Applied Mechanical Design
ME-403

taught by

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Integrated Aerial Patient Transfer System for Helicopter Rescue Operations

Project Introduction and Scope Statement

Fall 2024

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1. Introduction

The project-based course *Applied Mechanical Design* addresses students' interests in mechanical design. During this semester, students are encouraged to practice their design and modeling skills to come up with a proof of concept.

1.1. Learning Outcomes

By the end of the course, the student must be able to:

- Analyze/listen to customer requests and define the specifications
- List the functions of an existing or new product based on the specifications
- Choose the main solutions and identify the respective components to fulfill one function, taking into account performance, technology, and price constraints
- Evaluate the methodological choices of building a model and validate the results concerning the analysis and modeling objectives
- Choose material and relative treatments based on their use, performance, and compatibility with the manufacturing process of the final product
- Design a system based on the specifications utilizing suitable tools
- Identify the class, the constitutive elements, and the performances of a machine or a mechanical system

2. Project details

2.1. Problem Statement

Rega, a leading Swiss air rescue organization, plays a vital role in providing emergency medical assistance across Switzerland's challenging terrains, including mountainous regions and remote areas. The Rega Helicopter H145 by Airbus is a crucial asset in medical rescue operations due to its versatility and advanced capabilities. However, current rescue protocols often involve complex and time-consuming procedures. Typically, rescuers pick up the patient, fly to a nearby landing spot, land the helicopter, and then bring the patient into the aircraft before proceeding to the hospital. This multi-step process increases the time required for critical patient transfer and introduces additional risks associated with multiple patient handling and exposure to environmental hazards.

These challenges highlight the need for a more efficient and streamlined approach to patient transfer in helicopter rescue operations. The primary challenge lies in developing a system that allows for the safe and continuous transfer of patients from the ground directly into the helicopter without the need to land. Such a system would significantly reduce operational time, minimize risks to patients and rescue personnel, and improve access to difficult or hazardous environments.

This project aims to design and develop an Integrated Aerial Patient Transfer System (IAPTS) specifically for the Rega Helicopter H145. This system will enable the secure lifting of patients into the helicopter in one uninterrupted motion, bypassing the need to land at an intermediate site. The design must prioritize patient safety and comfort while enhancing the overall efficiency of rescue operations, adhering to stringent aviation and medical standards, and being adaptable to a wide range of rescue scenarios.

2.2. Customer Specifications

Following the stated problems and motivations, the customer's requirements which are to be satisfied are summarized in Table 1.

Table 1: Customer Specifications

Name	Value			Units
	Min	Nominal	Max	
Helicopter				
Downwash	55		110	km/h
Patient Aerodynamic Overweight	40	50	60	kg
Max Take-off Weight			3800	kg
Zero Fuel Mass		2824.6		kg
Take off Fuel Mass		450		kg
Landing Fuel Mass		80		kg
Weight of Doors (Side)		30		kg
Weight of Doors (Back)		50		
Helicopter Weight Distribution				
CG position	Should stay within CG envelopes (annex)			
Zero Fuel CG Position (STA, BL)		4491, -2		mm, mm
Take-off CG Position (STA, BL)		4473, -2		mm, mm
Landing CG Position (STA, BL)		4466, -2		mm, mm
Helicopter Geometry				
Internal Volume		6.04		m^3
Floor Area		4.72		m^2
Internal Length		4.65		m
Internal Width		1.4		m
Side Door Width		2.39		m
Side Door Height		1.22		m
Back Door Width		1.4		m
Back Door Height		1.22		m
Stretcher Length		2.25		m
Stretcher Width		0.6		m

Medical Cabinet Width		0.55		m
Medical Cabinet Length		1.13		m
Winch Operation				
Supply Electrical Power			3.5	kW
Load Capacity	270			kg
Cable Length	90			m
Raising Cable Speed	0.8			m/s
Lowering Cable Speed	1.2			m/s
Lifetime	42000			cycles
Operation				
Patient position	Seated and lying down			
Temperature	-30		45	°C

3. Organization

Table 2: Course Plan

	Contents
1.	Introduction and Project Presentation Design Process (1/3)
2.	Project Planning and Management
3.	Design Process (2/3)
4.	Fostering Creativity
5.	Q&A
6.	Q&A
7.	Q&A
8.	Design Process (3/3)
9.	Q&A
10.	Q&A
11.	Q&A
12.	Q&A
13.	Q&A
14.	Group Presentations

3.1. Practical Aspects

Students will form groups of four for the duration of the project and each group will be followed by a coach. The deadline to fix the group composition is the end of the 2nd week of the course. It is recommended to form the group already by the 1st week. The plan for the course is given in Table . The course is divided into three major parts:

- Problem definition
- Concept generation
- Detailed design

3.1.1. Weekly Sessions

During each project session, the group will present the work accomplished during the past week to their respective coach as well as the objectives for the next week (5 slides, maximum 15 minutes, including updates on time sheets). The presentation will be followed by an open discussion with the coach, be it technical, methodology, or management questions. The group is the driver of these discussions

