Recommendation for an Auditory Quality Control (QC) Process for JohnnyFPV and Other BLDC Motors

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Current Test Arrangement

Currently, QC is done with an RCbenchmark.com motor test tool series 1580 which serves to measure a myriad of variables such as vibration, current, and xyz acceleration. The motor to be tested is attached to the test fixture with two metric screws which are hand tightened. The motor is attached via three wires connected in any configuration to a Lumenier 35A BLHeli_S OPTO-2-6s electronic speed controller (ESC). The input voltage for the 35A ESC is set to 8.3v on an external power supply unit (PSU) with no current limit set. A USB cable is attached from the RCbenchmark.com motor test tool to a computer running the RCbenchmark software where custom javascript code allows the software program to vary the speed of the motor via the esc command which steps up the esc value (essentially the speed or RPM) from 1000 (being not running) to 2000 (being the fastest the motor can run at that given voltage) and collects data at certain points.

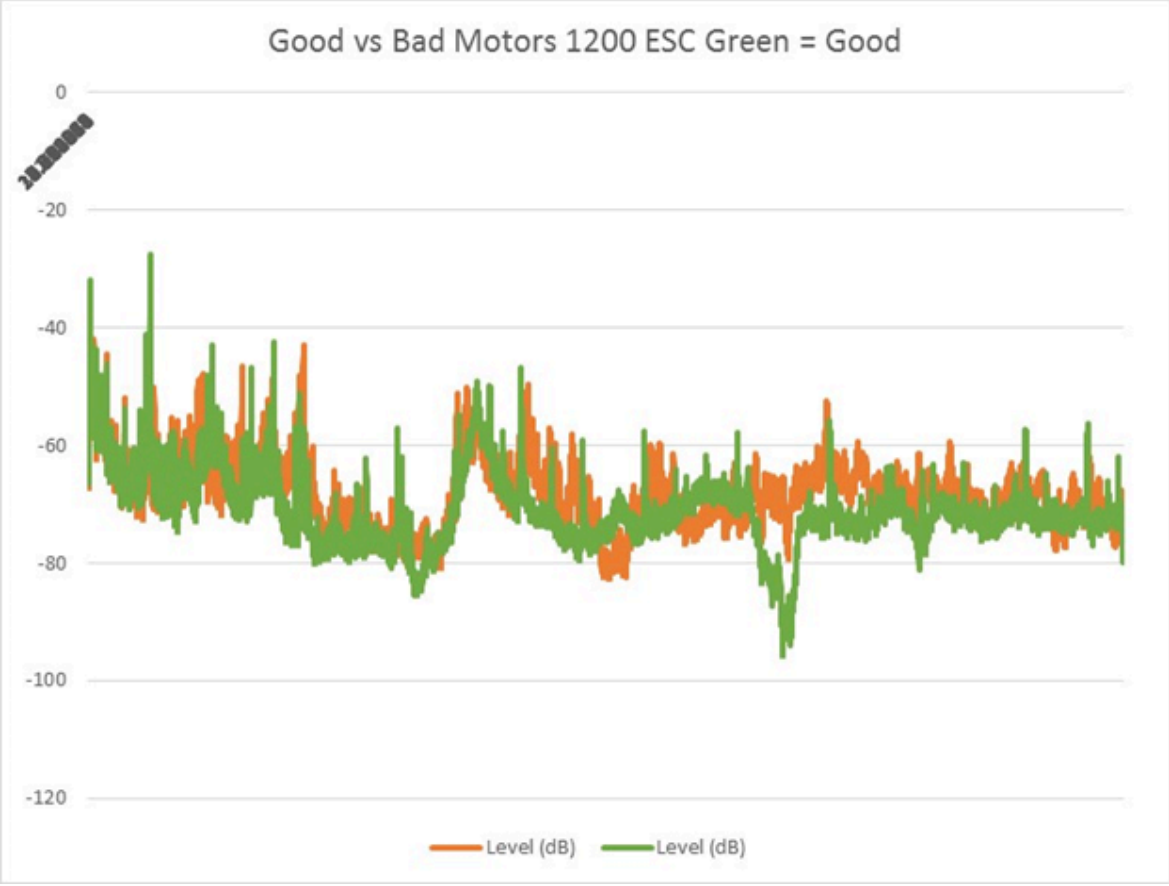
An attempt was made to utilize the current test setup to determine if a QC process could be developed based on motor vibration data already gathered by the RCbenchmark tool at different ESC levels; however, after extensive testing it was discovered that motor vibration data in conjunction with the other data gathered by RCbenchmark was too variable for use in a QC application and that there was no statistical difference between a “good” and “bad” JohnnyFPV motor when using such metrics.

