Memorandum

To: Dr. Kosaraju

From: Team 04

Date: 03/07/2014

Re: Midpoint Report

Dr. Kosaraju,

This is the second progress report for the up scaling of the U13A remote controlled helicopter.

In this document you will find, a summary of our teams' problem, as well as our need and goal statements, and a discussion of the progress we have made with respect to 3D printing and the power train.

Also in this document, is the schedule that our team has laid out for the remaining semester. This schedule is devoted to construction and testing.

Remote Control Helicopter

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Progress Report Document

Submitted towards partial fulfillment of the requirements for

Mechanical Engineering Design II – Spring 2014



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Abstract

In this document, we will be discussing the scaling U13A remote controlled helicopter. To begin with, we will be giving a brief description of our client and an overview of the problem description from our client. Next we will be identifying the need, project goal, constraints, objectives, 3D printing parts and the powertrain of our project.

3D printed parts modification will be addressed for the main core and the blades, where more testes will be applied to determine the quality of the design after the modification. Powertrain including motors, batteries, Receiver, and speed controller will be discussed, along with determining the mechanism of how the design will be functioning. Also remote control calibration was obtained, and each button will has its own unique function. Next, Construct and build the helicopter after some test flights with the current blades made from ABS plastic. The final material for the blades will be soon determined weather Aluminum or Ultem depending on the availability and the quality for the final design. Gantt chart will be provided to construct a due dates plan where the team will be following it throughout the rest of the semester to finish the task on time.

At the end of the report a modification on the Cad design for the main core and clamp will be provided to show what modification has been done to validate the design for performing the test flight.

Chapter 1. Introduction

1.1 Introduction

We are team four, and our capstone project is the remote controlled helicopter. In this report we will be discussing, who our client is, what our project is, as well as, needs, goals, constraints, objectives, 3D printed parts, prototype, powertrain, and a quality function deployment chart for our project. We will also give a brief look at what is in the near future for team four through a Gantt chart. To begin with we will introduce our client Dr. Srinivas Kosaraju.

1.2 Client Information

Our client is the capstone instructor Dr. Srinivas Kosaraju. He is a current mechanical engineering professor at Northern Arizona University. He has his doctorate in mechanical engineering. He had an idea that it would be a great all around engineering project to have students buy and research a remote controlled helicopter that was roughly ten inches and then upscale it for various applied applications. This project includes many different engineering subjects such as machine design and aerodynamics. It will prove to be a challenging project, but our team is very enthusiastic and ready to do what is necessary for a successful project.

1.3 U13A Remote Control Helicopter For this project we will be up scaling a

U13A Remote Controlled Helicopter made by UDIR shown in Figure 1. The helicopters body is 11 inches long and 2 1/4 inches wide. One of the blades of the center rotor is 4 3/4 inches long and



Figure 1: U13A Helicopter

the rear rotor is 1 7/8 inches. It has four blades on the center rotor two blades are spinning clock wise while the other two are spinning counter clock wise. The helicopter has several led lights on it one in the front and five along the tail. This helicopter has a 3.7 V battery it lasts for 5 to 8 minutes per 90 minutes of charge. This helicopter is already equipped with a camera so it has the capability to take photos and video which can be viewed through a micro S.D. card. This helicopter does not have live feed. There is a gyroscope inside of the helicopter it also has a balance beam along the top of the center rotors both of there are to help keep the helicopter stable during flight.

