Overview

Currawong Engineering’s CBS-20 CAN servo is designed to meet the highest requirements of reliability by using class leading components to minimise wear. These components include a brushless motor, metal gears and aluminium chassis.

To investigate the reliability in a real-world setting, Currawong conducted a 1000-hour endurance test on the CBS-20 servo. The experiment was a case study of a production servo (serial number 105), which underwent tests for linearity, backlash, and performance under load at routine intervals. The tests as outlined in this report demonstrated that the performance degradation of the servo over the thousand hours under typical use was minimal, with an almost complete restoration to baseline following the installation of new gears.

For further information on the features of the servo such as the CAN communications protocol, PID control and torque curves go to currawong.aero

Figure 1- CBS-20 Servo

Methods

Physical wear assessment

The following examinations were conducted at 0, 300, 400, 600 and 1000 hours.

Backlash

The backlash of the output shaft was measured at the output shaft in degrees.

Gear inspection

The gears were inspected and photographed under a microscope to highlight physical wear to the servo drivetrain. At 400 hours the gears were greased to supplement grease lost during the inspection process.

Linearity

The linearity of the servo was measured to ensure that the potentiometer was giving good feedback. At every 100-hour interval the servo reported position was compared to true position for a 180° sweep.

Performance assessment

The servo underwent the following tests at 0, 300, 600 and 1,000 hours to examine how the performance evolved throughout the test. Additional testing was done at 1,000 hours to examine any performance recovery from installing new gears. Data was collected in Currawong Engineering's software CEquip.

Load response test

The load response test commanded the servo to follow a 50 second repeating profile of ramp, step and high frequency movements (Figure 6). The servo drove a zero-offset linear torsional spring load with a peak torque of 1Nm (10.2kg-cm) at full deflection of ±35° (Figure 2). The servo was configured with default settings (velocity limit 500°/s, acceleration limit 60°/s^2), except for the motion endpoints which were set to ±35°. Default settings were chosen to match the configuration that most customers use.

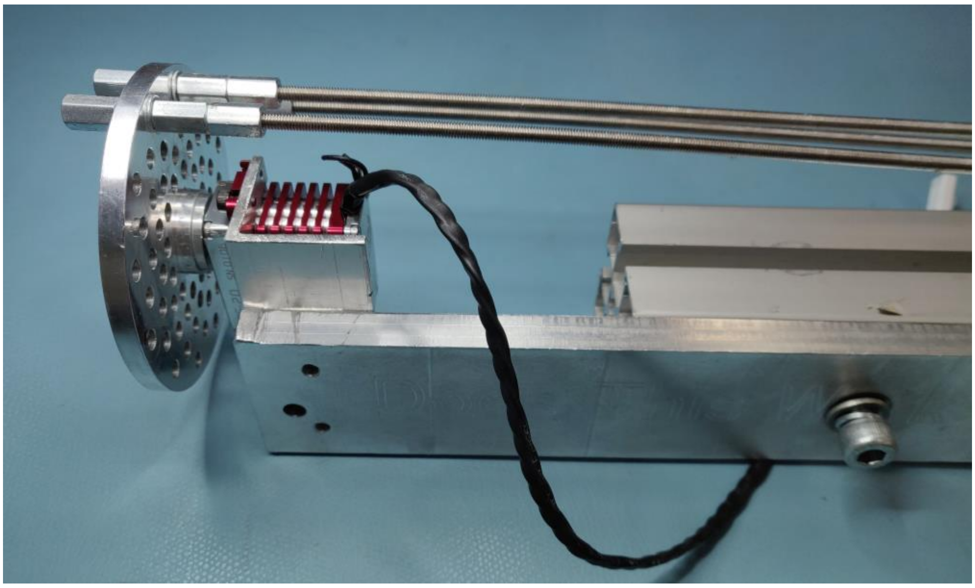

Figure 2- Servo in test jig (zero-offset linear torsional spring)

Step response test

The servo was commanded to follow a 0.5Hz, 50% duty cycle square wave from -90° to 90° (Figure 3) for a minimum of 50 steps (low-high-low). The servo had its velocity and acceleration limits removed to ensure that changes to peak acceleration and velocity would be measurable.

