improved vibration damping, and superior energy absorption. These properties make them particularly attractive for aerospace applications, where lightweight and high-performance structures are crucial. However, integrating auxetic structures into macroscopic components remains challenging due to the complex interplay between mesostructural design and overall structural behavior. This study introduces an optimization methodology that enables independent shape adjustments of auxetic mesostructures within different regions of a macroscopic component. Using a Bayesian optimization algorithm, the unit cell geometry is optimized to maximize energy dissipation, enhance dynamic stiffness, and minimize mass, ensuring a well-balanced trade-off between these competing objectives. A macroscopic cantilever beam composed of reentrant auxetic unit cells serves as a real-world-inspired case study and is analyzed under dynamic loading conditions, demonstrating the effectiveness of the optimized mesostructure in improving structural performance. Beyond the optimized structure itself, this study provides an in-depth analysis of the optimization process, offering valuable insights into the application of auxetic metamaterials in engineering practice. Additionally, a mesh convergence study is conducted to validate numerical accuracy. The results underscore the potential of auxetic metamaterials for aerospace applications, highlighting their performance-driven optimization and real-world applicability.*

Keywords: Auxetics, Shape Optimization, Bayesian Optimization, Lightweight, Energy Dissipation, Aerospace

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BENCHMARKING SURROGATE MODELS OF VARIABLE FIDELITY FOR THE DRAG COEFFICIENT PREDICTIONS OF AIRFOIL AERODYNAMICS WITH DIFFERENT AIRFOIL PARAMETRIZATION TECHNIQUES

Ivo Zell, Maurice Zimmnau, Eike Stumpf

Institute of Aerospace Systems
RWTH Aachen University
Wuellnerstrasse 7, 52062 Aachen, Germany
ivo.zell@rwth-aachen.de, zimmnau@ilr.rwth-aachen.de, stumpf@ilr.rwth-aachen.de

Abstract. *This contribution examines various existing surrogate models, including variable-fidelity models, to evaluate their suitability within the conceptual aircraft design, and compares them against one another. The drag coefficient calculation for two-dimensional airfoil sections serves as a benchmark. The benchmarking framework developed includes the integration of sampling strategies, automatic generation of modified airfoils, and calculation of the training datasets for surrogate model training. The geometric representation of airfoils is achieved through the parametrizations PARSEC and NURBS, offering varying levels of input dimensionality. Low-fidelity (LF) data is computed using xFoil, while higher-fidelity (HF) data and test datapoints are generated with MSES. The Surrogate Modeling Toolbox (SMT) is used to analyze different types of surrogate models. In addition to single-fidelity models, three types of variable-fidelity models are tested. Training datasets contain up to 8,192 data points with 8 to 23 input variables and the drag coefficient as target variable. The models are assessed based on prediction error, training time, and memory usage. The results reveal significant trends in surrogate model performance across different dataset sizes and configurations. For smaller training datasets, the Kriging model exhibits the highest accuracy, while Artificial Neural Networks deliver the lowest prediction error for larger datasets. Among variable-fidelity models, the direct incorporation of LF data as a mean function of the surrogate model achieves the lowest error for small (8-64 points) HF datasets, making them ideal for applications where HF data is sparse or expensive to generate. For medium-sized datasets (128–512 points), Co-Kriging achieves the best results. In cases with large datasets (1,024–8,192 points), single-fidelity ANN models provide the lowest prediction errors. The study also shows that LF data can be used to reduce complexity and therefore allow easier surrogate model building when the underlying correlation structure of the data is suitable for the model.*

Keywords: Surrogate models, Machine Learning, Kriging, Artificial Neural Network, NURBS, PARSEC

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ON THE AEROACOUSTIC FEEDBACK LOOP IN SUPERSONIC IMPINGING JETS

António Rebelo[†1], Maxime Fiore[‡2] and Fernando Lau[†3]

†: Instituto Superior Técnico
Universidade de Lisboa
1049-001 Lisboa, Portugal

‡: ISAE-SUPAERO
Université de Toulouse
31055 Toulouse, France

Abstract. *An Aeroacoustic Feedback Loop (AFL) generates intense tonal noise in supersonic impinging jet flows, potentially impacting the integrity of structures, noise emissions and even aircraft performance. This work investigates the AFL closure mechanism by analysing wave propagation data through a numerical model and a stability simulation of the supersonic jet column, aiming to identify the wave mode responsible for closing the feedback loop. A two-stage methodology is applied: first, a one-dimensional jet containing a mixing region is modelled by coupling a differential equation with an analytical far-field solution, reformulating the problem as an Initial Value Problem. Second, a biglobal (2D) stability analysis using an in-house Finite Element Method solver, adapted for compressible jet flows, is performed on an analytical 2D jet flow, with wave mode stability examined through a complete post-processing framework that identifies upstream and downstream-propagating jet modes. Results confirm that upstream-propagating modes responsible for AFL closure (so-called "closing modes") are guided by the jet rather than propagating purely in the quiescent medium or within the jet column. Stability analysis reveals the presence of a high number of unstable eigenvalues, attributed to boundary condition artefacts, indicating the need for an update on the simulation's numerical setup. The predicted frequency ranges for the closing modes align well with experimental data, supporting the validity of the approach.*

Keywords: Aeroacoustics, Aeroacoustic Feedback Loop, Supersonic Jet, Global Stability Analysis and Jet Column Modelling.

[1]Master in Aerospace Engineering; antonio.rebelo@tecnico.ulisboa.pt

[2]Associate Professor at *Département Aérodynamique, Énergétique et Propulsion* (DAEP); maxime.fiore@isae-supaero.fr

[3]Associate Professor at *Centro de Ciências e Tecnologias Aeronáuticas e Espaciais* (CCTAE); lau@tecnico.ulisboa.pt

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INVESTIGATING THE INFLUENCE OF A TIP PROPELLER'S VERTICAL OFFSET ON A TRAILING WING'S LIFT AND DRAG DISTRIBUTIONS

Gustavo Padovany da Silva[1], Shamsheer S. Chauhan[2], Gustavo L. O. Halila[1*], Joaquim R. R. A. Martins[2], and João Luiz F. Azevedo [3]

1: Mechanical Engineering Graduate Program (PPGEM)
Pontifícia Universidade Católica do Paraná (PUCPR)
Curitiba, PR, Brazil
guspadovany@gmail.com
*gustavo.halila@pucpr.br

2: Department of Aerospace Engineering
University of Michigan
Ann Arbor, MI, USA
{sschau,jrram}@umich.edu

3: Instituto de Aeronáutica e Espaço
São José dos Campos, SP, Brazil
joaoluiz.azevedo@gmail.com

Abstract. *Wingtip-mounted tractor propeller configurations are receiving attention across the aerospace industry because of their aerodynamic benefits. However, results displaying spanwise lift and drag variations due to changes in the propeller-wing vertical offset for such configurations are scarce in the literature. In this paper, we investigate the changes in a rectangular wing's spanwise lift and drag coefficient distributions by varying the propeller-wing vertical offset of a wingtip propeller. For this, we perform steady Reynolds-averaged Navier–Stokes computational fluid dynamics simulations using the open-source flow solver ADflow with the Spalart–Allmaras turbulence model and an actuator-disk approach. We present results for two angles of attack with a range of propeller-wing vertical offsets for both inboard-up and outboard-up propeller rotation. We include plots for spanwise lift and drag coefficient distributions, integrated lift and drag coefficients, and lift-to-drag ratios. Our results show that changing the propeller-wing vertical offset can significantly change a trailing wing's lift and drag distributions, which strongly depend on the direction of the vertical offset. Additionally, this work paves the way for further studies that benefit from ADflow's efficient gradient-computation capabilities.*

Keywords: Propeller-wing interference, propeller-wing integration, distributed propulsion

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MISSION-INFORMED SAMPLING STRATEGY FOR AN AERODYNAMIC MULTI-FIDELITY SURROGATE MODEL

Maurice Zimmnau, Eike Stumpf

Institute of Aerospace Systems
RWTH Aachen University
Wuellnerstrasse 7, 52062 Aachen, Germany
zimmnau@ilr.rwth-aachen.de, stumpf@ilr.rwth-aachen.de

Abstract. *In this contribution an adaptive sampling strategy for surrogate models based on Gaussian process regression for expensive to evaluate aerodynamic predictions is presented. In contrast to off-the-shelf adaptive sampling strategies such as expected improvement, which use statistics from the Gaussian process and function evaluation values, this strategy incorporates information from the conceptual aircraft design process, i.e. the mission simulation. Relative frequencies of the flight conditions are collected from the mission information and a kernel density estimation is performed. The kernel density estimate as well as the posterior standard deviation of the Gaussian process are used to select the next sample location. The objective of this strategy is not to find an optimum, but to enhance the accuracy of the surrogate model at locations of interest. The sampling strategy is compared to common adaptive sampling strategies. Effects of the hyper parameter choice of the Gaussian process on the predicted sample locations are analyzed. Different methods for the bandwidth choice for the kernel density estimate are evaluated. Applicability, limitations and potential stopping criteria are investigated in detail. A special focus lies on the cases, where the optima of the kernel density estimate are located at the boundary of the design space.*

Keywords: Gaussian process regression, surrogate models, multi-fidelity, aerodynamics, conceptual aircraft design

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MULTI-OBJECTIVE AERODYNAMIC DESIGN OPTIMIZATION USING GRADIENT-ENHANCED SURROGATE MODELING

Emre Özkaya, Long Chen and Nicolas R. Gauger

Chair for Scientific Computing
University of Kaiserslautern-Landau (RPTU)
Paul-Ehrlich-Strasse 34
67663 Kaiserslautern, Germany
emre.oezkaya, long.chen, nicolas.gauger@scicomp.uni-kl.de, https://scicomp.rptu.de/

Abstract. *We present a multi-objective Bayesian optimization framework that integrates a derivative-enhanced Gaussian Process Regression surrogate model to efficiently explore the Pareto front in aerodynamic design problems. The framework leverages gradient-enhanced surrogate modeling to incorporate arbitrary directional derivatives of multiple objective functions alongside their functional values, significantly improving prediction accuracy and model fidelity. By effectively capturing the underlying trends in the design space, this approach mitigates the issue of over-exploration, a common challenge in Bayesian optimization, leading to a more targeted and efficient search for optimal trade-offs. To demonstrate the effectiveness of this framework, we apply it to the shape optimization of the RAE2822 airfoil, aiming to minimize drag while maximizing lift and satisfying cross-sectional area constraint. The results show that selectively incorporating gradient information into the surrogate model leads to a substantial improvement in the convergence rate and the quality of the identified Pareto front. This highlights the potential of gradient-enhanced surrogate models in accelerating multi-objective aerodynamic design optimization while maintaining robust and accurate Pareto front approximations.*

Keywords: Pareto front, Bayesian optimization, surrogate modeling, design optimization

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MAGNETIC-ANOMALY POSITIONING FOR GNSS-INDEPENDENT UAV NAVIGATION

D. Pisarski, R. Faraj, Ł. Jankowski, B. Popławski, R. Konowrocki

Department of Intelligent Technologies
Institute of Fundamental Technological Research
Polish Academy of Sciences
Pawińskiego 5b, 01-106, Warsaw
dpisar@ippt.pan.pl, http://www.ippt.pan.pl

Abstract. *The paper introduces an original method for accurate positioning of an unmanned aerial vehicle (UAV) operating within a magnetic anomaly field. To estimate the UAV's position in GNSS-denied environments, the proposed positioning method relies on particle filtering with an enhanced velocity propagation model. This approach employs data fusion of kinematic measurements from the Inertial Measurement Unit (IMU) and magnetic field readings from a scalar magnetometer, which are correlated with a magnetic anomaly map. Notably, this method utilizes magnetic field measurements in two distinct ways. Firstly, the rate of change of the magnetic field along the UAV's trajectory is fed to the propagation model where the Bayesian inference is used to fuse the IMU and magnetometer measurements to estimate the particles velocity. Then, the absolute magnetic field values are compared with a magnetic anomaly map to recompute the particles' weights and refine the position estimate. The method was tested offline using in-flight recorded data. The analyses demonstrated the high performance of the particle filter with the enhanced velocity propagation model compared to dead reckoning navigation. As a result, the UAV's position error was significantly reduced. The study also includes a discussion on the method's robustness under different levels of IMU errors and the accuracy of magnetic field measurements.*

Keywords: magnetic anomaly navigation, Particle Filter, Bayesian inference, unmanned aerial vehicle, sensor fusion.

