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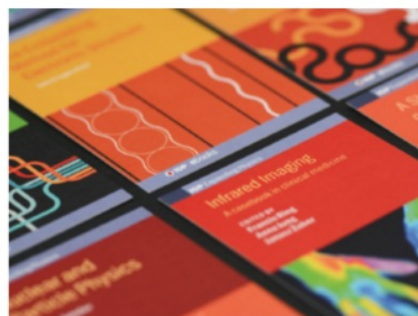
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Quadcopter Surveyor Drone Wind Velocity Data Characteristic for Optimal Hotwire Sensor Position

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Abstract. In a research and survey sector, drone usually equipped with extra measuring equipment depends on needed. The purpose is to make a survey tools with extra ability to collect data in a wide area with fast and remotely. This type of drone known as a modified drone or a surveyor drone.

One of surveyor drone type is a quadcopter wind velocity surveyor drone. The problem is, drone also knowing have a turbulent air effect surround its propellers, and its suspected to affect the ability of the anemometer collecting the correct data.

This research will investigate that phenomenon, focused on the data of wind velocity with a variety of drone propeller rotation speed. Wind velocity anemometer sensor position places surrounding the drone. The drone use in this research is a prototype drone which is equipped with hot wire anemometer data logger. hot wire anemometer memory card data logger type uses in this research is a regular type and already modified to installed it on a drone.

Research will be focused on the search of an answer about how big the deviation of wind velocity data affected by drone propeller wind turbulence.

1. Introduction

Quadcopter drones are drones that are more widely as surveyor drone. This type of drone is also more easily modified to attach additional tools outside the body. Aerodynamic interference problems that arise in this type of drone when paired with additional equipment can be said to be minimal. Four propellers on a drone can counter air resistance to stabilize the drone in the steady position.

The use of drones as a survey supporting tool is widely found. This type of drone is usually called a surveyor drone. The types of drones that are commonly used as surveyor drones are drones with the type of Unmanned Aerial Vehicle (UAV) drone which is a drone shaped like an aircraft, the next type is a quadcopter type drone which is a drone shaped like a helicopter but has 4 arms with propellers.

Quadcopter drones are drones that are more widely used because the price is more competitive than UAVs. This type of drone is also more easily modified to attach additional tools outside the body. Aerodynamic interference problems that arise in this type of drone when paired with additional equipment can be said to be minimal. Four propellers on a drone can counter air resistance to stabilize the drone in the steady position. With its ability to maintain this steady position, this type of drone is considered more suitable to be used as a drone surveyor. Coupled with competitive prices can be another positive value.



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In the **energy** sector, one example of using a quadcopter surveyor drone is as a drone to collect wind velocity data in a survey of the potential wind energy in an area. By utilizing a drone surveyor, data retrieval at certain altitudes and elevations can easily be done. The drone only needs to be moved to a desired geographical node, then data can be retrieved immediately.

Some of the concerns from this survey method are that we know that drones have the effect of turbulent airflow arising from the turning of the propeller when used. This turbulent air can cause a kind of chaotic flow around the propeller.

NASA has made a simulation of the air flow that occurred around a rotating quadcopter propeller. From the simulation it can be seen that the air flow that arises from the rotation of the propeller is turbulent and that there is chaotic flow. Differences in pressure and air velocity occur around the propeller. This chaotic flow will increase as the propeller rotation velocity increases.

The propeller creates a kind of turbulence due to its movement. How the turbulence pattern that occurs around the propeller is still a scientific study. Turbulence that occurs is very difficult to predict for their behaviour and patterns.

The best way to guarantee the sensors of our measuring instruments can operate properly is to put them as far away from the propeller as possible. But with the limited size of the quadcopter, long distances can also be an obstacle. Some questions to be answered are like how far the sensor should be placed and where the best sensor must be placed so that it is not disturbed by chaotic flow generated by propeller.

