WHAT IT TAKES TO FLY: EXPLORING THE EFFECT OF VARIANT PROPELLER PITCHES AND LENGTHS ON THE EFFICIENCY OF PROPELLER-POWERED HOVER BOARDS

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ABSTRACT

This paper details the modeling of a propeller-powered hover board and provides an investigation into how the pitch and diameter of the propellers impacts the efficiency of the device. Hover boards are a potentially valuable technology, and the most accessible means of producing lift on hover boards is with propellers. It is important to understand how the pitch and diameter of a propeller impact the amount of weight a hover board can lift, but due to the overwhelming range of propellers that exist, it is difficult to choose the most efficient variation. Thus, we determine a propeller's maximum upward force at a given current and the effect of pitch and diameter on its performance to ultimately forward the development of this technology. A testing apparatus was constructed to investigate each propeller and measure both the maximum mass the propeller could lift, as well as the current that was drawn at this maximum point. Our results found that the propellers with a greater pitch were more efficient when their diameter was greater and the propellers with a smaller pitch were more efficient when their diameter was smaller. Through extrapolating using the trend line, it is possible to calculate how many 3.8-pitch or 6-pitch propellers of any diameter would be needed to lift a human being. Through these equations, if the diameter of a 3.8-inch pitch or 6-inch pitch propeller is known, then the maximum lift and the current drawn to achieve said lift can be found. Future investigation into these trends over a greater range of propeller diameters and pitches is recommended in order to gather more conclusive results.

Cet article discute de la modélisation d'un aéroglisseur propulsé par une hélice, et fournit une enquête de l'effet du pas et du diamètre des hélices sur l'efficacité de l'appareil. Les aéroglisseurs sont une technologie potentiellement valable, et la façon la plus accessible à produire de la portance sur les aéroglisseurs est l'utilisation d'hélices. Il est important de comprendre l'impact du pas et du diamètre sur la quantité de poids que l'aéroglisseur peut soulever, mais à cause de la gamme écrasante d'hélices qui existe, il est difficile de choisir la variation la plus efficace. Donc, une expérience fut créée pour déterminer la portance maximale d'une hélice avec un certain courant et l'effet du pas et du diamètre sur sa performance, menant en fin de compte au progrès dans le développement de cette technologie. Un model d'expérimentation a été construit pour évaluer chaque hélice et mesurer le poids maximale qu'il peut supporter, ainsi que le courant maximale à ce point. Nos résultats montrent que les hélices avec un pas plus grand étaient plus efficaces lorsque leur diamètre était plus grand, alors que les hélices avec un pas plus petit étaient plus efficaces lorsque leur diamètre était plus petit. En extrapolant les données en utilisant la ligne de tendance, il est possible de déterminer combien d'hélices d'un pas de 3,8 pouces ou de 6 pouces, de n'importe quel diamètre, seraient requises pour soulever un être humain. Avec ces calculs, si le diamètre d'une hélice d'un pas de 3,8 pouces ou d'une hélice d'un pas de 6 pouces est connu, la portance maximale et le courant requis pour atteindre cette portée peuvent être déterminés. Une investigation future dans ces tendances à travers une gamme plus large de diamètres et de pas d'hélices est recommandée afin de recueillir des résultats plus concluants.

KEY WORDS

Hover board; Propeller; Lift; Pitch

INTRODUCTION

Propeller-Powered Hover boards

A hover board is a small aerial vehicle that can fly, hover and propel itself (Praveen, 2014). Many models have been created using various other methods of levitation, such as the Lexus Hoverboard, which achieves quantum levitation through superconductors and magnetic quantum locking (LEXUS, 2016). Hover

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boards can take off and land vertically from any terrain and can consist of multiple propellers powered by high-speed brushless electric motors, which are often fuelled by lithium polymer batteries (Praveen, 2014). Moreover, the use of different pitches, diameters and quantities of propellers affects the aerodynamic efficiency of the hover board (Garner, 2009).