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MULTIDISCIPLINARY DESIGN AND OPTIMIZATION OF STRUT-BRACED HYBRID-ELECTRIC AIRCRAFT UNDER MULTI-TRAJECTORY SCENARIOS.

Pablo Norczyk Simon[1*], Rauno Cavallaro[2]

Barcelona Supercomputing Centre (BSC), Spain
pnorczyk@bsc.es

Department of Aerospace Engineering, Universidad Carlos III de Madrid, Spain
rauno.cavallaro@uc3m.es

Abstract. *Hybrid-electric aircraft present a promising approach to reducing aviation emissions, yet the integration of novel powerplant components and their mission-level control pose significant design challenges. This study employs TOPAZ, a GEMSEO-based multidisciplinary optimization framework, to perform comprehensive sizing and optimization of the INDIGO aircraft, a high aspect ratio wing design with distributed hybrid electric propulsion optimized for low landing and takeoff (LTO) impact. The research compares optimization strategies across three scenarios: (1) single trajectory analysis, (2) multiple trajectories with a common control strategy, and (3) multiple trajectories with mission-specific control strategies. Results demonstrate the critical importance of multi-point analysis for achieving robust and reliable aircraft design. While mission-specific control strategies yielded more optimal outcomes, they simultaneously increased mission planning complexity. Additionally, the study investigates the design implications of aircraft certification under five distinct failure scenarios, providing insights into the resilience and adaptability of hybrid-electric propulsion architectures. These findings contribute to a more nuanced understanding of optimization methodologies for emerging hybrid-electric aircraft configurations.*

Keywords: MDAO, INDIGO, Multi-point, Aicraft synthesis, Hybrid Electric, LARW, DHEP

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EXPLOITING POST-BUCKLING NONLINEARITIES FOR GUST LOAD REDUCTION IN HIGH ASPECT-RATIO AIRCRAFT WINGS

Pedro Farinha[1*,2], Francesco Toffol[2] and Chiara Bisagni[2]

1: Universidade de Lisboa
Instituto Superior Técnico
Av. Rovisco Pais 1, 1049-001, Lisboa, Portugal
pedro.lourenco.farinha@tecnico.ulisboa.pt, https://tecnico.ulisboa.pt

2: Department of Aerospace Science and Technology
Politecnico di Milano
via la Masa 34, 20156, Milano, Italy
{francesco.toffol,chiara.bisagni}@polimi.it, https://www.polimi.it

Abstract. *The ERC Advanced Grant Project NABUCCO (New Adaptive and BUCkling-driven COmposite aerospace structures) seeks to develop innovative concepts for adaptive and buckling-driven composite structures for next-generation aircraft. By exploiting the buckling phenomena as a design opportunity, the project focuses on utilizing the stiffness redistribution in the post-buckling regime. This study, part of the NABUCCO Project, exploits the structural nonlinearities in the post-buckling regime to mitigate peak loads experienced by high aspect-ratio wings, particularly under gust responses. A novel methodology is being developed to incorporate localized nonlinearity introduced by buckling, while maintaining the efficiency of conventional approaches for dynamic load computation. This work focuses on the structural analysis of a wingbox. First, a parametric analysis is conducted to assess the impact of various parameters on the buckling load of a wing section near the root. Based on the results, a new configuration for this section is proposed. Subsequently, a nonlinear analysis is performed on a simplified model to evaluate the stiffness reduction associated with the new configuration. This updated configuration is integrated into the aeroelastic model, and the corresponding results are presented. A structural analysis is carried out to evaluate composite failure, as well as bending and torsion effects on the wing. Preliminary results indicate that the post-buckling response of certain wing components can effectively reduce peak loads caused by gusts, promoting more sustainable aviation practices.*

Keywords: Buckling, post-buckling, gust loads alleviation, structural analysis

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EXPLORING COUPLING EFFECTS BETWEEN AIRFRAME AND PROPULSION IN PARAMETRIC MODELS FOR ELECTRIC REGIONAL AIRCRAFT WITH RANGE EXTENDER

Didier Brousset-Matheu[1*2*3], Eric Nguyen Van [1*2], Sebastien Defoort [1*2], Xavier Roboam[3] and Bruno Sareni[3]

1: DTIS, ONERA,
Université de Toulouse
31400, Toulouse, France
2: Fédération ENAC ISAE-SUPAERO ONERA
Université de Toulouse
31400, Toulouse, France
{didier.brousset-matheu, eric.nguyen, sebastien.defoort}@onera.fr
3: Laplace (UMR CNRS-Toulouse INP-UPS)
Université de Toulouse
ENSEEIHT 2 Rue Camichel, 31071 Toulouse, France
{xavier.roboam, bruno.sareni}@laplace.univ-tlse.fr

Abstract.

Recently, the Hybrid Aircraft: academic reSearch on Thermal and Electrical Components and Systems (HASTECs) project developed an advanced serial hybrid electric propulsion system, for regional transport aircraft, with a parametric model in each propulsion component. This approach integrated main physical phenomena covering several fields (electrical, mechanical, thermal) for sizing and evaluation of device losses and weights. The study highlighted the necessity for propulsive system optimization rather than component optimization, intending to achieve an optimal balance between efficiency and mass. However, the project decoupled the airframe from the propulsion system, resulting in the inability to ascertain if this compromise was reflected in the overall aircraft optimization. Concerning the Overall Aircraft Design (OAD) front, the FAST-OAD software has been used in several studies to analyze the propulsion-airframe integration but it relied on low-fidelity models for the hybrid propulsion system. This approach introduces significant uncertainties in the results, especially due to the lack of consideration for certain electrical phenomena, such as partial discharges, making it difficult to satisfy design constraints.

The objectives of this study are twofold: first, to present a new OAD process by coupling HASTECs and FAST-OAD software; second, to structure the oad process with the integration of different topologies of aircraft (turboelectric, serial-hybrid, full electric), the number of motors, and a method to determine the maximum possible range in pure electric mode. Finally, the objective is to ensure the robustness and relevance of the final OAD results despite strong interactions with an acceptable computation cost facing the system complexity for further optimizations. The case study for the new design process is the design exploration of an electric regional transport aircraft with a range extender.

Keywords: Hybrid, aircraft, Electric, powertrain, system, multidisciplinary, design, optimization

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CALIBRATION OF TRANSITIONAL MODEL FOR LOW REYNOLDS NUMBER FLOWS AT HIGH ANGLES OF ATTACK USING SURROGATE-BASED OPTIMIZATION FRAMEWORK

Pranesh Chandrasekaran[1*], Dilan Kilic[1] and Melike Nikbay[1]

1: Faculty of Aeronautics and Astronautics
Istanbul Technical University
ITU Ayazaga Campus, 34469, Maslak/Istanbul
chandrasekaran@itu.edu.tr, kilicd15@itu.edu.tr, nikbay@itu.edu.tr

Abstract. *Growing popularity of micro-air vehicles (MAVs) has resulted in an increased interest in the study of aerodynamics at low Reynolds numbers (10^4-10^5). At such low Re, the lifting surfaces of these vehicles may experience regions of laminar, transitional, and turbulent flow, all of which could significantly impact their aerodynamic characteristics. Therefore, in order to obtain solutions that are adequately close to experimental results, it is imperative for any computational technique to model each of these regions accurately. The aim of the present work is to calibrate the model coefficients of the transitional γ-Re_θ model, for making improved predictions at high angles of attacks, using a surrogate model-based optimization framework. The reliability of the computational procedure at low angles of attack, along with the challenges in achieving good agreement with experimental results at high angles of attack, is demonstrated by simulating the flow around a NACA 0012 airfoil at Re = 50,000, Tu = 0.1%, and within the angle of attack (α) range of $0^\circ \leq \alpha \leq 12^\circ$. A one at a time sensitivity analysis is conducted to identify the ten most influential model coefficients that affect the performance of the transitional model. The identified model coefficients then serve as the design variables in the optimization studies, which aim to minimize the absolute difference between the numerical results from the present work and the experimental results available in literature. A surrogate-based optimization framework is developed to identify the optimal combination of model coefficients to enhance the model's prediction accuracy. Kriging-based approach is used for constructing surrogate models while a population-based Genetic Algorithm is used as the optimizer. An exploitation-based infill strategy is used to update the surrogate at every design iteration. Finally, the performance of the calibrated model is validated at different angles of attack that were not involved during the optimization process.*

Keywords: computational fluid dynamics, turbulence modeling, boundary layer transition, low Reynolds number, calibration, surrogate-based optimization

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AERODYNAMIC SHAPE OPTIMIZATION OF RAE-2822 AIRFOIL BY PHYSICS-INFORMED PARAMETRIC MODEL EMBEDDING

Damiano Squillace[1], Umberto Iemma[1], Domenico Quagliarella[2], Matteo Diez[3], and Andrea Serani[3]

[1]Department of Civil, Computer Science and Aeronautical Technologies Engineering
Università Roma tre
Via Vito Volterra, 62, 00146 Roma RM, Italy
{damiano.squillace,umberto.iemma}@uniroma3.it, https://www.uniroma3.it/en/

[2]CIRA — Italian Aerospace Research Centre
Via Maiorise, 1, 81043 Capua CE, Italy
d.quagliarella@cira.it, https://www.cira.it/en/

[3]National Research Council – Institute of Marine Engineering
Via di Vallerano, 139, 00128 Roma RM, Italy
{matteo.diez,andrea.serani}@cnr.it, https://www.inm.cnr.it/

Abstract. *The efficiency of optimization algorithms in engineering design is often hindered by the curse of dimensionality, where increasing problem complexity degrades algorithmic performance due to the high dimensionality of the design space. To address this challenge, dimensionality reduction techniques that minimize the number of variables or constrain their variability are essential. This study introduces physics-informed parametric model embedding (PI-PME), a novel approach specifically designed for aerodynamic shape optimization of transonic airfoils. PI-PME extends the parametric model embedding (PME) framework by integrating physics-based insights, enhancing its capability to guide the optimization process toward physically relevant variations in the design space. By leveraging principal component analysis, PI-PME efficiently reduces dimensionality while maintaining the ability to reconstruct variables in the original space, avoiding the limitations of purely geometry-based formulations. To demonstrate its potential, PI-PME is applied to the optimization of the RAE-2822 airfoil at Mach 0.3, a benchmark case in aerodynamic design. Results are compared against PME and full-domain optimization, showing that PI-PME not only reduces computational complexity but also identifies superior configurations in the reduced design space. These findings underscore the practicality and robustness of PI-PME for industrial applications requiring efficient and reliable optimization strategies.*

Keywords: Curse of Dimensionality, Dimensionality Reduction, Simulation-based Optimization, Aerodynamic Shape Optimization, Principal Component Analysis, Parametric Model Embedding

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GREEN AVIATION MANUFACTURING: ADDRESSING ENVIRONMENTAL IMPACTS WITH MDO METHODOLOGIES

Shantanu Sapre[1]*, Joseph Morlier[2] and Christian Gogu[2]

1: ISAE-SUPAERO
Université de Toulouse
Toulouse, France
shantanu-rajendra.sapre3@isae-supaero.fr

2: ICA, ISAE-SUPAERO, MINES ALBI, UPS, INSA, CNRS
Université de Toulouse
Toulouse, France
{joseph.morlier,christian.gogu}@isae-supaero.fr

