Thrust Measurement and Optimization of a New Model Airplane Engine at Flight Conditions

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Motivation

M-Fly, a student project team, represents the University of Michigan in the Society of Automotive Engineers (SAE) Aero Design competition. Teams across the country design and fly a remote-controlled aircraft capable of carrying the heaviest possible payload. Competition requirements recently changed to allow a new type of engine (the Magnum XLS-61A).

2012 M-Fly Balsa Wood Glider at Competition

M-Fly uses data for engine performance to predict the maximum payload capacity for their design. Thrust as a function of airspeed (dynamic thrust) is the most important factor in the model, and must be measured for the new engine. Based on the dynamic thrust data, the best propeller-motor combination may be chosen for use in the final design.

Summary

The M-Fly student team is exploring powering their new aircraft design with the Magnum XLS-61A engine for the first time. No thrust data currently exists for the Magnum engine, and M-Fly requires this data to predict plane performance. This Aero 405 project team has been tasked with first breaking-in this new motor through the construction of a static “break-in” stand. Only then can thrust data be collected for 6 different propellers at a range of air speeds in the 2’x2’ wind tunnel.

After successfully completing our assigned tasks, we recommend the Magnum XLS motor and 12”x7° motor-propellor combination for use in the 2013 SAE Aero Design competition. This propeller produced the highest static thrust of 12 lb at 0 ft/s, making it the most effective candidate. Moreover, the thrust produced by this motor-propeller combination surpasses the thrust from the O.S. engine currently installed on the M-Fly plane by at least 2lbs over all flight speeds. Since the lower performance O.S. engine has already been proven on previous M-Fly plane designs, we know that our recommendation is feasible. Finally, we recommend the Magnum XLS motor and 12”x7° motor-propellor combination because it generated the maximum power for a given fuel consumption rate.

Criteria Rationale

We evaluated the six different propeller candidates based on three distinguishing criteria. In order of importance, they are effectiveness, feasibility, and desirability. The most effective propeller will have the highest static thrust. This is a measure of the maximum force generated by the motor and increases the acceleration from rest. This is required in order to lift off before the runway terminates—our benchmark is the previous M-Fly static thrust of approximately 7 lbs.

A feasible motor-propeller combination will have a dynamic thrust equal to or greater than the O.S. Engine and 12”x8° used previously. This ensures that the plane will have sufficient thrusting capability over the entire flight envelope.

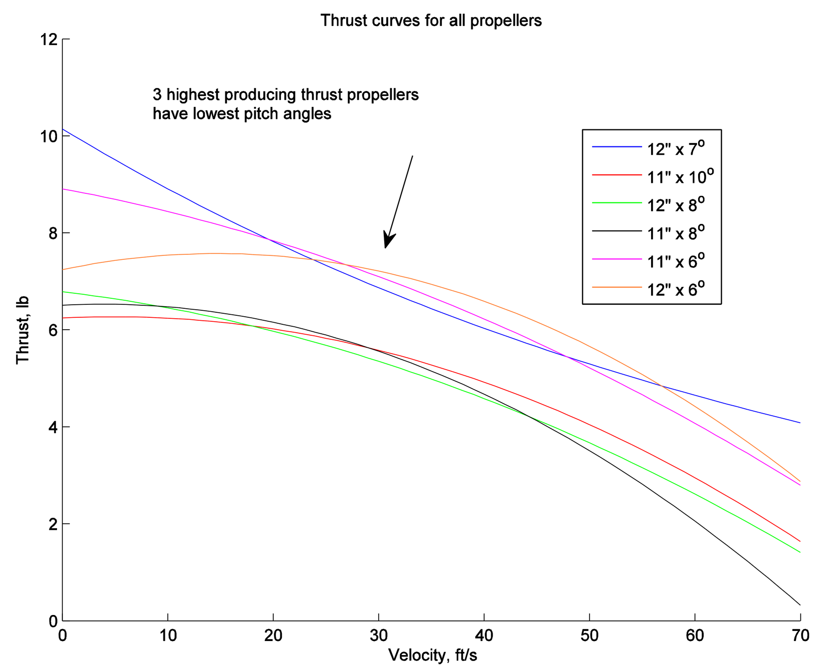
Finally, the most desirable candidate will extract the most power from the glow fuel relative to the other propellers. over the expected flight speeds. Given a constant fuel consumption rate, this becomes a measure of the efficiency of the candidate.