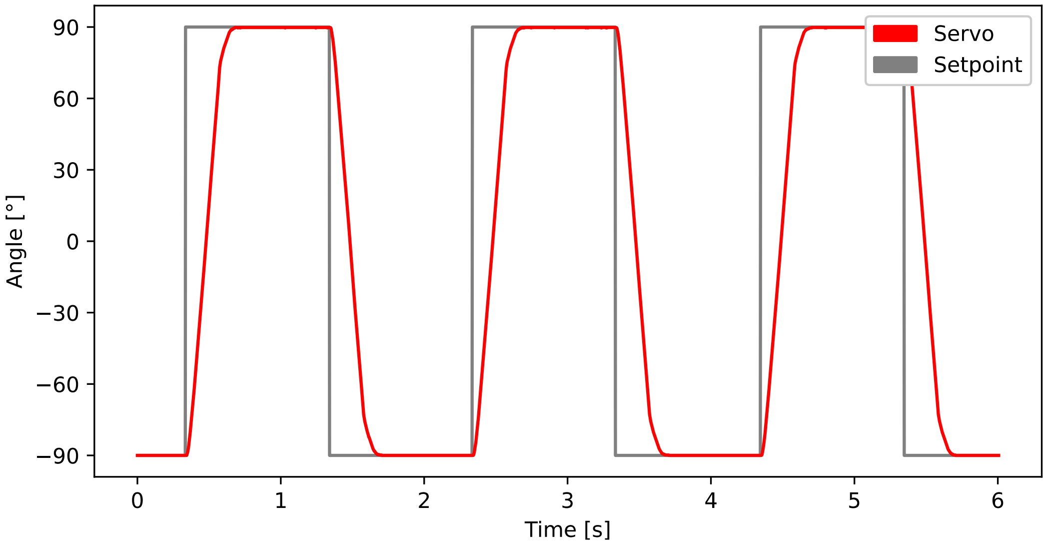

Figure 3- Step response assessment profile

Endurance assessment (ongoing)

For the continuous endurance test, the servo was run under the load with the settings and profile outlined in the section Load response test. The servo was run continuously in an unregulated (15-25°C) temperature environment. After 1,000 hours the servo had accumulated over 40 million cycles (defined as crossing the centre point of rotation).

Results

Linearity

The servo did not show any measurable potentiometer wear. The servo angle tracked the actual angle ±0.5° at every test interval.

Output shaft backlash

The servo exhibited signs of wear in the mechanical drivetrain at 400 hours of testing. On the output shaft 2±0.5° of backlash (slop) was measured (Table 1).

Time (hrs)	Backlash (°)
0	0
300	0
400	2±0.5
600	2±0.5
1000	2±0.5
1000 (new gears)	0

Table 1- Servo output shaft slop

This backlash was caused by worn teeth on the output shaft gear and the mating gear. The worn teeth increased the clearance between the teeth so that the shaft could move without resistance (in the 2° range). Installation of the new gears eliminated the backlash.