Abstract. *The aeronautical industry faces increasing pressure to reduce its environmental footprint while meeting the growing demand for aircraft. Although the operational phase remains the most significant contributor to environmental impact, the manufacturing phase may gain prominence as aviation transitions to alternative fuels and innovative designs. This study addresses the need for sustainability in aircraft production by integrating environmental considerations into key stages of the aircraft lifecycle, particularly during preliminary design. The study evaluates aircraft mass and material composition using a bottom-up approach, considering buy-to-fly ratios, greenhouse gas emissions, energy consumption, and waste generation of the legacy aircraft. To mitigate environmental impact, this research explores a multi-objective optimization technique for selecting environmentally friendly material composition while maintaining performance standards. A key focus is the role of multidisciplinary design optimization (MDO) in balancing sustainability with functional and economic requirements during the overall aircraft design. Ultimately, this study highlights the need for introducing material composition selection as a new parameter within the classical MDAO framework.*

Keywords: Environmental impact, Material selection, Eco-design, Multiobjective Optimization

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OPTIMAL WING FOR LONG ENDURANCE UAV APPLICATIONS

Abhiyan Paudel[1], Sharanjeet Kaur[1], Nikhil Vijay Shende[2*] and N Balakrishnan[1]

1: Computational Aerodynamics Lab
Department of Aerospace Engineering
Indian Institute of Science
Bangalore 560012, Karnataka, India
nbalak@iisc.ac.in, https://www.iisc.ac.in

2: S & I Engineering Solutions Private Limited
Bangalore 560024, Karnataka, India
nikhil.shende@sandi.co.in, https://www.sandi.co.in

Abstract. *This paper presents a methodology for aerodynamic optimization of a long endurance unmanned aerial vehicle (UAV) wing employing genetic algorithm (GA). It is well known that genetic algorithm–based optimization procedure requires a large number of function evaluations to arrive at a globally optimal configuration. In the present study, the function under consideration is the endurance parameter which depends on the lift and drag coefficients of the wing. Use of Computational Fluid Dynamics (CFD) tools for function evaluation is prohibitively expensive. To address this, a low–fidelity aerodynamic tool based on numerical lifting line theory (NLLT) working in conjunction with high–fidelity sectional aerodynamic data set generated using RANS solver is developed. NLLT significantly reduces the cost of function evaluation without compromising accuracy. The endurance parameter of the optimal wing obtained through a GA–based optimization procedure employing the NLLT tool is compared with CFD and the results show a very close match between them. This clearly brings out the efficacy of the present procedure to obtain an aerodynamically optimal wing for long endurance UAV configuration. In addition, the study also establishes the need for considering a large population for a reliable GA-based optimization process for achieving optimal solution.*

Keywords: Unmanned Aerial Vehicles, Aerodynamic shape optimization, Genetic algorithm, NACA 4–Digit Airfoils, Lifting Line Theory, Reynolds Averaged Navier–Stokes Equations

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SOLVING NONLINEAR PERIODIC AEROELASTIC SYSTEMS USING BOUNDARY VALUE FORMULATION AND CONFORMAL MAPPING

Anshuman Mehta, Pankil N. Mishra and Abhijit Gogulapati

Department of Aerospace Engineeing, IIT Bombay, Powai, Mumbai, Maharashtra, India - 400076

Abstract. *Traditional approaches for simulating nonlinear aeroelastic systems typically rely on initial value problems (IVPs), which do not fully exploit the inherent periodicity of these systems. Our research addresses this limitation by reformulating the problem as a periodic boundary value problem (BVP), leveraging numerical optimization techniques to enhance computational efficiency and system insights. This study focuses on the optimization of nonlinear periodic aeroelastic systems using a BVP formulation.*

A trust-region-based optimization framework was implemented to solve the periodic BVP, incorporating nonlinear constraints and periodic boundary conditions. The aerodynamic analysis employed Joukowsky conformal mapping-based inviscid aerodynamic models to simulate unsteady flows around airfoils undergoing periodic kinematics, including pitch, plunge, and lead motions. The formulation also accounts for leading-edge vortices, ensuring accurate representation of the complex wake dynamics and key physical conditions.

The proposed framework was validated through numerical simulations of oscillating airfoils, demonstrating its robustness across a range of reduced frequencies and dynamic configurations. A systematic comparison of various formulations, based on choices of objective functions and nonlinear constraints, highlighted significant reductions in computation time while maintaining solution accuracy. Additionally, the study identified the required wake length for accurately capturing the periodic system behavior, which significantly reduces computational power compared to traditional approaches.

This research presents a novel methodology for the analysis and design of nonlinear aeroelastic systems, offering enhanced computational efficiency and deeper insights into system behavior. The integration of mid-fidelity aerodynamic models and advanced optimization algorithms establishes a robust framework for multidisciplinary aerospace design, particularly for applications involving periodic phenomena.

Keywords: Boundary value problem (BVP), trust-region optimization, Joukowsky conformal mapping, inviscid aerodynamic models, periodic kinematics, leading-edge vortices

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FREQUENCY-AWARE SURROGATE MODELING WITH SMT KERNELS FOR ADVANCED DATA FORECASTING

N. Gonel[1,2*], P. Saves[3], J. Morlier[4]

1: Fédération ENAC ISAE-SUPAERO ONERA,
Université de Toulouse,
31000, Toulouse, France.

2: IFP Energies nouvelles,
Institut Carnot IFPEN Transports Energie,
92852 Rueil-Malmaison, France.
nicolas.gonel@ifpen.fr

3: IRIT,
Université de Toulouse, CNRS, Toulouse INP, UT3, UT Capitole,
Toulouse, France.
paul.saves@irit.fr

4: ICA,
ISAE–SUPAERO, INSA, CNRS, MINES ALBI, UPS,
Université de Toulouse,
31400 Toulouse, France.
joseph.morlier@isae-supaero.fr

Abstract. *This paper introduces a comprehensive open-source framework for developing correlation kernels, with a particular focus on user-defined and composition of kernels for surrogate modeling. By advancing kernel-based modeling techniques, we incorporate frequency-aware elements that effectively capture complex mechanical behaviors and time-frequency dynamics intrinsic to aircraft systems. Traditional kernel functions, often limited to exponential-based methods, are extended to include a wider range of kernels such as exponential squared sine and rational quadratic kernels, along with their respective first- and second-order derivatives. The proposed methodologies are first validated on a sinus cardinal test case and then applied to forecasting Mauna-Loa Carbon Dioxide (CO_2) concentrations and airline passenger traffic. All these advancements are integrated into the open-source Surrogate Modeling Toolbox (SMT 2.0), providing a versatile platform for both standard and customizable kernel configurations. Furthermore, the framework enables the combination of various kernels to leverage their unique strengths into composite models tailored to specific problems. The resulting framework offers a flexible toolset for engineers and researchers, paving the way for numerous future applications in metamodeling for complex, frequency-sensitive domains.*

Keywords: Frequency correlation kernels, Gaussian process, Aircraft data prediction, Surrogate Modeling Toolbox, Open-Source Software

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HIGH-FIDELITY MULTI-DISCIPLINARY OPTIMISATION PROCESSES FOR SOLVING AERO-STRUCTURE PROBLEMS: RECENT DEVELOPMENTS FROM AN INDUSTRIAL PERSPECTIVE.

J. Brezillon[1]*, I. Fadli[1], K. Thanissaranon[1] and C. Conlan-Smith[2]

[1]: Flight Physics Capability Development
Airbus Operations S.A.S.
316 route de Bayonne
31060 Toulouse Cedex 09
France
[2]: Flight Physics Capability Development
Airbus Operations GmbH
Airbus-Allee 1
28199 Bremen
Germany

{Joel.Brezillon, Imane.Fadli, Kittinan.Thanissaranon, Cian.Conlan-Smith}@airbus.com,
http://www.airbus.com

Abstract *The purpose of the paper is to present the Multidisciplinary Design Optimisation (MDO) capabilities developed at Airbus within the EU-funded Horizon Europe NEXTAIR project (multi-disciplinary digital-enablers for NEXT-generation AIRcraft design and operations), with applications on the DLR-F25 configuration, a small/medium range aircraft featuring high-aspect ratio wing. A simplified but realistic use case around an aero-structural wing optimization problem has been defined by Airbus and proposed to partners of the project, with the intention to demonstrate the feasibility and maturity of MDO processes based on medium to high-fidelity simulations in early design trades. From an industrial viewpoint, the selection of the MD architecture to solve such a problem is key: while Multi Disciplinary Feasible approach is certainly proven to efficiently solve aero-structural MDO problems, it turns out to be difficult or impracticable to operate in industrial context where mono-disciplinary capabilities are already well established and mature. Alternative distributed MDO architectures offer the opportunity in reusing these disciplinary processes and to go at-scale in MDO complexity. Finally, the Bi-Level formulation, originally proposed by IRT-Saint Exupery and at disposal in the workflow orchestrator GEMSEO, has been down selected to solve the aero-structural optimisation problem. GEMSEO is used here to orchestrate and connect the in-house aerodynamic shape optimisation capability PODShaperOpt with the loads-structure sizing suite CPACS-MONA developed by DLR through a HTTPS client-server. First results on the DLR-F25 configurations highlight possibilities and difficulties of this Bi-Level formulation for solving aero-structural wing design problems.*

Keywords: MDO, Aero-structure, Optimisation, Distributed Architecture, Bi-Level MDO formulation, Adjoint

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DEFORMATION STRATEGIES IN FUSELAGE AERODYNAMIC SHAPE OPTIMIZATION USING PAYLOAD VOLUME CONSTRAINTS

Luís D. Pinheiro[1,2]*, Nuno M. B. Matos[1,2] and André C. Marta[2]

1: Research and Development
Tekever UAS
Rua das Minas, 2, 2500-750 Caldas da Rainha, Portugal
{luis.pinheiro, nuno.matos}@tekever.com, https://www.tekever.com

2: IDMEC
Instituto Superior Técnico
Universidade de Lisboa
Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal
{luis.pinheiro, andre.marta}@tecnico.ulisboa.pt, https://mdo.tecnico.ulisboa.pt

Abstract. *The usage of powerful optimization tools is becoming common in solving many engineering problems due to available computational resources and mature numerical algorithms. In this work, an adjoint-based high-fidelity aerodynamic shape optimization framework is used to manipulate a generic aircraft fuselage shape to minimize the total aerodynamic drag with specific payload volume constraints. The external fuselage shape is modified using the free-form deformation (FFD) technique to allow greater flexibility. The impact of using different deformation strategies applied to the displacement of FFD control points is studied, including displacements along the normal direction, the transverse axis directions, and cambering along the longitudinal axis direction. It is demonstrated that the combination of flexible control point displacement in multiple FFD box cross-section planes together with a streamwise cambering can produce a very significant drag reduction, in excess of 40% compared to the selected baseline shape, while still satisfying volume constraints to account for internal or protruding payloads.*

Keywords: aircraft design, gradient-based optimization, adjoint method, free form deformation, high-fidelity analysis, aerodynamic performance

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EFFICIENT GRADIENT-BASED STRUCTURAL OPTIMISATION WITH MODAL AND BUCKLING CONSTRAINTS ASSISTED BY ALGORITHMIC DIFFERENTIATION

Luca Scalia[1], Rauno Cavallaro[1], Andrea Cini[1], Nicolas R. Gauger[2], Max Sagebaum[2]

1: Department of Aerospace Engineering
Universidad Carlos III de Madrid (UC3M)
lscalia@pa.uc3m.es
rcavalla@ing.uc3m.es
acini@ing.uc3m.es

2: Chair for Scientific Computing
University of Kaiserslautern-Landau (RPTU)
nicolas.gauger@scicomp.uni-kl.de
max.sagebaum@scicomp.uni-kl.de

Abstract. *The pursuit of sustainable aviation has led to the exploration of unconventional aircraft configurations, such as high-aspect-ratio wings, blended-wing bodies, and strut-braced wings. Performance assessment of novel layouts cannot rely solely on conventional design approaches built upon legacy experience. Instead, high-fidelity analysis tools are required from the early design stages.*

Building upon a previously developed framework for efficient gradient-based aero-structural optimisation enhanced by algorithmic differentiation, this work extends the structural module to enable modal and buckling analyses through the solution of generalised eigenvalue problems, along with the development of their associated sensitivities. Designed for industrially relevant applications, the framework is implemented with parallel computing capabilities to ensure scalability and efficiency.

