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P2 1 Sonic The Hedgehog: the Physics behind the fastest creature alive

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Abstract

In this report, we examine the drag forces acting upon Sonic the Hedgehog while running at Mach 1 (343 m s^{-1}). By modelling Sonic as an object with a rectangular frontal surface area of 0.5 m^2 , we calculate a drag force of 38 kN and energy consumption rate of 13 MJ s^{-1} . Using these results, and deducing Sonics heat transfer, we evaluate the environmental impacts Sonic may produce, highlighting real-world limitations.

Introduction

SEGA's Sonic the Hedgehog, is known for his supersonic speed. In this report, we investigate the physical effects of Sonic's Mach 1 velocity (343 ms^{-1}), focusing on drag, energy consumption, and environmental impacts. Modeling Sonic as a rectangle, we estimate the required inputs needed to overcome drag.

Theory

First, we calculate the drag force on Sonic at cruising speed, assuming his front face is approximately rectangular.

$$F_d = \frac{1}{2} C_d \rho v^2 A \quad (1)$$

Given Sonic's height of $h = 1 \text{ m}$ [1] and assuming a width of $w \approx 0.5 \text{ m}$, area is calculated, $A \approx 0.5 \text{ m}^2$. The drag force, F_d , is calculated at $v = 343 \text{ ms}^{-1}$, the speed of sound in air at room temperature, with a density $\rho = 1 \text{ kg m}^{-3}$. Drag coefficient, C_d , is a dimensionless value that is a function of Reynolds number, Re , a value which describes the flow of a fluid and can

be deduced from the fluids dynamic viscosity (μ) at which a mass (m) of velocity (v) and height (h) is traveling through. Given length constraints of this paper, Re is not calculated in this specific situation. So, we make an appropriate approximation for drag coefficient in accordance with our model as $C_d \approx 1.28$ [2].

Using Equation 1, we find the drag force on Sonic as $F_d \approx 38 \text{ kN}$. As discussed, this result heavily relies upon drag coefficient, estimated as 1.28, which is not very aerodynamic for a humanoid structure where typical values range from 0.6 - 1.1 [3]. High drag forces acting upon Sonic continuously whilst running would require an enormous energy input rate, power (P).

$$P = F_d \cdot v \quad (2)$$

Substituting in $F_d = 38 \text{ kN}$ and Mach 1 velocity (v), we find $P \approx 13 \text{ MW}$ (or 13 MJ s^{-1}). In order to maintain his velocity, Sonic would need to match this input.

Using the Richter scale, a measure of earthquake severity [4], a minor 1.5 magnitude earthquake is equivalent to 4.5 MJ of energy released [5]. So, from our calculations, for each second of running, Sonic would produce equivalent energy 3× greater than a micro-earthquake. While initially insignificant, prolonged energy release could cause soil liquefaction, damaging structural integrity. Though, the severity of these effects is reliant on surface density.

Discussion and Conclusions

In terms of thermal transfer, when running, humans only use about 25% of the input energy as useful work, the rest is wasted as heat energy [6]. Assuming Sonic’s efficiency is similar and all heat energy is dissipated into the ground, we scale his input energy rate of 13 MJ s⁻¹ by a factor of 4, giving a total input energy of 52 MJ s⁻¹, with 39 MJ s⁻¹ used as heat. Referring to the heat energy equation:

$$\Delta T = \frac{Q}{mc} \quad (3)$$

Where Q is the heat energy (39 MJ s⁻¹), m is the mass of the ground affected, c is the specific heat capacity of the ground, and ΔT is the temperature change. From the product of: speed (v), Sonic’s width (w), and a shallow ground depth ($d = 5 \times 10^{-2}$ m to account for the immediate thermal impact on the surface as well as a deeper layer of thermal diffusion) we can calculate volume, V , to be 8.6 m³ of ground affected per second. Now, assuming that the ground has similar properties to dirt such that $c_p = 800$ J kg⁻¹ K⁻¹ and $\rho_{dirt} = 1220$ kg m⁻³ [7], the mass of the ground affected can be estimated as $m \approx 1 \times 10^4$ kg. However, given the rapid interaction time between Sonic and the ground, heat propagation likely does not penetrate deeply, meaning the actual affected layer may be thinner. Using these values, we find a temperature change of $\Delta T = 4.9$ K every second Sonic is in motion. While this result

seems low given the immense energy transfer, it reflects the large volume over which energy is dissipated and the short time available for heat to accumulate uniformly. For context, this temperature rate is comparable to the warming effect of sunlight but over a much shorter duration. In actuality, Sonic’s drag coefficient would probably be lower than that calculated due to his streamlined running posture, this would lower drag forces and overall make this temperature increase even smaller.

Additionally, an input energy rate of 52 MJ s⁻¹, Sonic would need to consume over 12,000 kcal per second of travel. So, although a real-world Sonic the Hedgehog may not cause immense physical damage, he would almost certainly cause a food shortage.

References

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