The controller for the helicopter, as seen in Figure 2, controls the functions such as up and down and right and left. It also has a screen on the controller to display the throttle percent and the trim of the helicopter. The screen also displays how well the frequency is reaching the

controlling radius of 40 m. the controller is powered by four AA batteries and displays how much power is left in the batteries on the display. The controller has buttons on it to use the video and the camera fetchers and the display shows which fetcher is being used at a given time. The controller also has a button to turn on or off the lights and a button to accelerate the helicopter.

helicopter. The remote sends out a 2.4 GHz signal and has a



Figure 2: U13A remote control

1.4 Needs

The main need created by our group for this project, through discussion with Dr. Kosaraju, is that the U13A helicopter is too small. Through this statement, we have broken it up in to several smaller needs to make the process of working on it more fluent. One of the first needs we have to work on is studying this helicopter and determining any problems with it that we may need to fix or any aspects of the helicopter that we can improve upon. We will need to upscale the model by 1.5 per the client's request. Lastly, one of the client's requests was to have capability for attachments so we need to determine what attachments may be useful and how to attach them.

1.5 Goals

From studying all the clients requests and all the needs we have determined a goal for this project. Our goal is to "successfully improve and upscale a remote controlled helicopter by 1.5 with the ability to add mission specific accessories." We believe at this point this goal covers all the aspects of this project. As we work on this project we may have to alter our goal but this will happen as we go.

1.6 Objectives

The objective for this project is to design and build a remote controlled helicopter that has interchangeable attachments. A live feed camera will be attached to the final design that can provide live video to the users. The helicopter weight will be minimize in order to have the ability to add many attachments if needed.

The design should be able to accept batteries from different manufacturers. This includes using the ability to switch adaptors that can connect the battery to the helicopter. There will be two sets of batteries, one set in the helicopter, and one set in the remote control. The helicopter will contain a chargeable battery that can lasts for one-third the charging time. The remote control will consist of four AA batteries that provide a power to send/receive signal to the helicopter.

Carrying capability will be maximized in the prototype design. The materials that will be used in our design should be light and stiff, to maintain a high level of performance. The carried weight will be used to achieve stability in our design. Also the weight will be placed in the center of mass in the helicopter to increase the stability and resist wind flow.

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Ideas were generated about having waterproof materials in building the design, in order to use the helicopter in different weather conditions. However, due to lack of time further investigation in this field were not as significant as other areas in this project. Also the cost factor was considered since these materials will be expensive and hard to obtain for a small RC helicopter. Since it is a minor modification on the design, time and effort were spent on major issues to achieve the task successfully.

The altitude that the helicopter will achieve is forty meters in all directions. Currently we are considering stiff plastic propellers will be used in building the design to minimize the overall weight of the helicopter and create a maximum lift for the prototype. The range will be determined more specially based on the attachments and the weight lifted for each different run. The table of objectives can be seen in the following table, Table 1.

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Objectives	Measurement Basis	Units
Design and build a RC helicopter	Amount of materials	Dollars
Attachments	Camera parts	Dollars
Batteries	Two sets of batteries	Dollars
Carrying Capabilities	Weight	lbs
Lift Capabilities	Height range	Meters

1.7 Constraints

For the final design of the upscale remote control helicopter, the preliminary constraints are the following:

The helicopter must be at least 1.5 times the size of the model helicopter. In order to successfully upscale the helicopter 1.5 times, the dimensions of all of the components of the design, ranging from the tail length to the frame width must be at least 1.5 times larger than the original remote control helicopter.

The helicopter must be made out of a durable material that is also lightweight. In order for the helicopter to succeed at flight and survive all of the stresses associated with flying,

landing, and even crashing the helicopter, it must be made of a lightweight and durable material with a high strength to density ratio.

Additionally, the operator must be able to control the helicopter at a long range. The range at which the helicopter can be controlled will be measured by the longest distance at which the remote control can still communicate with the helicopter.

The helicopter must have a satisfactory battery life. The duration of time that the helicopter can stay in the air for a single flight is determined by the battery life; it must be maximized to allow for the longest flight possible.

In addition to the battery life, the battery power must be capable of creating a lift force great enough to carry the weight of the helicopter and any accessory that may be mounted to the helicopter.

In order to demonstrate that accessories can be added to the helicopter, an onboard video camera will be mounted to the design. The data gathered aboard the helicopter must be communicated to the operator at real time and the helicopter must transmit a live video feed from the onboard camera to the remote operator.

