Theme 4 Project:
Test, Analysis and Simulation

Aerodynamic Analysis of a Strut-Braced Wing

	name	contact	date
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1. The 4th Thematic Project

1.1. The scope and objectives

The thematic projects in the Aerospace Engineering Bachelor Program aim to provide learning experiences that will enable you to better integrate the theoretical content of the courses in a practical, active setting. The projects are mandatory elements of the program. Each semester contains one thematic project.
The theme of the 4th semester is "Test, analysis, and simulation". The courses in this semester, in general, have this theme in common. This theme also is the focus in this 4th semester AE2224-I project.

1.2. Activities within the project

The project will run in the second semester of the second year. Table 1 gives an overview of the activities during the project.

The deadlines within the project are:

16 February 2024, 17:30	Hand in annotated bibliography and genre analysis. You will be provided with the relevant instructions in the introductory lecture in week 3.1. The report will not be graded.
8 March 2024, 17:30	Hand in literature review for scientific reporting. You will be provided with the relevant instructions in the introductory lecture in week 3.1. The report will not be directly graded.
8 March 2024, 17:30	Hand in research plan to tutor. This research plan should contain the first research steps (type of activity and distribution of tasks) you intend to take. It will help you to start and better define the research. In addition, it allows your tutor to give to-the-point feedback. This report will not be directly graded.
8 March 2024, 17:30	Submit individual introduction to scientific writing. You will be provided with the relevant instructions in the introductory lecture in week 3.1. The report will not be directly graded.
28 March 2024, 17:30	Submit self-reflection report to the project supervisor. This self-reflection should not exceed 1 A4 and should reflect on your own contribution to the project: - How did it go so far? - What are your insights on your own functioning within a group? - What have you identified as your strengths? - What weaknesses need to be improved upon? How do you intend to ensure these improvements?

26 April 2024, 17:30	Submit introduction and methods section for scientific reporting for teacher feedback.
15 May 2024, 17:30	Submit draft of scientific report for the peer review process (please note this is on a Wednesday)
24 May 2024, 17:30	Submit peer review
14 June 2024, 17:30	Submit final version of scientific report to Brightspace, tutor and scientific reporting teacher

1.3. Grading

You will be graded at the end of the project based on the following items:

1. The scientific report. A **group grade** will be given based on the technical quality of the report. Each group member should indicate what part of the report he/she has produced. This will be used for grading.
2. Your attitude during the project. It is based on regular meetings with your tutor and your self-reflection and is an **individual grade**.
3. The project ends with an oral exam. During this exam the tutor, together with one of the project coordinators or teaching assistants, will test your understanding with regards to the research, resulting in an **individual grade**.
4. You all will be asked to review the report of another group individually. The quality of the review will be accounted for as an **individual grade**. This grade is provided by the tutor of the group whose report is reviewed.

Partial grades will be rounded to 1 decimal. The tutor grade holds for all ECTS of AE2224-I. The quality of the report is also assessed by the Scientific Reporting tutor who gives a pass/fail grade on the report.

In order to pass the project, the following needs to be fulfilled:

1. The whole project has been completed and all compensatory assignments have been completed successfully and,
2. No more than one grade is lower than 6.0 and all grades are 5.0 or higher,
3. A pass is attained on the Scientific Reporting component.
4. All rules regarding absence are met.

If any of the above conditions are not met, a final grade of 1.0 is awarded for the project. If you fail the project you have to reregister to redo the project the following academic year.

Table 1. The project activities.

When	Activity
Week 3.1	- Introductory lecture - Kick-off: meeting with the tutor - Annotated bibliography and genre analysis

Week 3.2	- Information literacy 2 course - Start literature survey
Week 3.3	- **Scientific reporting coaching session 1 (for half the cohort)** - Literature survey
Week 3.4	- **Scientific reporting coaching session 1 (for the other half the cohort)** - Finalize literature survey - Write research plan - Start with data analysis - Submit literature review (8/3/2024) - Submit research plan to tutor (8/3/2024) - Submit Individual Introduction (8/3/2024)
Week 3.5	- Continue data analysis
Week 3.6	- Continue data analysis - **Scientific reporting coaching session 2 (for half the cohort)**
Week 3.7	- **Scientific reporting coaching session 2 (for the other half the cohort)** - Continue data analysis - Work on scientific report - Submit the self-reflection report (28/3/2024)
When	**Activity**
Week 4.1	- Continue data analysis - Work on scientific report
Week 4.2	- **Scientific writing coaching session 3 (for half the cohort)** - Continue data analysis - Work on scientific report
Week 4.3	- **Scientific writing coaching session 3 (for the other half the cohort)** - Continue data analysis - Work on scientific report
Week 4.4	- Continue data analysis - Work on scientific report - Draw conclusions - Submit draft of scientific report (15/5/2024), please note the deadline is on a Wednesday! - Submit peer review report (24/5/2024)
Week 4.5	- **Scientific writing coaching session 4 (<u>for all students</u>)** - Peer review of scientific reports
Week 4.6	- Register for a group session with your scientific writing teacher to receive feedback and for questions regarding the implementation of the peer review comments (the schedule for these sessions will be provided at the Scientific reporting coaching session 3). - Implementation of the comments from the peer review and finalize data analysis - Work on scientific report
Week 4.7	- Register for a group session with your scientific writing teacher to receive feedback and for questions regarding the implementation of the peer review comments (the schedule for these sessions will be provided at the Scientific reporting coaching session 3). - Implementation of the comments from the peer review and finalize data analysis - Work on scientific report
Week 4.8	- Deliver final report (14/6/2024)
Week 4.9 - 4.10	- Oral exam - Grading

