An Innovative Procedure and Indexes for UAS Testing

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ABSTRACT

The paper describes a proposal to support the rapid maintenance of Unmanned Aerial Vehicles (UAVs). The proposal consists of an instrumented test platform, allowing a constrained-flight evaluation of the UAV, and of a test procedure, where overall indexes about the health state of the UAV are evaluated. In the paper, the platform is briefly described, the health state indexes are defined and the test procedures are reported.

1.0 INTRODUCTION

In both civil and military applications, the safety of flight operations of Unmanned Aerial Vehicles (UAVs) is of primary importance. Such safety can only be assured by the verification of the flight equipment by means of proper testbeds and procedures.

In the literature, several platforms have been proposed, which are able to evaluate the UAV and to assess if its components comply with the design specifications. In Faundes (2013), several platforms are analysed which are able to evaluate different UAV components or subsystems, such as the motor-propeller couple or the control systems. Moreover, a testbed for the drive train evaluation is proposed, together with parameters and procedures. In Adamo (2017) a benchtop test system for motor and propeller assemblies of UAVs was proposed, able to measure the thrust force and the propeller angular speed. The former is obtained by means of a load cell fixed under the housing where the motor is installed. The latter is measured by means of a photoemitter and photoreceiver couple. For the evaluation of the control systems, under the effect of wind, testbeds in wind tunnels are often used, as in Lyu (2017). In this work, the Authors designed a quadrotor tail-sitter Vertical Take-Off and Landing UAV and conducted wind tests to characterize the aerodynamics of the aircraft and obtain a model which was used for the control system. In some cases, tests are specifically designed to characterize the behaviour of UAV parts in specific conditions, e.g. low air pressure. In this category falls the paper Scanavino (2020), where a specific test stand was designed, consisting of a welded steel construction with a central hollow tube filled with sand. The test stand was equipped with a JR3 30E15A4 sensor, able to measure thrust and torque generated by the UAV along three directions. The test was placed in a hypobaric climatic laboratory where it was possible to set extreme environmental conditions.

The above mentioned platforms are designed to test a single drone part or subsystem, such as the motor-propeller couple or to identify a proper UAV model that could be used to develop a model-based control. Few efforts instead have been devoted to platforms for a full characterization of the UAV for maintenance purposes, where overall indexes about the UAV working conditions and performance are evaluated. In Daponte (2017) a platform for such type of tests, called *DronesBench*, was firstly presented. It allows to measure the attitude of the UAV in terms of pitch, yaw, and roll angles; accelerations; power consumption; and thrust force exerted by UAV. Moreover, in the paper, a figure of merit representing the UAV efficiency was proposed. In Brzozowski (2018) a new version of the *DronesBench* was presented, allowing the remote control of the testing procedure over the Internet.

In this paper, a proposal of indexes and procedures for the rapid maintenance of UAVs is presented, based on the *DronesBench* testing platform.

The paper is organized as it follows. In Section 2.0, the *DronesBench* test bed is briefly described and its measurement capabilities are presented. In Section 3.0, 4.0, the proposed indexes for measuring the UAV efficiency and flight time are derived and the relative test procedures are described. Section 5.0 concludes the paper and draws future work.

2.0 THE *DronesBench* TEST BED

2.1 Description of the test bed

The *DronesBench* test bed (Daponte, 2017) was designed to test light Vertical Take-off and Landing (VTOL) UAVs. The version described in this paper has the following characteristics: weight lower than 5 kg, diagonal wheelbase not exceeding 1000 mm, current consumption lower than 100 A, battery voltage not exceeding 50 V. Other 2 models have been designed to work with smaller or bigger drones, respectively, the former up to 1kg, the latter up to 15kg.

The test bed, depicted in Figure 1, consists of a UAV accommodation plane, where the UAV is placed for the test, a power supply system, allowing to power up both the test platform and the UAV, and a monitoring board, containing the electronic sensors and the data acquisition system.

