A1 1 The First Butterflight

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Abstract

In this study, the viability of human flight with butterfly wings is discussed. It is determined that when considering an adult man with wings of a painted lady butterfly, the surface area of wings needed must be approximately 84.0 m^2, suggesting a wingspan of 30.4 m.

Introduction

Inspired by fairies and films such as Barbie Mariposa [1], where insect wings are used on human-like creatures to allow for flight, we set out to determine the size of butterfly wings needed for a human to fly and whether these wings are viable for human flight.

Theory

For a butterfly to hover, its lift force must be equivalent to its weight. Where the weight, W, is defined as:

$$W = mg \qquad (1)$$

where m is the mass and g is the acceleration due to gravity, and the lift, L, is defined as:

$$L = \frac{1}{2}\rho v^2 A C_L \qquad (2)$$

where ρ is the density of air, v is the velocity, A is the surface area of the wings, and C_L is the coefficient of lift [2]. To consider the situation where a butterfly is hovering, setting Equation 1 equal to Equation 2 gives:

$$A = \frac{2mg}{\rho v^2 C_L} \qquad (3)$$

The coefficient of lift can be written as:

$$C_L \approx 2\pi(\alpha - \alpha_{L=0}) \qquad (4)$$

where α is the angle of attack and $\alpha_{L=0}$ is the angle of zero lift, the angle in which no net lift is produced by an airfoil, in radians [3]. Considering the system of a human with butterfly wings, the mass can be defined as:

$$m = (m_{human} + \rho_{wing}At) \qquad (5)$$

where m_{human} is the mass of a human, ρ_{wing} is the density of the butterfly wings, and t is the thickness of the wings. Therefore, the surface area can be written as:

$$A = m_{human}\left(\frac{\pi\rho v^2(\alpha - \alpha_{L=0})}{g} - \rho_{wing}t\right)^{-1} \qquad (6)$$

Assuming that the wing of a butterfly is an ellipse, the surface area of both wings can be written as:

$$A = \frac{\pi}{2}wc \qquad (7)$$

where w is the wingspan of the butterfly and c is the root chord length, these aspects of a butterfly are shown in Figure 1.

Results

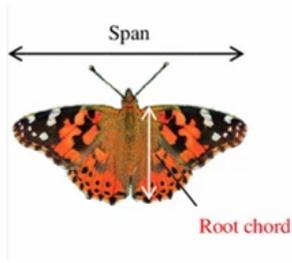To determine the size of butterfly wings that a human would need in order to achieve flight,

Figure 1: Image depicting the wingspan and root chord length of a butterfly [4].

consider the painted lady butterfly (Vanessa cardui), which travels at 15 km/h ($\approx$ 4.17 m/s) [5] with wings made of chitinous membrane [6]. Assuming the angle of attack is 5° ($\approx$ 0.0873 rad) and approximating the butterfly wing to have a similar curvature to that of a NACA 4412 airfoil, a camber of 4% [7], thus the zero angle of attack of the wings can be assumed to be $-4°$ (≈ -0.0698 rad). Therefore, the coefficient of lift for this system is calculated with Equation 4 to be 0.987.

Assuming the mass of a man is 85.1 kg [8], the density of a butterfly wing is 1437 kg/m^3 [9], the thickness of the wing is 80 μm [10], and the values of g and ρ are 9.81 m/s^2 and 1.29 kg/m^3 [11] respectively. Inputting these values into Equation 6 gives a surface area of 84.0 m^2 needed for a person to be able to fly with butterfly wings. Assuming that the height of the man is 1.76 m and that the height of a human being is equivalent to the root chord length of a butterfly, the wingspan of the man found using Equation 7 was 30.4 m.

Discussion

Films that depict the use of butterfly wings in place of fairy wings, such as in Barbie Mariposa have a size of approximately 10 m^2, assuming Barbie's character in the film is approximately 1.6 m and a wingspan of approximately 4 m determined from the movie poster [12]. The surface area of 84.0 m^2 calculated above, is over a factor of 8 larger. This suggests that there is a scaling issue within these movies, and that the wings depicted are of insufficient size to actually carry the characters weight.

A limitation in the calculated wing size is the surface area needed for a human to hover. For a person to actually fly, a larger lift force will need to be utilised, and therefore a larger surface area for the wings will be necessary. However, considering that butterflies clap their wings together in order to remain airborne, this value could also be an overestimate. Therefore, we assume that these two factors negate one another's influence.

Compared to the size of a person, the wing size determined is quite large, with the wings spanning 15.2 m either side of a person, the wingspan would approximately be the length of a large blue whale [13]. Thus, during day-to-day activities, current global infrastructure would be insufficient if humans were to have butterfly wings attached to their backs due to the sheer size of the items.

Conclusion

In this paper, the feasibility of butterfly wings on a human is described. It was determined that the size of painted lady butterfly wings required for a human to fly is approximately a surface area of 84.0 m^2, suggesting that films in which human-like creatures are depicted, the wing size is unrealistic and physically impossible. And if, as humans, we were to have wings of this size, they would likely be 'too large' due to the wingspan being approximately the length of a large blue whale.

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