Development of PID Controller for Controlling the Phase Difference Between Coaxial Rotors

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Coaxial rotors have two rotors on top of each other that rotate in opposite directions, which provides a distinct advantage over a conventional single-rotor helicopter. It offers better stability and maneuverability since it removes the tail rotor on a helicopter. However, the two rotors in the coaxial rotor result in high aerodynamic interactions, which are not well studied across different conditions.

I have been working in the Applied Fluids Research Group (AFRG), which has the objective of studying and understanding the aerodynamics of coaxial rotors across different conditions. The lab has a medium to small-scale coaxial rotor setup for studying their aerodynamics and performances at various Reynolds number conditions. The medium-scale and small-scale coaxial rotor setup are similar to the standard coaxial rotor design with a medium-scale rotor on top and a small-scale rotor on the bottom. During my time at AFRG, I have learned that the lab uses an experimental technique known as Particle Image Velocimetry (PIV) to study the aerodynamics of the coaxial rotor system. The technique involves the use of lasers, smoke particles, and high-speed cameras to find the velocity field at a specific 2D plane.

Throughout the course of their experiments, the lab has identified that the phase difference between the two rotors is an important issue that affects the flow field below the rotor. The phase difference can be represented by the angle between the blade of the upper rotor to the bottom rotor. The current setup has two rotors that are mechanically uncoupled, such that the individual performance of each rotor can be studied. Therefore, electronic control over the phase difference between the rotors is required. The rotors are actuated using a brushless DC motor (BLDC motor) which can function efficiently at high speeds but is not equipped with positional feedback for controlling the phase difference.

I began my research with a small-scale single-rotor BLDC motor and an IR sensor. My initial objective was to create a control system using a feedback loop with these two devices to be able to control the RPM of the motor using a user-defined setpoint. The objective of this task was to gain a basic understanding of control theory and the program LabView and eventually use this knowledge to control the phase difference between two motors.

The next objective was to gain a mathematical representation of the physical system. I created a simulation within Simulink that used the data from the physical system to accomplish this. The speed of the BLDC motor is determined by a value between 0 and 1, called the duty cycle. First, I determined the relationship between the inputted duty cycle and the outputted RPM of the motor. I then determined the time it took for the motor to reach the expected RPM at different duty cycles. Using the data from these tests, Simulink generated a second-order function that represented the system.

However, numerous objectives remained unobtained. The phase difference between the two test case rotors still needs to be conducted, which will be done so by using a high-precision encoder. This will allow positional feedback from the BLDC motor actuating the rotors. Once a robust coaxial test system has been constructed on this test setup, the current technique will be employed in the medium and small-scale coaxial rotor setups in the AFRG lab.

Statement of Research Advisor

With the increasing rate of adoption of drones in civilian and military applications, it is very important to understand the aerodynamic interactional forces between the two rotors of a coaxial rotor. This study is a starting point to identify the physical interactional mechanisms of the aerodynamic loading on coaxial rotors of small-scale rotors. Synchronizing these rotors is very important since that will enable an improved understanding of aerodynamic loads. In the future, the plans are to adopt synchronization techniques to study aerodynamic interactions.
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Authors Biography

Andrew H. Parker is a senior-year student pursuing a B.S. degree in Mechanical Engineering at Auburn University. He conducted research on control systems and implemented what he learned into the physical system through computer coding.

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