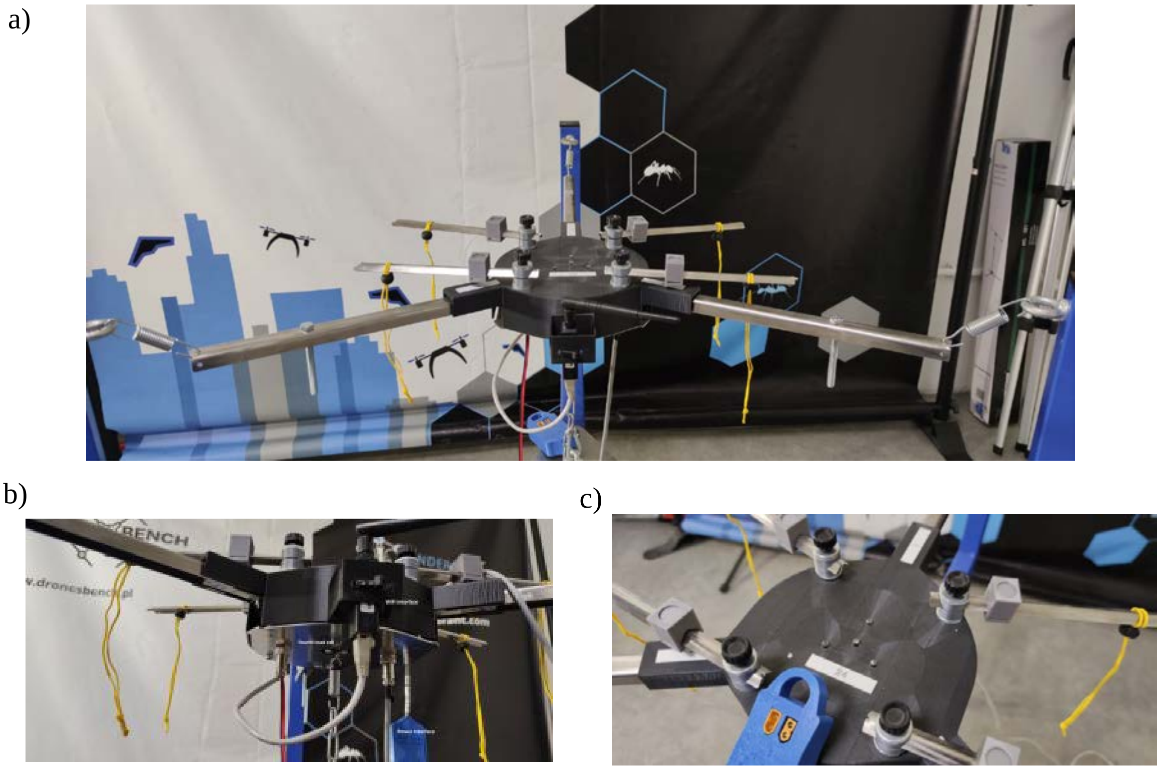

Figure 1: The *DronesBench* test bed: a) the measurement head including the load cells and the monitoring board, b) detail about the load cell located under the measurement head, c) the power detector.

The detail of the test bed is shown in Figure 1, where it is possible to appreciate the measurement head of the test bed, consisting of three arms, displaced 120° each other. Each arm is equipped with a load cell, allowing to measure the force on each arm. A fourth load cell (Figure 1b) is located under the head.

A block scheme of the monitoring board is instead reported in Figure 2. The board is equipped with: (i) an ATmega328 microcontroller, which is in charge of acquiring the data coming from the sensors and providing them to the host computer by USB, RS485 or WiFi (ii) four HX711 load cell amplifiers, each integrating a variable gain amplifier and a 24-bit Analog-to-Digital Converter, (iii) a power detector circuit, containing an ACS781 Hall effect current sensor, and an LTC1966 True-RMS to dc converter, to measure the RMS value of the current drained by the battery; (iv) a noise meter, consisting of a capacitive microphone and an amplifier circuit; (v) a GY801 inertial module, equipped with a L3G4200D triaxial gyroscope, a ADXL345 triaxial accelerometer, a HMC5883L triaxial magnetometer and a BME280 to read barometric pressure, temperature and humidity. The inertial module and the BME280 are connected with the microcontroller by the I2C interface.