The suggested tool capability is demonstrated on two structural optimisation testcases, involving, enforcing isolated and combined, stress, frequency, and buckling constraints. Results highlight the critical role of simultaneously imposing multiple constraint types in ensuring robust and optimal wing designs.

Keywords: Structural optimisation, algorithmic differentiation, finite element method, gradient-based optimisation, adjoint method, buckling constraint

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AN MDAO FRAMEWORK APPROACH EXTENDED TO UNSTEADY MULTIPHYSICS: KEY INGREDIENTS AND EXAMPLES

Florian Roß, Simon Ehrmanntraut, Constantin Höing, Sebastian Gottfried and Arthur Stück

German Aerospace Center (DLR)
Institute of Software Methods for Product Virtualization
Nöthnitzer Straße 46b, 01187 Dresden
florian.ross@dlr.de, simon.ehrmanntraut@dlr.de,
constantin.hoeing@dlr.de,sebastian.gottfried@dlr.de, arthur.stueck@dlr.de
https://www.dlr.de/en/sp

Abstract. *State-of-the-art MDAO frameworks like* OpenMDAO *and* GEMSEO *facilitate the setup and the gradient-enabled solution/optimization of large multidisciplinary problems, which are predominantely of steady-state type. Time-dependent MDAO problems, however, pose additional challenges, particularly in conjunction with cost-intensive high-fidelity simulations. This work demonstrates how advanced MDAO-framework capabilities can be transferred from the steady-state to the unsteady domain. To this end, an MDAO framework approach is presented integrating* OpenMDAO *with the HPC ecosystem* FlowSimulator *including high-fidelity simulation plugins like the CFD-software* CODA*. Among the key capabilities of the time-accurate framework approach are a complete system representation on the framework level resolving all input- and output dependencies to yield a monolithic time-resolved view, and checkpointing-enabled reverse gradient accumulation over time. A gradient-based optimization was conducted in the framework for an elementary Van der Pol oscillator case carrying out an unsteady reverse-in-time sensitivity analysis. Moreover, it was successfully shown and verified that the framework is capable of performing unsteady adjoint viscous/turbulent CFD computations for a NACA0012 and the CRM/DPW-5 wing-body configuration, paving the way for large adjoint-enabled unsteady MDAO applications.*

Keywords: Unsteady MDAO, MDAO Frameworks, Sensitivity Analysis, Checkpointing

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PRELIMINARY NUMERICAL AND EXPERIMENTAL COMPARISON OF TWO TYPES OF PLA BCC LATTICE STRUCTURES MANUFACTURED VIA FDM AND SUBJECTED TO IMPACT TESTING

G. Iacolino[1]*, C. Orlando[1], D. Tumino[1], G. Catalanotti[1], E.V. González[2], G. Mantegna[1] and A. Alaimo[1]

1: Department of Engineering and Architecture
Kore University of Enna
Cittadella Universitaria, 94100, Enna (EN), Italy
*: giuseppe.iacolino@unikorestudent.it
2: AMADE, Polytechnic School, Universitat de Girona
Campus Montilivi s/n, Girona, 17071, Spain

Abstract *Lattice structures have gained increasing attention due to their exceptional mechanical properties combined with significant weight reduction. Recently, their application in engineering has expanded, driven by the ease of production enabled by innovative technologies in Additive Manufacturing such as Fused Deposition Modelling (FDM). Additionally, Polylactic Acid (PLA) offers excellent mechanical properties alongside environmental sustainability, making it an ideal material for aerospace, automotive, and other industries requiring efficient energy absorption and lightweight solutions. In this regard, this study investigates the impact response of PLA body-centered cubic (BCC) lattice structures manufactured via FDM. Specifically, a preliminary numerical-experimental comparative analysis was conducted on two BCC configurations with strut diameters of 1.5 mm and 2 mm. The experimental tests were performed using a drop-tower setup, while the numerical simulations were carried out in Ansys LS-DYNA. The findings demonstrate the suitability of FDM-printed PLA BCC lattice structures for applications requiring lightweight energy-absorbing components. Moreover, the integration of numerical and experimental approaches confirms the accuracy of simulations in predicting structural behaviour under dynamic loading conditions.*

Keywords: Lattice Structures, Additive Manufacturing, PLA, Drop-Tower Impact Testing, Numerical-Experimental Comparison

1. INTRODUCTION

Cellular solids represent a specific macro-area of structures employed in the engineering field. In [1], Tao et al. classify these structures into two categories: stochastic structures (foams), and non-stochastic structures (lattices) reported in Fig. 1. As highlighted in [2], they can be employed in sectors such as aerospace, automotive, infrastructural, and biomedical industries. The distinctive feature of these structures lies in their ability, unlike other types, to exhibit excellent mechanical properties [3]. The literature comprises numerous studies investigating the mechanical properties of BCC structures, such as [4], and [5]. Furthermore, others investigate their performance under impact testing. For instance, Acanfora et al. [6], analyzed impact absorbers with BCC cores manufactured via additive manufacturing (AM) and

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STATISTICAL ANALYSIS OF THE ROBUSTNESS OF OPTIMALLY DESIGNED LATTICE STRUCTURES

Geethesh Naiyyalga[1*], Amuthan A. Ramabathiran[2]

1: PhD scholar, Department of Aerospace Engineering
Indian Institute of Technology Bombay
Mumbai, India 400076
geethesh@aero.iitb.ac.in, https://www.iitb.ac.in

2: Assistant Professor, Department of Aerospace Engineering
California Polytechnic State University
Grand Avenue, San Luis Obispo, CA 93407
aramabat@calpoly.edu, https://www.calpoly.edu/

Abstract. *Understanding and quantifying the response of structures when subject to localized damage is crucial for several engineering applications. Lattice structures have recently emerged as robust alternatives to traditional designs since they have several redundant internal load paths to distribute external loads. We present in this work a statistical analysis of the robustness of a class of lattice structures that are obtained using a recently published algorithm in the literature called phasor-noise dehomogenization (Woldseth et al. 2024). The phasor-noise dehomogenization algorithm translates a homogenized solution obtained using a topology optimization method into a phasor sine wave, and subsequently extracts a lattice structure from this phasor sine wave on a finer grid by performing several postprocessing steps to refine the structure. We introduce localized defects in these structures by modifying the original algorithm to remove material in a small ball around a randomly chosen point in the design domain, with the radius of the ball chosen from a specified probability distribution. We perform finite element analysis of these defective structures in a wide variety of two dimensional structures and analyze the statistical distribution of various performance metrics like compliance and maximum von Mises stress, as the volume fraction of the defect is varied. We thus employ the same modification to study defective structures produced by the well-known SIMP algorithm for topology optimization and perform an analogous statistical study. We then compare the robustness of structures produced by these different topology optimization algorithms. The methods developed in this work provide a simple and practical method to study the robustness of lattice structures and can thus serve as an efficient metric to evaluate the quality of different flavors of topology optimization algorithms that produce lattice structures under the same design constraints.*

Keywords: Topology optimization, SIMP, homogenization method, dehomogenization, defect, robust design, lattice structure

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PRECONDITIONING TECHNIQUES FOR GENERAL CONSTRAINED OPTIMIZATION PROBLEMS: APPLICATION TO INDUSTRIAL AEROSPACE COMPONENT DESIGN

Shouvik Bandopadhyay[1], François Gallard[1], and Simone Coniglio[1]

1: Methods and Tools for the Development of Complex Systems
MDO Competence Centre
IRT Antoine de Saint Exupéry
CS34436, 3 Rue Tarfaya, 31400 Toulouse
shouvik.bandopadhyay@irt-saintexupery.com

Abstract. *This research addresses a typical source of inefficiency in Multidisciplinary Design and Optimization (MDO) when the problems are highly non-linear. Ill-conditioning of the objective function or constraints' Hessian matrices is known to hinder the convergence of optimizers and increase the computational cost of finding the solution. It leads to well-known zigzag convergence paths, even for quasi-Newton methods, because the typical BFGS Hessian approximations have difficulties in capturing the range of eigenvectors and eigenvalues, resulting in excessive intermediate evaluation points. Preconditioning, a method of transforming numerical problems to improve stability and convergence, has been extensively developed for solving linear algebraic systems. Optimization problems, such as constrained multidisciplinary design optimization (MDO), can be viewed as generalizations or extensions of these linear systems (eg. via residual minimization). However, despite this close relationship, the use of preconditioning in constrained MDO remains relatively under-explored. This study compares two preconditioning strategies: a static external preconditioner, built from previous optimizations and applied before the optimization starts, and a dynamically updated preconditioner, computed during sub-optimization cycles of the Augmented Lagrangian method. They are solved using the P-L-BFGS-B algorithm, an extension of the L-BFGS-B optimizer for unconstrained preconditioned problems, and the SNOPT algorithm, which allows black-box preconditioning thanks to its exact linear constraint management. The methods are first validated on analytical test cases. Further validation is performed on a representative industrial application, the sizing optimization of the wing structure of the Airbus XRF-1 research aircraft configuration, where significant speed-up of 66.8% and 60% were observed for the dynamic preconditioning strategy and the static external preconditioning strategy respectively. These methods have been integrated into GEMSEO, an open-source MDO library, making them available for wider industrial and research applications.*

Keywords: optimization, Preconditioning, Algorithms, Aerospace, Industrial MDO

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HIGH ASPECT-RATIO COMPOSITE WING AEROSTRUCTURAL OPTIMISATION OF A SHORT-MEDIUM RANGE AIRCRAFT

Luís M. M. Pacheco[1,2*], Fabian Volle[3], Ögmundur Petersson[2] and André C. Marta[1]

1:IDMEC
Instituto Superior Técnico, Universidade de Lisboa
Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal
*: luis.miguel.martins.pacheco@tecnico.ulisboa.pt

2: Airbus Defence and Space
Department of Stress Methods and Optimisation
Rechliner Straße, 85077, Manching, Germany

3: DLR
Institute of Aerodynamics and Flow Technology
Lilienthalplatz 7, 38108, Braunschweig, Germany

Abstract. *As global priorities increasingly shift towards ambitious climate objectives, achieving sustainability has become the foremost challenge for the aviation industry. A key pathway towards climate-neutral aviation lies in the adoption of high-aspect-ratio wings, which reduce aerodynamic induced drag, and consequently improve fuel efficiency. A recently developed high-fidelity multidisciplinary design optimisation framework, incorporating DLR's aerodynamic TAU solver and Airbus' structural Lagrange solver, is used for the aeroelastic structural sizing optimisation of two high aspect-ratio composite medium-range transport aircraft wings. Three distinct objective functions are considered: i) the classical minimisation of mass, ii) the maximisation of aerodynamic efficiency, and iii) the maximization of range. A gradient-based algorithm with adjoint sensitivity analysis is used. The design variables include structural sizing parameters such as the thickness or cross-sectional area of the skin, spars, and stringers. Constraints reflect industry requirements, encompassing structural strength, buckling stability, and manufacturing criteria. The findings highlight the advantages of high aspect-ratio wings in reducing drag and improving overall aircraft performance, despite the increase in structural weight. The use of less conventional optimisation objectives for structural sizing yields distinct optimal designs from those obtained through mass minimisation. Optimising for Breguet range results in a well-balanced trade-off between structural and aerodynamic performance, demonstrating that the benefits of considering a multidisciplinary performance-based objective in the preliminary design phase outweigh the additional computational cost associated with high-fidelity aerodynamic analysis.*

Keywords: Multidisciplinary Design Optimisation, Structural Sizing, High Aspect-Ratio, Breguet Range, Aerodynamic Efficiency, Composite Wing

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DATA-DRIVEN ACCELERATION OF MULTIDISCIPLINARY SIMULATIONS FOR MULTI-QUERY APPLICATIONS IN AEROSPACE ENGINEERING

Susanna Baars[1*] and Ulrich Römer[1]