Collecting, analysed and compared data for each other variety scenario will be done for general progress. If the data show the deviation, then we will continuous analysed the data to find a number of deviation constant number. Research will be focused on the search of an answer about how big the deviation of wind velocity data affected by drone propeller wind turbulence.

2. Method

Hot wire type wind velocity sensor commonly used in winds velocity surveyor drones must be positioned at the right location to avoid propeller chaotic flow which can interfere the accuracy of the data.

We can predict that the lower part of the propeller is an area with most turbulence occurs and the air flow is more complex than the topside of the propeller which tends not to occur turbulence.

Through this research the safe position of the sensor when paired with a quadcopter will be sought. This research will place sensors in this study that use air velocity sensors. The wind velocity sensor will be installed in several positions around the quadcopter body which is suspected to have the potential for high chaotic flow interference. wind velocity data will be taken at points of observation that have been determined using a data logger.

A quadcopter drone will be modified to be equipped with a hot wire anemometer. Hot wire anemometer will be positioned in several parts of the drone, namely: 1) The upper centreline of the propeller with variations in distance and propeller RPM, 2) The bottom centreline of the propeller with variations of the distance and propeller RPM. 3) At the edge of the top drone propeller at the top with a variation of the distance and propeller RPM 4) At the edge of the bottom drone propeller at the bottom with a variation of the distance and propeller RPM. We will also vary the sensor placed in the direction of wind flow and perpendicular to the wind flow. The distance vary is 0.15 m for each data collecting node. By observing propeller using tachometer we have data that the idle drone propeller rotation speed is 1154 RPM and 7166 RPM for maximum.

Data collecting will be carried out in an enclosed room that is isolated from air blow from outside. The drone will be positioned steady in the middle of the room so that there is no flow back wind due to colliding with the wall or floor of the room. The drone propeller will be turned on at the idle speed and maximum speed. Data will be recorded for later analysis. Data interval will be set to a second for each data collecting. The nodes high differences set to 10 cm. We make a centre of propeller as a datum which is it will be labelled with 0 cm. Nodes above the datum will be labelled positive and otherwise nodes below the datum will be labelled negative.

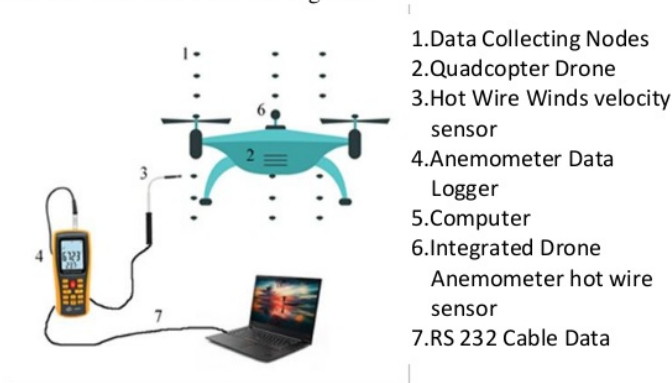


Figure 1. Research Apparatus Setting



Figure 2. Drone with hot wire anemometer data logger

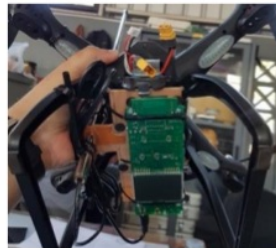


Figure 3. Hot Wire Sensor In Anemometer Data Logger

3. Results

Table 1. Wind velocity create by drone propeller for linier sensor position (direct)

RPM	Position	Times (s)	sensor in the direction of wind flow							
			Under the blade				Above the blade			
			Average velocity (m/s)							
			-10 cm	-20 cm	-30 cm	-40 cm	10 cm	20 cm	30 cm	40 cm
1154	propeller centerline	1 to 40	5,1	4,1	3,1	2,1	0,3	0,2	0,1	0,0
7166	edge of propeller	1 to 40	4,9	3,8	3,0	2,0	0,1	0,0	0,0	0,0
1154	propeller centerline	1 to 40	5,6	4,6	3,6	2,6	0,5	0,4	0,3	0,2
7166	edge of propeller	1 to 40	5,4	4,3	3,5	2,5	0,3	0,2	0,0	0,0