Moreover, the *DronesBench* includes a propeller tachometer, built by means of a photoemitter and photoreceiver couple, connected to an analog input of the microcontroller, allowing to measure the angular speed of a selected propeller.

The version of the *DronesBench* described in this paper has a weight of 23 kg and can be packed in a box of 100 cm x 50 cm x 12 cm.

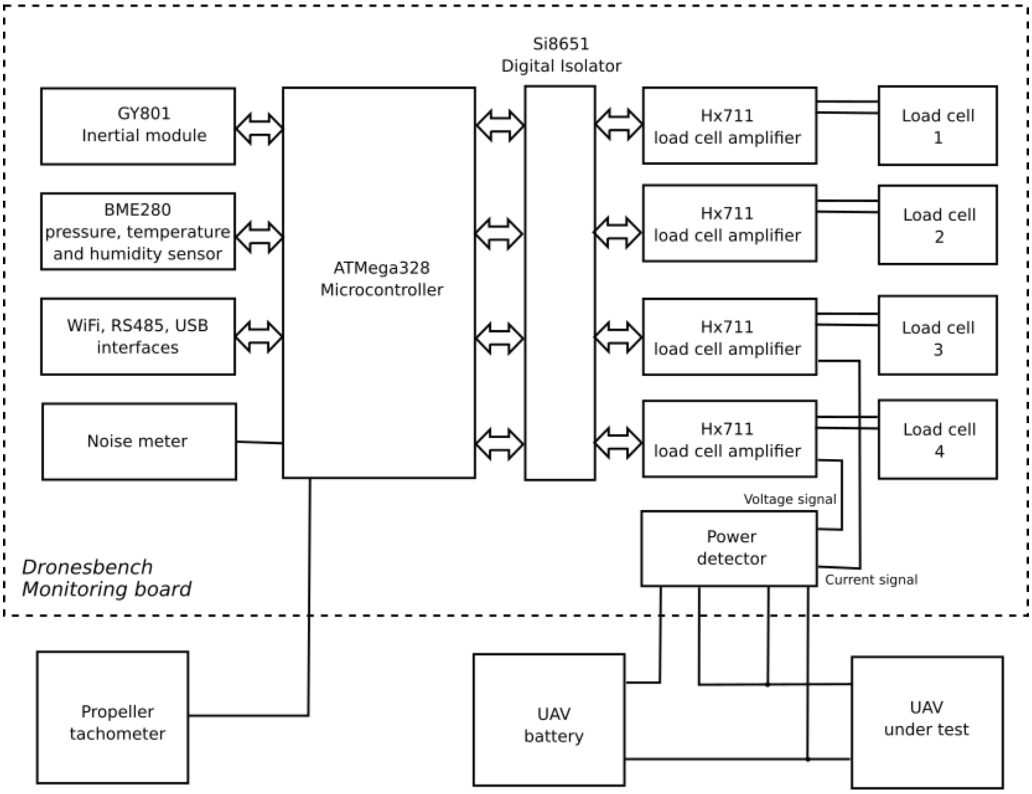

Figure 2: Block scheme of *DronesBench* monitoring board.

2.2 *DronesBench* measurement capabilities

In the following, the measurement capabilities of *DronesBench* are detailed.

2.2.1 Weight and Center of Gravity

Thanks to the load cells integrated in the *DronesBench* frame, it is possible to measure the total weight of the UAV, including the battery, when the motors are disarmed. This measurement should be carried out in the payload configuration with the heaviest load among all possible configurations.
Moreover, the three arms are equipped with a load cell each, it is also possible to evaluate the weight balance of the UAV and determine its center of gravity. It is well-known that a well-centered position of the center of gravity with respect to the point equidistant from the axis of the propellers guarantees greater autonomy and better ease of piloting the UAV.
In the user interface, during the measurement, the position of the center of gravity is shown in real time.

