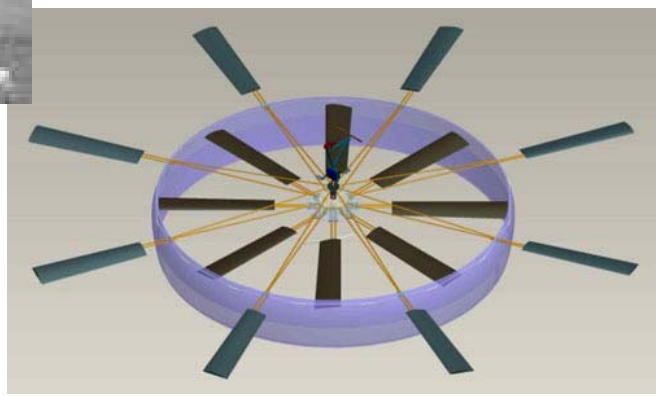
TU Delft

AE3-001
Project Description

DESIGN OF A HUMAN POWERED HELICOPTER



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DAR

TU Delft	**AE3-001** **Project Description**

Responsible chair:	Design, Integration and Operations of Aircraft and Rotorcraft, DAR
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Project title:	**DESIGN OF A HUMAN POWERED HELICOPTER**
Mission Objective	Designing of a human powered helicopter to win the "Igor I. Sikorsky Human Powered Helicopter Competition" of the American Helicopter Society
Keywords	Design, Helicopters, Human Power, Hover
Abstract	Already more than 400 years ago, Leonardo da Vinci drew a sketch of the first helicopter. Even earlier, in China, small rotorcraft toys were made for the children. Since those days, helicopters were developed and refined. But a human powered helicopter was never developed due to the difficulties of hovering under human power. In the 1980's, the American Helicopter Society set out an award of 20.000$ for the first human powered helicopter flight of 1minute hover at an altitude of 3 metres. By now, several universities around the world have attempted to achieve controlled helicopter flight through human power. The current record (since 1994) is 19.46 seconds of flight, and is held by Yuri-1 at Nihon University in Japan. The goal of the present exercise is to break this record in the Sikorsky competition.

Introduction

It has always been the hope of the human being that one day, a Human Powered Aircraft will be designed which will be fully manoeuvrable, meet an airworthiness standard and be able to fly in normal day to day conditions. For fixed-winged aircraft that day is in the not too distant future, for rotary-wings, a human powered rotorcraft is still a great challenge. One of the first inventors of this dream of flight, Leonardo da Vinci, made the first real studies of flight in the 1480's. He had over 100 drawings that illustrated his theories on flight. His "Ornithopter" flying machine has never been actually built. It was a design that Leonardo da Vinci created to show how man could fly. The modern day helicopter is based on this concept. Today, we have the technology to turn old stories from legend into experimental development.

In 1980's the American Helicopter Society (AHS) decided to sponsor a human powered helicopter contest. In all probability, the contest would generate student interest in helicopters and further the educational involvement of future helicopter engineers. The competition was named after the great inventor Igor I. Sikorsky as "Igor I. Sikorsky Human Powered Helicopter Competition" [1]. Until the very present this competition has never been won.

The goal of the present project is to design a human powered helicopter complying with the AHS Sikorsky competition requirements. The solving of the unsolvable problem, doing something that has never been done before is the challenge of this design exercise and a prize of $20,000 is offered by the American Helicopter Society for a successful controlled flight of a human powered helicopter.

Basically, the contest requirement is to design a helicopter capable to hover for 1 minute, reach an altitude of 3 meters and stay within an area of 10 meters on a side under human power. A detailed rulebook is given on the AHS internet site [2] and in Appendix A. Thus far many attempts have been made to win this competition (see Refs [3-9]). The biggest challenge is to make the hover possible under human power. In 1989, California Polytechnic State University's Da Vinci III (see Figure 1) demonstrated that the Sikorsky Award was achievable, albeit distantly. In the past twenty years, California Polytechnic State University, Massachusetts Institute of Technology, and Nihon University in Japan all put forth amazing contributions, though none was capable of capturing the Sikorsky Prize. The closest attempt was a 19.46 second controlled flight, performed at the College of Science and Technology at Nihon University in Japan in March 1994 (see Figure 2). Presently, work continues on this idea with modest progress.