Chapter 2. 3D Printing

We have been discussing the option of 3D printing for this project with Dr. John Tester. Our team has come to the conclusion that twenty four parts will be 3D printed. The material used will be Ultem 9085 in the Forester 3D printing machine. As of this report, the Forester 3D printing machine is still out of order, only leaving ABS as an option for materials, which may pose some problems such as diminished material strength and diminished precision in the printed dimensions.

2.1 3D Printing Modifications

In order to begin printing, we first had to meet with Dr. Tester to determine what modifications needed to be made to the parts before printing can be started. After reviewing our SolidWorks drawings for a few parts, he was able to show us how to can strengthen the parts for printing; he suggested filleting or chamfering all corners and filling some areas in completely. Additionally, Dr. Tester looked at the propeller for the helicopter, pointing out that the propeller was made the way it was, not for aerodynamics, but for ease of injection molding. In noting this it was decided that we should go back to the drawing board and do some research to completely overhaul the blades so that maximum aerodynamic potential is reached.

Two of the main components, the main body and the blades, required major design modifications to maximize the strength of the part. Figure 3 shows the new design for the main body of the helicopter after design modifications were made. The initial geometry was mostly rounded, but after consulting Dr. Tester, we found that the shape needed to be made more rectangular by adding corners and fillets where it was once rounded.



Figure 3: Main body of helicopter after design modifications.

Additionally, the new blade geometry can be seen in Figure 4. In the case of the blade, the old shape was abandoned and a new geometry was made from scratch that would produce a greater amount of lift. One concern does exist with this design, as the constant cross width along its length means that a large amount of mass will be located far from the support; this lack of a taper may result in a bearing stress so large that the part fails. This concern is especially high if the Ultem machine is not fixed in time for us to print the blades with; if the ABS proves too weak to handle this bearing stress more than one option exists. The first option is to add a taper and/or add additional material to the base of the blade to combat the bearing stress. The second option includes using a CNC machine to craft the blades out of aluminum for the additional material strength; however, this introduces other potential problems such as shaft fracture because the blades will be the strongest component of the design.



Figure 4: Blade of helicopter after making modifications to the design.

2.2 Preliminary 3D Printing Efforts

After preparing the designs to be printed, the Forester 3D printing machine used for Ultem had still not been repaired. In order to get started at all with the power train, however, some of the main components of the body needed to be printed. For this reason, a few of the parts including the main body, the blades, and the square-ball rotor stabilizer were printed using the ABS machine.

In addition to allowing progress to be made on the power train, printing these prototype parts highlighted potential issues with each respective design. With respect to the main body, a necessary design component was overlooked; the housing for the motors needed to allow with a space in the perimeter for the motor-wires to feed through. This design modification which is currently being integrated into the SolidWorks file was accomplished on the prototype main body with the use of a dremel. This prototype, after the modifications, is shown in Figure 5.



Figure 5: Main body of helicopter printed in ABS with after-print modifications.

Additionally, the 3D printing file for the main body may have an error. As seen from the differences between Figure 3 and Figure 5, the bottom half of the part was not printed. This could be the result of an operator error, a singular glitch in the printing process, or a missing plane in the 3D-printing file. The printing file is being reviewed to see if the problem is on our end of the process.

After printing the prototype for the square-ball rotor stabilizer out of ABS, a few more flaws in the initial design were found. Shown in Figure 6, the first problem with this part was the thin amount of material in the corners of the central square. The part was much more flexible than desired and without any modifications, it is likely that it will not support the necessary loads.



Figure 6: ABS Prototype for the square-ball rotor stabilizer.

This part has been redesigned so that the next printed version is much stronger. The redesigned square-ball rotor stabilizer is shown in Figure 7. This version clearly has much more material around the center square to ensure that it does not fail.



Figure 7. Improved version of square-ball rotor stabilizer.