2.2.2 Thrust and force balance

Since the multiple load cells are able to measure the forces in three directions, it is possible to evaluate the balance of the thrust force exert by the motor-propeller couples, when the motors are armed, e.g. during hovering and during maximum thrust command. It is worth noting that the result of this measurement differs from the sum of the forces if measured for each couple motor-propeller, as it also takes into account the loss of thrust due to the obstruction of the air flow by the UAV frame and to the mutual interference of the propellers.

This measurement allows to check whether the drone thrust forces are properly balanced for the take-off. Unwanted horizontal forces are detected and can be safely removed before flying the drone.
The forces should be measured both when the motors are actuated by the remote control and when the motors are directly instructed. In the latter case, the command is actually given by means of a Ground Control Station software, properly connected to the UAV. Even when the remote control is instructed to give maximum thrust, the motors are not actually fully loaded, as an amount of thrust is left for translational flight. Therefore, by the difference of the two measurements, it is possible to obtain, for the UAV under test, the amount of power left for translational flight.

Therefore, the following measurements can be obtained:

- Maximum thrust: maximum load that the UAV can raise while flying along the Z axis (vertical), being instructed by the remote control (See Section 4.0).
- The presence of horizontal forces that can be compensated by acting on the remote control trims. This adjustment can be made on the test bed, instead of during flight.
- Maximum propulsion: maximum load by directly driving the motors.
- Thrust index: maximum thrust / weight of the drone.
- Loss of thrust due to the obstruction of the air flow by the UAV frame.

2.2.3 Electrical Parameters

Thanks to the current sensor and the voltage meter, the *DronesBench* is able to measure the following electrical parameters:

- Voltage generated by the battery.
- Current absorbed for take-off.
- Current absorbed when the maximum motor thrust is instructed by the remote control.
- Current absorbed when the maximum motor thrust is instructed by directly controlling the motors.
- Total power consumption of all UAV components.

- Actual battery capacity, as the energy consumed by the UAV in a conventional mission that starts with full battery and ends with a forced landing due to battery discharge. Being the UAV in static conditions, the battery capacity should be evaluated with an additional thrust beyond what it is needed for hovering, emulating the thrust needed for translational flight.
- Available flight time, that is the UAV autonomy measured starting from the fully charged battery until the battery is so low that the motors are unable to support the weight of the drone (see Section 4.0).
- Check of battery-UAV pairing. By comparing the current that the battery can actually provide and the UAV current requirements, it is possible to verify the capability of the battery of actually power the UAV.
- On-board electronics power consumption with motors disarmed.
- Power losses in the battery cables at take-off.
- Power losses in the motor cables at take-off.
- Power losses in connectors at take-off.

2.2.4 Combined mechanical/electrical measurements

By combining thrust measurements and electrical measurements (e.g. current, voltage or power) it is possible to obtain the following indexes:

- Specific power: power absorbed by the UAV divided by the thrust, when the thrust equals the UAV weight.
- Curve of the thrust to power ratio: thrust to power ratio measured for different values of the power.
- *DronesBench* index: the thrust to power ratio at the hovering condition, that is when the thrust equals the UAV weight (See Section 3.0).

2.2.5 Kinetic parameters

The *DronesBench* is equipped with a propeller tachometer, able to measure the angular speed of a selected propeller. Thanks to this measurement, to the force measurement and to the data input from the operator, it is possible to obtain the following kinematic parameters:

- Maximum theoretical altitude reachable by the drone;
- Maximum difference between the speed of the air entering and exiting the propeller;
- Maximum pressure difference between the inlet and outlet of the propeller;
- Maximum vertical acceleration;
- Maximum vertical speed;
- Maximum horizontal acceleration;
- Maximum speed and maximum horizontal thrust and maximum pitch angle;
- Maximum kinetic energy with motors disarmed;
- Maximum kinetic energy at maximum throttle of the motors;
- Class of operation of the UAV under test.

