2 Deegree of Freedom Labotory Helicopter System

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***Abstract*—The 2-degree-of-freedom (2-DOF) helicopter system is a lab aid used to study control systems as well as aerodynamic properties. The system allows for rotation in the pitch and yaw directions. A series of measurement encoders will precisely measure these pitch and yaw angles and will be able to communicate the output data to MATLAB and Simulink. The 2-DOF system will be an economic alternative to testing full scale systems. Furthermore, the small-scale project will be safer than testing the control systems on such vehicles. This system will have an economic advantage when compared to similar products on the market**.

I. Introduction

2-Degree of Freedom (DOF) helicopters are used to run experiments and aid in presenting and educating on control systems related to helicopters. In this situation, the helicopter gathers data as it rotates, in the yaw and pitch directions, around certain points. This data is then used to calculate the helicopters overall yaw and pitch angles. Finding the pitch and the yaw angles can provide understanding of aerospace concepts, such as drag and thrust, as well as different control systems. The 2-DOF helicopter can be used in simple undergraduate level experiments to industry research. This helicopter system will send information directly to a computer program where the user can then interact and manipulate the control systems of the helicopter.

II. Mechanical Design

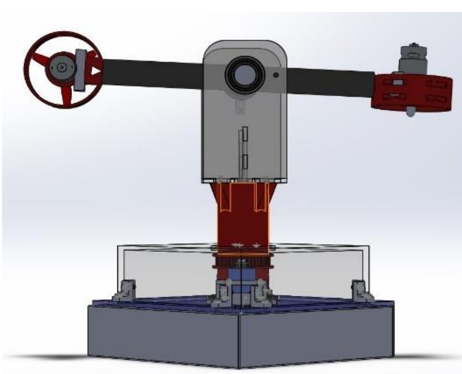

Figure 1. Helicopter full assembly.

The 2 degree of freedom (2 DOF) system functions by having two distinct mechanical sub-systems, each with its own set of encoders. One sub-system is the pitch component which is responsible for the angle of the horizontal shaft while in use. Meanwhile the yaw encoder records the rotation of the vertical shaft which supports the helicopter system. The motion generated is then converted via encoders and captured in MATLAB/Simulink.

A. *Pitch component*

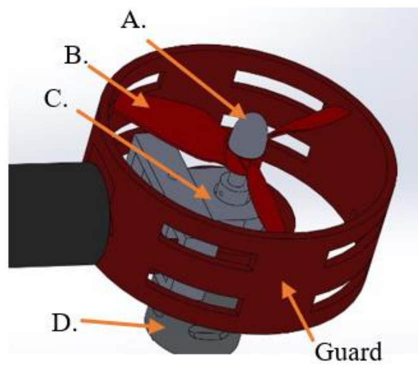

Figure 2. Rotor assembly. Cap(A). Rotor (B). Encoder(C). Motor (D)

The pitch component consists of two identical rotor assemblies on either side of a PVC pipe each orthogonal from each other's orientation (see Fig 1). From top to bottom on the adapter piece, that acts as the motor shaft (see Fig. 2), the assembly begins with a rotor cap to secure the rotor (A). Next is the rotor (B) followed by the rotary encoder and the necessary mounting bracket for said encoder (C). Finally, the motor is the end piece (D) and is fitted in the rotor guard (Fig. 2) which allows this assembly to be mounted at the end of a PVC pipe. In the middle of said pipe a dowel rod sits inside orthogonally to the PVC thus allowing it to be mounted to the acrylic yoke. At the end of the dowel an encoder is mounted to detect the angle at which the system moves. The acrylic yoke attaches to the bottom bracket and moves as a single piece in the yaw direction.