Table 2. Wind velocity create by the drone propeller for perpendicular sensor position (indirect)

RPM	Position	Times (s)	sensor perpendicular of wind flow							
			Under the blade				Above the blade			
			Average velocity (m/s)							
-10 cm	-20 cm	-30 cm	-40 cm	10 cm	20 cm	30 cm	40 cm			
1154	propeller centerline	1 to 40	0,2	0,1	0,0	0,0	0,0	0,0	0,0	0,0
7166	edge of propeller	1 to 40	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1154	propeller centerline	1 to 40	0,3	0,2	0,0	0,0	0,0	0,0	0,0	0,0
7166	edge of propeller	1 to 40	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0

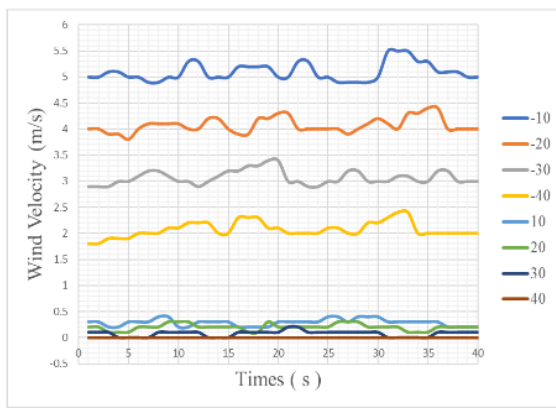


Figure 4. Graph of wind velocity data takes under and above the propeller, straight to propeller **centreline**, with propeller speed rotation holding in **idle** speed.

Hot wire sensor places face **direct** to wind flow.

The graph legends show the distance from the centre of the propeller as a datum.

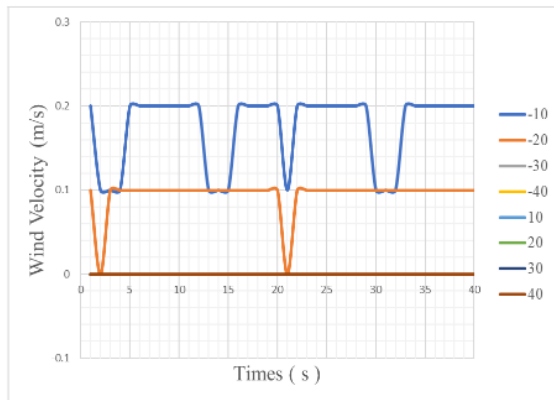


Figure 5. Graph of wind velocity data takes under and above the propeller, straight to propeller **centreline**, with propeller speed rotation holding in **idle** speed.

Hot wire sensor places perpendicular or **indirect** to wind flow.

The graph legends show the distance from the centre of the propeller as a datum.

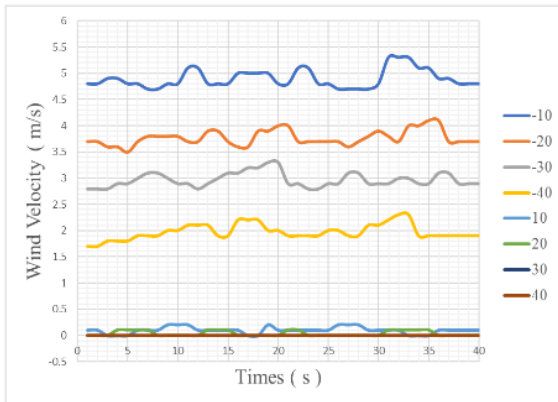


Figure 6. Graph of wind velocity data takes under and above the propeller, straight to propeller **edges**, with propeller speed rotation holding in **idle** speed. Hot wire sensor places face **direct** to wind flow. The graph legends show the distance from the centre of the propeller as a datum.

