# Journal of Physics Special Topics


## P3_1 Helicarrier: Highly Feasible or Hollywood Hijinks?


Ashley Clark, Kate Houghton, Jacek Kuzemczak, Henry Simms

*Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH.*



November 21, 2012



**Abstract**

This paper investigates the plausibility of using a fictional helicarrier, as depicted in the 2012 Marvel Avengers film, as a potential way of flying. It was concluded that the propellers could not function at the minimum frequency required to sustain flight, found to be 374RPM or 324RPM whilst functioning with three or four propellers respectively, as modern rotors would not be able to provide adequate propeller frequency for such large blades.


**Introduction**

A helicarrier is a fictional flying aircraft carrier as depicted by Marvel Comics and the 2012 Avengers film [1]. It is an extremely large flying vessel that is a cross between an aircraft carrier and VTOL (Vertical Take-Off and Landing) aircraft, which is supposedly able to sustain flight via four large propellers that allow it to hover. This is an investigation into the feasibility of this design, and also if one propeller failed would the helicarrier still be capable of flight, as portrayed in the film.

**Theory**

The lift force $F_L$ from each blade due to the air being pushed through it is

$$F_L = \frac{1}{2}\rho\langle v^2\rangle A n_b C_L \,, \quad (1)$$

where $\rho$ is the density of air, $<v^2>$ is the mean squared velocity of the aerofoil with respect to the air around it, $C_L$ is the lift coefficient (~2.0 for a flat plate perpendicular to the flow) and $A$ is the area of each propeller blade. Assuming the spaces between each blade are negligible, then the area of each blade is approximately equal to $\pi R^2/n_b$, where $R$ is the length of each rotary blade as depicted by figure 1 and $n_b$ is the number of blades in each rotor. It is assumed that the lift coefficient is constant across the blade area for simplicity.

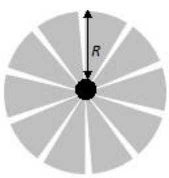


**Figure 1**: Schematic of the model for the helicarrier propellers.

For a more accurate determination of the lift force provided by the propeller blades, a detailed analysis of the shape of each aerofoil and the way it varies with the length along the blade would need to be considered. However the model considered here is sufficient to provide an estimate.

Equation 1 must be multiplied by a factor of $n_p$ to account for number of propellers on the helicarrier (this factor will change from four to three when considering one broken propeller). For the helicarrier to achieve take off, the lift force must overcome the force of gravity, $F_g$, as given by Newton's second law of motion. This inequality is shown by equation 2, where $M$ is the mass of the helicarrier and $g$ is gravitational acceleration.

$$F_L > F_g \,,$$

$$\tfrac{1}{2}\rho\langle v^2\rangle A n_b n_p C_L > Mg \,. \quad (2)$$

As the velocity, $v$, of each blade will vary along its length, the mean squared velocity must be used. Given that velocity is equal to $r\omega$, where $\omega$ is angular frequency and $r$ is the length along the blade, the mean squared velocity is given by;

$$\langle v^2 \rangle = \omega^2 \langle r^2 \rangle = \omega^2 \frac{\int_0^R r^2\,dr}{\int_0^R dr}. \quad (3)$$

$$\therefore\ \langle v^2 \rangle = \frac{\omega^2 R^2}{3}. \quad (4)$$

Rearranging equation 2 in terms of $\langle v^2 \rangle$ and equating it to equation 4, an equation can be found for angular frequency, $\omega$. This allows the frequency, $f$, to be found as $\omega$ is equal to $2\pi f$, given by

$$f = \left(\frac{3Mg}{2\pi^2 \rho_{air} A n_b n_p C_L R^2}\right)^{\frac{1}{2}}. \quad (5)$$

This gives the minimum frequency of the propellers that is required for the helicarrier to overcome the force of gravity acting on it, and as a result achieve take off.

**Results**

Using an image of the helicarrier from the film [2], the number of pixels that correspond to an F-22 aircraft with a length of 19m [3] was found, and the length that one pixel represents was calculated. This scale was used to estimate the length and the width of the helicarrier to be 583m and 134m respectively. The blade diameter was calculated using the same method, and found to be 62m, with each blade of length 30m (accounting for a central axle). It was assumed that each propeller has 10 rotary blades.

The helicarrier was assumed to have the same proportions and density as a Nimitz-Class aircraft carrier (depth 74m, width 77m, length 333m and mass 9.07 x $10^7$kg [4]). Taking a ratio of the helicarrier width to that of the Nimitz-Class and multiplying it by the Nimitz-Class depth, the helicarrier depth is found to be 129m. By comparing the volume of both aircraft carriers it was possible to estimate the mass of the helicarrier, $M$, which was found to be 4.87x$10^8$kg.

Substituting these estimations into equation 5, where the density of air at sea level is 1.225kgm$^{-3}$ [5], gives the frequency of the propellers helicarrier to be 5.40Hz for the four propeller model. Hence each propeller must rotate at around 324RPM when at sea level.

Should a propeller be disabled, if Hawkeye fired an explosive arrow into a propeller engine for example, the frequency of each remaining propeller in a three propeller system would need to be 6.23Hz. This is a frequency of 374RPM for each propeller to keep the helicarrier airborne.

**Conclusion**

For a three or four propeller helicarrier, the 30m blades must function with propeller frequency of 374RPM and 324RPM respectively. It is unlikely that propellers of these proportions could achieve the minimum frequency required for flight, due to the large number of revolutions per minute that are required. For comparison, a helicopter with propeller blades of 54ft (16.5m) rotates, at its maximum engine power, with a frequency of only 258RPM [6]. In conclusion, the Avengers helicarrier is not a feasible method of transport, unless Stark Industries can help!

**References**

[1]*"Avengers Assemble"*, 2012, Joss Whedon (Director), Marvel Studios, USA.
[2]www.wired.com/images_blogs/wiredscience/2012/07/1000px-Helicarrier_rises-6601.jpg accessed on 23/11/2012.
[3]www.af.mil/information/factsheets/factsheet.asp?id=199 accessed on 23/11/2012.
[4]www.wisegeek.com/how-are-aircraft-carriers-made.html accessed on 23/11/2012.
[5]www.engineeringtoolbox.com/standard-atmosphere-d_604.html accessed on 23/11/2012.
[6]www.popularmechanics.com/technology/aviation/news/4224761 accessed on 23/11/2012.