1: Institute for Acoustics and Dynamic
Technische Universität Braunschweig
Langer Kamp 19, 38106 Braunschweig, Germany
s.baars@tu-braunschweig.de, https://www.tu-braunschweig.de/inad

Abstract. *Aviation design and analysis demand precise multiphysical predictions, exemplified by fluid-structure interaction (FSI). For complex problems, partitioned approaches are often the only viable option, requiring strong coupling to handle feedback loops. Significant progress has been achieved in efficiently simulating strongly coupled systems using data-driven approaches. Key developments include quasi-Newton methods such as the matrix-free interface quasi-Newton method. Recently, surrogate-based enhancements for these methods have been explored, where the surrogate provides both an initial guess and a supplementary Jacobian. In multi-query applications like optimization and uncertainty quantification, information from previous parametric evaluations can further accelerate computations using data-driven surrogates, although this area remains underexplored. Our goal is to address this gap by developing a scheme for parametric multidisciplinary problems. We use previous parametric evaluations to refine the Jacobian approximations and data-driven surrogates for initial estimates of coupling variables and illustrate the approach with two numerical examples.*

Keywords: Multidisciplinary analysis, Surrogate model, Quasi-Newton method, Multi-query application

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MULTI-PATCH HYBRID OPTIMIZATION OF COMPOSITE WINGS

D. Zamani[1*], A. Pagani[1], M. Petrolo[1] and E. Carrera[1]

1: MUL2 Lab
Department of Mechanical and Aerospace Engineering
Politecnico di Torino, Italy
Corso Duca degli Abruzzi 24, 10129 Turin, Italy
dario.zamani@polito.it, http://www.mul2.com

Abstract. *The demand for lightweight and structurally efficient composite aerospace structures continues to stimulate the advancement of refined optimization methodologies. This paper proposes a novel multi-patch, multi-objective optimization framework to minimize mass and strain energy in composite wing-box structures. The optimization problem is inherently mixed-integer, as it involves discrete design variables alongside continuous variables, necessitating tailored solution strategies. Two distinct optimization approaches are compared: the traditional multi-objective genetic algorithm NSGA-II and a hybrid method integrating evolutionary and gradient-based optimization. The gradient computations are directly performed at the fundamental nuclei level derived within the Carrera Unified Formulation (CUF), significantly enhancing computational efficiency and accuracy. We provide a scalable low- to high-fidelity methodology for gradient computation, where the CUF framework enables seamless transitions between different levels of accuracy by adjusting the expansion order. Each wing-box segment, modeled as an independent patch, is optimized separately, enabling tailored fiber angle distribution. The effectiveness of the proposed hybrid optimization strategy is demonstrated through numerical case studies, highlighting superior convergence characteristics and improved optimality compared to the NSGA-II standalone approach. The sensitivity of the optimal design solutions to varying structural modeling approaches within the CUF framework is also briefly discussed, providing valuable insights into the practical implementation of multi-patch gradient-enhanced composite structure optimization.*

Keywords: Composite Structures, Multi-objective Optimization, Mixed-Integer Optimization, Carrera Unified Formulation, Multi-patch Optimization

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Optimizing UAV Winglets: A Multiobjective Approach with Surrogate Models

M. Almutairi[1*], P. Dunning[1], and A. Maheri[1]

1: School of Engineering, Fraser Noble Building

University of Aberdeen, Aberdeen, United Kingdom

m.almutairi.21@abdn.ac.uk, https://www.abdn.ac.uk/people/m.almutairi.21
peter.dunning@abdn.ac.uk, alireza.maheri@abdn.ac.uk

Abstract. *This study presents a multi-objective optimization approach to enhance the aerodynamic performance of unmanned aerial vehicle winglets using high-fidelity computational analysis and surrogate modeling. Kriging and polynomial surrogate models, trained on high-fidelity computational fluid dynamics (CFD) simulations, are integrated with a multi-objective genetic algorithm (NSGA-II) to explore the design space and identify optimal trade-offs. The optimization focuses on two multi-objective problems: maximizing the lift-to-drag ratio while minimizing the root bending moment and maximizing lift whilst minimizing drag. A comparative analysis of the surrogate models reveals that Kriging excels with smaller datasets, particularly in RBM prediction, while polynomial regression improves with larger datasets, demonstrating superior drag prediction accuracy. Results indicate that using 50 samples provides the optimal balance between prediction accuracy and computational efficiency. The findings highlight the effectiveness of Kriging for predicting structural performance and polynomial regression for aerodynamic performance. These insights contribute to UAV and aerospace applications, emphasizing the importance of integrating both aerodynamic and structural objectives for effective winglet design.*

Keywords: UAV, Winglet, CFD, Surrogate Modelling, Multiobjective Optimization

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A VELOCITY-FIELD LEVEL-SET BASED TOPOLOGY OPTIMIZATION OF STRUCTURES SUBJECTED TO AEROTHERMODYNAMICS LOADS

Apoorva Kanti[1*], Pankil N. Mishra[2] and Abhijit Gogulapati[3]

1: B.Tech. student (210010013@iitb.ac.in)
2: PhD candidate (pankilmishra@iitb.ac.in)
3: Assistant Professor (abhijit@aero.ac.in)

Department of Aerospace Engineering
Indian Institute of Technology Bombay
IIT Bombay, Powai, Mumbai 400 076, Maharashtra, India

Abstract. *Level-set-based topology optimization is used to identify optimal material layout in compliant structures operating in high-speed flow. The static stability of a two-dimensional panel, described using a thermal buckling metric, is used as the objective function. The panel has fixed-fixed boundary conditions and is subjected to hypersonic flow over its top surface. The aerothermal loads due to flow are computed using a combination of the piston theory and Eckert's reference enthalpy. The topology optimization is based on a velocity field level set method (VFLSM). This approach describes the level set using a signed distance function, with the solid boundary as the zero-level contour. The velocity field is defined over the design domain using piecewise basis functions. An in-house modular and scalable Python code has been developed to perform the topology optimization of the panel under consideration. The sensitivity analysis is performed analytically using an adjoint-based method. The stepping is based on the method of moving asymptotes (MMA), which allows efficient handling of multiple constraints and additional types of design variables. Two case studies will be presented. The first involves a panel with a uniform thermal (temperature) load. The second explores a coupled aero-thermo-elastic scenario with a non-uniform temperature and a fixed solid top surface. These studies are a precursor to VFLSM-based topology optimization of coupled aero-thermo-elastic systems.*

Keywords: velocity field level-set method, topology optimization, thermal buckling, coupled aerothermal loads, fluid-thermal-structural interactions

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TOWARD DISTRIBUTED AND SCALABLE MULTI-DISCIPLINARY OPTIMIZATION WITH GEMSEO

Jean-Christophe Giret[1*], François Gallard[1], Antoine Dechaume[1], Jérôme Fasquel[1], Jean-François Figué[1] and Anne Gazaix[1]

1: IRT Saint Exupéry
4, Rue Tarfaya CS34436 Toulouse, France
jean-christophe.giret@irt-saintexupery.com, http://www.irt-saintexupery.com

Abstract. *Multidisciplinary design optimization (MDO) workflows are often executed locally on a single computer node. However, industrial-scale or collaborative MDO projects frequently require processes that span multiple machines. This need arises from the demand for specialized resources such as specific software, operating systems, hardware, or increased computing power through horizontal scaling. Additionally, multi-partner collaborations often prioritize intellectual property protection by obfuscating internal models while exposing only interfaces and input-output contracts.*

Although enabling technologies like job schedulers, SSH and HTTP client and servers, and cloud platforms are widely available, their adoption in MDO workflows remains limited. Implementing these technologies presents significant challenges for both end-users and MDO process integrators.

In the frame of the HORIZON European Projects NEXTAIR and RECET4RAIL, efforts have been put to bring a range of platform capabilities to selectively and seamlessly offload parts of the MDO process to remote machines, thus enabling extended-enterprise MDO: - A job scheduler discipline to delegate computations to HPC with job schedulers such as LSF or SLURM. - An SSH discipline that enables the delegation of the computation of a discipline to a distant node accessible via the SSH protocol - An HTTP discipline that provides a client and a server that enables the exposure of GEMSEO disciplines as web services.

These features introduce new challenges to the decentralized MDO process, particularly regarding observability and reliability. For reliability, given the risk of hardware failures or network instability in remote computing, specific developments have been made to selectively address errors and exceptions that may arise from hardware or network issues. Finally, capabilities have been developed to enable observability across the remote components of the distributed MDO processes.

Keywords: MDO, SSH, HTTP, Cloud computing, HPC, RPC, Job Scheduler, Data Management

DESIGN OF ENERGY ABSORBING STRUCTURES UNDER IMPACT LOADING USING TOPOLOGY OPTIMIZATION INCORPORATING PATH-DEPENDENT SENSITIVITY ANALYSIS

Bhanu Pratap Sharma[1]*, Pankil Narendra Mishra[1*] and Abhijit Gogulapati[2]

1: Ph.D. Student
2: Assistant Professor
Department of Aerospace Engineering
Indian Institute of Technology Bombay
Powai, Mumbai – 400 076, Maharashtra, India

Abstract *Foam-like collapsible materials have high specific energy absorption and are suited for applications involving high rates of loadings. The energy absorption characteristics of such materials rely heavily on the internal cellular structure.*

Methods like topology optimization have been used extensively to generate cell topologies for elastoplastic materials with the specific objective of energy absorption in mind. However, prior studies are limited to displacement-controlled loads, and low rates of applied loading. Our study presents topology optimization of an elastoplastic material subjected to a force-based impact load.

For topology optimization, we link the MMA algorithm to a commercial FE solver (ABAQUS). The material properties are penalized using the SIMP model. We compute the path-dependent sensitivity following the approach described in the literature. The objective is to maximize the plastic dissipation in the material. Additionally, we impose an implicit constraint on the peak value of the transmitted pressure.

The overall goal is to generate a mesoscale cellular topology. For this, we use periodic constraints to obtain a lattice type structure. To enhance the convergence rate of MMA optimizer, we use the ADAptive Moment Estimation (ADAM) algorithm. A comparison of the results generated with and without ADAM are also presented.

Keywords: foams, metamaterials, topology optimization, energy absorption, SIMP, ADAM, path-dependent sensitivity

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HYDROGEN-POWERED AIRCRAFT DESIGN: A MULTIDISCIPLINARY APPROACH TO MINIMIZE EMISSIONS AND COST

Raúl Quibén Figueroa[1*], Rauno Cavallaro[1], Andrea Cini[1] and Manuel Soler Arnedo[1]

1: Department of Aerospace Engineering
Universidad Carlos III de Madrid
Av. de la Universidad 30, 28911 Leganés, Madrid
{rquiben, rcavalla, acini, masolera}@ing.uc3m.es

Abstract. *Hydrogen fuel is increasingly recognized as a transformative solution to address the environmental and operational challenges of traditional fossil fuel-based propulsion systems in aviation. This disruptive technology holds the potential to revolutionize the industry, but its successful integration demands a comprehensive evaluation of both its economic feasibility and environmental benefits. This study exploits a novel, integrated design and optimization tool tailored for conceptualizing hydrogen-powered aircraft. The framework, named MOTIVATION and built on OpenMDAO, employs gradient-based optimization and total derivatives computation for complex models, enabling the efficient evaluation of the problem regarding all involved flight performance and climate-related disciplines. Different modules are designed to comply with CS/FAR 25 requirements and airworthiness constraints, while also estimating specific aircraft responses and evolution, particularly suited for hydrogen-powered systems. Special attention is also given to direct and indirect emissions, ensuring comprehensive impact evaluations. The presented optimization campaign assesses the feasibility of retrofitting an A320neo with hydrogen propulsion, focusing on the associated uncertainties due to the lack of established reference designs for such innovative systems. Key aspects of this research include analyzing various configurations for hydrogen storage while ensuring structural and operational feasibility through equilibrium and stability evaluations. Comparative analyses are conducted to quantify the costs and emissions, including carbon dioxide (CO2), nitrogen oxides (NOx) and water vapor (H2O). Parametric studies further investigate the influence of mission profiles and advancements in hydrogen technology, identifying critical thresholds for viability and significant opportunities for climate impact mitigation. This study provides valuable insights into the potential pathways for integrating hydrogen into sustainable aviation.*