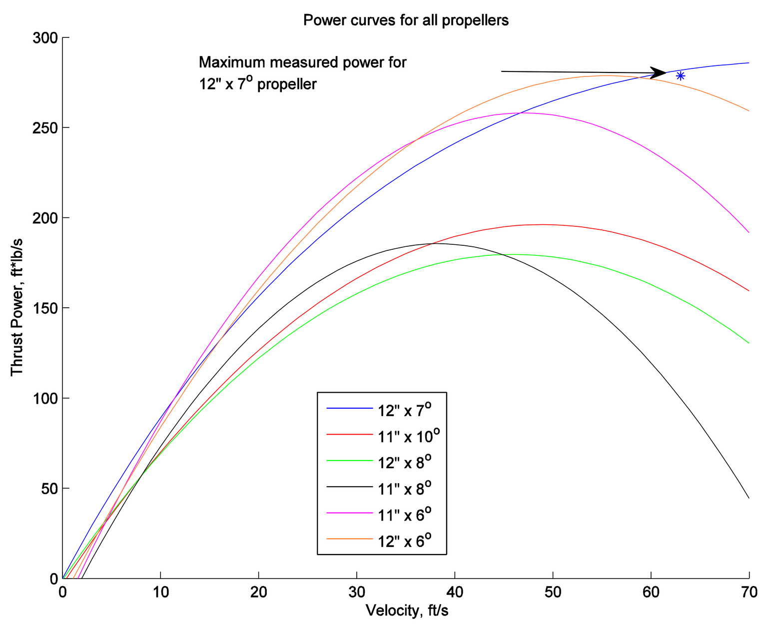
Results

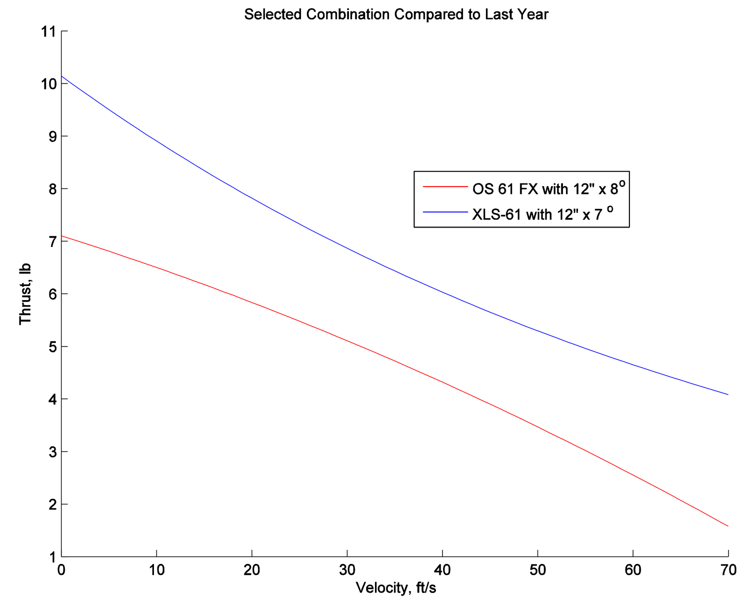
The results for most propellers indicated that the Magnum XLS motor produces similar or greater thrust at full-throttle throughout the dynamic range than the O.S. Engine previously used by M-Fly. Thrust depends more on pitch than diameter, with lower pitch (6 or 7 degrees) producing markedly higher thrust than high pitch propellers. The optimal propeller for the Magnum engine is the 12” x 7° . At 12 lbs of force. this propeller produces almost two pounds more static thrust than the other propellers, and produces similar thrust at higher airspeeds.

The 12” x 7° propeller with the Magnum motor also outperformed the previous M-Fly propulsion system by at least 2lbs over all flight speeds. This guarantees that the engine will have adequate propulsive thrust over the entire flight envelope.