Another problem with the printed parts is embedded in the mating between the blades and the square-ball rotor stabilizer. The base of the blades is supposed to fit snug within the gap in the stabilizer, however, the dimensions were off such that the blade-bases were either too thick of the stabilizer gap was too small. To ensure that this does not happen in later printings, minor adjustments to these dimensions have been made.

2.3 Next Steps in 3D Printing

The next step to be made in 3D printing is to decide whether to go forward, without the use of Ultem. Printing with Ultem provides a higher strength and precision than printing with

ABS. Additionally, not all of the parts designed may be suitable for the decrease in strength found when switching materials from Ultem to ABS. If this is the case, we will be required to find alternative materials for these parts. This decision will be made within the next few days with the goal that all of our parts are printed, whether it is made out of Ultem or ABS, by the start of Spring Break.

2.4 Modeled U13A

Our current model of the up scaled helicopter can be seen in Figure 8. This model is constantly changing due to strengthening modifications which must be made for the use of Ultem in the 3D printing process. While many modifications will occur, they will likely not be visible on the outside of the helicopter. Figure 9, shows the exploded up-scaled helicopter.



Figure 8. SolidWorks model of the U13A helicopter



Figure 9: Exploded SolidWorks model of the U13A helicopter.

Chapter 3: Powertrain

Team has all necessary components of the powertrain ready to be assembled onto the initial Ultem 9085 3D printed prototype. There have been numerous tests run on the powertrain components to ensure optimal flying conditions are met when the final helicopter is ready.

3.1 Batteries

The up scaled helicopter is to have three Lithium-Polymer (LiPo) batteries on board during normal operation. These batteries are 2S, 7.4V, 1600 mAh batteries. The battery pack can be seen in Figure 10 to the right. The 2S designates two cells connected in series. The series connection allows for more voltage from the battery pack but the size of the cells gives a 1600 mAh runtime. Series packs are more versatile and more abundant and gives the increase in power needed to perform any necessary maneuvers. Without the benefits of a parallel connection the Team chose a higher capacity battery to give long life. So the helicopter will have ample power to climb and do maneuvers all while having a respectable battery life. To add to the battery life each motor will have its own dedicated battery to ensure if one system fails another will be fine and the helicopter can safely hover to the ground. The battery dedicated to the small motor is to power any other accessories that are added to the helicopter without dedicated batteries. Though several tests it was found that the batteries can last at least 10 minutes. Though this test was performed with the motors running at full speed and it was stopped when the batteries showed signs of losing power. Through another test the Team was able to charge the batteries in only 20 minutes. After more research a preferred charging rate can be found and the time required to charge should decrease.



Figure 10: LiPo Battery

3.2 Motors and Speed Controllers

As specified there are three motors that control the altitude, turning, and direction. There are two 5000 KV motors that control the two main rotors. The top rotor is just responsible for altitude and the bottom rotor helps with both altitude and rotation. The third motor is a smaller 1000 KV motor. The units to these voltage measures mean that for every volt supplied to the motors it adds as many RPMs listed. The motors can be seen below.



Figure 11: 5000KV and 1000KV Motors

These motors are both outboard motors which are designed to output more torque than a typical brushless motor. The added torque will be beneficial during initial take off and rapid climbs.

Attached to these motors are Electronic Speed Controllers (ESCs). The ESCs take an input from the receiver and send the appropriate voltage to the motors. These ESCs are the only way to safely control the RPMs of the motors without burning them out. The ESC can be seen in Figure 12 below.

3.3 Transmitter and Receiver

The transmitter and receiver tie the entire powertrain together. The transmitter is the remote control for the entire helicopter. The receiver is what receives the transmitter signal from a specific channel and sends it to the ESC. The receiver and entire powertrain can be seen in Figure 12 below.