Keywords: hydrogen, climate impact, sustainability, multidisciplinary, design, optimization, aerospace

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EFFECTS OF TRAILING EDGE MODIFICATIONS ON NEGATIVE LIFT CHARACTERISTICS OF SYMMETRICAL AIRFOILS AT TRANSITIONAL LOW REYNOLDS NUMBERS

Pranesh Chandrasekaran[1*], Emre Güler[1] and Melike Nikbay[1]

1: Faculty of Aeronautics and Astronautics
Istanbul Technical University
ITU Ayazaga Campus, 34469, Maslak/Istanbul
chandrasekaran@itu.edu.tr, gulere22@itu.edu.tr, nikbay@itu.edu.tr

Abstract. *Numerical investigations on the flow over blunt trailing edge airfoils, obtained by symmetrically increasing the trailing edge thickness of NACA 0012 and NACA 0015 airfoils, were carried out for various angles of attack at a chord-based Reynolds number (Re) of 40,000 and a turbulence intensity (Tu) of 0.1%. The aim of the present work is to investigate the effects of trailing edge modifications on the aerodynamic characteristics, particularly the non-intuitive negative lift phenomenon, of symmetrical NACA airfoils at transitional low Reynolds number regime. The geometries were generated and initially analyzed using XFLR5, a low-fidelity tool that employs integral boundary layer formulation and is capable of modeling flow transition. These preliminary results are then compared with high-fidelity results obtained using ANSYS FLUENT, allowing for an in-depth assessment of the aerodynamic performance. A detailed analysis of the flow field characteristics was conducted by plotting the pressure distribution on the airfoil surface and visualizing the streamlines around these airfoils. The locations of separation, transition and reattachment are also presented to facilitate the identification of various flow regimes, thereby offering valuable insights into the unusual aerodynamic behavior of these airfoils. Results indicated that the separated region over the upper surface of the airfoils created a reflex camber near the trailing edge, leading to negative lift at low positive angles of attack. The specific range of angles at which this phenomenon occurs is documented.*

Keywords: negative lift, transitional flow, low Reynolds number, trailing-edge, NACA 0012, XFLR5.

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HIGH-FIDELITY NUMERICAL INVESTIGATIONS OF FOLDING WINGTIPS ON HIGH ASPECT RATIO WINGS

Pranesh Chandrasekaran[1*], Emre Güler[1] and Melike Nikbay[1]

1: Faculty of Aeronautics and Astronautics
Istanbul Technical University
İTÜ Ayazaga Campus, 34469, Maslak/Istanbul
chandrasekaran@itu.edu.tr, gulere22@itu.edu.tr, nikbay@itu.edu.tr

Abstract. *The growing demand for sustainable aviation solutions has led to an increased focus on innovative wing designs. Of interest to us in this work is the high aspect ratio (HAR) wings, which can offer a notable reduction in lift-induced drag. One of the inherent difficulties in designing HAR wings is satisfying the dimensional constraints related to the runway and taxiway separation, which places severe demands on the maximum allowable wingspan. In this regard, the concept of folding wingtips offers a unique solution to mitigate the ground handling difficulties faced by the HAR wings. The aim of the present work is to investigate the effect of folding wingtips on the aerodynamic performance of representative HAR wings. Most previous studies on HAR wings with folding wingtips have employed low-fidelity tools to demonstrate the performance benefits associated with this concept. In contrast, the present study employs a high-fidelity open-source CFD tool, SU2, for computing and analyzing the flow field around these wing geometries. A rectangular wing with an aspect ratio of 17.93 is considered, and the impact of various geometrical parameters such as fold angle and location of the hinge line from the wing root are studied. The configurations examined include wingtip fold angles of 15°, 30°, and 45°, as well as the hinge locations at around 75% and 85% of the wingspan. Results revealed that the effect of fold angle on aerodynamic parameters is relatively more pronounced at high angles of attack, while its effect was found to be negligible at low angles of attack.*

Keywords: aerodynamics, folding wingtips, computational fluid dynamics, high aspect ratio wings, hinge location, fold angle

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AEROACOUSTIC SENSITIVITY ANALYSIS OF GEOMETRICAL PARAMETERS FOR OPEN-CAVITY FLOWS

Ramazan Kaba[1*] and Melike Nikbay[2]

1: Modelling and Simulation Department
Turkish Aerospace
Istanbul, Türkiye
ramazan.kaba@tai.com.tr
2.: Astronautical Engineering Department
Istanbul Technical University
University
34469, Istanbul, Türkiye
nikbay@itu.edu.tr

Abstract. *Open cavity flows commonly encountered in aerospace applications such as weapon housing areas and compartments for landing gear. These flows can generate a substantial amount of noise and may reduce the aircraft's stability, especially at high speeds near the speed of sound, known as the transonic regime. This study examines how changes in the design can affect the noise produced by a specific type of open cavity, named the M219 generic open cavity (with a length-to-depth ratio of L/D=5), when flying at a speed of Mach 0.85. Researchers employed computational methods, specifically using Computational Fluid Dynamics (CFD) simulations with the Spalart-Allmaras turbulence model on a simpler mesh in the OpenFOAM-HISA solver, to test 100 different shape variations. They systematically modified aspects such as the slant angle of the rear wall (θ), and the length (l), angle (β), and thickness (h) of a baffle at the leading edge to determine their impact on noise levels, measured by the Overall Sound Pressure Level (OASPL). To efficiently predict how these geometric changes affect noise, a mathematical model known as a Kriging surrogate model was constructed. This approach allowed researchers to understand the relationship between shape changes and noise without testing each one comprehensively. A Sobol' sensitivity analysis was conducted to identify both individual and combined effects of these shape modifications on noise levels. The results revealed that it is possible to significantly reduce noise, by about 30 decibels, mainly by adjusting the baffle angle positively. The analysis highlighted the baffle angle (β) as the key factor most influencing noise levels. Although the baffle length (l) had little direct effect by itself, it had a notable impact when combined with the baffle angle. The impact of the slant angle of the rear wall (θ) and the baffle thickness (h) was minor within the tested ranges. This study provides useful insights into achieving quieter aircraft designs by focusing on these critical shape adjustments.*

Keywords: Cavity flow, aero-acoustic, sensitivity analysis, surrogate modeling

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EXTENSION OF THE TWIST-KIRCHHOFF ELEMENTS TO THE BUCKLING ANALYSIS OF PLATES

Hugo A.F.A. Santos[1*] and Thomas J.R. Hughes[2]

1: Departamento de Engenharia Mecânica, UnIRE, CIMOSM
Instituto Superior de Engenharia de Lisboa
Instituto Politécnico de Lisboa
Rua Conselheiro Emídio Navarro, 1, Lisboa, 1959-007, Portugal
hugo.santos@isel.pt

2: Computational Mechanics Group
Oden Institute for Computational Engineering and Sciences
The University of Texas at Austin
201 East 24th Street, 1 University Station C0200, Austin, TX 78712, USA
hughes@oden.utexas.edu

Abstract. *We extend the first two members of the twist-Kirchhoff family of arbitrary quadrilateral elements to the linear buckling analysis of plates. While standard polynomial C^0-continuous approximation functions are adopted for the transverse displacements, Raviart-Thomas vector-field approximations are considered for the rotations. Continuity of the normal components of the rotation vector across mesh edges is preserved by using the Piola transformation to map the rotations from the parent domain to the physical domain. The elements possess a unique combination of efficiency and robustness in that minimal quadrature rules are sufficient to guarantee stability without rank deficiency. We numerically study the convergence and accuracy of the elements on square, circular and skew plate buckling problems.*

Keywords: Thin plates, twist-Kirchhoff theory, buckling, quadrilateral finite elements, Raviart-Thomas vector fields

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DEEP LEARNING-BASED FLOW FIELD RECONSTRUCTION FOR M219 CAVITY FLOW

Berkay Pirlepeli[1*], Burak Berkan Bedir[1] and Melike Nikbay[2]

1: AeroMDO Lab
Faculty of Aeronautics and Astronautics
Istanbul Technical University
34469
pirlepeli18@itu.edu.tr, bedirb16@itu.edu.tr

2: Astronautical Engineering Department
Faculty of Aeronautics and Astronautics
Istanbul Technical University
34469
nikbay@itu.edu.tr

Abstract. *Modern military aircraft weapon bays require accurate flow field and acoustic predictions for design optimization. While the computational fluid dynamics methods provide high-fidelity simulations, they demand significant computational resources and time. Conventional reduced-order modeling approaches such as proper orthogonal decomposition and dynamic mode decomposition can accelerate predictions but often struggle to capture complex nonlinear dynamics and unsteady characteristic of cavity flows. This study presents a deep learning framework to accelerate these predictions while maintaining accuracy, specifically designed for sensitivity analysis and uncertainty quantification studies of transonic cavity flows. The present framework is developed using the M219 cavity configuration by validating a Detached Eddy Simulation model implemented in OpenFOAM against the experimental results available in the literature. The presented architecture learns nonlinear mappings between limited pressure measurements enabling more accurate reconstruction of flow field and preserving coherent structures and turbulent fluctuations compared to traditional modal decomposition methods. The model is trained using a comprehensive dataset spanning different Mach numbers and cavity geometries to ensure robustness. The framework provides faster flow field predictions for uncertainty quantification and sensitivity analysis compared to full computational fluid dynamics simulations, while maintaining higher accuracy than conventional reduced-order models.*

Keywords: Deep learning, Cavity flow, M219 cavity, Flow reconstruction, Surrogate model

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A STUDY ON THE MULTIDISCIPLINARY DESIGN OPTIMIZATION OF HYBRID-ROCKET PROPULSION

Joana Matos[1*], Frederico Afonso[1], Girolamo Musso[1], Iara Figueiras[1], Alain Souza[1], Inês Ribeiro[1], Fernando Lau[1] and Joseph Morlier[2]

1: IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
{joanafmatos,frederico.afonso,girolamo.musso,iara.figueiras,alain.souza,ines.ribeiro,lau}@tecnico.ulisboa.pt

2: ICA, Université de Toulouse, ISAE-SUPAERO, INSA, CNRS, MINES, ALBI, UPS, Toulouse, France
joseph.morlier@isae-supaero.fr

Abstract. *Hybrid rocket engines are considered a promising option for reducing the environmental impact of microsatellite launchers. They offer higher safety than solid propulsion systems and better manufacturing conditions compared to liquid propulsion. However, their lower regression rate and combustion efficiency have hindered their widespread adoption. This paper aims to explore different types of printable fuels combined with* N_2O *to maximize performance while minimizing environmental impact, all within the context of a predefined sounding rocket geometry. To achieve this, a Multidisciplinary Design Optimization (MDO) approach will be developed using an in-house framework designed for launcher design. Possible design variables include the type of fuel, the volume of oxidizer tank, the oxidizer to fuel mass ratio, total mass of propellant (fuel and oxidizer), throat diameter, and nozzle area ratio (expansion ratio). This approach integrates propulsion, thermochemical equilibrium, initial sizing of the propulsion system, and a Life Cycle Assessment (LCA) that considers both production and use phases.*

Keywords: Eco-design, hybrid-rocket propulsion, printable fuels, life cycle assessment, multidisciplinary design optimization

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INVERSE ESTIMATION METHOD FOR THE CHARACTERISATION OF ELASTIC PROPERTIES OF ANISOTROPIC OPEN-CELL MATERIALS

Huina Mao[1*], Xuefeng Li[2], Gunnar Tibert[1] and Romain Rumpler[2,3]

1: Aerospace Engineering
Dpt of Engineering Mechanics
KTH Royal Institute of Technology
SE-100 44, Stockholm, Sweden
{huina,tibert}@kth.se, www.kth.se

2: The Marcus Wallenberg Laboratory for Sound and Vibration Research (MWL)
Dpt of Engineering Mechanics
KTH Royal Institute of Technology
SE-100 44, Stockholm, Sweden
{xuefengl,rumpler}@kth.se, http://www.kth.se - MWL

3: Digital Futures and The Centre for ECO2 Vehicle Design,
KTH Royal Institute of Technology
SE-100 44, Stockholm, Sweden
{rumpler}@kth.se, www.digitalfutures.kth.se, www.eco2vehicledesign.kth.se

Abstract. *Open-cell architected materials exhibit highly tunable elastic properties governed by both the geometry of their cellular architecture and the intrinsic behaviour of their solid frame. This work presents a simulation-based framework for the characterisation and design of anisotropic stiffness in such materials. A parametrised geometric model based on modified Kelvin structures is introduced to explore the impact of twist, tilt, and stretch transformations on effective elastic behaviour. Directional moduli and stiffness surfaces are computed using beam-based finite element models under periodic boundary conditions, revealing systematic trends in anisotropy. Complementing this, an inverse estimation method is employed to identify the anisotropic Hooke's tensor of the solid phase from macroscopic mechanical responses. The method formulates a constrained optimisation problem linking simulated displacement fields to homogenised stiffness responses, enabling identification of the solid's orthotropic elastic parameters. Comparison between geometric predictions and inversely estimated tensors highlights the central role of microstructural distortion in shaping anisotropic material properties. Together, the results demonstrate a robust and generalisable approach for the analysis and design of architected cellular materials with directional stiffness characteristics, relevant to aerospace structures and acoustic metamaterials.*

Keywords: Anisotropic cellular materials, inverse characterisation, stiffness tensor, Kelvin structure, homogenisation, lattice modelling

Authors did not submit manuscript yet...

