Technical note

Evaluation of the performance of electric motor and the effect of salt water on it.

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This technical note is describing the procedure we created and followed for assessing the performance of any given electric motor, and further to evaluate the effect of immersing it in salt water, by means of degrading the motor 's performance. The method is quantitative, consistent and easy to reproduce. This same method can also be used to evaluate other impeding factors like wearing, aging etc. in controlled procedure.

Introduction

Flying drones above salt water environment presents serious challenge for the mechanical and electronic parts of the device. This problem gets even more serious when such drone is expected to land in the water and stay there for a couple of minutes and even hours until it is retrieved. The salt water is notorious for its corrosive effect to electronics, destroying insulations and introducing shorts. Additionally, when drone is dried and salt water is evaporated, a salt crystals (NaCl) can form on the whole surface, especially in the small cavities through all the body of the drone, where it will be difficult to rinse them out. When such crystals form inside moving parts (linkages, bearings etc.) they will impede the performance and can even lead to failure, especially in the case of the electric motor. The following methodology and experiments are aiming to assess this effect in quantitative way.

Materials and Methods

A. Evaluation of Motor performance

The first step is to build consistent method for evaluation of the Motor Performance. The following materials and apparatuses were used for this task.

1. **Motor**: Extron brushless motor KV 800, 2814/20
2. **Propeller**: unknown manufacturer, Diameter: 9 inch, Pitch: 4.7 inch
3. **ESC**: 40A SBEC by HobbyKing
4. **Watt Metter**: Voltage 0-60V, Current 0-100A
5. **Digital Laser Tachometer**: HoldPeak HP-7236C
6. **Battery** 4S, 14.8 V, 2200 mAh/30000mAh
7. **Calliope mini** – microcontroller for the PWM to drive the ESC
8. **Non-contact laser thermometer** – for monitoring

On fig.1 is presented the scheme of the measuring setup, and on fig.2 the photo of the actual setup. The casing around the motor was for safety concerns. Also, in this photo, note the red laser point from the tachometer on the motors wooden base. During measuring the tachometer beam is perpendicular to the propeller spinning surface in order to count the revolutions per minute (RPM).