Figure 1: Da Vinci human powered helicopter of Cal Poly University

Figure 2: Yuri-1 Human Powered Helicopter of Nihon University

Requirements

The objective of this project is to design a human powered helicopter which is in accordance with the restrictions of the AHS Igor I. Sikorsky competition, and with the following requirements:

Aircraft: The machine shall be a heavier-than-air machine. No use of lighter-than-air gases is allowed.

The machine shall be a rotary wing configuration capable of vertical takeoff and landing in still air, and at least one member of the crew shall be non-rotating.

No devices for storing energy either for takeoff or for use in flight shall be permitted. Rotating aerodynamic components, such as rotor blades, used for lift and/or control are exempt from consideration as energy storing devices.

Flight: Hovering for one minute while maintaining flight within a 10-meter square. During this time the lowest part of the machine shall exceed momentarily 3 meters above the ground.

The one minute hovering time and the momentary achievement of 3 meters altitude is required to win the AHS prize. (However, the FAI 1980 regulations specify that only the duration of the flight and a momentary achievement of 3 meters altitude will be recorded for the FAX world record attempt, making it possible to achieve a world record without satisfying the AHS prize requirements.)

Literature

1. The American Helicopter Society Igor I. Sikorsky Human powered Helicopter Competition. http://www.vtol.org/awards/hph.html

2. Igor I. Sikorsky Human Powered Helicopter Competition – Regulations http://www.vtol.org/awards/hphregs.html

3. Human Powered Helicopter Project at the University of British Columbia http://batman.mech.ubc.ca/~hph/index2.html

4. Human Powered helicopter design at Michigan University http://www.umich.edu/~umhph

5. Zain, Mohammad Zain, et. al., “Redesign of the Bothezat Helicopter: the way Forward for the Rotorcraft Industry”, AIAA 2002-1736, 43rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials conference, 22-25 April 2002, Denver, Colorado

6. California Polytechnic State University – Da Vinci III, http://www.calpoly.edu/~wpatters/helo.html

7. Patterson, William B., "The design and test of a human powered helicopter", 42nd AHS Forum of the American Helicopter Society, Washington |DC, June 1986

8. S. Mourtisen, "An Aerodynamic and Design Analysis of the Human Powered Helicopter," SAWE Paper 1924, 1990

9. A. Naito, "A Study of Human Powered Helicopter in Japan," SAWE Paper 1925, 1990

Review Milestones, Objectives and Deliverable Items

1. Project Plan (PP)
   - Date: **before 21 April**
   - Objectives: Consolidating a provisional, systematic project plan
   - Deliverable items: see table below The project plan shall include items like an Organisational Breakdown Structure (organogram), a Work Breakdown Structure (WBS), a schedule for the OS design project with project phasing and the planning for the delivery of the items presented in a bar chart, a project logic diagram (activity flow), and an approach with respect to sustainable development.
2. Baseline Review (BR)
   - Date: **before 28 April**
   - Objectives: To understand the Sikorsky competition requirements and start reviewing previous attempts for winning this competition. Once understood, to flow-down these requirements into a list of design requirements and a preliminary analysis how to achieve them.
   - Deliverable Items: see table below. The Baseline Report shall include a requirements specification, with items like a requirements discovery tree, functional flow diagrams and a functional breakdown of the system. Also the requirements for the sustainable development should be included. Of course, by its name, a human-powered helicopter is an environmentally friendly helicopter. Nevertheless, one can still think for example of a choice between low impact and recyclable materials that keep the structure light.
3. Mid-Term Review (MTR)
   - Date: **t.b.d.**
   - Objectives: Predict if a machine of manageable size could be made to hover under human power. Define different conceptual designs addressing the list of requirements, define design drivers and based on their importance select the most suitable concept.
   - Deliverable Items: see table below The Mid-Term Technical Design Report (size approx. 50 pages) has to include design concepts, candidate techniques, critical aspects (design options tree), the trade-off method with the design justifications, a resource allocation (budget and

performance predictions). In addition, sustainable development issues should be included in the report.