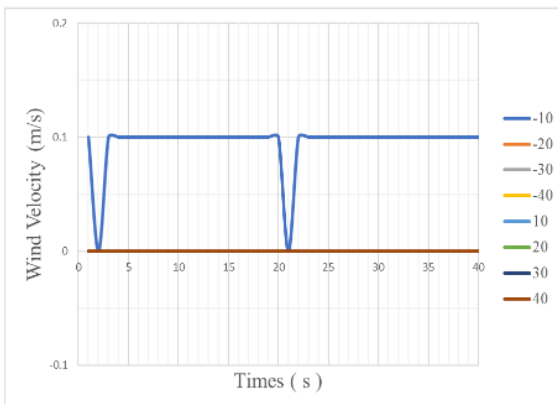


Figure 7. Graph of wind velocity data takes under and above the propeller, straight to propeller **edges**, with propeller speed rotation holding in **idle** speed. Hot wire sensor places perpendicular or **indirect** to wind flow. The graph legends show the distance from the centre of the propeller as a datum.

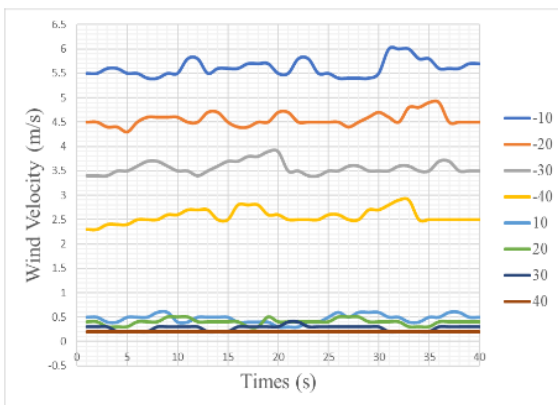


Figure 8. Graph of wind velocity data takes under and above the propeller, straight to propeller **centreline**, with propeller speed rotation holding in **maximum** speed. Hot wire sensor places face **direct** to wind flow. The graph legends show the distance from the centre of the propeller as a datum.

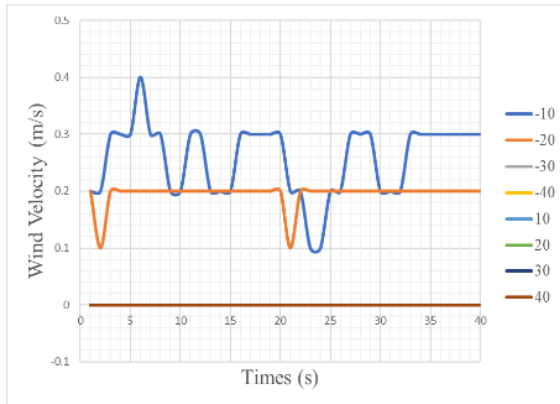


Figure 9. Graph of wind velocity data takes under and above the propeller, straight to propeller **centreline**, with propeller speed rotation holding in **maximum** speed.

Hot wire sensor places perpendicular or **indirect** to wind flow.

The graph legends show the distance from the centre of the propeller as a datum.

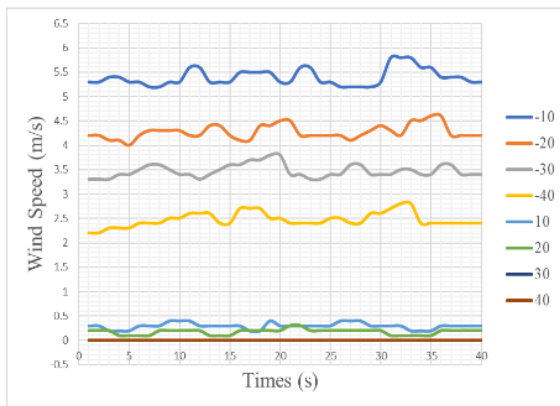


Figure 10. Graph of wind velocity data takes under and above the propeller, straight to propeller **edges**, with propeller speed rotation holding in **maximum** speed.