2.2.6 Noise measurements

A noise meter is placed onto the monitoring board of the *DronesBench*. Therefore, it is possible to obtain a measure of the noise produced by the UAV, both in hovering or at its maximum thrust. However, due to the different UAV size and shape, the distance between the propellers and the microphone can differ. In order to have more accurate measurements at a fixed distance from the propellers, an external phonometer can be used. It is suggested that it is placed on the vertical plane passing through the center of the propeller and the vertical axis of the UAV, on the direction at 45° with the vertical line and at a distance of 1 m.

2.2.7 Fatigue tests

To get information on the probability of failure of a drone, fatigue tests can also be carried out for a long time with an external power supply instead battery. During these tests it is possible to analyse the drone efficiency variations and the most critical parts in order to compile the manual of scheduled maintenance and to have the Mean Time Before Failure (MTBF) of the entire drone. This test has a duration that depends from the first drastic failure of the drone and is a destructive test. The time and the component corrupted are the response of this test that may be useful to program the maintenance.

2.2.8 Burn-in

The drones leaving the production process can carry out a burn-in process, i.e. uninterrupted operation of a period equal to a certain number of missions, such to overcome the period of infant mortality of the product.

Burn-in tests can be carried out on the *DronesBench* with:

- external power supply instead of the drone battery;
- additional load of 10%;
- 6 cycles up to maximum power for one second;
- testing time equal to the full UAV autonomy.

After a generalized test on all drones, if the occurrence of failures is very low, it is proposed to carry out the burn-in on a sample, to verify that the production standards are maintained.

If the failure happens too often, a fatigue test is suggested and as a result, it could be needed to modify some aspects of the design or some UAV parts.

3.0 UAV EFFICIENCY AND THE *DronesBench* INDEX

3.1 *DronesBench* index definition

By comparing the power absorbed by the motors and the thrust generated by the UAV, it is possible to diagnose the deterioration of the UAV propulsion subsystem due to aging or any fault occurring in such subsystem.
In fact, in the presence of faulty or aging-related phenomena such as wear of the bearings, wear of the propellers, plastic deformations of the driving shafts or wear of the servo-drives, foreign bodies in the motor, the thrust provided by the UAV with a given amount of power decreases significantly.

The above observation has led to the proposal of an efficiency index, here called *DronesBench* Index (DBI), that could be used as a metrics for the health state of the UAV.

The DBI is defined as the ratio between the thrust and the power needed to obtain it (Daponte, 2017):

$$DBI = \frac{|\vec{F}|}{P}, \tag{1}$$

where, $\vec{F}$ is the resulting force exert by the UAV and P is the corresponding power. This value is estimated by using the force and the power consumption measurements at the take-off instant. In this instant, the *DronesBench* platform and the drone under test are considered in static equilibrium.

This parameter could be checked on the ground, before to start the mission. If the DBI is found under a certain safety threshold, the mission is not started unless a maintenance intervention restores the UAV health state and a value over the threshold is obtained by a new measurement.

3.2 Effect of environmental conditions and DBI normalization

The environmental conditions, i.e. air pressure, temperature and humidity, affect the force produced by the couple motor-propeller. Considering the hovering condition, where the thrust must equal the weight of the UAV, the propellers must rotate at a higher speed when the air density is lower, to produce the same thrust, therefore a higher power is consumed. The power required in hovering condition is given by (Gordon Leishman, 2006):

$$P = \frac{W^{3/2}}{f\sqrt{2\rho \cdot A}}, \tag{2}$$

where, W is the total weight of the UAV, including battery and payload, f is a figure of merit of the rotor, A is the rotor disk area, which is the area swept by the blades of the rotor, and ρ is the air density, which in turn is affected by air pressure and temperature as:

$$\rho = \frac{p_a}{R_a \cdot T} + \frac{p_v}{R_v \cdot T}, \tag{3}$$

with p_a the partial pressure of dry air, R_a is the specific gas constant of dry air, p_v is the water vapour pressure, R_v is the specific gas constant for water vapour, and T is the temperature.

Eq. (3) can be rewritten as:

$$\rho = \frac{p - U_r\, p_{sat}}{R_a \cdot T} + \frac{U_r\, p_{sat}}{R_v \cdot T}, \tag{4}$$

where p is the total air pressure, U_r is the relative humidity, and p_{sat} is the saturation vapour pressure.