Auditory QC Process

The process I propose involves the sampling of audio emitted by the BLDC motor at a given ESC speed and voltage with an analog, highly directional microphone. Such audio will be represented at the output of the microphone by a low voltage AC signal that will be applied to an input channel on an oscilloscope with a fast fourier transform (FFT) feature. The amplitude of certain frequencies will then be compared against a standard (good motor) to determine if the motor passes that aspect of QC. Variables that will need to be controlled for include:

- Microphone distance (from mic to motor)
- Input voltage into ESC (I used 8.3v)
- Oscilloscope used

I carried out a FFT analysis on 5 “good” and 5 “bad” JohnnyFPV motors and determined that there exists a frequency range where the “bad” and “good” motors differ in intensity. Good JohnnyFPV motors exhibit a much lower amplitude audio signal (they are quieter) between 10031 Hz and 10885 Hz. I utilized a ‘Blue Snowball’ microphone which is omnidirectional and not ideal for this process. Said microphone was used to record an ~10 sec .wav file per motor over USB to a computer where it was then processed with the software program Audacity. In Audacity, I selected the entire length of the file, clicked Analyze > Plot Spectrum then dialed in the settings to: Algorithm: Spectrum; Function: Hanning window; Size :32768; Axis: Log frequency and exported the data as a .txt file. Said data was imported into MS Excel and averaged between 5 good and 5 bad motors and was then plotted on a graph with frequency in the x axis and amplitude in dB on the y axis. This is the graph seen below:



The reduction in amplitude of the good motors around 10 kHz as seen in the graph leads me to believe that this is a viable test for a BLDC motor QC process.

For this test to be viable, one must be able to ascertain whether a given motor exhibits a certain frequency sound at a certain amplitude in real time. Such an arduous process with Audacity would never be feasible in a production facility, as such, I recommend the purchase of a Sennheiser MKE 600 (https://en-us.sennheiser.com/camera-mic-dslr-shotgun-video-mke-600) unidirectional microphone and either a high-end soundcard with the free realtime FFT capable software program SPAN (http://www.musicainformatica.org/resources/span-a-real-time-fft-audio-spectrum-analyzer.php) or a mixed domain ociliscope with FFT capabilities like this Rigol DS1054Z available here https://www.amazon.com/gp/product/B012938E76/) for $349. It has real-time FFT capabilities and isn't very expensive. It has also received a glowingly positive review here (https://www.youtube.com/watch?v=ETCOhzU1O5A).

What is FFT?

The FFT is an algorithm that reduces the calculation time of the DFT (Discrete Fourier Transform), an analysis tool that lets you view acquired time domain (amplitude vs. time) data in the frequency domain (amplitude and phase vs. frequency). In essence, the FFT adds spectrum analysis to a digital oscilloscope. For a mathematical explanation of FFT see: https://www.youtube.com/watch?v=spUNpyF58BY

Problems and Concerns

A few notable concerns with this process come to mind and include extraneous noise in the factory, gathering of reliable test data, and interpretation required by the QC operator.

So long as extraneous noise does not fall with the ~10-11 kHz range or any other range used by the test setup it will not affect the results. Human speech has all of the test frequencies included within it, so speaking during the QC process will affect the results. The degree to which said results will be affected is unknown at this time. Further testing will reveal whether the unidirectionality of the microphone will be enough to mitigate extraneous noise, or whether additional noise mitigation factors will need to be employed.

Reliable test data to use in the QC process will need to be gathered for every motor as each likely has a different frequency response at a fixed ESC level. Such data will need

to be gathered from a sample (5 or more) of known good motors that have passed a rigorous manual QC process. This will set the benchmark to test all other motors against. A limitation with the JohnnyFPV test was that I did not have sufficient “good” motors with which to test against and consequently, the data gathered is not, in my opinion, ready to use immediately.

The form in which the data from the QC process will be displayed will look like the above green and orange graph. A fair amount of analysis on the part of the QC operator is required to ascertain if a motor has passed or failed this QC step. This may be problematic as that level of analytical capability may not be present in many or even all QC operators.

Conclusion

I believe that through the implementation of an auditory QC process, issues that were detected by manual audio QCing can be discovered and reprocessed through general motor repair before the motors leave the factory. Such a process requires an input (microphone) and would be carried out while the motor is still on the RCbenchmark test stand. This process right now is not incorporated with the running of the RCbenchmark motor control process and would need to be carried out simultaneously. My biggest concern would be that of external noise interference; however, said problem could likely be mitigated with a sound canceling enclosure that could be placed over the test setup. Overall, I believe that prior implementation of this process would have prevented the JohnnyFPV motors from passing QC and if implemented would prevent future recurrences of this issue.