4. Final Review (FR)
   - Date: **t.b.d.**
   - Objectives: Perform a first loop of design for the selected concept, size the configuration selected and determine whether it achieves the Sikorsky competition requirements.
   - Deliverable Items: see table below Final Technical Design Report (size max. 150 pages all-in) has to include all topics mentioned for the Mid-Term Technical Design Report (see table below), and an Executive Summary in English.
5. Any additional milestones
   - Date:
   - Objectives
   - Deliverable Items

No	Product	Project Plan	Baseline Report	Mid-term Report	Final Report
1	DSE work-flow diagrams	●		●	
2	DSE work break-down structure	●		●	
3	DSE project-approach description	●		●	
4	DSE Gantt chart	●		●	
5	DSE team organization/organogram & HR allocation	●		●	
6	Functional flow diagram(s)		●		●
7	Functional breakdown		●		●
8	Requirements discovery tree		●		
9	Resource allocation/ Budget breakdown		●		●
10	Technical risk assessment/risk map		●	●	●
11	Design option structuring (tree)		●	●	
12	Interface definition/N2 charts			●	
13	Trade method, rationale and organization			●	
14	Trade criteria			●	
15	Criteria weight factors			●	
16	Trade summary table			●	
17	Operations and logistic concept description			●	●
18	Project design & development logic				●
19	Project Gantt chart				●
20	Cost break-down structure				●
21	H/W, S/W block diagrams (interactions, flows)				●
22	Electrical block diagram				●
23	Data handling block diagram				●
24	Sustainable development strategy		●	●	●
25	Compliance Matrix (table with tick marks for all requirements that are met)				●
26	Communication flow diagram				
27	Manufacturing, Assembly, Integration plan (production plan)				
28	Return on investment, operational profit				
29	Market needs estimate				
30	Reliability, Availability, Maintainability, and Safety (RAMS) characteristics			●	●
31	Performance analysis (e.g. flight profile diagrams, payload-range diagrams, climb performance, noise characteristics, emissions, etc.)			●	●
32	Configuration / layout (internal /external)			●	●
33	Spacecraft system characteristics (e.g. communications link				

No	Product	Project Plan	Baseline Report	Mid-term Report	Final Report
	budget, memory size, etc.)				
34	Aircraft system characteristics (e.g. fuel and hydraulic system lay-out, auxiliary power estimate, environmental control, etc.)			●	●
35	Aerodynamic characteristics estimate (e.g. lift, drag, aerodynamic moments, drag polar, etc.)			●	●
36	Structural characteristics (e.g. loading diagrams, stresses, bending, flutter, etc.)			●	●
37	Stability and control characteristics (e.g. control forces, c.g. limits, etc.)			●	●
38	Material characteristics (e.g. yield, ultimate, fatigue, etc.)			●	●
39	Astrodynamic characteristics (e.g. orbit, trajectory, decay rate, ΔV-budget)				

Note: preset (●) and set by PT (●)

Project Outline

Phase 1 Analysis of Requirements and Project Planning
(Kick-off till Baseline Review)

- Based on the Sikorsky competition requirements, the team has to elaborate a list including all the requirements that describe the helicopter in terms of technical, functional and environmental parameters. Also, the team has to study the previous attempts of the human powered helicopter. Attention should be given to the following areas: performance, stability and control, maximum loads, operations, manufacturing costs, maintainability, relaying intelligence to a ground control station, costs of development, sustainable development.
- For each requirement specify metrics and criteria capable to measure the most appropriate concept
- The requirements are to be presented in a concise final list
- The team must be prepared to describe the motivation behind each requirement
- Flow-down of the top-level requirements into design requirements for the system elements.
- Project planning.
- Divide the project into work packages, tasks and subtasks and time available for each task, the relation between tasks and important milestones. Represent these results in an organogram.
- Assign responsibilities for each member of the team in the organogram according to his/her 'speciality'; choose a coordinator of the project and assign his/her responsibilities.