Air density is often considered referring to the ICAO International Standard Atmosphere (ISA) conditions (ICAO, 1993), i.e. a temperature of 288.15 K (15° C), a pressure of 1013.25 hPa and relative humidity of 0%.

However, the actual value of the air density must be considered for the determination of the thrust.

By substituting (2) in (1), and considering the thrust equal to the total UAV weight, the dependence of the DBI on the air density can be expressed as:

$$DBI = f\sqrt{\frac{2\rho \cdot A}{W}} \tag{5}$$

Basing on the above observations, it is worth noting that the DBI should be normalized such to be referred to the ISA conditions, whatever the test conditions are. Therefore, a normalized DBI is defined as:

$$DBI_s = f\sqrt{\frac{2\rho_s \cdot A}{W}} \tag{6}$$

where ρ_s is the air density at ISA conditions.

Table 1 shows the percentage relative difference between DBI and DBI_s. It represents the relative error that is committed by considering standard conditions instead of the actual ones. It can be seen that in the considered conditions (relative humidity = 40%, temperature range [-10 - 40] °C and pressure range [960 - 1060] hPa) a maximum absolute difference of about 7% is observed.
Therefore, in order to make it independent on atmospheric conditions, the DBI can be referenced to the ISA conditions by the following equation:

$$DBI_s = DBI \frac{\sqrt{\rho_s}}{\sqrt{\rho}} = DBI \frac{\sqrt{1{,}2247 kg/m^3}}{\sqrt{\rho}} \tag{7}$$

where the actual air density ρ should be evaluated by the (4), starting from the measurements of temperature, relative humidity and air pressure. Therefore, in order to obtain the DBI_s, the *DronesBench*, first reads the measurements of temperature, relative humidity and air pressure from the BME280 sensors and then normalizes the DBI, by evaluating the (7).

Table 1: Percentage relative difference between DBI and DBI_s for a relative humidity of 40% at sea level.

	Pressure [hPa]										
Temperature [°C]	960	970	980	990	1000	1010	1020	1030	1040	1050	1060
-10	1,8%	2,4%	2,9%	3,4%	3,9%	4,5%	5,0%	5,5%	6,0%	6,5%	7,0%
-5	0,9%	1,4%	1,9%	2,4%	3,0%	3,5%	4,0%	4,5%	5,0%	5,5%	6,0%
0	-0,1%	0,5%	1,0%	1,5%	2,0%	2,5%	3,0%	3,5%	4,0%	4,5%	5,0%
5	-1,0%	-0,5%	0,0%	0,6%	1,1%	1,6%	2,1%	2,6%	3,1%	3,6%	4,1%
10	-1,9%	-1,4%	-0,9%	-0,4%	0,1%	0,6%	1,1%	1,6%	2,1%	2,6%	3,1%
15	-2,8%	-2,3%	-1,8%	-1,3%	-0,8%	-0,3%	0,2%	0,7%	1,2%	1,7%	2,2%
20	-3,7%	-3,2%	-2,7%	-2,2%	-1,7%	-1,2%	-0,7%	-0,2%	0,3%	0,8%	1,2%
25	-4,5%	-4,0%	-3,5%	-3,0%	-2,6%	-2,1%	-1,6%	-1,1%	-0,6%	-0,1%	0,3%
30	-5,4%	-4,9%	-4,4%	-3,9%	-3,4%	-3,0%	-2,5%	-2,0%	-1,5%	-1,0%	-0,6%
35	-6,3%	-5,8%	-5,3%	-4,8%	-4,3%	-3,9%	-3,4%	-2,9%	-2,4%	-1,9%	-1,5%
40	-7,2%	-6,7%	-6,2%	-5,7%	-5,2%	-4,7%	-4,3%	-3,8%	-3,3%	-2,9%	-2,4%

3.3 DBI measurement procedure

For the DBI measurement, the following procedure is proposed:

1. Adjust to zero the *DronesBench* measures of weight and power;
2. Put the UAV with its battery fully charged on the *DronesBench* and adjust it to have the center of gravity at the center of the measurement head;
3. Tie the UAV to the bench;
4. Set the UAV to manual mode;
5. Arm and give thrust slowly till hovering;
6. Keep the hovering conditions until at least 20 measures are acquired;
7. Turn off the drone. The control panel of *DronesBench* will report the DBI and the DBI_s.