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MULTI-OBJECTIVE SURROGATE-BASED OPTIMISATION OF ROCKET FIN DESIGN

José Silva[1*], Frederico Afonso[2] and Fernando Lau[2]

1: Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
jose.goulao@tecnico.ulisboa.pt, https://tecnico.ulisboa.pt/

2: IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
{frederico.afonso,lau}@tecnico.ulisboa.pt, https://www.idmec.tecnico.ulisboa.pt/

Abstract. *This work presents a multi-objective optimisation approach for rocket fin design, focusing on drag coefficient reduction and lift coefficient increase, while ensuring rocket stability and avoiding fin flutter. To achieve these goals, a multi-fidelity surrogate model trained with high and low fidelity three-dimensional computational fluid dynamics simulations is used. The surrogate model, specifically an artificial neural network, is capable of predicting both the lift and drag coefficients, enabling a broader study of fin configurations that would otherwise be computational demanding. Genetic algorithms are then applied to identify the optimal fin shapes and dimensions. Geometric parameters, flutter velocity, and static margin constraints are imposed beforehand to ensure that the optimised fin designs meet the respective requirements. The optimisation was performed across diverse flow conditions, at multiple Mach numbers and corresponding altitudes according to a preliminary flight profile, and at* 0 *and* 5 *angles of attack. The model yielded significant improvements in both aerodynamic coefficients, indirectly contributing to a more sustainable rocket design.*

Keywords: Fin multi-objective optimisation, Multi-fidelity artificial neural network, Genetic algorithm, Multi-disciplinary constraints

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DESIGN OPTIMIZATION OF ELASTOMER MOUNTS TO ASSESS WHIRL FLUTTER PHENOMENON IN A WIND TUNNEL

A. Fereidooni[2], E. Chen[2] A. Grewal[2], V. Wickramasinghe[1], and A. Ben amar[2]

1: Flight Research Laboratory
National Research Council Canada
K1A 0R6
Viresh.Wickramasinghe@nrc-cnrc.gc.ca, https://nrc.canada.ca/en

2: Flight Research Laboratory
National Research Council Canada
K1A 0R6
{Anant.Grewal, Amin.Fereidooni, Eric.Chen, Adam.BenAmar}@nrc-cnrc.gc.ca,
https://nrc.canada.ca/en

Abstract

With the growing use of electric motors in propeller aircraft, concerns around the propeller designs and their potential safety implications due to the whirl flutter phenomenon have become increasingly important. Whirl flutter is an instability that arises when the motion of an elastically supported rotating propeller interacts with the propeller aerodynamic forces. This coupling leads to a decrease in the overall dynamic stability of the propeller, engine and pylon system, potentially leading to catastrophic failure of aircraft components. Previous work in the literature has demonstrated multiple parameters that affect whirl flutter, namely, the propeller rotational speed, the structural damping and the stiffness of the power plant assembly in the pitch and yaw planes. Based on this knowledge, the current study investigated the optimization of the elastomer engine mounts to asses the whirl flutter phenomenon in a wind tunnel environment. For the preliminary mount design, an analysis software has been developed with the capability of providing accurate analytical predictions of the whirl flutter behavior. This software uses two different approaches to generate results, namely, the Ribner approach which is focused on the structural damping and the Houbolt approach which is focused on the viscous damping. Using these two numerical models has resulted in the improved prediction of whirl flutter and enhanced the design of the elastomer mounts. The study concluded that the wind tunnel test and the results from the analysis are able to asses the whirl flutter phenomenon and optimize the elastomer-based engine mount designs.

Keywords: Whirl flutter, stiffness, damping ratio, aeroelastic, wind tunnel, HEAT aircraft,

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COLLABORATIVE TOPOLOGY AND FIBER ORIENTATION OPTIMIZATION SIMPLIFIED VIA MULTI-RESOLUTION ANISOTROPY REPRESENTATION

Shuya Nozawa and Gokhan Serhat

Department of Mechanical Engineering
KU Leuven
Spoorwegstraat 12, 8200 Bruges, Belgium
{shuya.nozawa, gokhan.serhat}@kuleuven.be

Abstract. *The use of fiber-reinforced composites in the aerospace industry has been continuously increasing over the last decades due to their exceptional stiffness-to-weight ratio. Consequently, the development of efficient design methodologies for composites has become crucial. Topology optimization (TO), the geometrical design technique with the highest degree of freedom, offers great utility in this context. The performance of composite structures can be further enhanced by exploiting the material's anisotropic nature through the optimization of spatial fiber orientations. These two design approaches have been often used together in recent works since the advances in additive manufacturing have enabled straightforward fabrication of composite parts with complex geometries and curved fibers. However, combined optimization of structural topology and fiber angle distribution frequently causes numerical instability and local optimality problems due to the large number of design variables having different nature. To circumvent these issues, we propose a novel anisotropic TO methodology in this study. Our approach relies on initiating the optimization iterations from isotropic design and decoupling the update processes for the topological density and fiber orientation distributions. In addition, different from the conventional methods, we assign auxiliary design variables controlling fiber directions to the nodes of an unstructured triangular mesh created over the density distribution. The fiber angle value in each finite element is interpolated based on the information from the surrounding control nodes. The effectiveness of the proposed approach is demonstrated through case studies involving different geometrical constraints and load cases.*

Keywords: Fiber-reinforced composites, Stiffness tailoring, Topology optimization, Fiber path design, Additive manufacturing

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ASSESSING WIND EFFECTS ON THE OPTIMAL TRAJECTORIES OF EXTENDED FORMATION FLIGHTS IN COMMERCIAL AVIATION

M. Cerezo-Magaña[1*]

1: Department of Aerospace Engineering
Universidad Carlos III de Madrid
Leganés, Spain
mcerezo@ing.uc3m.es

Abstract. *This study presents a qualitative analysis to evaluate the impact of wind on the design of formation flights. The formation mission design problem is formulated as follows: given several commercial flights, three in this study, along with weather forecasts and fuel-saving schemes for formation flight, the objective is to determine the optimal trajectories that minimize operating costs. To integrate wind effects into the problem formulation, the mission is modeled as a switched dynamical system, where aircraft can operate in two modes: solo flight and formation flight. Switching between these modes is governed by logical constraints in disjunctive form. To address the computational challenges, an embedding approach is employed to convert the logical constraints into smooth inequality and equality constraints, resulting in a conventional optimal control problem. This transformation eliminates the need for multiple phases or integer variables, thus avoiding combinatorial complexity and allowing the problem to be efficiently solved using traditional optimal control techniques. To analyze the influence of wind, various case studies were performed, covering different days throughout 2024. Wind data was obtained from the ECMWF Reanalysis - ERA5 dataset, ensuring accuracy and reliability. Initially, the algorithm's efficiency in solving the formation flight problem was validated using high-fidelity aircraft models and meteorological data. The results indicate that wind patterns substantially affect the optimal formation topology, influencing both formation flight benefits and configuration. Significant variations in optimal topology were observed, including shifts from three-aircraft formations to two-aircraft formations, with one aircraft flying solo throughout the journey. These findings highlight the importance of accounting for wind in the formulation of the problem, as wind significantly affects trajectory predictability and cost savings. Incorporating high-fidelity models is essential to accurately capture wind influence and maximize formation flight efficiency.*

Keywords: Optimal Control; Trajectory optimization; Formation flight; Wind effects; Switched dynamical system

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COMPARISON OF CONSTRAINT MANAGEMENT STRATEGIES FOR HIGH DIMENSIONAL BAYESIAN OPTIMISATION USING CLUSTERED ACTIVE SUBSPACES

Maxime Chapron[1*,3], Christophe Blondeau[1], Itham Salah El Din[2], Denis Sipp[2] and Michel Bergmann[3]

1: Department of Aerodynamics, Aeroelasticity, Acoustics (DAAA)
ONERA, Institut Polytechnique de Paris
92320, Châtillon, France
maxime.chapron@onera.fr

2: Department of Aerodynamics, Aeroelasticity, Acoustics (DAAA)
ONERA, Institut Polytechnique de Paris
92190 Meudon, France

3: MEMPHIS Team
INRIA Bordeaux
200 avenue de la Vieille Tour, 33405, Talence, France

Abstract. *The increasing number of design variables in industrial-scale aerodynamic shape optimisation has prompted a re-evaluation of state-of-the-art optimisation strategies. Bayesian Optimisation (BO) is well-suited for cases where multimodality challenges gradient-based methods and heuristic approaches are computationally intractable. The curse of dimensionality in Bayesian Optimisation can be mitigated using dimension reduction techniques such as Active Subspaces (AS), which enable accurate surrogate modelling within physics-informed reduced-order bases. The Clustered Active Subspaces (CAS) method, previously introduced by these authors, improves upon AS by employing a piecewise approximation to better capture complex high-dimensional objective functions. CAS has also been successfully integrated into a reduced-dimension BO framework, facilitating global optimisation of aerodynamic designs.*

In this work, we compare multiple constraint management strategies for the Clustered Active Subspaces framework, assessing their impact on optimisation performance. Specifically, we examine how expensive nonlinear constraints such as the lift coefficient can be efficiently handled within the reduced-dimension Bayesian Optimisation. The proposed approaches are evaluated on high-dimensional analytical test functions and demonstrated on the constrained global optimisation of a NACA0012 airfoil in transonic viscous flow.

Keywords: Optimization, Dimension Reduction, Clustering, Bayesian Optimization, Active Subspaces

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OPTIMIZING TRANSITION PROFILES FOR TAILSITTER UAVS: A GRADIENT DESCENT APPROACH

Alexandre Athayde[1*], Alexandra Moutinho[1] and José Raúl Azinheira[1]

1: IDMEC - Instituto de Engenharia Mecânica
Instituto Superior Técnico
Universidade de Lisboa
1049-001, Lisbon, Portugal
alexandre.athayde@tecnico.ulisboa.pt, alexandra.moutinho@tecnico.ulisboa.pt,
jose.raul.azinheira@tecnico.ulisboa.pt

Abstract. *Tailsitter uncrewed aerial vehicles (UAV) operate in two primary flight modes: hovering, where the UAV weight is sustained only by the thrust of the motors, and aerodynamic flight, where lift generated by the wing contributes to weight support, similar to fixed-wing aircraft. Transitioning between these modes presents a significant challenge due to the limited control authority of the elevons at low airspeeds, as their effectiveness depends on the slipstream from the propellers. Conventional transition strategies rely on simplistic methods, such as accelerating until sufficient airspeed is reached for effective control surface actuation, or by changing the reference attitude from one mode to the other. Naturally, these approaches often lack precision and can lead to inefficient or even unstable transitions.*

To address the specific challenge of tailsitter transitions, the research conducted in this article proposes an optimized strategy based on a comprehensive mapping of stable trim points across a range of airspeeds and climb angles. Using an iterative gradient descent optimization method, a complete envelope of steady-flight trim conditions is obtained, and is then analysed to determine regions of viable operation and evaluate control limitations. From this analysis, a structured transition profile is derived, specifying optimal pitch angles and airspeeds for both forward (vertical to aerodynamic flight) and backward (aerodynamic to vertical) transitions. The proposed profiles are then tested using MATLAB/Simulink based simulations, incorporating an incremental control approach to regulate the transition process.