Finally, our measure of propulsive power (thrust multiplied by velocity) was indicative of motor efficiency. We found that the 12” x 7° propeller produced the most power of 180 ft-lb/s. Thus we conclude that the Magnun XLS and 12” x 7° motor-propeller combination meets or exceeds all benchmarks and is the optimal candidate for the M-Fly 2013 balsa wood plane.

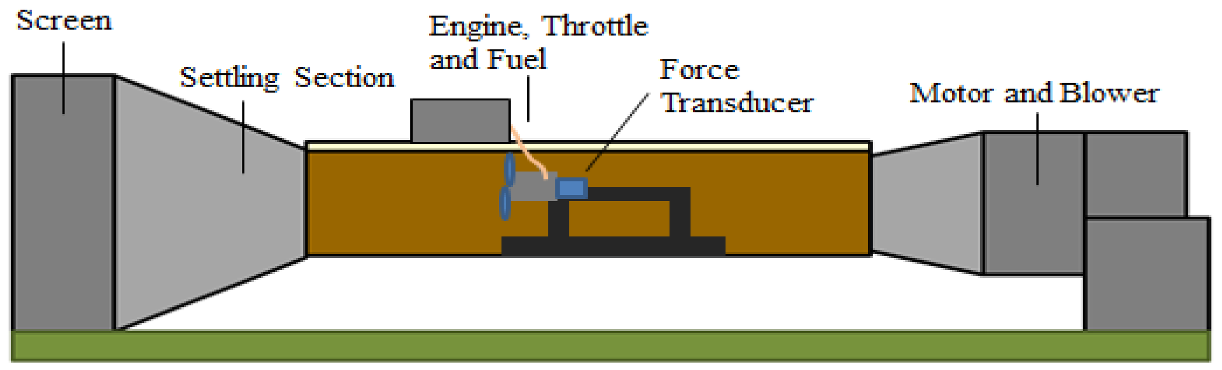




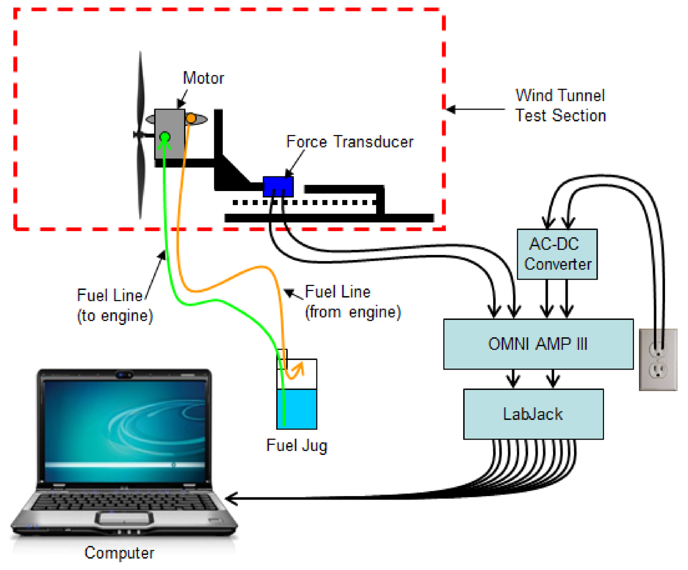


Experimental Setup and Procedure

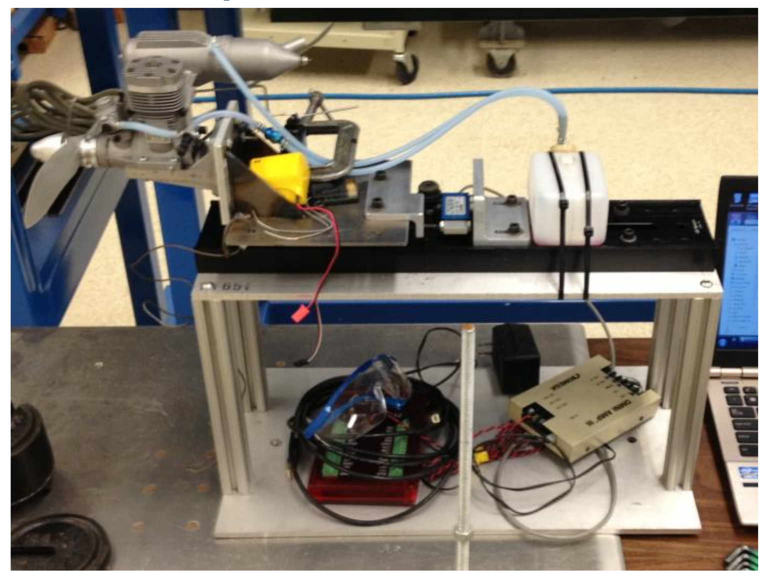
Testing was conducted in the Gorguze Family Laboratory 2’x2’ wind tunnel. The motor, fuel tank, and motor control servo were affixed to the electronic force transducer on Terry Larrow’s thrust stand. Our data acquisition system was calibrated both before and after operation. Six different propellers were tested at maximum throttle over a 70 ft/s range of airspeeds. We were able to filter out vibrational noise by time-averaging the thrust at discrete airspeeds. The longer sampling times increased the confidence in our results.



Wind Tunnel and Hardware Setup



Data Acquisition Equipment



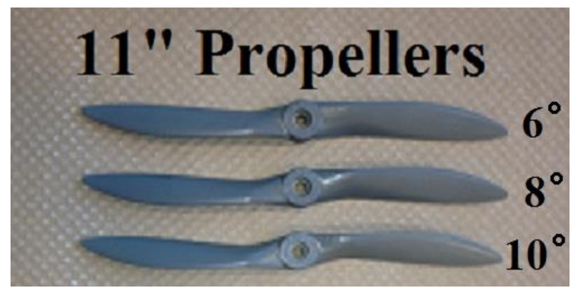
1-Axis Thrust Stand

Magnum XLS Motor

The Magnum XLS motor is a two-stroke, single-cylinder model airplane engine produced by the Magnum Company. It runs on “glow fuel”, a mixture of methanol, nitromethane, and castor oil to provide a fuel less volatile but more energy dense than gasoline. with self-lubricating properties. Both the older O.S. motor and the new Magnum XLS-61A motors have a 0.607 cubic inch displacement and a 0.866 inch stroke.