3.2. Coaching

Each group will be followed by a coach with whom respective group members need to interact during the project, including the grading process. Questions of general interest asked during the weekly meetings will be discussed with the whole class. The coaches are:

- Andrii Artomov, andrii.artomov@epfl.ch
- Gabriele Iovanna, gabriele.iovanna@epfl.ch
- Anupam Jena, anupam.jena@epfl.ch
- Konstantin Andreas Jacoby, konstantin.jacoby@epfl.ch
- Issam Soukhmane, issam.soukhmane@epfl.ch
- Arnau Catala I Rams, arnau.catalairams@epfl.ch
- Selahittin Atilay Zervent, atilay.zervent@epfl.ch
- Emanuele Pallaoro, emanuele.pallaoro@epfl.ch

4. Deliverables

For this course, you will be required to deliver in groups:

1. Weekly presentations to the coach
2. Individual time sheets
3. Three written reports
4. A final presentation to the class and project leaflet

Reports must be submitted on time through Moodle by the due date and time. Delays will be handled as follows: up to 30 minutes -0.5, up to a day -1, up to two days -2, and so on. The maximum number of pages does not include the title page, table of contents, list of figures and tables, appendices, and bibliography. See section 4.6 for more information on the grading process.

4.1. Weekly Timesheets

As part of the project, you will also be faced with project management needs: identification of tasks, follow-up of progress, group work coordination, and so forth. One important aspect of project management is time management. To train you in this very common aspect of work in the industry, you will have to fill out weekly time sheets. The idea is that each group member indicates on a per-week basis how many hours (or a fraction of an hour), he/she/they spent on predefined tasks. The group leader aggregates the individual reports and uses them to balance the workload. To be useful for your group, you must report accurate values.

4.2. Report 1

Report 1 covers the points related to the understanding and analysis of the requested design task. **It should not be longer than 10 pages (can be less)** and should include the following points:

1. Project plan for the whole semester (timeline and distribution of tasks).
2. Brief presentation of the system to be designed and review of existing designs.
3. Functional analysis with a precise definition of the main function and flows (Energy, Material, Information)
4. Functional decomposition with the identification of the sub-functions and the flux transformation
5. A technical scope statement (based on functional analysis), leading to revised consumer specifications.
6. A short critical self-assessment on how the group performed, what was good and less, encountered issues, and how they were solved.

Deadline: Friday 04 October 2024, 18:00

4.3. Report 2

Report 2 covers all aspects related to the conceptual design and early embodiment of a solution. The goal is to explain and document the creative and selection process that you followed and present early drafts of the selection solution. **It should not be longer than 20 pages (can be less)** and should include at least the following points:

1. Updated project plan: How does it differ from the original version and why did it change (text and updated Gantt chart)? Based on your time sheets (to be included in the report), discussion on workload and work sharing among team members.
2. Updated specifications and functional decomposition, if changes were required since report 1.
3. Solution listing with hand-drawn drafts for each function and sub-function of the system. Representation in a morphological
4. Evaluation of the feasibility, advantages, and challenges of each solution.
5. Documentation of the selection process, solution selection, and justification of the chosen concept.
6. Preliminary study of the selected concept including a first sizing and design drafts.
7. Draft proposal of the design with static and kinematic linkage diagrams. The proposal should also include an early 3D representation of the concept.
8. Risk analysis of the selected solution and your project.

9. A short critical self-assessment on how the group performed, what was good and less, encountered issues, and how they were solved.

Deadline: Friday 08 November 2024, 18:00

4.4. Report 3

Report 3 covers the aspects related to the final embodiment and the detailed design of the solution you selected. The goal is to explain and document the detailed design process you followed. In particular, you should highlight the changes since Report 2. **It should not be longer than 30 pages (can be less)** and should include at least the following points:

1. Updated project plan: How does it differ from the original version and why did it change (text and updated Gantt chart)? Based on your time sheets (to be included in the report), discussion on workload and work sharing among team members.
2. A summary of possible concepts from report 2 and selection of the final concept.
3. Presentation of the final solution using a kinematic linkage diagram, 3D views, assembly drawing, and textual explanations.
4. Detailed design of the final solution including sizing of all parts and estimation of the cost.
5. Risk analysis including risks for the project (imagine you continue the development until official release) and for the product (what are the risks associated with this product design).
6. Critical thinking about your solution: How does it perform compared to the specifications? What are the future steps that should be followed?
7. A short critical self-assessment on how the group performed, what was good and less, encountered issues, and how they were solved.

Deadline: Friday 10 January 2025, 18:00

4.5. Final presentation and leaflet

During the last week (14), each group will do the final presentation (10 minutes + 10 minutes questions) to the class. You should do the presentation as if the audience was the client. The content of the presentation will be a technical sales pitch. It should showcase the design and highlight the main functions, features, and performance characteristics of the product. Attendance for the duration of the presentations is expected.

Additionally, the group should prepare a leaflet for distribution to the class on the day of the presentation (do not print out copies of the leaflet for all your peers). The leaflet can be seen as an executive summary as part of the presentation. The leaflet should showcase the design and highlight the main functions, features, and performance characteristics of the product. The leaflets should be in A4 format (double-sided) with your group number present on the leaflet.

