White Paper: Modular Thrust Stand

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Description

This project identifies a direct need from the Aerospace 495 System Engineering Leadership Course (Aero 495) for testing hardware specifically for electric propeller-driven aircraft. The course focuses on leveraging three existing Student Project Teams: Michigan Vertical Flight Technology (MVFT), Michigan Drone Racing (MDR), and MACH (University of Michigan AIAA Design, Build, Fly Team). These three teams all rely on electric motors and propellers to propel their vehicles for competition. Each team uses different motor and propeller combinations ranging from roughly 5 inch propellers (MDR) to propellers larger than 15 inches (MVFT) and all teams need to perform in-house thrust testing to ensure consistent and reliable performance of their motors. As such, this team has been formed to develop a thrust testing system that can adequately meet the needs of the teams in Aero 495 as well as any future teams that may participate in the course or any other student project teams that use electric motors and propellers as their main propulsion system.

Our thrust testing system must be able to accommodate a range of propeller sizes and record thrust, revolutions per minute (RPM), motor torque, and power draw, as well as any other data that the aforementioned teams may want to analyze during their testing. Our system will also be safe, reliable, easy to repair and operate, meet the course cost cap, and use any and all available resources. We will be developing this testing system to be utilized by the aforementioned course and project groups. The goal being to create and test a more quality product than what is available off-the-shelf with much more operational flexibility and much higher quality results. This will be developed over the course of the Winter 2021 semester at the University of Michigan Aerospace Engineering facilities with the oversight and support of Professors George Halow (Aero 495) and Tim Smith (Aero 405).

Justification

The creation of the Aero 495 System Engineering Leadership Course this year has brought together many aerospace focused student project teams. These project teams share a need for thrust data from various electric motors. This has inspired our proposal of a modular thrust testing stand. This project will allow for streamlined thrust testing across all teams involved in the course. Individual solutions to this common problem cost students valuable time and money. In the spirit of collaboration, our unified modular solution will allow for rapid testing and data analysis for all teams involved. Our sponsor, Professor Halow, has enthusiastically endorsed this project for the value it brings to the project teams.

Impact/Effect

We estimate that our project will affect roughly 100 people per semester since it mostly benefits student project teams that work with propeller-based propulsion systems, in addition to the 495 lab. The main benefit of our project will be that it will allow for easier thrust testing of propellers for project teams

within the Aerospace Engineering Department. This removes the need for teams to purchase or build their own thrust stands which may vary in reliability, safety and accuracy. Our aim is to improve upon existing thrust stands available for purchase like the RCbenchmark 1585 series thrust stand [1] which only allows for testing up to 5 kgf of thrust and a limited range of propeller diameters. We want to be able to test a range of propellers approximately between 5 and 20 inches in diameter which can easily go well above 5 kgf of thrust. As a result, we will be designing our thrust stand to be as modular as possible to allow for a wide range of motor sizes with minimal modification to the design as a whole. In addition to thrust, we want to be able to measure additional metrics such as voltage, current, torque, and RPM so we can also analyze the power and efficiency of the propulsion system being tested. Our thrust stand will be capable of recording all of this data autonomously and also perform some basic analysis to determine some dimensionless performance coefficients. To improve dynamic thrust testing accuracy, we will also attempt to minimize the cross section of this design to minimize flow-blockage. Finally, we will add electrical, physical, and procedural safety features into our design so the thrust stand can be used in the future without incident.

Sponsor

The main sponsor for this project is Professor George Halow specifically to benefit the Aero 495 System Engineering Leadership Course. The established communications plan is to combine our scheduled team briefings with Professor Tim Smith as part of the Aero 405 course with our briefings with Professor Halow. These meetings will maintain a bi-weekly schedule via Zoom and provide both interested parties the necessary information to remain up-to-date with our progress and ensure our system continues to meet the requirements of our sponsor as well as the Aero 405 course. Internally, team communication will be an obstacle, given the restrictions due to COVID-19. Our team has a designated channel on Discord to discuss project related matters at any time. We also plan to meet weekly via a Discord voice channel.

Evaluation of Resources

Thrust stands able to measure thrust, RPM, motor torque, and power draw have been previously built and can be bought off the shelf [1]. However, existing off-the-shelf thrust stands are normally lower quality in construction and cost significantly more than building a custom stand. There have been custom built thrust stands for various projects, but they are normally built for their individual projects in the case of Duvall and Theys [2,4]. These stands serve their purpose very well, but since they are designed for such a small use-case, they do not offer very much modularity for different sized propulsion systems. There have also been other innovative small propeller thrust stands, including utilizing strain gauges to determine thrust from beam bending, but this solution was unable to gather any torque or RPM data [3]. We believe we can fill an existing need by developing a modular thrust stand that is higher quality than those found off the shelf and that can be general use and accommodate a wide range of propeller sizes.

References

[1] "Brushless Motor and Propeller Thrust Stands," *RCbenchmark* Available: https://www.rcbenchmark.com/.

[2] Duvall, Brian E.. "Development and Implementation of a Propeller Test Capability for Gl-10 "Greased Lightning" Propeller Design," *Master of Science (MS), thesis, Aerospace Engineering, Old Dominion University*

[3] Marchman, C. S., "Thrust sensing for small UAVs," *Masters Theses, Missouri University of Science and Technology*, 2016

[4] Theys, B., Dimitriadis, G., Hendrick, P., and Schutter, J. D., "Influence of propeller configuration on propulsion system efficiency of multi-rotor Unmanned Aerial Vehicles," *2016 International Conference on Unmanned Aircraft Systems (ICUAS)*, Jun. 2016.