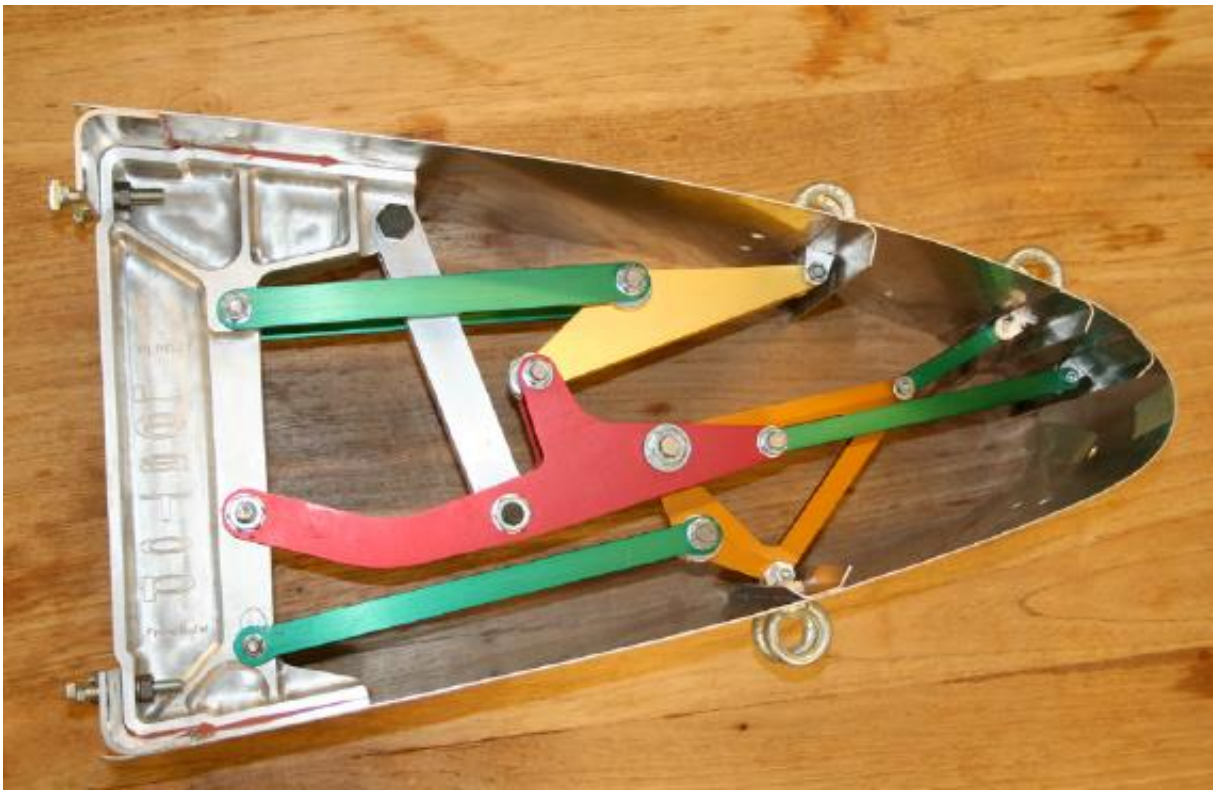
Theme 4 Project:
Test, Analysis and Simulation

Experimental Evaluation of the Morphing Leading Edge Concept



	name	contact	date
Tutor	Hammad Rahman	h.rahman@tudelft.nl	30-01-2022

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 AE2223-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:

4 March 2022, 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.
4 March 2022, 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.
25 March 2022, 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?
22 April 2022,17:30	Submit introduction and methods section for scientific reporting for teacher feedback.
11 May 2022, 17:30	Submit draft of scientific report for the peer review process (please note this is on a Wednesday)
20 May 2022, 17:30	Submit peer review
10 June 2022, 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 for the course Scientific Reporting.
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 and the final grade will be rounded to the nearest halve grade. The tutor grade holds for 4 ECTS and 1 additional ECTS is given by the Scientific Reporting tutor for the quality of 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. 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
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 of the cohort)** -Finalize literature survey - Write research plan - Start with data analysis - Submit literature review (4/3/2022) - Submit research plan to tutor (4/3/2022)
Week 3.5	- Continue data analysis
Week 3.6	- Continue data analysis - **Scientific writing coaching session 2 (for half the cohort)**
Week 3.7	- **Scientific reporting coaching session 2 (for the other half of the cohort)** -Continue data analysis - Work on scientific report

	- Submit the self-reflection report (25/3/2022)
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 reporting coaching session 3 (for the other half of 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 (11/5/2022), please note the deadline is on a Wednesday!
Week 4.5	- **Scientific writing coaching session 4 (<u>for all students</u>)** - Peer review of scientific reports - Submit peer review report (20/5/2022)
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 (10/6/2022)
Week 4.9 - 4.11	- Oral exam - Grading

1.4. Required presence and absence rules

Currently, the project is scheduled to be on campus. If the circumstances will require it the project might be carried out online using MS Teams. 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 (both online and on-campus). 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 sessions.