Propellers and Their Characteristics

A propeller is a mechanical device that uses angled blades rotating around a central hub to move air and produce thrust (Garner, 2009). The diameter of a propeller is equivalent to twice the distance from the center of the propeller hub to the tip of one blade (Garner, 2009). The pitch is a measure of the forward distance travelled in one revolution if it were moving through solid material and there was no slippage (Garner, 2009). Tangibly, pitch is a measure of the curvature of the propeller. For example, a 10-pitch propeller would move forward ten inches in one revolution. The size of a propeller is commonly expressed in the form diameter x pitch. For example, a 7”×3.8 propeller has a 7-inch diameter and 3.8-inch pitch. Changing these characteristics of propellers affects performance (Garner, 2009). The diameter of the propeller contributes to a larger mass to turn, which creates greater thrust or speed for a given pitch (Garner, 2009). Since the pitch of a propeller determines the amount of forward movement the propeller will create with one revolution, lower pitch propellers are ideal for greater thrust and higher pitch propellers are ideal for greater speed (Anderson, 2011). We hypothesized that because a greater pitch increases the speed of the air leaving the propeller, a larger pitch will produce a greater upward force in the experiment and prove to be more efficient through data analysis. Thus, we predict that the 6-pitch propellers will produce a greater upward force than the 3.8 pitch propellers. Furthermore, because the diameter of the propeller increases both speed and thrust, it is hypothesized that the largest propeller diameter to be tested combined with a 6-inch pitch, the 10”x6 propeller, will produce the greatest upward force. It is important to understand that only certain propellers can be used on certain motors because using a propeller that is too large will force the motor to work harder than it was designed to, which leads to overheating and permanent damage (Garner, 2009).

Internal Forces and Lift

The internal forces of an object or a system are generally not considered in basic force calculations because they cause no motion and cancel each other out (Feynman, 1963). When the propeller is hovering, meaning the velocity in the y-axis is zero, the upward force applied by the propeller is approximately equal to the force of gravity (Bruni, 2012). The only external forces acting on the system in the vertical axis are the upward force the propeller is exerting (lift) and the downward force of gravity so that when the propeller is hovering they cancel each other out, which is demonstrated in Figure 1. The force of friction within the motor and the friction caused by the air on the blades of the propeller are acting inside the system, or not entirely in the y-axis, so they are neglected for the purpose of simplifying the experiment. The upward force that is responsible for lifting the propeller and resisting gravity is equal to the product of the total mass the propeller is lifting (includes the weight of the propeller because it is lifting itself) and the downward acceleration of gravity (Bruni, 2012). The upward force (lift) acts opposite in direction but is equal in magnitude to the force of gravity and measurement of this variable was the main focus of the experiment. The maximum upward force measured is the maximum upward force that was achieved at the current measured. This value is not the absolute maximum upward force the propeller can achieve, because if a propeller were attached to a different motor that was powered by a battery that could supply a greater or lesser current to the motor, the upward force would change as well because a different amount of current would be drawn.

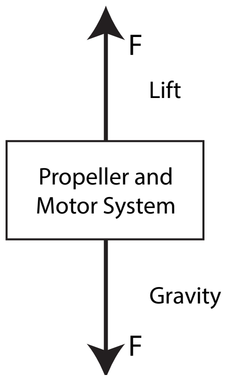

Figure 1: Free Body Diagram of System
Visual representation of the equilibrium between the lift of the propeller and the force of gravity

MATERIALS & METHODS

Materials

A total of eight propellers were involved in this experiment. The same four propeller diameters (7 inches, 8 inches, 9 inches, 10 inches) in two different pitch variations (6 inches, 3.8 inches) were tested in order to see trends in diameter so that the different pitches could be compared. The propeller was attached to a 1360 kV brushless outrunner motor, which is how it was rotated. Also, a 30 A electronic speed controller was placed in series with the motor and an 11.1 V lithium polymer battery (LiPo fuel source).

Constructing the Testing Apparatus

An 18” by 18” square was cut in a piece of wood to act as a base for the testing apparatus, as seen in Figure 2A and Figure 2B. A hole was drilled in each corner and a threaded rod was secured into each hole. The motor was screwed into and attached onto a 1”x1” square piece of wood. Four coat hangers were then flattened into straight wires. The edges of the straight coat hangers were rounded with pliers so that they would fit under the screws on the base of the motor and would wrap widely around each threaded rod. Using zip ties, a fish scale was then attached to both the motor base and to the structure base. The speed controller was connected to the motor and current switch (the dial that turns the propeller on). Then, the speed controller was connected to the battery and the current switch was connected to a separate 12 V battery. An ammeter was also connected in series so that current could be measured. The apparatus is shown in Figure 2.