Step Response

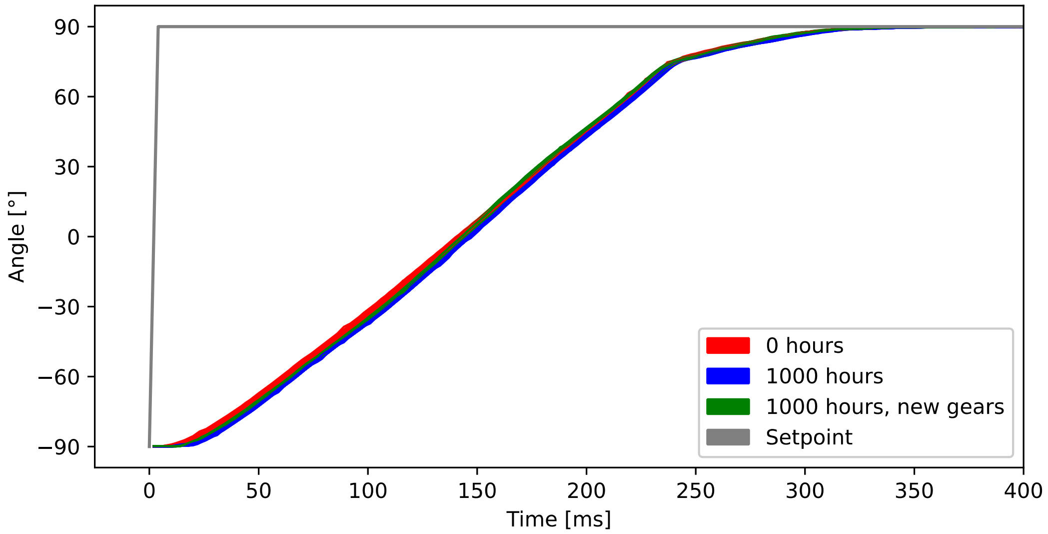

Figure 4- Step response at various test intervals

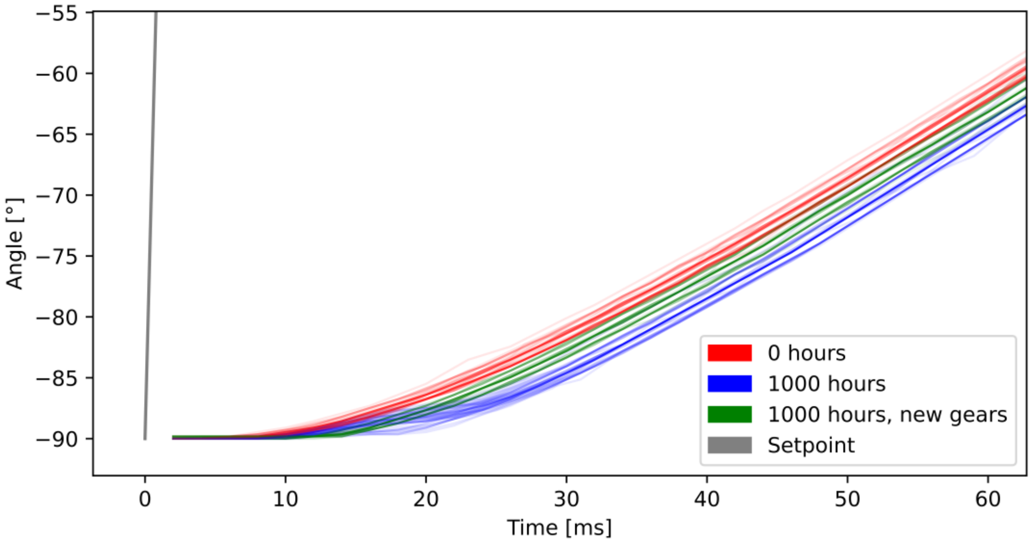

Figure 5- Step response at various test intervals (zoomed)

Following 1000 hours of testing the step response was still strong albeit slightly slower than the baseline test at 0 hours. The tracking error (see Appendix A) was measured and compared at each interval.

Time (hrs)	Tracking Error (%)	***p-value***
0	10.88	
300	10.94	0.40
600	11.06	<0.005
1000	11.11	<0.0005
1000 (new gears)	10.90	0.7

Table 2- Step response tracking error

The tracking error was unchanged until after 300 hours (Table 2). Whilst after 300 hours there was a statistically significant increase in the tracking error, for most customer applications this small degradation in transient response is not relevant, especially if a velocity/acceleration limit is in effect.

Installing new gears restored the servo to baseline tracking error. Note that from 160ms to 220ms in Figure 4 the '1000 hours, new gears' is closer to the setpoint than the '0 hours' data. This occurred as by chance the new set of gears/lubrication produced more precise function during this period. This indicates that in practical applications variance in tracking error between servos could dominate the tracking error increases due to wear. However, this was not proven in this case study.

