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A4_9 Water-Propelled Jetpacks

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Abstract

Theoretically it would be possible to create a jetpack that used water as a primary propulsion method. This paper looks at the physics behind such a proposition, by deriving a relationship between the mass of the water required m and the time spent airborne t. The masses of water involved are analysed for practicability, and it is found that 99.0 kg of water is required per second of flight, which is concluded to be an unfeasibly large amount.

Introduction

In theory, a hose directed downwards firing enough water fast enough creates a thrust, thus enabling an object to become airborne. An example of this effect was tested in an episode of *Mythbusters* broadcast on Sep 3, 2008, when a car was successfully lifted into the air using fire hoses. The video that inspired the Mythbusters' test can be watched on YouTube [1].

This principle can be applied to a mode of transport not uncommon in books, television and film - the jetpack. Although the jetpack comes in many forms, ranging from the Bell Rocket Belt used by James Bond in *Thunderball* to Mario's FLUDD device in *Super Mario Sunshine*, it is the latter variety of jetpack - that is to say, the water-propelled jetpack - to which this paper devotes its attention.

Thrust

To begin, it is useful to consider the equation relating the rate of change of volume I_v to the cross-sectional area A (in this case of the nozzle) and the velocity of the water u [2],

$$I_v = Au \Rightarrow u = \frac{I_v}{A}, \tag{1}$$

before considering the equation relating the rate of change of mass $\dot{m}$ to thrust $\mathbf{F}$ and velocity $\mathbf{u}$ [3],

$$\mathbf{F} = -|\dot{m}|\,\mathbf{u} \Rightarrow u = \frac{F}{\dot{m}}, \tag{2}$$

which can easily be equated:

$$u = \frac{F}{\dot{m}} = \frac{I_v}{A} \Rightarrow I_v \dot{m} = FA. \tag{3}$$

Assuming an external water source for the jetpack (assuming that the water is pumped to the jetpack and then used to provide thrust rather than the presence of an on-board water tank), the term $\dot{m}$ can be treated simply as m/t, and as such, Eq. (3) can be expanded:

$$I_v = \frac{V}{t} \text{ and } \dot{m} = \frac{m}{t} \Rightarrow \frac{Vm}{t^2} = FA. \tag{4}$$

The mass of the water required to remain airborne is the quantity that it is desirable to calculate, and as such, the volume V is related to the density of water ρ_{w} and a relation between the mass of the water and the time spent airborne is derived:

$$V = \frac{m}{\rho} \Rightarrow \frac{m^2}{\rho_{\mathrm{w}} t^2} = FA. \tag{5}$$

At this point it is also useful to consider the calculation for the thrust F. In this paper, a hovering jetpack will be assumed for simplicity, and therefore,

$$F = Mg, \tag{6}$$

where M is the combined mass of the jetpack and its pilot, and the acceleration due to gravity g. Rearranging Eq. (5) to make it equal to m and substituting in Eq. (6) yields:

$$m = t\sqrt{AMg\rho_{\mathrm{w}}}. \tag{7}$$

Discussion

As can be seen in Eq. (7), the mass m of water required to stay airborne for a time t depends on knowing the area of the jetpack nozzle A, the combined mass of the jetpack and its pilot M, the acceleration due to gravity $g = 9.81$ ms^{-2} and the density of water $\rho_{\mathrm{w}} = 1000$ kg m^{-3}.

In this paper, we will assume values for the area of the nozzle $A = 10^{-2}$ m^{2*} and the combined mass $M = 100$ kg in order to perform the calculation in Eq. (7). These numbers result in a final equation relating the mass m and the time spent hovering t:

$$m = 99.0t. \tag{8}$$

Conclusion

As can clearly be seen from Eq. (8), the mass of water required to hover for 1 s is 99 kg. To hover for an

*For context, the area of the nozzle of a fireman's hose assuming a 1.5" diameter [4] is 4.56×10^{-3} m^2.

hour (3600 s) would require 356,400 kg of water, which is 3564 times the mass of the pilot and jetpack - this would appear to render the concept of a jetpack with its own water on-board immediately impractical, but a full treatment of the rocket equation is required to fully analyse this. This is left as a potential area of further investigation.

However, could such a jetpack be of any use for travel if accompanied by a water reservoir? The Dennis Sabre XL Rescue Pump is one of the fire engines currently in use by fire brigades in the United Kingdom, and has a capacity to carry 1800 L of water with a pump capable of delivering 2250 L/min (37.5 L s^{-1}) [5]. Since 1 L of water is equivalent to 1 kg, it can quickly be seen that not only does the pump not output water fast enough to provide the required thrust, but the available water supply from the fire engine would expire after approximately 18 s of flight. This would appear to render the idea of a tethered water jetpack completely unworkable as a mode of transport.

REFERENCES

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