Figure 12: Powertrain

As stated earlier the transmitter has different channels each of which correspond to a different direction. The transmitter can be seen in Figure 13 below. The transmitter operates at 2.4GHz, which is an industry standard, to avoid any possible interference. The transmitter has been tested at approximately 80 yards but further testing will be done to document the maximum range of the transmitter.



Figure 13: Transmitter

You can see the four different directions of the transmitter which each have their own channels. The two knobs, one of which is the fine tuning can be assigned their own channels or be mixed with the others.

3.4 Gears and Shafts

There are two main shafts that transfer the power to the blades. Attached to these shafts are two 65 tooth gears. The gears are a made from a lightweight aluminum in order to keep a strong contact between the pinion and gears even during very high torque operations such as rapid climbs. The pinions are made from brass and have 11 teeth. There is not a significant reduction in RPM because the blades still depend heavily on the rate at which they spin. The motors themselves provide plenty of torque even without the aid from a gear reduction. You can see how the pinion, gear and shaft will mate in Figure 14 below.



Figure 14: Gears and Shafts

Conclusion

In conclusion the Team is set to finish a full prototype made from Ultem polymer. Once the full prototype is finished printing all components will be attached and full flight testing can begin. The Team will go over blade design and modify if necessary. Also any surplus material will be removed from the helicopter to save on weight. The Team is on schedule to have a working prototype by the end of the Spring Break. Also any main powertrain components that need to be modified or changed will be changed to optimize flight performance. As you can see in the Appendix the only part of the schedule where the Team is not on schedule is the actual 3D printing of the prototype. Since the Utlem machine is now available the Team is back on track for a test fight and all subsequent modifications.

References

- Budynas, Richard G., Nisbett, J. Keith, <u>Shigley's Mechanical Engineering Design</u>, Ninth Edition, McGraw Hill Inc., New York, New York, 2011.
- [2] Philpot, Timothy A. <u>Mechanics of Materials: and Integrated Learning System</u>, John Wiley and Sons Inc. Rolla Missouri, 2011.
- [3] Audio / Video Spy Camera Transmitter. Security and Self Defense Store, n.d. Web. 27 Oct. 2013.
- [4] http://www.ereva.com/ft/EVA.pdf
- [5]Heli Chair, 2011, "Aerodynamics 101", from http://www.helichair.com/aerodynamics_101.html
- [6]Heliguy, 2010, "Remote Control Helicopters FAQ", from http://www.heliguy.com/nexus/newbie.html
- [7] 2013, "HV Power Systems, why they are better," TJinTech, from

https://sites.google.com/site/tjinguytech/charging-how-tos/hv-power-systems

- [8] Leishman, J. Gordon. Principles of Helicopter Aerodynamics. Cambridge: Cambridge UP, 2000. Books.google.com/. Google.Web. 27 Oct. 2013.
- [9] 2013, "Lithium Polymer Battery," Wikipedia, from http://en.wikipedia.org/wiki/Lithium_polymer_battery
- [10]"R/C Wi-Spi Helicopter." ThinkGeek. ThinkGeek, n.d. Web. 27 Oct. 2013.
- [11]"Security & Self Defense Store." Security & Self Defense Store.N.p., n.d. Web. 27 Oct.2013.
- [12]Seddon, J., 1990, Basic Helicopter Aerodynamics, Mackays of Chatham, Chatham, Kent.
- [13]"Smaller, Lighter with Built-in Wi-Fi." HERO3 White Edition.GoPro, n.d. Web. 27 Oct.2013.
- [14]Squire, J., 2010, "Airfoil lift and drag coefficients", University of Maryland Baltimore County, from http://www.csee.umbc.edu/~squire/cs455_lairfoil.shtml
- [15] 2013, "Understanding RC LiPo Batteries," RC Helicopter Fun, from http://www.rchelicopterfun.com/rc-lipo-batteries.html
- [16]Wolfgang, R.C., 2006, "Lift Produced by Multi-Blade Heads", from http://rc.runryder.com/helicopter/t276865p1/



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Final Design Due