During the execution of the procedure, it should be considered that although the increase of power is very fast, the corresponding thrust is reached after some time due the mechanical inertia, therefore the DBI should be considered after this transient has passed. To overcome these drawbacks, a filter is introduced that selects only the measurements matching the following conditions:

- The power derivative is lower than an adjustable value;
- The derivative of the thrust is lower than an adjustable value.

When both conditions are met it means that the measurement reached the steady state condition and the DBI can be properly evaluated.

4.0 AVAILABLE FLIGHT TIME

4.1 Available flight time definition

A lot of freedom is left in the manufacturers' declarations on the UAV autonomy, therefore indexes and procedures for the evaluation of the UAV flight time in a repeatable and verifiable way could be beneficial. Available Flight Time (AFT) is defined in this paper as the actual flight time of a UAV from the take-off to the moment when the battery is no longer able to generate the power needed to support it. The AFT is expressed in minutes and seconds.

Since, as shown in Section 2.0, the power consumption depends on the air density and in turn on the atmospheric conditions, similarly to the DBI, it is necessary to refer the measurement to standard atmospheric conditions, namely AFT_s.

The flight time is inversely proportional to the power consumption, which in turn is inversely proportional to $\sqrt{\rho}$. Therefore, a similar relation to (8) exists between AFT and AFT_s:

$$AFT_s = AFT\frac{\sqrt{\rho_s}}{\sqrt{\rho}} = AFT\frac{\sqrt{1{,}2247 kg/m^3}}{\sqrt{\rho}} \tag{8}$$

Since the relation between the AFT and the AFT_s is the same as the DBI, percentage relative differences between the two values are the same as reported in Table 1 for DBI.

In a similar way to the DBI, the AFT is determined in hovering condition, e.g. when the thrust generated by the UAV equals its weight. This measurement can be very different from the actual flight time that the UAV will experience as only the thrust for hovering is considered, whereas in actual condition, an additional considerable amount of thrust is required for longitudinal thrust. For this reason, it could be convenient to determine a new index, that is here called AFT*x*, where the AFT is determined with an additional load equal to *x* % of the UAV weight. The additional load will emulate the thrust necessary for longitudinal flight. The value *x* % should be chosen by the maker such to accurately represent the thrust for longitudinal flight which depends on the type of UAV.

4.2 Procedure for AFT evaluation

The AFT can be evaluated by the following procedure:

1. Adjust to zero the *DronesBench* measures of weight and power;
2. Put the UAV at nominal weight, including the payload with its battery fully charged on the *DronesBench* and adjust it to have the center of gravity at the center of the measurement head;
3. Tie the UAV to the bench;
4. Set the UAV to manual mode;
5. Start the time count;

6. Power up the UAV and keep it on for the entire autonomy, with the thrust equal to *x*% over of the UAV weight,

7. When the battery is discharged such that the UAV is unable to sustain the thrust, stop the time count and report the read value as the AFT*x*.

5.0 MAXIMUM THRUST

5.1 Maximum thrust definition

It can be useful to determine the maximum thrust that the UAV can generate. This is related to the maximum payload that the UAV can bear. The maximum thrust is defined as the thrust generated at the maximum angular speed of the propeller.

According to the well-known Rénard 1st law, the maximum thrust has the following expression:

$$F_{\max} = \tau\rho\omega_{\max}^2 R^4, \tag{9}$$

where τ is a coefficient that depends on the shape of the propeller, R is the radius of the propeller disk, and $\omega_{\max}$ is the maximum angular speed, corresponding to the full throttle command to the motors, by the remote control.