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 per period (half semester) 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.

1.4.1. Addition to absence ruling in projects (Q3 + Q4 academic year 2021/22)

Rationale
We acknowledge that in the coming months, Covid-19 infection rates amongst students may remain high. We don't want students to become the victims of this. On the other hand we also want to guarantee, as much as practically possible, access to on-campus educational activities. Working in hybrid for projects is considered a last resort. This ruling will be monitored in light of possibility for on-campus project sessions and Covid-19 measures.
Furthermore, we also expect that students act responsibly. We also acknowledge that the Dutch health authorities have ruled that people that have been in close contact with an infected person no longer need to quarantine when having had the booster vaccination.

The current absence ruling allows the students to be absent for two project sessions without having to face further consequences. This ruling is meant for both unforeseen and foreseen leave of absence (with exception of extenuating circumstances). Covid-19 infections and quarantine mandates may lead to more than usual absence. Therefore, we will apply the following additional absence ruling in semester 2 of the academic year 2021/22.

Additional absence ruling

1. When a student shows symptoms of an illness, he or she stays at home. The normal rules of absence will be valid.
2. When Covid-19 is suspected, the student gets him/herself tested as soon as practically possible.
3. When Covid-19 is confirmed and he or she is still able to continue working, the whole group switches to an online working mode.
4. When the student is not able to continue working, the rest of the group continues working on campus until the moment the infected student can resume working again. When the infected student may come out of isolation the group can work on campus. If the student is able to participate but still needs to quarantine, the group works fully online.
5. In these cases, the illness does not count towards the standard leave of absence. It is up to the staff of the project to decide when the number of missed sessions becomes too large to meet the learning objectives of the project. When that happens, the staff can decide on additional assignments to make up for the missed sessions.
6. The project organization may determine specific educational activities for which on-campus attendance is mandatory. In this situation, a “repair opportunity” for this activity needs to be offered. This “repair opportunity” may not cause an undue workload for the staff.

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.

2. The Assignment

2.1. Background

The current assignment is based on a part of the CleanSky Green Regional Aircraft Integrated Technology Demonstrator, with a focus on the LeaTop project. The project consisted of a completed development process starting with a conceptual design and concluding with a manufactured demonstrator with an extensive testing program to demonstrate morphing capabilities of the leading edge concept. The aim was to demonstrate morphing capabilities of at least 5° leading edge rotation by inducing bending deformations in the airfoil skin along with a close match to the target shape predicted using finite element analysis.

An integrated conceptual design methodology using an aeroelastic framework was developed at Delft University of Technology requiring that a functional seamless morphing leading edge demonstrator can effectively transition from original configuration, cruise shape, to target configuration, landing shape, while withstanding full aerodynamic forces. The demonstrator was then tested with experimental trials including strain evaluation in the airfoil skin, morphing mechanism locking capability and shape measurements of the morphed skin.

The results of this study were published at the AIAA SciTech conference proceedings in 2015 and in the Journal of Intelligent Material Systems and Structures in 2019. The papers can be accessed from the AIAA ARC website and Sagepub respectively.

J. Sodja, M. J. Martinez, J. C. Simpson, and R. de Breuker, “Experimental Evaluation of the Morphing Leading Edge Concept”, in AIAA 2015-0791.

J. Sodja, M.J. Martinez, J.C. Simpson, and R. de Breuker, “Experimental evaluation of a morphing leading edge concept’, Journal of Intelligent Material Systems and Structures, Vol 30, No. 18–19, 2953–2969, 2019.

2.2. Objective & Research Questions

The objective of this exercise is to determine if the LeaTop project was successful in achieving its two basic aims as mentioned above in section 2.1, one being the minimum rotation of 5° of the leading edge and the second one being the target shape matching. Some implicit verification also needed to be carried out, such as whether the deformation in the skin was of a purely bending type or not.