Load Response

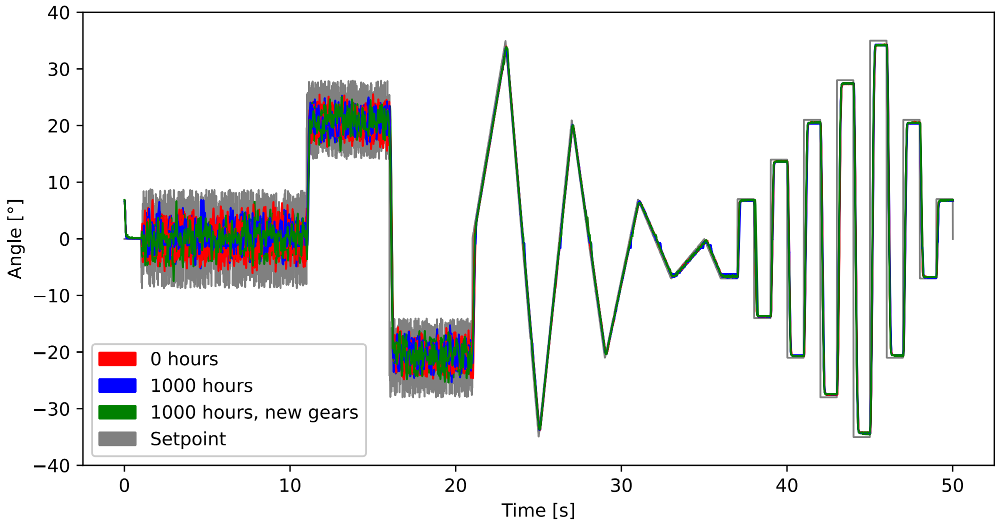

Figure 6- Load response at various test intervals

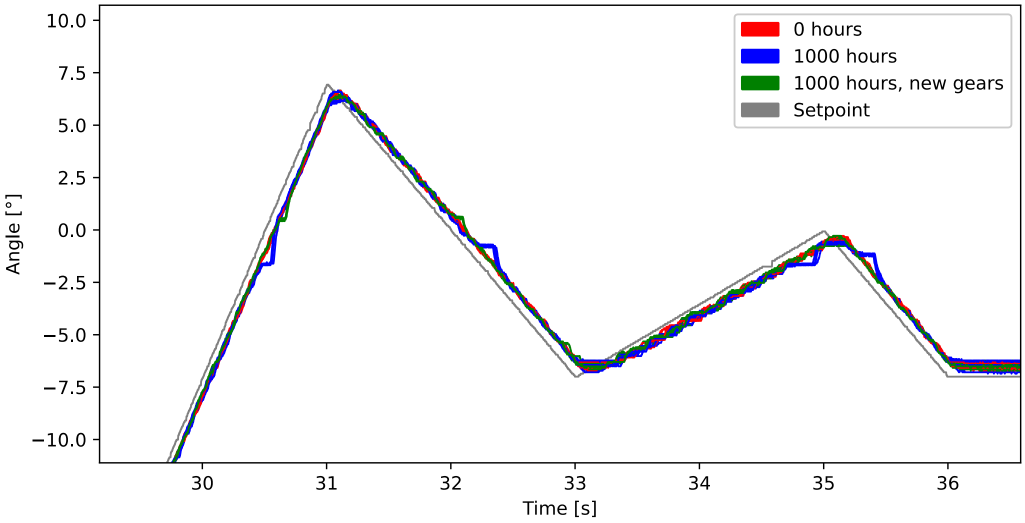

Figure 7- Load response at various test intervals (zoomed)

Under load, the servo exhibited wear around -1°, where instead of smoothly tracking the triangle wave it would stop moving for 150ms. This was attributed to wear on a particular gear tooth on the output shaft. Whilst no particular gear was identified, given that 'blip' did not repeat up the triangle wave we can ascertain it was almost certainly the output shaft. As the gear replacement corrected the issue, potentiometer wear was ruled out as a cause.

Gear inspection

The servo gears were routinely inspected; however it was only after 1000 hours and cleaning the lubricant that inspection was able to reveal the full extent of the wear. The lubricant on the gears was discoloured due to metal filings from wearing gears.

Each of the photographs (Figure 9 to Figure 13) highlights the most worn section of the gear. On the output shaft in Figure 10 the flanks were worn exposing a rough surface. In Figure 13 the tooth thickness increases at the base of the gear where the mating gear did not contact the entire gear tooth face.

Currawong notes that in rare cases some customers have experienced pinion gear (motor gear) failure whilst running the servo under very hard conditions with reduced, or in some instances removed velocity and acceleration limits. Whilst Figure 9 shows that the pinion gear does exhibit wear, the wear is characteristic of a servo with a thousand hours of loaded use and does not match the accelerated wear experienced in the aforementioned cases.

Figure 8- Servo gears, cleaned after the test ready for inspection. Gears referenced as 1 to 4, left to right.