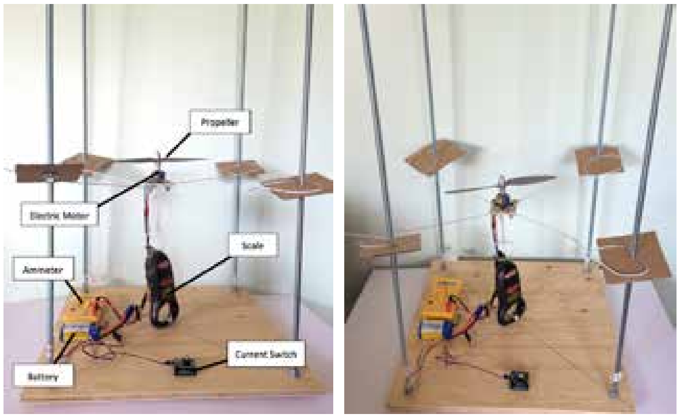

Figure 2: Stationary Testing Apparatus-
A: Labelled front view of testing apparatus
B - Aerial view of testing apparatus

Figure 3: Testing Apparatus in Motion
Visual of testing apparatus as propeller begins to hover

Testing Procedure

A propeller was attached to the motor shaft and the current switch was turn fully to the left so the maximum amount of current was being drawn. The propeller would then hover and the fish scale would display how much it was lifted. The scale reading and the current were recorded once the current switch was fully turned to the left and the propeller was hovering in equilibrium. The maximum mass displayed on the scale was recorded and determined by the maximum mass that was lifted when the maximum upward force was applied. Three trials were conducted for each propeller, and the average of all values was recorded. The weight of the motor, motor base and propeller (weight of materials) were recorded and added to the average scale reading to determine the total weight lifted by the propeller. The total weight lifted by the propeller is the sum of the maximum mass the propeller lifted and the mass of the materials.

Data Recording

The general data collected during the trials was recorded in a table. A “Propeller” column was used to record each propeller tested during the experiment. A “Pitch” and a “Diameter” column were used to represent each propeller’s pitch and diameter, respectively. Next, a “Weight Lifted” column was used to present the sum of the maximum mass the propeller lifted and the mass of the materials (propeller, motor, wooden platform). These values were summed because the propeller’s upward force was lifting both its own mass and a mass equivalent to the fish scale reading. A “Lift” column in presented the values of the maximum measured upward force of each propeller. The upward force for each propeller was calculated by making it equal in magnitude, but opposite in direction, to the force of gravity when it was hovering and had approximately zero velocity in the y-axis. These calculations were recorded in another table and used the values recorded in the “Weight Lifted” column of the first table. Finally, the average current measured in each trial when the maximum weight was lifted was recorded in a column titled “Current” in the first table.

Data Assortment

The upward force, total weight lifted, and the remainder of the data presented in Table 3 were calculated through simple operations and graphed/recorded accordingly. In order to see a comparison in efficiency, the current drawn and the upward force measured for every diameter of each propeller was graphed. The data for both pitches was displayed on the same graph to ensure that results could easily be seen by simply looking at the graphs and comparing the data for each pitch. The trend line equations were not calculated, but were found using the trend line function on Microsoft Excel. The data was interpreted by observing if the trend line was increasing or decreasing and comparing the steepness of the trend lines for each pitch.

RESULTS

General Data

The data collected and calculated during the trials is presented in Table 1 and Table 2. It is observed that the magnitude of the upward force, the current and the weight lifted increase as the propellers of both pitches increase in size

Table 1 - General Data

Propeller	Pitch (inches)	Diameter (inches)	Weight Lifted (kg) (scale reading + weight of materials)	Lift (Newtons)	Current (Amperes)
7” X 3.8	3.8	7	0.43 kg	4.21 N	10.85 A
8” X 3.8	3.8	8	0.55 kg	5.39 N	13.59 A
9” X 3.8	3.8	9	0.74 kg	7.25 N	17.50 A
10” X 3.8	3.8	10	0.86 kg	8.43 N	20.13 A
7” X 6	6	7	0.47 kg	4.61 N	13.44 A
8” X 6	6	8	0.61 kg	5.98 N	15.76 A
9” X 6	6	9	0.79 kg	7.74 N	17.64 A
10” X 6	6	10	0.91 kg	8.92 N	18.64 A

