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P1 4 The Thermodynamics of Undead Motion: Energy Required to Animate a Severed Hand

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Abstract

In this paper, the energy requirements to animate a severed hand (such as *Thing* in Netflix's *Wednesday*) are estimated by considering the mechanical work per step, 0.343J, the chemical energy supplied by ATP hydrolysis, 1.37J, and the inefficiencies inherent in biological motion, with 75% of chemical energy dissipated as heat per step. This study also investigates electrical energy sources, of magnitude $\sim 10^7$ J, that could power a severed hand. A conclusion is made that, while the energy demands per step are modest compared to biological norms, sustaining this motion would require a continuous and reliable energy reservoir.

Introduction

From *Frankenstein's* monster to modern cinema, the reanimation of dead tissue is a recurring theme in pop culture. In the Netflix series *Wednesday*, the character *Thing* - an animated severed human hand - is speculated to have been powered by a large electrical surge in the 1990's [1]. This raises the question: how large must this electrical surge have been to power such motion if the laws of physics are applied?

Animating a severed hand presents two core challenges: generating sufficient mechanical energy required to achieve locomotion, and sustaining such energy in the absence of a complete organism. This paper develops a quantitative framework for evaluating the energy budget of *Thing*, combining mechanical work estimations, metabolic conversion via ATP hydrolysis (which releases chemical energy usable for mechanical work), heat loss and electrical analogies suggested by the narrative.

Theory and Results

The motion of *Thing* is approximated as one step involving a vertical lift, $h = 0.05$ m, and a horizontal translation, $d = 0.1$ m across a surface with a frictional resistance $\mu = 0.2$, and taking one second to complete. The mechanical work required per step is then:

$$W_{\text{step}} = W_{\text{lift}} + W_{\text{friction}} = mgh + \mu mgd, \quad (1)$$

giving a value of 0.343J when we take *Thing* to have mass, $m = 0.5$ kg. This mechanical work is then converted into biochemical demand, assuming a muscular efficiency, $\eta_{\text{muscle}} \sim 25\%$ [2] and using the equation:

$$E_{\text{chemical}} = \frac{W_{\text{step}}}{\eta_{\text{muscle}}}, \quad (2)$$

the biochemical demand, E_{chemical} , is found to be 1.37J per step. Substituting this value into:

$$N_{\text{ATP}} = \frac{E_{\text{chemical}}}{E_{\text{ATP}}}, \quad (3)$$

where the ATP hydrolysis energy, $E_{\text{ATP}} = 5.06 \times 10^{-20} \text{J}$, is calculated using the equation:

$$E_{\text{ATP}} = \frac{G_{\text{ATP}}}{N_{\text{A}}}, \quad (4)$$

taking the Gibbs free energy per ATP hydrolysis as $G_{\text{ATP}} = 30,500 \text{Jmol}^{-1}$ [3], and Avogadro's constant as $N_{\text{A}} = 6.022 \times 10^{23} \text{mol}^{-1}$, we find that the number of ATP molecules required is $N_{\text{ATP}} = 2.71 \times 10^{19}$.

The discrepancy observed between E_{chemical} and W_{step} corresponds to heat loss, $E_{\text{lost}} = 1.03 \text{J}$. This shows that roughly $\sim 75\%$ of the energy input is lost as heat per step, raising the question of whether *Thing* is capable of recycling his own thermal energy. The maximum mechanical work extractable from a thermal reservoir is limited by the Carnot efficiency:

$$\eta_{\text{Carnot}} = 1 - \frac{T_c}{T_h}. \quad (5)$$

For an ambient temperature, $T_c = 295 \text{K}$, and a hand temperature, $T_h = 310 \text{K}$, even when modeling *Thing* as an ideal heat engine, the Carnot efficiency is 4.84%. Hence, the maximum mechanical power extractable from body heat is:

$$P_{\text{max}} = P_{\text{heat}} \times \eta_{\text{Carnot}}, \quad (6)$$

where P_{heat} is the thermal power emitted given by multiplying the approximate heat flux of human skin, $q = 35 \text{mWcm}^{-2}$ [4], by the approximate surface area of a hand, $A = 0.015 \text{m}^2$. Thus giving $P_{\text{max}} = 0.254 \text{W}$. Since we modeled one step to take 1s to complete, and $P = E/t$, we see that the required mechanical power per step is greater than the maximum mechanical power extractable from body heat ($0.343 \text{W} > 0.254 \text{W}$), proving that body heat alone does not provide sufficient energy to animate a severed hand.

This leaves us with the argument that *Thing* was powered by an electrical surge. The electrical energy needed to power one step is given by:

$$E_{\text{electrical}} = \frac{W_{\text{total}}}{\eta_e}. \quad (7)$$

Kinetic energy must now be considered since we require the total instantaneous energy cost of motion, as opposed to the mechanical work required per step being the sustained power output from a thermal engine, *Thing*, where kinetic energy does not accumulate. Hence, the total work, $W_{\text{total}} = 0.346 \text{J}$, is the mechanical work, W_{step} , plus the kinetic energy, $KE = \frac{1}{2}mv^2$, required for *Thing* to move one step. Taking $m = 0.5 \text{kg}$, $v = 0.1 \text{ms}^{-1}$ and the electrical actuator efficiency, $\eta_e \sim 70\%$ [5], we receive an electrical energy, $E_{\text{electrical}} = 0.494 \text{J}$ for one step or 39.1MJ for *Thing*'s current speculated lifetime of 30+ years [1] if he were to take an average of 7000 steps a day.

Discussion

The energy demands of *Thing* are within the physiological range of human musculature, suggesting that a living body could in theory power such motion. However, the obvious absence of circulatory and metabolic infrastructure raises the key problem of energy storage and resupply. While an electrical surge of $\sim 10^7 \text{J}$ is consistent with the narrative of a large explosion having powered *Thing*, sustaining motion for decades would require an implausibly large stored charge - far beyond what could be stored in biological tissue.

Conclusion

Through mechanical, chemical, and electrical energy estimates, this study shows that animating a severed human hand requires a plausible $\sim 0.346 \text{J}$ per step, but maintaining locomotion over decades demands an energy reservoir incompatible with conventional biophysics. While the motion of undead tissue is a fun fictional concept, applying thermodynamic laws and biophysics proves the impossibility of such becoming reality.

References

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