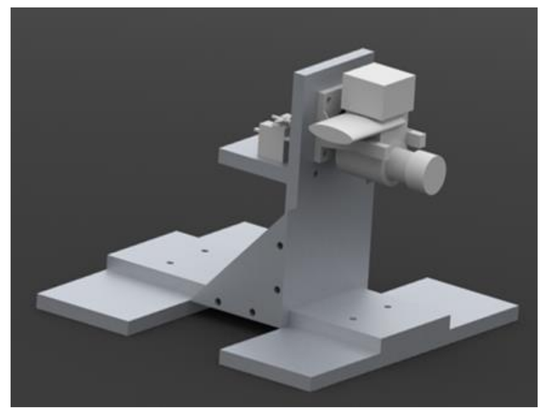
Propeller Selection

We made a selection of six different plastic propellers. We chose these based on their size and pitch to give us a wide range of possible combinations. Plastic propellers were chosen over the wooden propellers based on M-Fly’s preference. We had the option of choosing 11 or 12 inch propellers with pitches of 6, 7, 8, or 10. Our selected candidates provided us a greater understanding of whether thrust was more dependent on length or pitch. Our results showed that thrust depends on the pitch of the propeller and the length had little affect within the scope of our analysis. A pitch of 6 or 7 produced higher thrust than a propeller with a pitch greater than 7.



Motor Break In

Breaking in the motor was done using the recommended 12” x 7° propeller. This step was required to appropriately lubricate the engine prior to wind tunnel testing. We ran the motor for a total duration of 45 minutes, with 5 minute intervals of operation and cool down. The fuel mixture was leaned each time until the motor reached the nominal operating performance. This was judged both audibly and with the use of a tachometer. The fuel-to-air (FTA) ratio giving the maximum revolutions per minute is the optimal FTA mixture. This was determined to be exactly 5 quarter revolutions of the valve from closed.



Custom Made Brake-In Stand (Design)

Custom Made Brake-In Stand (Product)