Hot wire sensor places face **direct** to wind flow.

The graph legends show the distance from the centre of the propeller as a datum.

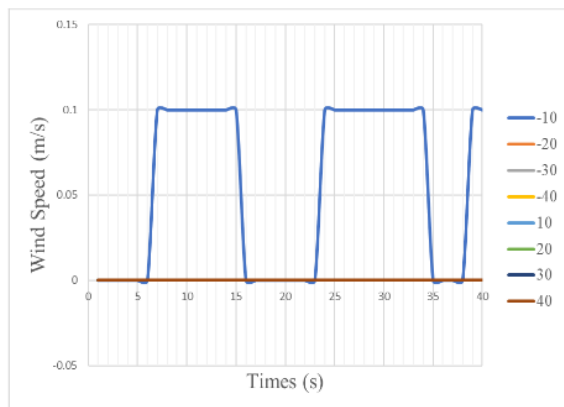


Figure 11. Graph of wind velocity data takes under and above the propeller, straight to propeller **edges**, with propeller speed rotation holding in **maximum** speed.

Hot wire sensor places perpendicular or **indirect** to wind flow.

The graph legends show the distance from the centre of the propeller as a datum.

4. Analysis

From table 1 and table 2, we can see that the wind speed recorded by the data logger is very volatile. Wind speeds tend to be high at the point of observation nodes close to the propeller. The farther the distance of the observation node from the propeller indicates the smaller the

wind is recorded. From this it can be concluded that the distance sensor with propeller greatly affects the accuracy of the data that we will take through the sensor that we will place in the drone. We must place the sensor as far as possible from the propeller to get zero wind interference arising from the propeller.

From table 1 and table 2, it can also be seen that even at idle speed, the sensor has recorded wind speed. propeller.

Disturbance will be recorded even greater if the propeller rotation speed is increased until it reaches its maximum rotation speed. Drone quadcopter in its operations often make efforts to stabilize the position so that it can be idle at the coordinate position specified by the user. This stabilization effort is carried out by increasing the rotation of the propeller on the side of the quadcopter arm of the drone which is in a lower position. The speed control from the mainboard will instruct the propeller motor on the quadcopter arm to increase the rotation speed until the drone returns to a steady position.

The position of the sensor also affects the presence or absence of interference with the sensor. In this research, we try to vary the position of the hotwire sensor so that it is dealing directly with the wind direction and the other is not directly facing the wind direction. We call this position the direct and indirect positions.

In table 1 and table 2 it can be seen that in the direct position, the recorded wind shows greater data when compared to the wind speed data recorded by the sensor when positioned indirectly. It can be concluded that if we want minimal interference from the wind, position the sensor with an indirect position to the propeller wind or in other words the sensor should not be positioned facing up or down, the sensor should be positioned facing the side.

Table 1 and table 2 also show that the placement of the sensor at the bottom of the propeller is able to record a greater wind speed when compared to the wind speed read by the sensor located at the top of the propeller. It can be concluded that a good sensor placement if you do not want to experience interference from the wind propeller is the sensor positioned at the top of the drone.

Table 1 and Table 2 show that sensors placed at the point of observation nodes located in the middle of the propeller read larger wind data when compared to sensors placed on the edge of the propeller. It can be concluded that to put the sensor should be placed close to the edge of the propeller. Placement will be optimal if placed on the middle side at the top of the drone. Because the upper center side of the wind drone recorded shows the smallest value compared to other positions.

To find out what is the minimum distance from the sensor to the propeller drone to be able to read accurate data without any interference from the wind that arises from the rotation of the propeller drone, then we can see the graph presented.

From the graphs in figures 4 and 5 if the sensor is positioned right at the center of the propeller centerline and propeller is turned on with an idle speed of 1154 RPM. For direct sensor position, the safe position to place sensor is above the propeller with minimum distance 40 cm above the propeller. All sensor positioned below the propeller will be disturbed by propeller wind. For indirect sensor position, the safe position to place sensor is

above propeller with minimum distance 10 cm above the propeller. If we placed sensor below the propeller then the safe position is at 30 cm below the propeller.