The requirements will be implemented into a "List of requirements" which will be reviewed in the Baseline Review. Sustainable development should be also discussed

Phase 2 Conceptual Design Concepts and Trade-off
(Baseline Review till Mid-Term Review)

Based on the list of requirements different conceptual designs of the human powered helicopter are to be generated by the group:

- First, study previous attempts in order to see what went wrong and what are the challenges
- Define new concepts and check them against a list of requirements
- Rank the elaborated concepts according to the criteria and metrics defined.
- Make the final down selection to one concept for more refined analysis

The chosen solution will be evaluated at the Mid-Term Review (MTR).

Phase 3 Refined Conceptual Design of the Selected Concept
(Mid-Term Review till Final Review)

After the MTR, the design project will zoom into the conceptual design of one solution

- Divide the team into main specialities such as:

    - Aerodynamics
    - Performance
    - Stability
    - Control & Simulation
    - Flying qualities
    - Structures
    - Materials, manufacturing and cost estimation, sustainable development

Section	Discipline	Relative importance %
1	Aerospace materials and manufacturing	**10**
1	Design and production of composite structures	**10**
1	Engineering mechanics	**5**
1	Fundamentals in advanced materials	**5**
1	Structures	**15**
2	Aerodynamics	**15**
2	PERFORMANCE Control and simulation	**15**
2	Design integration	**10**
2	Management	**5**
2	Operation of aircraft and rotorcraft	**5**
2	Wind energy	
3	Astrodynamics	
3	Mathematical geodesy and positioning	
3	Photogrammetry and remote sensing	
3	Physical and space geodesy	
3	Sustainable engineering	**5**
3	Systems integration space	
4	Other	

- Assign a speciality for each member of the team
- Analyse the preliminary design solution in each discipline in terms of more refined properties and criteria relevant for each discipline. Each specialist should write a brief overview of the analysis performed.
- Using concurrent engineering integrate all the disciplines and choose a compromise solution for the design. This is the final concept.

Appendix A

Igor I. Sikorsky Human Powered Helicopter Competition Regulations

Contents

6. General Conditions

1. General

1.1 The prize will be awarded by the AHS to the entrant who first fulfills the conditions.

1.2 Additionally, an attempt will be registered with the Federation Aeronautique Internationale (FAI) as a World Record for Human-Powered Helicopter Flight duration.

2. Prize

2.1 The AHS prize in U.S. $20,000.

3. Eligibility

3.1 The competition is international and is open to individuals or teams from any part of the world.

3.2 Any questions regarding the acceptance of entries, eligibility of entrant, pilot, crew or aircraft under these regulations, or any other matter relating to the AHS prize, the decision of the AHS is final.

3.3 All questions regarding the world record attempt will be governed by the sporting code of the FAI and rest exclusively with the NAC.

4. Conditions of Entry

4.1 Aircraft

4.1.1 The machine shall be a heavier-than-air machine. The use of lighter-than- air gases shall be prohibited.

4.1.2 The machine shall be a rotary wing configuration capable of vertical takeoff and landing in still air, and at least one member of the crew shall be non-rotating.

4.1.3 The machine shall be powered and controlled by the crew during the entire flight, including accelerating the rotor up to takeoff speed.

4.1.4 No devices for storing energy either for takeoff or for use in flight shall be permitted. Rotating aerodynamic components, such as rotor blades, used for lift and/or control are exempt from consideration as energy storing devices.,

4.1.5 No part of the machine shall be jettisoned during the flight including the rotor spin-up and takeoff.

4.2 Crew

4.2.1 The crew shall be those persons in the machine during takeoff and flight, and there shall be no limit set to their number.