The obtained results demonstrate that the optimized transition profiles allow for smooth and continuous transitions with low acceleration levels, minimizing abrupt changes in dynamics. Additionally, a trade-off is identified between transition smoothness and altitude gain, providing valuable insights for future implementations in experimental flight scenarios. This methodology offers a systematic and efficient approach to improving the manoeuvrability of tailsitters, contributing to enhanced stability and performance in transitioning flight conditions.

Keywords: tailsitter; UAV; VTOL; transition optimization; gradient descent

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MULTIDISCIPLINARY DESIGN OPTIMIZATION OF NONPLANAR LIFTING SYSTEMS FOR UNMANNED COMBAT AERIAL VEHICLES

Hassan Aleisa[1], Berkay Pirlepeli[2], Sihmehmet Yildiz[2], Konstantinos Kontis[1], and Melike Nikbay[3]

1: Aerospace Engineering Department
University of Glasgow
Glasgow, G12 8QQ, UK
2: AeroMDO Lab
Faculty of Aeronautics and Astronautics
Istanbul Technical University
34469
pirlepeli18@itu.edu.tr, yildizsih@itu.edu.tr
3: Astronautical Engineering Department
Faculty of Aeronautics and Astronautics
Istanbul Technical University
34469
nikbay@itu.edu.tr

Abstract. *This paper overviews the AVT-SP-002 research project collaborated between Istanbul Technical University and the University of Glasgow and supported by NATO Science and Technology Organization, focusing on the design and optimization of non-planar lifting systems for potential applications in civil and military aircraft. The research team employed a combination of computational and experimental methods to achieve project objectives. Through comprehensive experimental and computational fluid dynamics (CFD) investigations, this study demonstrates that UCAV lift and drag characteristics are significantly influenced by leading-edge sweep angle variations. The research reveals that non-constant leading-edge sweep configurations exhibit delayed stall and enhanced aerodynamic performance compared to constant sweep variants. A multidisciplinary design optimization framework integrating aerodynamic analysis with radar cross-section prediction enabled the development of nonplanar UCAV geometries characterized by improved stealth properties and superior aerodynamic efficiency. This framework was applied to the design of a novel non-planar wingtip extension for a flying wing UCAV. The project also involved wind tunnel testing of an aerodynamically optimized non-planar wing model to understand the flow physics associated. Wind tunnel testing conducted at the University of Glasgow's de Havilland facility validated these findings, confirming good agreement between experimental and numerical results. The complex vortical flow structures governing UCAV aerodynamic behavior were analyzed across various pitch and yaw angles, providing critical insights into leading-edge vortex formation, development, and breakdown phenomena. The experimental results were used to validate and refine the optimization algorithm. A rapid prototyped UCAV wind tunnel model demonstrated the usage without compromising performance accuracy. The testing results indicated that the obtained data from the test was of acceptable quality regarding aerodynamic performance. It was found that the optimized non-planar UCAV model exhibited enhanced aerodynamic performance*

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MULTI-FIDELITY BAYESIAN OPTIMIZATION FOR AEROSPACE ENGINEERING DESIGN

Sihmehmet Yildiz[1*], Melike Nikbay[2]

1: Aeronautical Engineering Department
Istanbul Technical University
University
34469, Istanbul, Türkiye
yildizsih@itu.edu.tr

2.: Astronautical Engineering Department
Istanbul Technical University
University
34469, Istanbul, Türkiye
nikbay@itu.edu.tr

Abstract. *Multi-fidelity Bayesian optimization (MFBO) has become a powerful tool for tackling computationally expensive engineering design problems by leveraging lower-fidelity approximations to guide the optimization process. This study explores the application of MFBO to efficiently solve these problems, demonstrating its superior performance compared to single-fidelity Bayesian optimization (SFBO). Engineering design frequently relies on computationally intensive high-fidelity simulations; MFBO mitigates this burden by integrating information from models of varying fidelity. The methodology employs advanced surrogate modeling techniques to capture the relationships between design variables and performance metrics across different fidelities while also investigating the impact of various acquisition functions on optimization trajectories. Comparative studies using analytical equations and simple engineering problems evaluate MFBO's performance in terms of convergence speed, computational cost, and the quality of the final design. The results highlight cases in which MFBO significantly reduces computational cost. Additionally, the sensitivity of MFBO to the choice of acquisition functions is analyzed to provide insights into its effective implementation.These findings contribute to research on efficient optimization strategies by highlighting the potential of MFBO to advance aerospace engineering design through an effective balance between accuracy and computational efficiency.*

Keywords: Multi-fidelity, Bayesian Optimization, Surrogate Modeling, Acquisition Function

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OBSTACLE AVOIDANCE FOR FIXED-WING AIRCRAFT BY USING CONTROL BARRIER FUNCTIONS

Huriye Nur Toprak[1]*, Emre Koyuncu[2]

1: Aviation Institute
Istanbul Technical University
toprakh16@itu.edu.tr

2: Aviation Institute
Istanbul Technical University
emrekoyuncu@itu.edu.tr

Abstract *With the improvements in aviation industry and increased manufacturing capabilities, aircraft are now being deployed in more complex environments and mission profiles. However, ensuring autonomous flight safety is still a challenging problem, particularly in environments with both static and dynamic obstacles. Among the various methods for ensuring safe operation, Control Barrier Functions (CBF) have emerged as a promising approach due to its ability to enforce system constraints both geometrically and dynamically, providing a robust framework for safe navigation. CBFs have been widely applied in robotics and autonomous vehicle systems to enhance obstacle avoidance. With the help of the geometric representation of the potential collision region, CBF can be defined. While there are many studies on CBF have been successfully applied to unmanned ground vehicles and quadrotors, its adaptation to fixed-wing aircraft remains challenging due to their nonholonomic motion constraints and highly nonlinear dynamic characteristics. This study aims to extend the CBF based obstacle avoidance approach to fixed-wing aircraft operating in environments containing both static and dynamic obstacles. The methodology involves dynamically constructing a collision region based on the aircraft's relative velocity with respect to obstacles and incorporating it into a CBF framework for real-time avoidance. To accommodate the specific dynamics and constraints of fixed-wing aircraft appropriate to CBF, an affine control system representation is considered. To evaluate the minimum control inputs satisfying the obstacle avoidance, CBF Quadratic Program (CBF-QP) is defined and solved by numerical optimization. Furthermore, the environment is modeled using Digital Terrain Elevation Data (DTED) to accurately represent real-world navigation conditions. By integrating CBF with fixed-wing aircraft dynamics, this study extends the usage of CBF based obstacle avoidance beyond ground vehicles and quadrotors, shows a feasible application for safe fixed-wing aircraft navigation in environments with obstacles.*

Keywords: CBF, CBF-QP, obstacle avoidance, fixed-wing aircraft

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AEROELASTIC MODELING AND DESIGN OF A FLEXIBLE BLENDED-WING-BODY (BWB) RESEARCH VEHICLE

Mario Bras[1*], Sid Banerjee[2] and Afzal Suleman[1,3]

1: Center for Aerospace Research
Department of Mechanical Engineering
University of Victoria
3800 Finnerty Rd, Victoria BC, V8P 5C2, Canada
{mbras,suleman}@uvic.ca, https://www.uvic-cfar.com

2: Advanced Design, Research & Technology
Bombardier
400 Côte-Vertu Road West, Dorval QC, H4S 1Y9, Canada
Sid.Banerjee@aero.bombardier.com

3: IDMEC
Instituto Superior Técnico
Universidade de Lisboa
Av. Rovisco Pais, No. 1, 1049-001, Lisboa, Portugal
suleman@tecnico.ulisboa.pt, https://www.idmec.tecnico.ulisboa.pt

Abstract. *The blended-wing-body (BWB) aerodynamic configuration has been shown to reduce drag, improve lift, and decrease weight and fuel consumption, making it a promising solution for future sustainable aviation. Understanding and controlling the aeroelastic behavior of BWB configurations with high-aspect ratio wings is a key challenge where scaled flexible-wing flight test demonstrators can provide a low-cost, low-risk alternative to full-scale aircraft flights.*

These research vehicles can be designed to exhibit aeroelastic instabilities at low speeds to help characterize the aeroelastic behavior of the full-scale aircraft. However, studies on the flutter mechanisms of BWB aircraft are scarce and these configurations can exhibit flutter modes typical of flying wing and conventional wing configurations. Characterizing their aeroelastic behavior is of extreme importance if such aircraft designs are to be flown in the future.

Towards that end, this paper presents a structural design study performed on a reduced-scale BWB research vehicle where the aeroelastic response of the aircraft was tailored to exhibit flutter at low speeds while guaranteeing structural integrity throughout the flight envelope. Aeroelastic models of the aircraft are developed in NASTRAN and ASWING. Different internal structural configurations are defined followed by a sweep of parametric studies. Flutter modes, as well as static wing displacements and stresses, are identified for each data point in the study. Finally, a comparative study between the two models is performed for the flutter modes, structural deformations, and internal stresses.

Keywords: aeroelasticity, flexible wing, blended-wing-body (BWB), flutter mechanisms

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AIRCRAFT WING STRUCTURAL SIZING COMPUTATIONAL TOOL TAILORED FOR A COLLABORATIVE MULTIDISCIPLINARY DESIGN FRAMEWORK

Pedro F. Albuquerque[1], Ana M. P. Silva[1] and André N. Pereira[1]

1: CEiiA - Centre of Engineering & Product Development
CEiiA — PACT - Herdade da Barba Rala, Rua Luís Adelino Fonseca Lote 1 A, 7005-841 Évora, Portugal
ana.silva@ceiia.com, https://www.ceiia.com/

Abstract. *This article presents two innovative tools,* ***WinG3N*** *and* ***WingSizer****, designed to streamline the traditional process of hand-made model development for aircraft wings.* ***WinG3N*** *enables the automatic generation of a wing finite element model within seconds, facilitating additional trade-off and sensitivity studies that would be impractical with manual methods. Complementarily,* ***WingSizer*** *automates the sizing process for static and buckling analyses, significantly reducing the time required compared to standard procedures, making it a valuable tool for efficient design. The* ***WingSizer****'s capability to compare metallic and composite structures allows for comprehensive trade-off studies, offering a quantitative assessment of the advantages and disadvantages of using composites. This feature enables a thorough evaluation of the potential benefits of altering the material composition of the entire wing assembly or specific components. While these tools are tailored for aircraft wing analysis, their applicability extends to the initial sizing of horizontal and vertical stabilizers, provided they feature no more than two longitudinal spars. The* ***WingSizer*** *versatility by seamlessly integrating into a multidisciplinary optimization framework has been tested during the 2023 International Forum for Aviation Research (IFAR) Young Engineers Challenge and presented at the 2024 International Council of the Aeronautical Sciences Congress. Two case studies are shown in the current article, one featuring the impact of buckling on a fully metallic wing and another comparing the structural mass of a fully metallic wing against a composite skin with metallic skeleton and a fully composite wing. The results corroborate prior research on the topic.*

Keywords: Aircraft Wing, Composite Aircraft, Structural Sizing and Optimization, Collaborative Design, Multidisciplinary Design