As shown in (9), the maximum thrust is also depending on the air density. Therefore, similarly to the previous cases, it is needed to define a standard maximum thrust in the ISA condition and to refer the measurements to such conditions:

$$F_{\max,s} = \tau\rho_s\omega_{\max}^2 R^4, \tag{10}$$

Since the thrust is linear with the air density, the following relation applies between the standard maximum thrust in ISA conditions and that in the general case:

$$F_{\max,s} = \rho_s \frac{F_{\max}}{\rho}, \tag{11}$$

In Table 2, the relative difference in percentage is reported for different values or the air pressure and temperature and humidity fixed to 40%. As it can be seen, the maximum thrust force can change up to about 15 %. This should be taken into account when planning missions in condition of low air pressure such as high altitudes.

Table 2: Percentage relative difference between $F_{\max}$ and $F_{\max,s}$ for a relative humidity of 40% at sea level.

		Pressure [hPa]										
		960	970	980	990	1000	1010	1020	1030	1040	1050	1060
Temperature [°C]	-10	3,7%	4,8%	5,9%	7,0%	8,0%	9,1%	10,2%	11,3%	12,4%	13,5%	14,5%
	-5	1,8%	2,8%	3,9%	4,9%	6,0%	7,1%	8,1%	9,2%	10,3%	11,3%	12,4%
	0	-0,1%	0,9%	2,0%	3,0%	4,0%	5,1%	6,1%	7,2%	8,2%	9,2%	10,3%
	5	-2,0%	-0,9%	0,1%	1,1%	2,1%	3,2%	4,2%	5,2%	6,2%	7,2%	8,3%
	10	-3,7%	-2,7%	-1,7%	-0,7%	0,3%	1,3%	2,3%	3,3%	4,3%	5,3%	6,3%
	15	-5,5%	-4,5%	-3,5%	-2,5%	-1,5%	-0,6%	0,4%	1,4%	2,4%	3,4%	4,4%
	20	-7,2%	-6,2%	-5,3%	-4,3%	-3,3%	-2,3%	-1,4%	-0,4%	0,6%	1,5%	2,5%
	25	-8,9%	-7,9%	-7,0%	-6,0%	-5,1%	-4,1%	-3,1%	-2,2%	-1,2%	-0,3%	0,7%
	30	-10,5%	-9,6%	-8,6%	-7,7%	-6,8%	-5,8%	-4,9%	-4,0%	-3,0%	-2,1%	-1,1%

35	-12,2%	-11,2%	-10,3%	-9,4%	-8,5%	-7,6%	-6,6%	-5,7%	-4,8%	-3,9%	-2,9%
40	-13,8%	-12,9%	-12,0%	-11,1%	-10,2%	-9,3%	-8,4%	-7,5%	-6,5%	-5,6%	-4,7%

5.1 Maximum thrust procedure

For the maximum thrust measurement, the following procedure is proposed:

1. Adjust to zero the *DronesBench* measures of weight and power;
2. Put the UAV with its battery fully charged on the *DronesBench* and adjust it to have the center of gravity at the center of the measurement head;
3. Tie the UAV to the bench;
4. Set the UAV to manual mode;
5. Arm and give slowly maximum thrust by the UAV remote control;
6. Keep the maximum thrust condition for 3 seconds;
7. Turn off the drone. The control panel of DronesBench will report the $F_{\max}$ and the $F_{\max,s}$.

5.0 CONCLUSION AND FURTHER WORK

In this paper, a test bench for the verification of UAVs before flight is presented, capable of measuring both mechanical and electrical UAV parameters, such as thrust, force and weight balance, absorbed current and power. Based on the presented test bench some indexes are proposed for UAV rapid maintenance are proposed. In particular, indexes related to UAV efficiency, the UAV flight time and the maximum thrust are defined in the paper. The dependence of the defined indexed on the atmospheric conditions, i.e. temperature, humidity and pressure has been derived and standard versions of the indexes are proposed to refer the measurement output to standard atmospheric conditions.

Future work will be devoted to the improvement of the test bench and to conduct systematic tests aiming at observing the decline of the DBI over time for typical UAVs. Moreover, actual measurements will be carried out with different UAV types and payloads in different conditions of air pressure and temperature.

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