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A2_2 Spider Silk

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Abstract

We look at the plausibility that a human can swing on a strand of spider silk, and how much silk is required to support a given mass. It is found that it is indeed possible to support a human on a very thin strand of silk.

Introduction

The film series Spider-Man depicts the character as being able to swing between the skyscrapers of Manhattan on nothing but a strand of spider silk [1]. This differs from some other interpretations in that the silk is created organically, and not from mechanical web-shooters [2]. In reality, would it be possible for a person mimic Spider-Man's acrobatic actions using a small amount of spider silk, and if so, what would be the minimum amount of silk required to support a human body?

Investigation

There are many different types of spider silk, each serving different purposes (some for strength, some for adhesiveness). For the purpose of this investigation, we will assume that the tensile strength, *T* of spider silk is 1100 MPa [3]. Assuming that Spider-Man uses a piece of silk ~1cm in diameter, the force, *F* that this piece of silk could withstand is

$$F = TA \\ = 8.64 \times 10^4 \text{ N}, \quad (1)$$

where A is the cross-sectional area of the silk. The force exerted by a person hanging from this silk will be equal to there mass multiplied by the acceleration due to gravity. Assuming the mass, *m* of an average person to be ~75kg, the force their body exerts on the silk would be

$$F_{body} = mg \\ \approx 736 \text{ N}, \quad (2)$$

which is far less than a piece of silk 1cm in diameter can withstand.

Now we know that it is entirely possible for a piece of spider silk 1cm in diameter to support a human body, what is the minimum amount of silk required to support a given mass? To do this we can use the following equation:

$$d = 2\sqrt{\frac{mg}{\pi T}}, \quad (3)$$

where *d* is the diameter of the silk. For a mass of 75kg, less than a millimetre diameter piece of silk is required to support it. Using this equation, a graph was plotted showing the thickness of silk required for a given mass and is shown below in Fig. 1.

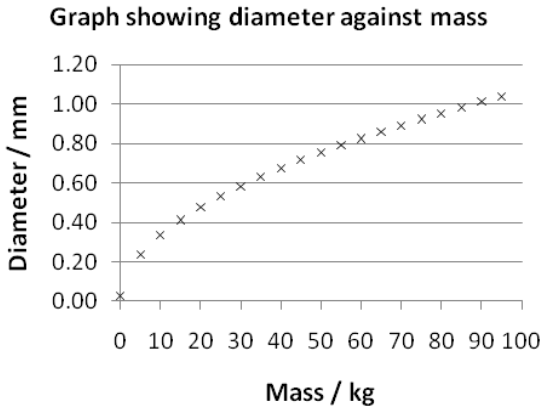

Fig. 1. Graph showing diameter against mass for spider silk

For comparison, the lowest mass represents that of the Goliath bird-eater, the largest known spider, with a mass of 70g [4].

Discussion

It can been seen in Fig. 1 that a piece of silk 1mm in diameter can support a mass of around 90kg, meaning it should be entirely possible for a human to swing between buildings on a strand ~1cm in diameter as Spider-Man does. It could be questioned as to why he uses such a large amount of silk, but this could be answered by at least two points. Firstly, safety can be taken into consideration, as having the silk break while potentially hundreds of metres in the air could be fatal. Secondly, if it is required of him to carry other people or objects, the extra silk would be very useful, as ~1 cm of silk could hold up to 8800kg. However, spider silk can also be stretched, by up to 40% [5]. This could provide a formidable hazard to anyone attempting to swing between buildings. Taking the Empire State Building for example, it stands at a height of 381m [6]. If someone was to swing using a strand of silk attached at the very top of the building, it could not be any longer than 272m, assuming it was stretched to its maximum length. This would have to be taken into consideration before each swing attempt was made.

Conclusion

It is indeed possible for a surprisingly small amount of spider silk to support a human body. This investigation however does not take into account the adhesiveness of the silk, although it could be assumed that Spider-Man uses a combination of the different types of silk that a spider is able to produce for his 'webbing'. If a normal person were to attempt this the silk would have to be securely anchored prior to the stunt. Given that such a small amount is required to support a human body, the applications of a material with a tensile strength greater than that of steel [7] would be tremendous, providing the elasticity could be taken into account. The difficulty here lies in manufacturing the spider silk though, as using spiders themselves to produce silk on an industrial scale would be impractical.

References

[1] Columbia Pictures, Spider-Man, 2002
[2] Lois H. Gresh and Robert Weinberg, *The Science of Superheroes*, John Wiley & Sons, Inc., 2002
[3] http://www.springerlink.com/content/t3rk2161k177866k. Retrieved 01/02/2011
[4] http://www.blueplanetbiomes.org/goliath_bird_eating_spider.htm. Retrieved 01/02/2011
[5] http://www.xs4all.nl/~ednieuw/Spiders/InfoNed/webthread.html. Retrieved 01/02/2011
[6] http://www.reuters.com/article/2010/08/23/us-newyork-empirestate-idUSTRE67M3NV20100823. Retrieved (01/02/2011)
[7] Paul A. Tipler & Gene Mosca, *Physics for Scientists and Engineers*, 6th Edition, W.H. Freeman and Company, 2007