Table 2 - Lift Calculations

Propeller	Lift Calculation
7” x 3.8	Lift = 0.43 kg×9.8 $\frac{m}{s^2}$ = 4.21 N
8” x 3.8	Lift = 0.55 kg×9.8 $\frac{m}{s^2}$ = 5.39 N
9” x 3.8	Lift = 0.74 kg×9.8 $\frac{m}{s^2}$ = 7.25 N
10” x 3.8	Lift = 0.86 kg×9.8 $\frac{m}{s^2}$ = 8.43 N
7” x 6	Lift = 0.47 kg×9.8 $\frac{m}{s^2}$ = 4.61 N
8” x 6	Lift = 0.61 kg×9.8 $\frac{m}{s^2}$ = 5.98 N
9” x 6	Lift = 0.79 kg×9.8 $\frac{m}{s^2}$ = 7.74 N
10” x 6	Lift = 0.91 kg×9.8 $\frac{m}{s^2}$ = 8.92 N

Amperes per Newton Ratios

Table 3 presents the magnitude of current drawn to produce one Newton of upward force for each propeller trial, which was calculated by dividing the current values by the lift values found in Table 1. Also found in Table 3 is the average change in this value as the propeller diameter increases by one inch. Both 3.8-pitch propellers and 6-pitch propellers saw a decrease in this value. The average decrease in this amount as the propeller diameter increases by one inch for the 3.8-pitch propellers was 0.063 A/N. This means that as the propeller diameter increased by a single inch, the amount of current drawn to produce one Newton of lift decreased by 0.63 A. The average decrease in this amount for a one inch increase in propeller diameter for the 6-pitch propellers was 0.277 A.

Table 3 - Calculating the Magnitude of Current Drawn to Produce One Newton of Lift and the Average Change in this Value As The Diameter of The Propellers Increased

Propeller	I/L (Amps per Newton)	Average Change Per Inch
7” X 3.8	2.58 A/N	-0.063 A/N
8” X 3.8	2.52 A/N	
9” X 3.8	2.41 A/N	
10” X 3.8	2.39 A/N	
7” X 6	2.92 A/N	-0.277A/N
8” X 6	2.64 A/N	
9” X 6	2.28 A/N	
10” X 6	2.09 A/N	

Graphs

Figure 4 and Figure 5 present graphical representations of the data found in Table 1. Figure 4 is a comparison of propeller diameter and upward force between the

3.8-pitch propellers and the 6-pitch propellers. Figure 4 shows that for each diameter tested, the upward force of the 6-pitch propeller is greater than the upward force of the 3.8-pitch propeller. The trend line for both pitches in Figure 4 are linear.

Figure 5 is a comparison of propeller diameter and current between the 3.8-pitch propellers and the 6-pitch propeller. The data for each set of pitches is linear, but the slope of the data collected from the 6-pitch propellers is not as large as the slope of the data collected from the 3.8-pitch propellers. The current measured for the 6-pitch propellers is greater than the measured current for the 3.8-pitch propellers when the propeller diameter is 7-9 inches, but when the diameter is 10 inches, the 10”x3.8 propeller drew a greater current than the 10”x6 propeller. Furthermore, the margin by which the 6-pitch propeller current was greater than the 3.8-pitch propeller current decreased as propeller diameter increased from seven to nine inches. Table 4 presents the equation of the linear trend lines for each set of data found in Figure 4 and Figure 5.

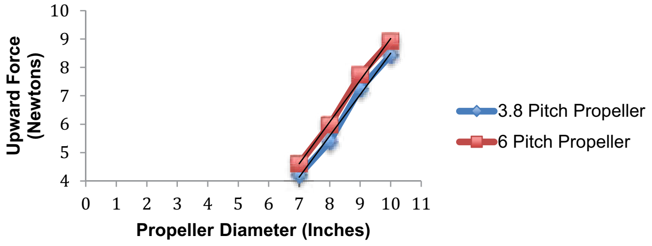

Figure 4: Propeller Diameter vs. Upward Force
Graph Comparison Between Propeller Diameter and Upward Force of 3.8 and 6 Pitch Propellers