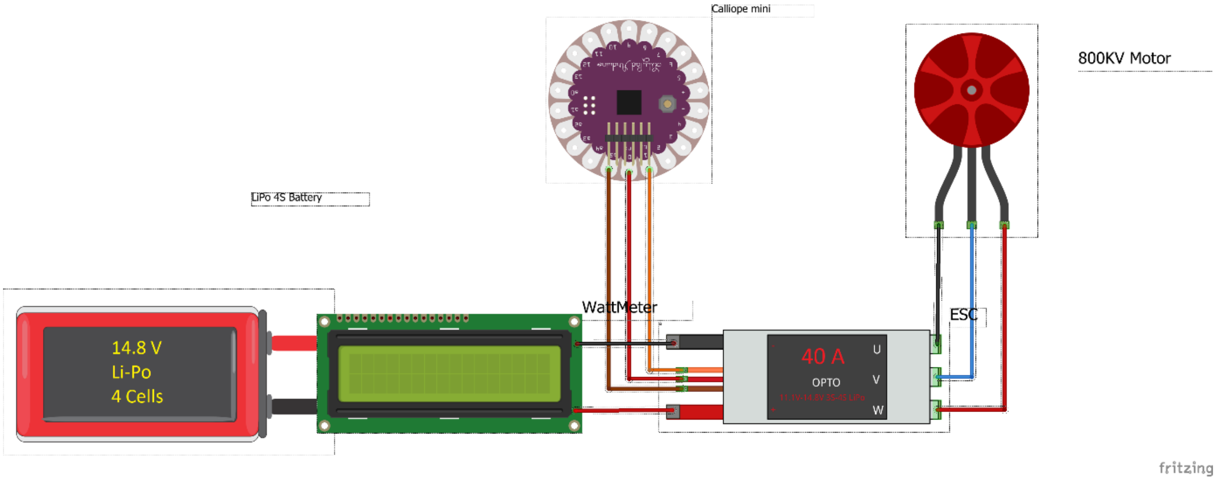

Fig.1 Scheme of the Setup

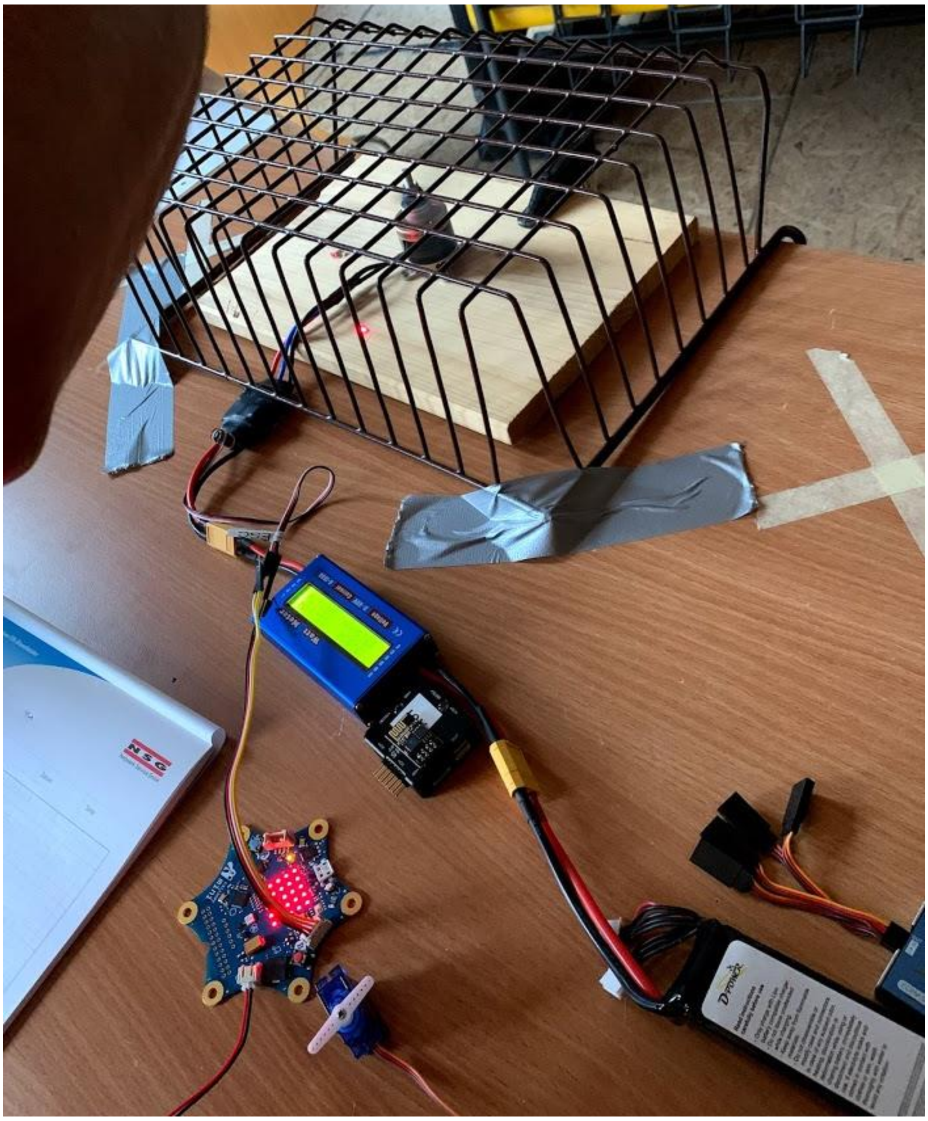

Fig. 2 Photo of the actual setup

The measuring procedure is the following:

With the microcontroller (Calliope mini) we present specific PWM, which is our independent variable. With the Tachometer we are measuring the actual RPM for the given PWM, which is quasi-independent variable (should correlate with the PWM). For the given PWM the Wattmeter gives the consumed Power, Voltage and Current by the motor which is the dependent variable (Watt) in our experiment. By sweeping up PWM we obtained 10 different discrete points for which we measured the corresponding RPMs and consumed power. Those data points were in the interval from 1000 up to 10 000 RPM. Each measuring sweep was repeated at least twice e.g. sweep_up and sweep_down. We also were using non-contact laser thermometer for monitoring the state of the motor during the whole test, however the temperature data was not collected for the whole process, but rather at the end. Of course, in future tests we can also include the temperature in the data acquisition for each point. The collected data (RPMs vs Watt) is representing the function of Motor's performance. It should be consistent over time when using the same materials e.g. propeller, ESC, battery. Additionally, we expect degradation of motor performance to affect the shape of this function and to increase the slope i.e. to consume more power for the same RPMs.

B. Salting procedure

For the salting procedure we used solution of 35 gr NaCl (Cooking salt) per liter fresh water. This ratio closely resembles the salinity of Mediterranean Sea. The solution was prepared in plastic box, in which the motor was immersed for about 30 min to mimic the real exposure.

Fig. 3 Preparing of the Salt solution

After immersion, the motor was retrieved and rinsed extensively with fresh water. After rinsing it was left to dry for few days before conducting the next tests.