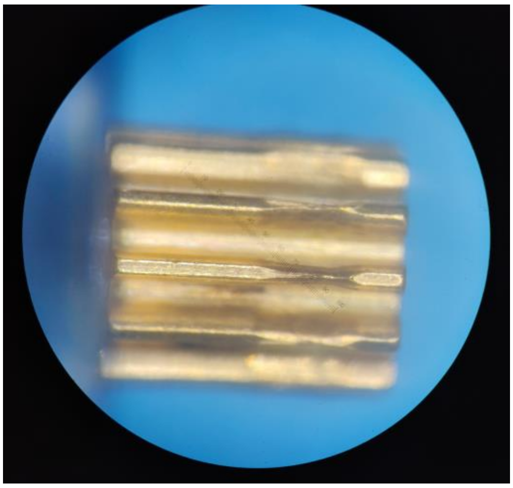

Figure 9- Pinion gear

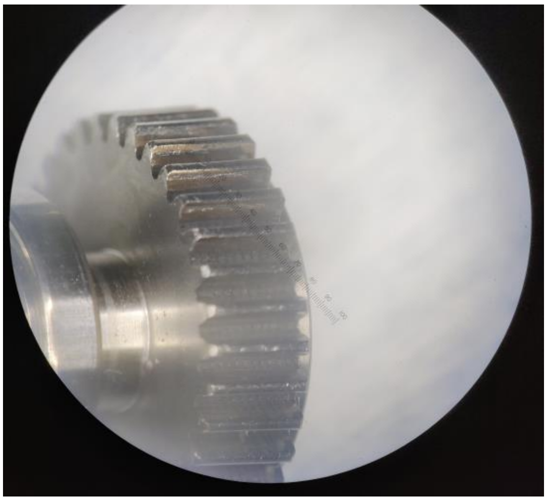

Figure 10- Gear 1

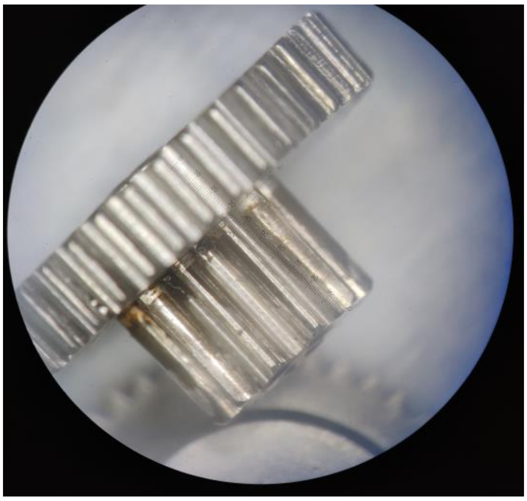

Figure 11- Gear 2

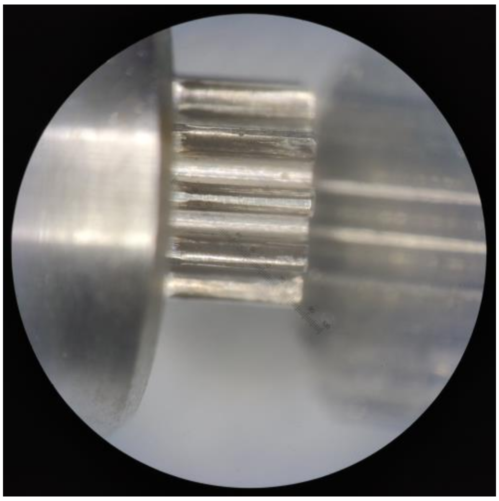

Figure 12- Gear 3

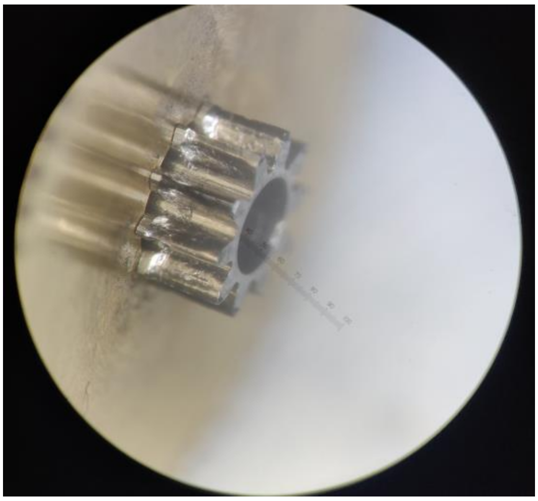

Figure 13- Gear 4

Conclusion

The servo exhibited reliable setpoint tracking and transient response after one thousand hours of use. Testing was conducted to mimic the real-life conditions of fielded servos. Component wear was limited to mostly replaceable parts such as the gears, with no wear observed until after 300 hours. The limited wear observed would likely be acceptable in most customer applications, though replacement gears are available for purchase at a low cost with easy installation.

Appendix

Appendix A

The average position error of the servo throughout a cycle was measured by summing the percentage error between the commanded position and the actual servo position.

$$E_{step} = \frac{1}{N} \sum_{i=0}^{N} \frac{|p_i - c_i|}{c_i}$$

Where E_{step} is the error in a single step cycle, N is the number of datapoints in the segment, p_i is the actual position at datapoint i and c_i is the command position at the datapoint.

By breaking the step response into segments (a single low-high-low transition), the error in each segment was measured. For example, a single 100 second (50 low-high-low transitions) test at 0 hours produced 50 error measurements which were compared to a different set of 50 measurements at 300 hours. The statistical significance between the groups was then calculated with a student's t test producing a *p*-value. The *p*-values in Table 2 are calculated from comparing the data at each of the hours to the 0-hour baseline. 50 measurements were used for each comparison.