To carry out the assignment, the students are required to first conduct a literature review in order to develop some baseline knowledge of following concepts:

a. What is morphing, what are the different morphing techniques, what are the benefits?
b. In the referenced paper in 2.1 an experimental set up is described. Perform a detailed review on:
    - Used experimental techniques
    - Data acquisition systems
    - Numerical methods (FEM) used for simulations

After the literature review, the following tasks are required to be performed:

a. Process the strain measurements and carry out comparisons to the FEM results.
b. Process the shape measurement experimental images and extract the target shapes from each data file. Compare these target shapes with the finite element analysis results.

Finally, the students need to interpret the results and they are required to answer the following research questions:

a. How does the experimental strain data compare to the FEM strain data? What could be reasons for the possible deviations?
b. Is the skin under pure bending? Is this desirable?
c. What is the maximum achieved leading edge rotation? Does it comply with the requirements?
d. Does the resulting deformed shape match up with the target shape? What is the error between the two?
e. Is the target shape as predicted by the FE analysis? If it is, how small is the error, and if not, what are the possible reasons for the error?
f. Can we make any changes to the experimental setup to improve the reliability of the measurements, if required?
g. Is the LeaTop a reliable and fail-safe design?

2.3. Data Provided & Format

Strain measurements from the fibre are provided along the arc length. The first line contains the arc length sections, followed by data in every consecutive line.

The images for shape target measurement are provided in folders with a key name. The camera was set to auto-focus, so the images seems to be displaced, but the data can be easily extracted by using conversion to grey-scaling followed by black and white conversion.

The FEM data is provided in two .out files per load step. The *disp.out files contain the node numbers, x,y,z coordinates of the skin and the displacements in x,y,z direction. The *str.out files contain the node numbers and the x,y,z,xy,yz and xz engineering strains on the inner (uneven rows) and outer (even rows) skin. The engineering strains are given in the global frame of reference.

In addition to the main dataset, actuator force and displacement are available. They are provided in a .txt file with three columns, time, displacement and force. An error must be removed from the data. This error can be found as an average of the data corresponding to time = -1 in this txt file.

A key list will be provided with the data explaining how the different datasets are linked to each other.

3. The project tutor

Provide your contact information here.

Name	e-mail	Tel.	Room	Section
Hammad Rahman	h.rahman@tudelft.nl	0687733536	NB2.03	ASCM

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

Name	e-mail	Tel.	Room	Section
Xiaopeng Ai	x.ai@tudelft.nl	0645749621	NB2.05	ASCM

4. Relevant courses

Relevant courses to the project include: Statics, Dynamics and Programming (Python/Matlab)

References/reading material

[1] J. Sodja, M. J. Martinez, J. C. Simpson, and R. de Breuker, “Experimental Evaluation of the Morphing Leading Edge Concept”, in AIAA 2015-0791.
[2] T. A. Weisshaar, "Morphing Aircraft Systems: Historical Perspectives and Future Challenges," Journal of Aircraft, vol. Vol. 50, No. 2, pp. 337-353, 2013.
[3] S. Barbarino, O. Bilgen, R. M. Ajaj, M. I. Friswell, and D. J. Inman, "A Review of Morphing Aircraft," Journal of Intelligent Material Systems and Structures, vol. Vol. 22, 2011.
[4] A. Güemes, A. Fernandez-Lopez, and Brian Soller, "Optical Fiber Distributed Sensing - Physical Principles and Applications," Structural Health Monitoring, vol. Vol. 9, No. 3, pp. 233-245, 2010.
[5] G. Thuwis, R. De Breuker, and J. Simpson, "Conceptual design of an actuation system for a morphing leading edge high-lift device using topology," in ICAST, Corfu, Greece, 2011.
[6] A. Mauchle, R. De Breuker, and J. Simpson, "Design and demonstration of a leading edge actuation system through topology optimisation," in ICAST, Nanjing, China, 2012.
[7] R. De Breuker and J. Simpson, "Manufacturing and Experiments of a Morphing Leading Edge Aactuation System Demonstrator," in ICAST, Palm Beach, Aruba, 2013.
[8] Luna Innovations Incorporated. ODiSIB10 Data-Sheet.
http://lunainc.com/wp-content/uploads/2012/11/LT-CD-ODiSIB10_Data-Sheet_Rev-07.pdf
[9] Linak. (2014, May) LA 23 Data sheet. http://www.linak.com/products/linear-actuators.aspx?product=LA23