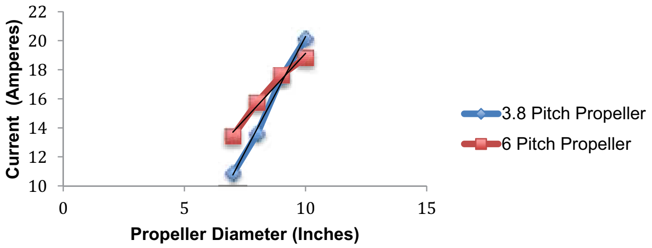

Figure 5: Propeller Diameter vs. Current
Graph Comparison Between Propeller Diameter and Current of 3.8 and 6 Pitch Propellers

Table 4 - Pitch Trendlines from Figure 4 and Figure 5

Propeller Pitch	Graph (Figure)	Equation of Trend line
3.8	Figure 4	Lift = 1.452(Diameter)-6.022
	Figure 5	Current = 3.175(Diameter)-11.47
6	Figure 4	Lift = 1.4686(Diameter)-5.6706
	Figure 5	Current = 2.109(Diameter)-2.659

Table 5 - Sample Calculation Using Equations from Table 4

Using 3.8-Pitch Propellers	Using 6-Pitch Propellers
Current = 3.175(20”)-11.47 = 52.03 A	Current = 2.109(20”)-2.659 =39.52 A
Lift = 1.452(20”)-6.022 = 23.02 N	Lift = 1.4686(20”)-5.6706 = 23.70 N
490 N / 23.02 N = 22 Propellers	490 N / 23.70 N = 21 Propellers
Some motors can draw up to 170 A of current (ex. Turnigy RotoMax 100cc).	Some motors can draw up to 170 A of current (ex. Turnigy RotoMax 100cc).
Theoretically, using this kind of motor:	Theoretically, using this kind of motor:
170 A / 52.03 A = 4	170 A / 39.52 A = 5
Thus, one motor can draw four times the current needed to have one 20”x3.8 propeller lift 23.02 N, so one of these motors will produce four times the upward force at this current.	Thus, one motor can draw five times the current needed to have one 20”x6 propeller lift 23.70 N, so one of these motors will produce five times the upward force at this current.
22 / 4 = 6	21 / 5 = 5
(All values were rounded up)	(All values were rounded up)

DISCUSSION

General Data Interpretation

Since the range of propellers tested was quite small any trends observed might not exist over a broader experimental scope. However, various relationships and trends were observed in the analysis of results. As hypothesized, the 10”x6 propeller produced the maximum lift, which was 8.92 N.

Propeller Diameter Vs Upward Force

When comparing the upward force to the propeller diameter, as seen in Figure 4, it became clear that for the same diameter, a 6-pitch propeller produces a greater lift than a 3.8-pitch propeller. In each trial the propellers with the larger pitch outperformed their smaller pitched counterparts. Thus, the greater the pitch, the greater the upward force. This relationship was expected as the pitch of a propeller determines the amount of forward movement the propeller will create with one revolution, thus a lager-pitched propeller could generate more thrust, and thus, would produce a greater upward force. Therefore, a propeller with a greater pitch would be recommended for a hover board because they can produce a greater upward force and thus be able to lift more.

Propeller Diameter Vs Current

When the propeller diameter and the current drawn were compared, the trend line of the 3.8-pitch propeller had a steeper slope than the 6-pitch propeller. Although a greater current was drawn at the point when maximum lift was achieved for the 6 pitch propellers of diameter 7", 8" and 9", the current drawn by the 10"x3.8 propeller was greater than that drawn by the 10"x6 propeller. Even for the other diameters, the discrepancy between the 6-pitch and the 3.8-pitch decreases as the propeller diameter increases. This would suggest that for propellers with large diameters, a propeller with a larger pitch actually draws less current.

A smaller slope is significant in this dataset as this suggests that as the diameter of the propeller increases, the current drawn does not increase as much compared to a dataset with a larger slope. This is significant because it means the propeller pitch is more efficient and does not draw a large increase of current to power a greater diameter. This also means a battery that can have a given current drawn from it can be compatible with a broader range of 6-pitch propellers than it can be compatible with a smaller range of 4-pitch propellers. The slope of the 6-pitch trend line (2.109) was less than the slope of the 4-pitch trend line (3.175), which means that as diameter gets larger, the 6-pitch propellers are more efficient than the 4-pitch propellers. Ultimately, it would be a more efficient choice to use a larger pitched propeller on a hover board than a smaller pitched one.