At the final presentation, the audience of peers will select the winning group for the three superlatives based on the presentations and the leaflets:

- Customer’s choice
- Most Creative
- Most Scalable

4.6. Grades

The final grade will be computed from the handout and final presentation grades with the following ratio:

- Report 1: 10%
- Report 2: 30%
- Report 3: 40%
- Final presentation: 20%

The weekly presentations and time sheets are evaluated as part of your project management. The total number of hours spent is not used for grading.

Note that a standard one-week grading period applies to all deliverables.

5. Course Resources

All project-related documents will be made available on Moodle http://moodle.epfl.ch/. Look for the ME-403 Applied Mechanical Design course.

Annex A: CG envelopes

The helicopter's center of gravity (CG) must stay within the CG envelopes specified below. There are two envelopes to be respected:

- Longitudinal: defined along the helicopter's station line (STA)
- Lateral: defined along the helicopter's buttock line (BL)

Both envelopes are presented in the figures below, along with CG positions at zero fuel (ZF), during take-off (T/O) and landing (LD).

Please note that the envelope to be respected for the longitudinal limitations is ABCD. The extended envelope AA'DD' is intended for specific scenarios and remains out of scope for this project.

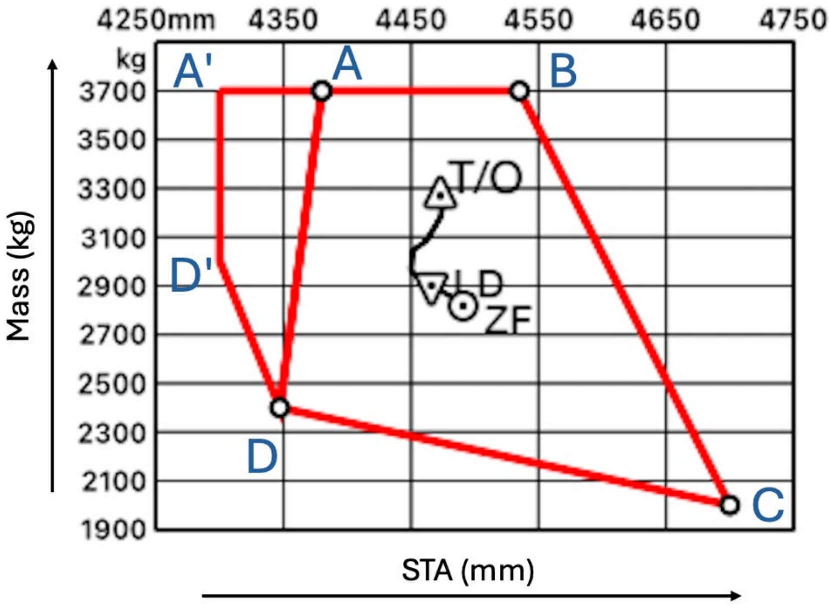

Figure 1: Longitudinal CG envelope

Point	Station line (STA) coordinate (mm)	Mass (kg)
A	4380	3700
B	4535	3700
C	4700	2000
D	4347	2400
A'	4250	3700
D'	4250	3000

Table 3: Longitudinal CG envelope limits

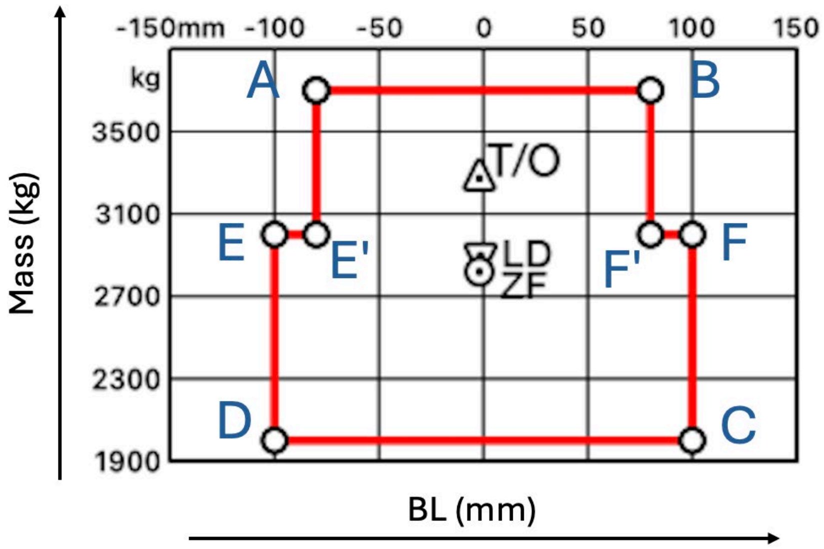

Figure 2: Lateral CG envelope

Point	Buttock line (BL) coordinate (mm)	Mass (kg)
A	-80	3700
B	80	3700
F’	80	3000
F	100	3000
C	100	2000
D	-100	2000
E	-100	3000
E’	-80	3000

Table 4: Lateral CG envelope limits