INTRODUCTION

This report summarizes a two-phase endurance program completed by Power4Flight to qualify the B29i-AXS engine system. The B29i-AXS engine is an air-cooled, 2-stroke, single-cylinder reciprocating engine with a displacement of 28.5 cubic centimeters (cc). The engine utilizes an electronic fuel injection (EFI) system provided by Currawong Engineering to regulate ignition and fuel delivery. The engine runs on unleaded gasoline at a 50:1 oil premix ratio. Power output is rated at 1.8 kW (2.4 hp) at 9000 RPM with a dry weight of 2.25 kg (4.96 lbs). A Cobra-Aero AXS exhaust was fitted to the engine. The engine is designed for a direct-drive propeller in pusher or tractor configuration. It also drives a generator to provide up to 250 W continuous power (500 W intermittent) to the user’s aircraft electrical busses.

More information can be found at www.power4flight.com.

TEST OUTLINE

Two 150-hour run routines were executed to determine the engine’s ability to withstand its own wear and tear under adverse, high-stress operating conditions (i.e. high speed, high-temperature, minimal servicing). After the completion and evaluation of the first 150-hour phase, the test was repeated in another 150-hour segment on the same engine. Besides achieving the 300-hour mark, the second phase testing sought to validate changes made to address the shortcomings of the first phase, as well as uncover hidden flaws that may otherwise be missed; it assures the first 150 hours were not a fluke.

Goals

Design of the test procedure for the B29i-AXS was framed by the following objectives:
1. Determine upper limits of stress under which the engine can operate in a specified period of time and identify items that need improvement

2. Provide customers with endurance data to meet engine selection requirements

3. Increase airworthiness confidence by qualifying engine reliability against known FAA standards

4. Calibrate reporting of fuel flow from the Engine Control Unit (ECU)

5. Collect data to be used in determining product operating limits, maintenance schedules and, ultimately, hourly operating cost with respect to product life cycle.

Setup

The B29i-AXS was set up on a stationary test stand in a sound-absorbing enclosure and run per a specified max temperature and speed profile for approximately 8 hours a day until a prescribed test period was complete. Component hours, engine telemetry, environmental conditions, fuel consumption and any other noteworthy events were recorded. Noninvasive inspections were conducted at the end of each daily test cycle against a checklist, and any anomalies were noted and addressed. The same engine serial number was used for the duration of both phases of the test. Upon completion of each phase, the engine was removed from the stand and a teardown was conducted on the top-end and exhaust.

Airworthiness benchmarks

At the time of writing, there are no formal airworthiness standards pertaining to engines specific to unmanned aircraft, commercial or otherwise. The Federal Aviation Regulation (FAR), Part 33, while not intended for unmanned applications, is currently the most relevant set of regulations related to aircraft engine reliability. Subpart D, relating to block testing of reciprocating aircraft engines, is commonly selected by UAV engine manufacturers as a valid airworthiness requirement to measure their product against. Testing for the B29i-AXS follows this convention.

FAR 33.49 (b) calls for an endurance test consisting of (7) run profiles lasting 20-30 hours each. Rather than proceed through each run before moving on to the next, the run intervals defined in the regulation were reorganized into daily runs derived by the US Army AMRDEC (Aviation & Missile Research Development & Engineering Center). This allows one to operate the engine through all the power settings specified in 33.49 (b) in a 7.5 hour cycle, which can be accomplished in one working day allowing time for setup and inspection. A total of 20 cycles is required to reach the full 150 hour requirement. 5-minute warm-up and cool-down periods were added at idle (3000 RPM) at the beginning and end of each cycle.
Where the FAR calls out maximum take-off power and maximum continuous power (MCNe), we selected to run the engine at max speed, that is, WOT = MCNe for the duration of the test. This places added stress on the engine by allowing the engine to run continuously at its peak output, which is not typical of manned aircraft engines tested under Part 33.

The end result, shown in Figure 1, shows the AMRDEC profile for one 7.5-hr test cycle, plus allowance for startup, shutdown and idle periods.
Figure 1: AMDEC Test Cycle

450 minutes (7.5 hrs) per cycle
Official test mode

Shut down
Cruise
WOT
MCNE
89%
91%
87%
94.5%
79.5%
MCNE
MCNE
MCNE
MCNE
MCNE
MCNE
MCNE

Startup
RESULTS

The engine completed two sets of 150-hour FAR33-compliant profiles with no need for overhaul. Specific component findings are summarized below.

Cylinder

A stuck ring and scoring were discovered on the exhaust side of the piston and cylinder during the 150 hour teardown inspection. Probable cause was determined to be high temperatures, breakdown of the protective oil film layer between the piston and the cylinder, and consequent loss of lubrication and increased friction. Engine power at WOT degraded by approximately 215 W (0.29 hp) through the course of Phase 1. The operating temperature and speed profile were such that the engine was deliberately stressed (the engine spends 2/3 of the test at WOT alone, where temperature was set to 160 °C), so these effects after 150 hours are not a surprise.

In Phase 2, the WOT CHT set point was reduced to 150 °C to find a lower CHT limit that allows continued oil film protection of the piston and cylinder. Although scoring was still evident after Phase 2, it had reduced considerably.

Nominal recommended CHT remains 120 °C. There is a long history of no cylinder or piston damage at this set point.

Air filter

For the full 300 hours of testing, the air filter suffered from inconsistent durability and restriction issues (largely due to suboptimal test stand conditions), both which could be remedied by a filter of a different design type. There were several instances where the filter would become either clogged to the point of reducing airflow, or worn from vibration. Filter life, which averaged 44 hours, was the elapsed time before the filter started to affect engine performance, or to shake loose from its mount. Since these effects depend highly on mounting type and environment, an air filter on a fielded engine should be routinely inspected and replaced as necessary.

Muffler screws

The AXS muffler had three internal standoffs secured with stainless or titanium screws that were prone to loosening, resulting in exhaust gas leak paths. Zinc-plated steel side screws, used with high-temperature thread locker, have demonstrated improved muffler reliability. During Phase 2, one screw was observed to have loosened during the final teardown inspection. This item did not affect engine performance but can be easily checked in the field as part of the engine pre-flight checklist.
Muffler mounts

The muffler mounting tabs – which attach the AXS exhaust to three points on the crank case – were inadequate to withstand operational stresses during Phase 1. The updated exhaust used in Phase 2 is functionally the same but incorporates added material to support the three mounting tabs (Figure 2). There were no failures of these tabs in Phase 2.

Figure 2: Muffler tabs end of Phase 1 (left); updated muffler (right)

CONCLUSIONS

- After two phases, the engine has accumulated over 300 hours of accelerated endurance cycle-based testing without need for overhaul. Items needing attention were line-replaceable.

- The muffler was far more reliable in Phase 2 with the addition of updated mounting points and new side screw fastening specifications. Failures at the mounting points were eliminated. All muffler screws and mounting points can be inspected as part of a pre- or post-flight.

- The air filter is still prone to shaking loose and clogging. Alternate types or designs of a filter would increase the endurance of the filter and breathability of the engine. The filter is easily accessible for inspection. The filter life could be increased with a cleaner operating environment.

- As expected, cylinder scoring was noticeably reduced with lower operating temperatures. The nominal CHT specification remains 120 °C. Testing will continue to find the upper temperature limit of the oil film on the exhaust side.

Further details on this endurance test have been deliberately excluded from this summary, but they are available upon request.