

Project Definition Document

*Aerospace Senior Projects (ASEN 4018 & 4028)
Fall 2004 and Spring 2005*

1.0 Information

1.1 Project Title

Highly Optimized Rotor System (HORS)

1.2 Project Customers

None

2.0 Background and Context

In 1980 the American Helicopter Society (AHS) organized a contest modeled after the Kremer Prize called the Igor I. Sikorsky Competition. As the Kramer Prize was awarded to the first team to successfully fly a human powered fix winged aircraft, the Sikorsky Competition is an open ended contest to award the first team to successfully fly a human powered rotor aircraft or helicopter.

There have been numerous attempts in the previous years to achieve the Sikorsky Prize with no success. Several of the teams in the past have built full scale models to verify and test their respective design with limited success. One disadvantage of full scale models is the extreme difficulty to conduct a parametric study. A parametric study is ideal in order to determine an optimized design by varying multiple parameters which can include but not limited to structural weight, gear ratios, and rotor design. A small scaled model of an equivalent human powered system on a test bed allows an inexpensive and feasible parametric study which can yield valuable data. This data can be used to plot multiple graphs that display the relationship between two or three parameters, and at what settings allow the system to produce the maximum amount of lift.

The focus of this project is to build a test bed which will include a rotor and drive train system powered by a motor equivalent to the power output of an average human being and measure various parameters which include but not limited to lift, power output of motor, power output of transmission, Reynolds number, rpm's, altitude, and weight. The baseline configuration of the test bed will be dependant upon specifications of previous full scale vehicles. After bench test parameters are measured and recorded, one aspect of the design parameter will be modified (for example different gear ratio) and new measurements will be recorded. This process will be repeated to continuously verify and iterate design parameters. Every parameter that is modified must be thoroughly designed prior to verification on the test bed.

3.0 Objectives

3.1 Overall Objective

HORS's overall objectives will be to determine whether or not it is possible for a human powered helicopter to satisfy the contest altitude requirement by conceiving, designing, fabricating, integrating, and verifying a test bed that will induce ground effect on a scaled human powered helicopter of various configurations during vertical flight while measuring lift at various altitudes.

3.2 Functional Objectives

Parameter	Measurement Method	Discussion
Altitude	Standard metric ruler	The overall system performance is measured by the altitude achieved compared to the target altitude of 0.3m which is 7.5% ¹ of a 4m diameter rotor and represents reduced ground effect.
Drive Train Efficiency	Power measured at output of motor and at output of drive train	Based on a bicycle drive train the efficiency will be a minimum of 90% ² to maximize power delivered to the rotor.
Lift	Load cell	Determine if lift produced is greater than the weight of the system.
Reynolds Number	Pitot tube Thermometer	Verify that the system's aerodynamic properties are representative of a full scale system. Reynolds number is $R = \frac{V * L}{\nu}$. The kinematic viscosity (ν) describes the test environment and is dependent on temperature. The freestream velocity can be determined by measuring total and static pressure of the flow at the blade tips. If the characteristic length (L) is decreased by a factor of 9 the velocity (V) has to be increased by the same amount so the Reynolds number is equal to that of the full scale system.
RPM	Tachometer	The rotor RPM is needed in analyzing the aerodynamic efficiency of the system and for determining the velocity at the rotor tips to reference the pitot tube measurement too.
Total System Mass	Scale	The mass budget for the system is divided up to 60% for representing the human and 40% for the structure.
Rotor Pitch Angle	Protractor	During the experiment the pitch angle of the rotors will be varied to increase lift.
Energy Density	Power measurement	The energy density is the power produced per unit mass and will be varied during the experiment to determine the lowest value that reaches the target altitude. The baseline is set at 4.71 W/kg as determined from past vehicles ¹ .
Rotor Configuration	Number of blades	The rotor configuration will be changed by adding blades and changing the blade profile.

4.0 Required Engineering Expertise

Technical Expertise	How Applied
Precision Mechanical Design	Generate 3 dimensional models of each component
Composite Manufacturing	Construction of rotor blades and possibly the drive shaft
Finite Element Analysis	Predicting the structural integrity and performance of the system

¹ <http://batman.mech.ubc.ca/~hph/index2.html>

Patterson, William B. "The Design and Test of a Human Powered Helicopter". Cal Poly, San Luis Obispo, CA. 1986.

² http://www.jhu.edu/news_info/news/home99/aug99/bike.html

Airfoil Design	Selection or design of efficient airfoil for rotor
Aerodynamic Theory	Research of aerodynamic theory governing rotorcraft in order to write analytical software
Gearing Design	Development and implementation of an efficient drive train system
Rotor Design	Design of rotor system, possibly coaxial, that will achieve altitude and mass requirements
Mechanical Fabrication	Machining components and equipment
Sensor Package	Measure lift, shaft rpm, motor output, torque, power to shaft
Testing	Verification of the project

5.0 Resources

5.1 Facilities

The project team will have access to the manufacturing equipment in the Aerospace Department Machine Shop and in the Integrated Teaching and Learning Laboratory on the campus of the University of Colorado at Boulder.

5.2 Additional Advisors

None

5.3 Funds

The project will rely on the \$4000 provided by the Senior Projects course (ASEN 4018 & 4028) as well as possible funds from sponsors outside of the University of Colorado.