Results and Discussion

Following the abovementioned measuring procedure, we conducted 3 series of data acquisitions: *control (blue)*, *1st salt immersion (green)* and *2nd salt immersion (orange)*. The results from those series are presented in fig.4a and fig.4b (magnified version of fig4a). With 1,2 (and 3) are noted the different measurement instances (sweeps). During the data acquisition we noted that RPMs and Watts were not steady for a given PWM value, as they were fluctuating in the range of 5-10%, which is normal behavior of Brushless motor. While there were concerns over the fidelity of our data, given those fluctuations, the results showed that the whole function is quite steady, and the quality of the data is sufficient for our task. The variances are local and the whole function shape stays clear enough. Nevertheless, this variation issue is undesirable in the testing, and further can be improved with integrating Watt meter. In such case the measuring will be limited for a certain time period ~ 5 seconds, and the integral Watt values will be considered. The tachometer we used has already such integrating function and could be used in this mode.

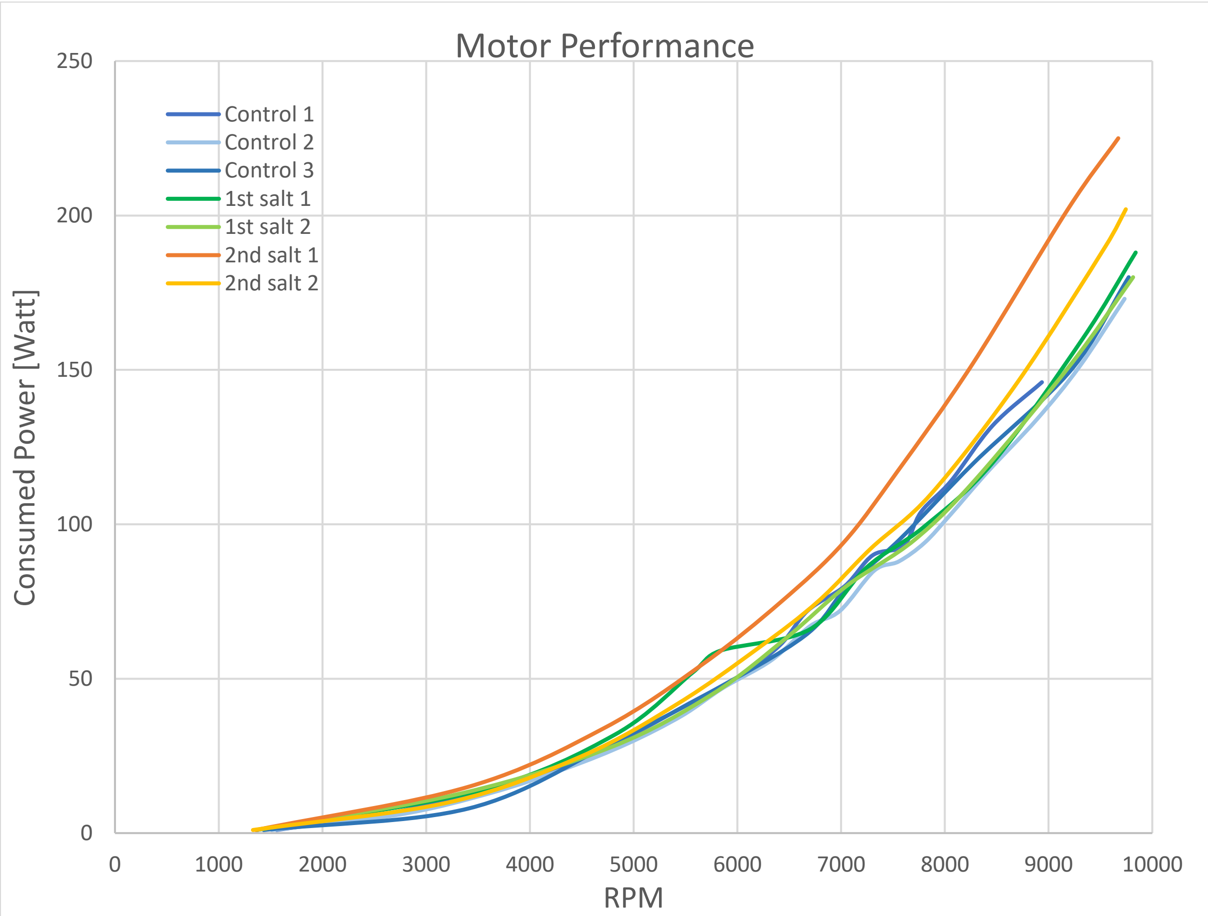

Fig. 4a

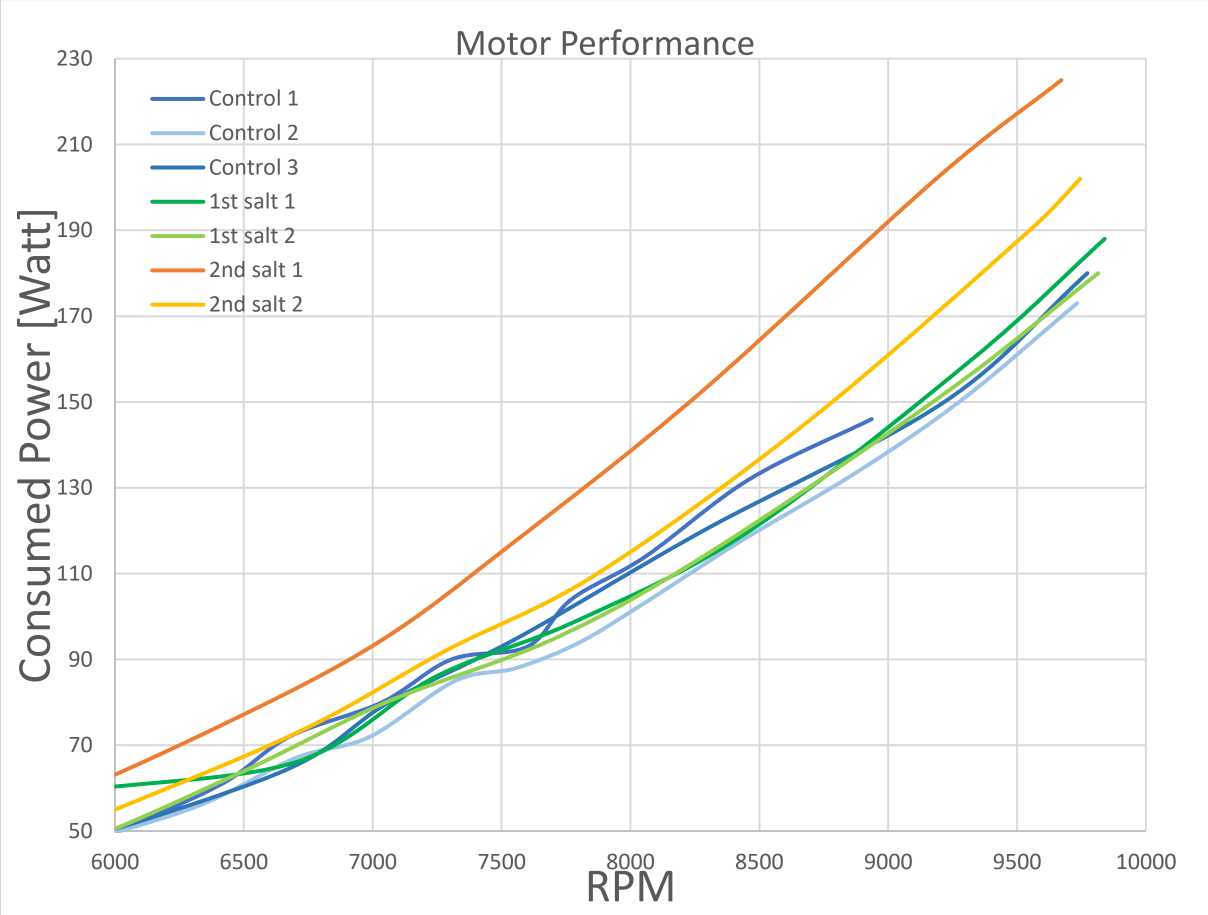

Fig. 4b

It is obvious from the graph that the control measurements are very close to the 1st salt immersion. We can conclude that the motor performance wasn't much affected by the first immersion. However, after the second immersion, the performance drastically degraded (orange). This also could be noted from the unusual very high-pitched sound coming from the motor. During the second sweep this sound disappeared, and while the function showed slight improvement (light orange), it is still worse than the control values. With the temperature monitoring, we also confirmed very high temperature for the *2nd salt 1* take, being about 65-70° Celsius. While control and 1st salt takes temperatures were about 37°. For context, the ambient temperature was about 27° Celsius.

Conclusion

The procedure to evaluate the motor performance was consistent and reliable. It further can be improved so it will have more resolution to distinguish lesser levels of degradation. The second salt immersion proved to be degrading for the motor performance. The high-pitched sound is further evidence that salt crystals were present in the bearings, which is the most likely mechanism of the observed degradation. The corresponding elevated temperature of 70° will most likely destroy the fuselage of the plane in real operation. Apart from that, there weren't any other visible traces of corrosion in the body of the motor or the wire wraps.