4.2.2 No member of the crew shall be permitted to leave or enter the aircraft t at any time during takeoff or flight.

4.2.3 No drugs or stimulants shall be used by any member of the crew. An assurance must be given to the official observers at the time of the attempt that this requirement has been met.

4.2.4 Up to two handlers or ground crew shall be permitted to assist in stabilizing the machine during takeoff and landing, but in such a manner that they do not assist in accelerating or decelerating any part of the machine.

4.3 Ground Conditions

4.3.1 All attempts, which shall include the takeoff, shall be made over approximately level ground (i.e., with a slope not exceeding I in 100 in any direction).

4.3.2 All attempts shall be made in still air, which shall be defined as a wind not exceeding a mean speed of approximately one meter per second (3-1 kilometers per hour, 2.23T statute miles per hour, 1.5 nautical miles per hour) over the period of the flight.

4. Flight Requirements

4.4.1 The flight requirements shall consist of hovering for one minute while maintaining flight within a 10-meter square. During this time the lowest part of the machine shall exceed momentarily 3 meters above the ground.

4.4.2 The machine shall be in continuous flight from takeoff to landing, and at no time during the flight shall any part of the machine touch the ground.

4.4.3 A reference point on the non-rotating part of the machine will be established an a means whereby the observers can judge that the machine stayed within the confines of the 10-meter square.

4.4.4 The one minute hovering time and the momentary achievement of 3 meters altitude is required to win the AHS prize. (However, the FAI 1980 regulations specify that only the duration of the flight and a momentary achievement of 3 meters altitude will be recorded for the FAX world record attempt, making it possible to achieve a world record without satisfying the AHS prize requirements.)

4.5 Observation

Every attempt shall be observed by the NAC or by any persons authorized by them to act as observers. It may take place in the competitors own country if it is affiliated to the FAI. In a country not so, it could be advantageous to conduct the flight in a neighboring country which is so affiliated.

5. Applications for Entry

5.1 Entry forms shall be obtained from and returned to the American Helicopter Society. 217 N. Washington St., Alexandria, VA 22314, (703) 684-6777. email: Staff@vtol.org

5.2 The entry fee shall be U.. $15 (made payable to the American Helicopter Society).

5.3 Each entry form shall contain an application for official observation of the competitors attempt.

5.4 The entrant shall undertake to abide by the conditions for official observation as set out on the entry form and application for official observation and shall undertake to defray all expenses incurred in connection with the official observation of the attempt.

5.5 The following fees and charges are made by the NAA for record attempts in Class I, Human Powered Aircraft. All attempts shall be for national and international records.

5.6 Final notice of the proposed time and place of the attempt requiring official observation may, if so desired, be sent to the AHS later than the entry form. It must in all cases be received at least thirty days before the proposed date f or the attempt. This time is required by the NAC (the NAA in the U.S.A.) to arrange for official observation. Applications will be considered in order of receipt.

5.7 Membership in the appropriate NAC and an FAI Sporting License in required for all crew members taking part in this competition. Application forms may be obtained from the NAC or the AHS. For this competition, a pilot's license is not required.

6. General Conditions

6.1 Insurance

The entrant must take out on behalf of himself, his crew, representatives or employees, liability insurance in such form and mount to be specified by the AHS, to. indemnify the American Helicopter Society, the NAC and the FAI against any claims. Evidence that such insurance has been effected must be submitted with the application for official observation.

6.2 Revision of Regulations

6.2.1 These regulations shall remain in force until such time as the AHS considers it necessary to amend them, or the prize has been won.

6.2.2 The AHS reserves the right to add to, amend or omit any of these regulations and to issue supplementary regulations.

6.3 Interpretation of Regulations

The interpretation of these regulations or any of the regulations hereafter issued rest entirely with the AHS. The entrant shall be solely responsible to the official observer f or due observance of these regulations and shall be the person with whom the official observers will deal in respect thereof, or any other question arising out of this competition.