The Magnitude of Current Drawn to Produce One Newton of Lift and the Average Change in this Value As The Diameter of The Propellers Increased

The ratio of the current drawn to achieve one Newton of lift was found by the dividing the maximum upward force by the current drawn at the maximum point in each trial. The greater the ratio, the more inefficient the propeller is, and this means that more current is required to achieve a single Newton of lift. As observed, when the propeller diameter increases by one inch for the 3.8-pitch propellers, the average decrease in the ratio was 0.063 A/N. This suggests that as the propeller diameter increased by a single inch, the amount of current drawn to produce one Newton of lift decreased by 0.063 A. The average decrease in current related to a one-inch increase in propeller diameter for the 6-pitch propellers tested was 0.277 A. This demonstrates that the current needed for a propeller to produce one Newton of upward force decreased faster with the 6-pitch propellers. In short, as 6-pitch propellers increase in diameter, less current is required to produce the same upward force as a 3.8-pitch propeller that is producing the same upward force. Ultimately, if one was considering a longer propeller, 6-pitch propellers proved more efficient with regards to how much current they drew compared to their 3.8-pitch counterparts. This is evident because in the 7" trials, the 7"x3.8 propeller drew 2.58 A to produce one Newton of lift and the 7"x6 propeller drew 2.92 A to produce one Newton of lift, so it is clear that the 6-pitch propeller is less efficient. Yet, in the 10" trials, the 10"x3.8 propeller drew 2.39 A to produce one Newton of lift and the 10"x6 propeller drew 2.09 A to produce one Newton of lift, so it is clear that the 3.8-pitch propeller was less efficient. It is important to note that in Figure 4, before the two data lines intersect, the 3.8-pitch propellers are more efficient, but after the intersection, the 6-pitch propellers are more efficient. Ultimately, the data demonstrates that larger pitch propellers are most efficient when the propeller diameter is large and smaller pitch propellers are most efficient when the propeller diameter is small. As the propeller speed is increased, the performance improves, and this result is most evident through increased propeller efficiency (Brandt, 2011). Although speed was not recorded in this experiment, it is known that all data was collected when the propeller was rotating at maximum speed because it was producing its maximum upward force. The data collected shows that the most efficient propellers (the 6-pitch propellers) reached greater speeds and produced greater upward forces and consequently, demonstrated better performance. Thus, the experimental data conforms to the data collected in other experiments.

Errors

This study's design was limited by the range of propellers that were tested and the limited set of variables studied. This was due to the fact that the motor is compatible with a limited range of propellers, and consequently, the range of data was limited. Further studies should explore if these trends would continue to be linear or even remotely similar for different propeller diameters and pitches, or if a different motor was used (different speeds could be achieved). Many other forces that act on the propeller were not considered in the collection and interpretation of data due to limited means to measure them. A rotating propeller is subjected to centrifugal, twisting and bending forces. These forces increase in proportion to the speed of the propeller, and impact the overall performance and efficiency of each propeller differently (FAA, 1976). The various forces act to change the shape of the propeller and would lead to some pitches and diameters being acted upon differently. For example, the aerodynamic twisting force turns the blades to a higher blade angle, whereas the centrifugal twisting force tries to force the blades toward a low blade angle (FAA, 1976). These forces affect the performance of propellers differently at various speeds, so testing a different range of propellers over different speeds could show different patterns in performance. These forces could potentially negate the linearity of the trends observed if a broader range of propellers was studied and different variables were examined, such as propeller speed and the effect of these listed forces.

Secondly, the scale used had a limited measuring capacity and was not sensitive enough to detect the mass the propeller was lifting to more than two decimal places.

Thirdly, many other factors are involved in determining the efficiency of propellers, such as material and the number of blades the propeller has. Only two characteristics (diameter and pitch) were investigated in this experiment, but they are not the only two that affect propeller efficiency, and the equations developed do not account for these characteristics.

Finally, differences in output could have been found if a different motor, battery, speed controller or other various materials were used. If this experiment were replicated with slightly different materials, different results might have been found.