1.4. Required presence and absence rules

Currently, the project is scheduled to be on campus. For each student group the project sessions will be scheduled, and a project space assigned (in case on campus education is possible). Within each group a member needs to be assigned who is responsible for recording the presence. Presence during the project is compulsory and will be checked. The following rules hold:

1. The student must attend all scheduled project sessions.
2. The student must attend the first week of the project. Not being present in the first week of the project results in exclusion from participating in the project in that academic year.
3. Attendance is mandatory during the scheduled project session hours.
4. Project session starts either at 08:45 or 13:45, the project ends at either 12:30 or 17:30. Missing time by either being late or leaving at any time before the project end time is registered as missed sessions.
5. Students should be working on the project between the scheduled session start and end time. If a student is not working on the project during the project session it is registered as a missed session.
6. A missed session must be compensated by fulfilling a replacement assignment. The replacement assignment will be provided by the responsible lecturer to the student.
7. No opportunities are offered outside the duration of the project for making up a missed sessions.
8. Students are allowed to miss a maximum of 2 project sessions in Q3 and only 1 project session in Q4 due to illness, family circumstances or relevant extenuating circumstances. Reason for absence should be reported to the course responsible and TA's as soon as possible but at least before the project session starts.
9. If a project has a supporting course the student is only allowed to be absent for one session of this course. This session is not counted as a missed project session as mentioned under 8.
10. The student cannot obtain a passing grade for the project if the number of session as stated in either 8 and/or 9 are exceeded.
11. Students who are of the opinion that there are relevant extenuating circumstances can turn to the academic counsellors for guidance.

In case a group member is absent, he/she must plan in cooperation with his/her group on how to make up for the absence. The result must be communicated to the supervisor and its realization is based upon the supervisor's approval. Absence at a scientific reporting session needs to be reported to the scientific reporting teacher. A compensatory assignment will be provided. The student is responsible for fulfilling the compensatory assignment, at a time or within a time limit set by the responsible lecturer (this also applies to supporting courses). The quality of the compensatory assignment is assessed by the responsible lecturer. Not finishing the assignment within the allocated time and/or with sufficient quality, results in failing the project.

1.5. Peer evaluation and logbook

During the project there will be 4 occasions when there will be a peer evaluation of your group members. This evaluation is used to monitor the contribution of all group members to the

project and to give feedback on their performance. The peer evaluations are scheduled roughly for week 3.4, 3.8, 4.4 and 4.8. Please note that these evaluations are not directly used for grading.

In addition, every student should maintain a logbook. At the end of each week this logbook should be updated and uploaded to Brightspace such that the TAs can review it. The logbook should contain the work that was carried out in the preceding week and the activities that will be done in the coming week. There can be a single logbook for each group, however the students are responsible for their individual entries.

1.6. Description of the oral exam

The format of the oral exam is as follow:

- The tutor is in charge of conducting the oral exam.
- The duration of the oral exam is about 10 minutes per student.
- The question at the oral exam cover:
    - General theoretical concepts involved in the project (both on the application and the methods used).
    - Specific question on the student's report and contribution.
    - Questions can cover part of the project the student was not specifically involved in (but that the rest of the group worked on).

1.7. Description of the teaching team

- The tutor is the main contact point for all specific aspects related to the project. The tutor is also the first point of contact for matters related to the group dynamics.
- The TAs are the main contact point for attendance and organizational matters of the project.
- The course coordinators (Dr. Modesti and Dr. Doan) should only be contacted in case large issues appear within the project (e.g.: conflict within the group, miscommunication with the tutor, ….)

2. The Assignment

In the contemporary global landscape, the imperative for decarbonization within the aviation sector has become increasingly urgent. The pressing need for mitigation of greenhouse gas emission in aviation underscores the industry's responsibility to adopt innovative, eco-friendly technologies and practices, heralding a paradigm shift toward a more sustainable and environmentally conscious future.

One of the most promising configurations to fulfill this objective is the strut-braced wing (SBW). Indeed, compared to a cantilever wing in which the increasing of span size to reduce induced drag is constrained by structural weight [1], the strut braced can have a longer span since the strut alleviates the bending moment in the main wing (in Fig. 1 an example of strut-braced wing is shown). Moreover, the strut enables the reduction of the main wing thickness-to-chord ratio, which ultimately leads to a decrease of the structural weight. These advantages coupled with its compatibility with conventional fuselage and empennage design make the strut-braced wing a perfect candidate for a near-term entry into service vehicle [2].