B. *Yaw component*

The yaw component of the 2-DOF helicopter allows for smooth 360-degree motion in the yaw direction. As the apparatus spins in the yaw direction, a belt pulley system

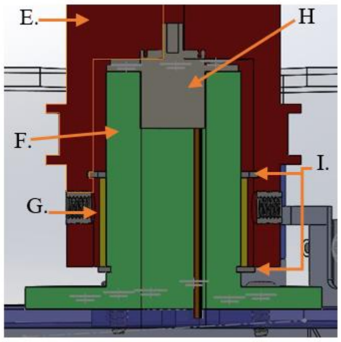

Figure 3. inner components (sliced view). Bracket bottom(E). Shaft (F). Needle Bearing(G). Slip ring(H). Snap ring(I).

turns the encoder shaft that is outfitted with a printed adapter piece to catch the timing belt. Figure 3 shows a section view of the belt pulley system. As the bracket bottom (E) turns, the yaw angle is recorded. In order to achieve this data acquisition, many components are required. The vertical shaft (F) is grounded to the base with four self-tappers. Two metal snap rings (I) are housed around the vertical shaft and inside the bottom bracket. A needle bearing (G) is then press fit onto the vertical shaft, which will allow for the yaw rotation. A slip ring (H) is screwed to the top of the vertical shaft, which allows wires to stay untangled as the components rotate. This slip ring fits into an opening in the bracket bottom which also fits over the needle bearing. Four, 8 mm set screws, threaded through heat sets in the bottom bracket, grip the needle bearing so the entire upper apparatus will rotate.

III. Electrical Design

A. *Electrical Components*

The Two Degree of Freedom Laboratory Helicopter System has many different electrical components that are necessary for the project's overall function. Primarily, the system is powered by a 12-volt AC to DC adapter. This adapter allows for the system to be plugged into normal wall outlets; thus, the system can be operational in any normal classroom. This power supply is attached directly to the motor driver of the system. The motor driver used for the system is a dual motor driver that could simultaneously drive both the pitch and yaw motors. The dual motor driver can operate with up to 28 volts giving the project enough voltage to operate. The motors used have an RPM of 3100 which is necessary for the system to take lift. The motor driver itself gets commands from a Raspberry Pi 3 Model B+ microcontroller. The microcontroller operates on low voltages received by user through a computer interface. The microcontroller also receives the data from the encoders in

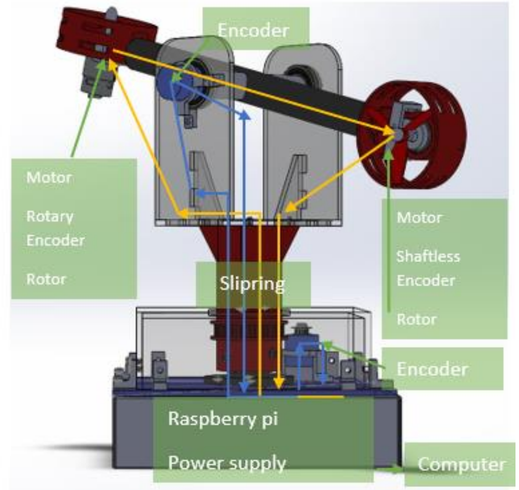

Figure 4. Block diagram of electrical components

the system. Our system has four encoders total (Fig. 4). Two of the encoders are shaftless rotary encoders that are attached to the motors themselves. These encoders are used to track the speed that the motors are operating at. The other two encoders are incremental encoders and are used to measure the pitch and yaw angles. As the system turns the encoders send data to the Raspberry Pi. One unique electrical component to the project is the slipring based in the vertical shaft of the system. The slipring allows the system to rotate freely without the inner wiring getting tangled.

B. *Matlab and Simulink Interface*

The user interface designated for the project is a MATLAB and Simulink interface. Simulink is a tool in MATLAB that many individuals use to develop control systems. A control system can easily be developed using block diagrams inside of Simulink. However, our system needed to be able to communicate to MATLAB. In order to do this, software was downloaded onto the Raspberry Pi's SD card to allow communication from the Raspberry Pi to the Simulink interface. Thus, now students can directly control the system directly through a PID controller developed on Simulink.

IV. Conclusion

The Two Degree of Freedom Laboratory Helicopter System is effectively able to send and receive data to MATLAB's Simulink tool. The system's final design was developed to achieve this goal. Students and researchers will now be able to use our system as a tool to better understand control systems and aerodynamics. Our system comes at a fraction of the cost as compared to other existing products on the market. Our system can also be easily maintained since most of the parts can be 3D printed or can be acquired relatively cheaply. Overall, the Two Degree of Freedom Laboratory Helicopter System can benefit those who want to better understand control systems and aerodynamics.