CONCLUSION

Findings

The research collected demonstrates that for any given propeller diameter, a 6-pitch propeller is capable of producing a greater upward force than a 3.8-pitch propeller of the same diameter. Although further research should examine a broader range of propeller pitches and diameters in order to be deemed conclusive, the data suggests that propellers with a greater pitch produce a greater upward force than a propeller of the same diameter with a smaller pitch.

Furthermore, as the propeller diameter increased, the current drawn to produce one Newton of upward force decreased faster in the 6-pitch propellers, meaning that as 6-pitch propellers increase in diameter, less current is required to produce the same upward force as a 3.8-pitch propeller that is producing the same upward force. The data also suggested that larger pitched propellers are most efficient when the propeller diameter is large and smaller pitched propellers are most efficient when the propeller diameter is small because as the 6-pitch propellers increased in diameter, they produced a greater upward force and drew less current than the 3.8-pitch propellers. Moreover, the four trend line equations that were found in the data can be used to extrapolate and estimate the maximum lift and the current drawn to achieve said lift for any diameter of a propeller with a pitch of 3.8 inches or 6 inches.

Applications of Equations

The trend lines of the data collected can be used to calculate the approximate upward force and current for a 3.8-pitch or 6-pitch propeller of any diameter. By entering the diameter value, the equations can allow one to extrapolate along the trend line of each pitch and attain these values. This is quite useful because the quantity of any diameter of 3.8-pitch or 6-pitch propellers that would need to be used and the current that would need to be supplied to lift any mass could be calculated. If someone were planning to build a propeller-powered hover board, these equations allow them to choose the most efficient propeller, and the number of them they would need.

Sample Use of Trend Line Equations from Table 4

To lift a person with a mass of 50 kg, the upward force required to lift them is 490 Newtons. If a 20” propeller were to be used to lift the person, then the number of 20”x3.8 propellers and the number of 20”x6 propellers needed to lift this person can be found using the trend line equations from Table 4 (extra propellers would need to be added to this value to compensate for the weight of materials and the energy lost due to friction). It was found that six 20”x3.8 propellers or five 20”x6 propellers would be needed to lift the 50kg person (calculations presented in Table 5).

Research Application and Future Directions

Further research should be conducted to validate these conclusions and determine if they exist over a wider range of propeller diameters and pitches. Although the premises of and the conclusions drawn in this paper are not novel, the tools and equations provided can be used to estimate what kind of propeller should be used to build a propeller-powered hover board or to lift any mass. Evidently, these equations are quite limited because they only apply to propellers with a pitch of 3.8 inches or 6 inches, so creating an equation that would allow any propeller pitch to be entered would be a valuable next step. In order for an efficient, yet cost-effective hover board model to be created, the tools to explore the subject area must be made available and the aim of this paper was to provide such a tool.

ABBREVIATIONS

Abbreviation	Full Form
LiPo	Lithium Polymer
V	Volt
kV	Kilovolt
A	Ampere
N	Newton
I	Current

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REFERENCES

1. Praveen, J; Prakash, R.V. Hover board, an aerial vehicle for commercial or surveying purposes. *ICCTET* [online] 2014, 14778941. *IEEE Xplore Digital Library*. (accessed June 21, 2016)
2. Lexus:Slide, 2016. http://www.lexus-int.com/amazinginmotion/slide/. (accessed October 15, 2016)
3. Garner, W. B.; Model Airplane Propellers, 2009. http://dc-rc.org/pdf/Model%20Propellers%20Article.pdf. (accessed June 21, 2016).
4. Anderson, J. D.; *Fundamentals of Aerodynamics*, 5; McGraw-Hill: New York, NY, 2011, 500-502, 760-761.
5. Feynman, R. P.; Leighton, R. B.; Sands, M. L. *The Feynman Lectures On Physics*; Addison-Wesley Pub. Co.: MA, 1963; Vol. 1, 9-1,9-2.
6. Bruni, D.; DiGiuseppe, M. Nelson Physics 12: University *Preparation*; Thomson/Nelson: Scarborough, Ont., 2012; 6-93.
7. Brandt, J. B. Propeller performance data at low reynolds numbers. In *49th AIAA aerospace sciences meeting* [online] 2011, 49, 9.
8. Federal Aviation Administration (FAA). Basic Propeller Principles, Propeller Operation. Airframe & Powerplant Mechanics; 1st edition; 1976; pg 325-328.