Although different number of studies have demonstrated the potential benefits of strut-braced and truss-braced wings [3 – 8], there is motivation for further investigations into a number of challenges that have to be addressed during the design phase. Since the strut-braced wings involves the use of additional struts or braces to support the wings, their feasibility relies heavily on the synergistic interaction between the wing and the strut, as well as meticulous design of the junctions.

The dataset provided for this project consists of a series of global and local aerodynamic coefficients distributions computed on a strut-braced wing at different angles of attack and at different flight conditions (CRUISE: h=22000 ft V=280 KTAS; CLIMB: h=12000 ft V=150 KCAS). This dataset was generated by means of high-fidelity Very Large Eddy Simulations (VLES) using the 3DS PowerFlow flow solver. Eventually a set of data obtained using low-fidelity approach (AVL+MSES) are also included.

The objective of the project is to investigate aerodynamic performances of a strut-braced wing compared to that of a cantilever wing. Therefore we could answer the question: does the loss of induced drag outweigh the increase in interference drag?

Tasks of the project

1. Compute aerodynamic coefficients (CL,CD,CM) and efficiency (E=CL/CD) from the force components given in the aircraft reference frame, for both the wings in both the flight conditions. Consider a reference surface of 73 m^2 and a reference length of 1.8 m. Based on this data, is there a range of lift coefficients in which one of the two kind of wings performs better ? How could you explain it ?
2. Compare Cl and Cd spanwise distributions for the two wings in CRUISE. What the main differences ?
3. Estimate the lift induced drag from the provided data and compare it with Prandtl formula. Make a comparison for both the wings. Does Prandtl formula fits well for the strut-braced wing ?
4. Plot the pressure coefficients at Y/b = 16, 31 and 70% for the SBW in CRUISE separating wing and strut contribution. What can you say about the loading on the strut compared to that on the wing ?
5. Compare the following data obtained for the SBW on PowerFlow with those obtained through low-fidelity approach (AVL+MSES):
    a. Cl(y) and Cd(y).
    b. Cp at 16, 31 and 70% in CRUISE.

   Does the low-fidelity approach fits well for the strut-braced wing ?

3. The project tutor

Name	e-mail	Tel.	Room	Section	Periods unavailable
Emanuele Sticchi	e.sticchi@tudelft.nl	-	6.08	Wind Energy	-

Please also provide a person to be contacted while you are unavailable:

Name	e-mail	Tel.	Room	Section
Daniele Ragni	d.ragni@tudelft.nl	-	5.08	Wind Energy

4. Relevant courses

Aerodynamics

References/reading material

[1] Martins, J. R. R. A., Kennedy, G., and Kenway, G. K., High Aspect Ratio Wing Design: Optimal Aerostructural Tradeoffs for the Next Generation of Materials, 2014. https://doi.org/10.2514/6.2014-0596.

[2] Chau, T., and Zingg, D. W., "Aerodynamic Design Optimization of a Transonic Strut-Braced-Wing Regional Aircraft," Journal of Aircraft, Vol. 59, No. 1, 2022, pp. 253–271. https://doi.org/10.2514/1.C036389.

[3] Gur, O., Schetz, J. A., and Mason, W. H., "Aerodynamic Considerations in the Design of Truss-Braced-Wing Aircraft," Journal of Aircraft, Vol. 48, No. 3, 2011, pp. 919–939. https://doi.org/10.2514/1.C031171.

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[5] Chau, T., and Zingg, D., "Fuel burn evaluation of a transonic strut-braced-wing regional aircraft through multipoint aerodynamic optimisation," The Aeronautical Journal, Vol. 127, No. 1308, 2023, p. 305–329. https://doi.org/10.1017/aer.2022.64.

[6] Moerland, E., Pfeiffer, T., Böhnke, D., Jepsen, J., Freund, S., Liersch, C. M., Chiozzotto, G. P., Klein, C., Scherer, J., Hasan, Y. J., and Flink, J., On the Design of a Strut-Braced Wing Configuration in a Collaborative Design Environment, 2017. https://doi.org/10.2514/6.2017-4397.

[7] Daniel Maldonado, Sally A. Viken, Jeffrey A. Housman, Craig A. Hunter, Jared C. Duensing, Neal T. Frink, James C. Jensen, Susan N. McMillin and Cetin C. Kiris. "Computational Simulations of a Mach 0.745 Transonic Truss-Braced Wing Design," AIAA 2020-1649. AIAA Scitech 2020 Forum. January 2020.

[8] Design Optimization of a Truss-Braced-Wing Transonic Transport Aircraft, Ohad Gur, Manav Bhatia, Joseph A. Schetz, William H. Mason, Rakesh K. Kapania, and Dimitri N. Mavris Journal of Aircraft 2010 47:6, 1907-1917.

- at least 2 books, to be handed out as a starting point for the work

[9] Anderson, J.D.. (2016). Fundamentals of aerodynamics (6th ed.). McGraw-Hill Education.
[10] Anderson, J. D. (2015). Introduction to Flight (8th ed.). McGraw-Hill Education.