From the graphs in figures 6 and 7 if the sensor is positioned right at the edges of the propeller and propeller is turned on with an idle speed of 1154 RPM. For direct sensor position, the safe position to place sensor is above the propeller with minimum distance 30 cm above the propeller. All sensor positioned below the propeller will be disturbed by propeller wind. For indirect sensor position, the safe position to place sensor is above propeller with minimum distance 10 cm above the propeller. If we placed sensor below the propeller then the safe position is at 20 cm below the propeller.

From the graphs in figures 8 and 9 if the sensor is positioned right at the center of the propeller centerline and propeller is turned on with a maximum speed of 7166 RPM. For direct sensor position, the safe position to place sensor is above the propeller with minimum distance 40 cm above the propeller. All sensor positioned below the propeller will be disturbed by propeller wind. For indirect sensor position, the safe position to place sensor is above propeller with minimum distance 10 cm above the propeller. If we placed sensor below the propeller then the safe position is at 30 cm below the propeller.

From the graphs in figures 10 and 11 if the sensor is positioned right at the edges of the propeller and propeller is turned on with an idle speed of 1154 RPM. For direct sensor position, the safe position to place sensor is above the propeller with minimum distance 30 cm above the propeller. All sensor positioned below the propeller will be disturbed by propeller wind. For indirect sensor position, the safe position to place sensor is above propeller with minimum distance 10 cm above the propeller. If we placed sensor below the propeller then the safe position is at 20 cm below the propeller.

It can be concluded that the safeties place to places sensor is above the propeller at the edges of the drone propeller or at the center of the drone. But If we place the sensor at the center of the drone it must be attention that at that area there is a meet zone of four propeller. It can have caused a vortex zone and can reduce the accuracy of the sensor.

Turbulence is known to be affected by wind speed and fluid density. If the speed of propeller increased the turbulence is increased also. It known as the linear equation relationship. To see if the air flow go turbulent or not we can predict it from its Reynolds number. We know that the Reynolds number equation given :

$$Re = \frac{\rho \cdot v \cdot L}{\mu} \quad (1)$$

From eddy's equation we know that :

$$\mu = \bar{\mu} \cdot f_{\theta} \quad (2)$$

Increasing Reynold turbulent will make easier flow become turbulent. So by that equation we can predict that to avoid the turbulence we must make a velocity more less or equals to zero, or other hand we make the distance of traveling fluid is more short. In drone case we just only setting the velocity become minimum or less zero to avoid the turbulence occurs.

4. Conclusions

1. The distance sensor with propeller greatly affects the accuracy of the data that we will take through the sensor that we will place in the drone. We must place the sensor as far as possible from the propeller to get zero wind interference arising from the propeller.
2. If we want minimal interference from the wind, position the sensor with an indirect position to the propeller wind or in other words the sensor should not be positioned facing up or down, the sensor should be positioned facing the side.
3. A good sensor placement if you do not want to experience interference from the wind propeller is the sensor positioned at the top of the drone.
4. The sensor should be placed close to the edge of the propeller. Placement will be optimal if placed on the middle side at the top of the drone. Because the upper center side of the wind drone recorded shows the smallest value compared to other positions.
5. The safeties place to places sensor is above the propeller at the edges of the drone propeller or at the center of the drone. But If we places the sensor at the center of the drone it must be attention that at that area there is a meet zone of four propeller. It can have caused a vortex zone and can reduce the accuracy of the sensor.

Appendices

$Re = \text{reynold number}$

$\rho = \text{Fluid density}$

$\vartheta = \text{fluid velocity}$

$L = \text{distance or long of fluid travelling}$

$\bar{\mu} = \text{eddy's fluid viscous} = \frac{D\vartheta}{Dt}$

$f_{\vartheta} = \text{function of fluid speed}$

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