P6_8 Killer Rabbits: In Transit

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Abstract

We look into the practicalities of transporting an army of 100 million Killer Rabbits from the film "Monty Python and the Holy Grail" across an ocean. We consider mass and buoyancy of the cargo, along with the drag exerted on the submerged fraction. We find that the power required to move the army at a constant velocity of 9 ms^{-1} is 3.11×10^9 W.

Introduction

In the production "Monty Python and the Holy Grail" we are introduced to the Killer Rabbit of Caerbannog. In this article we look into the practicality of transporting an army of such rabbits over an ocean. For the purposes of this, we assume an army size of 100 million rabbits would be required to wipe out a fictional nation of the same number of residents. We will calculate the power required to move the army of rabbits across an ocean. To do this, we first consider the total mass of the cargo if the rabbits are transported in their cages in standard 40' shipping containers. Then we consider buoyancy of the cargo and finally the drag force that must be overcome to move at a constant velocity through the Ocean. It should be noted that the rabbits ability to breath in the sealed container has not been considered in this article.

Theory

Cargo Mass - The total mass of the cargo (m_T) is the sum of the required number of shipping containers (N_c), rabbits (N_R) and hutches (N_h), multiplied by their respective masses - m_c, m_R & m_h. The number of containers can be cal-

	Container Internal [1]	Container External [1]	Hutch [2]
Length (m)	12.0	12.19	1.40
Width (m)	2.33	2.44	0.71
Height (m)	2.35	2.59	0.51
Mass (kg)	-	3950	11.2

Table 1: Storage dimensions

culated using Eq. (1), where L, W and H are the length, width and height of the container and the hutch, differentiated by the subscript c and h respectively. The hutches can house 2 rabbits and so the number of hutches required is $\frac{N_R}{2}$.

$$N_c = \left\lceil \frac{N_R}{2 \lfloor \frac{L_c}{L_h} \rfloor \lfloor \frac{W_c}{W_h} \rfloor \lfloor \frac{H_c}{H_h} \rfloor} \right\rceil \qquad (1)$$

Using the internal dimensions of the shipping container given in table (1), we find that we would require 520834 shipping containers.

$$m_T = N_R \left(m_R + \frac{m_h}{2} \right) + N_c m_c \qquad (2)$$

Using the value found for N_c in Eq. (2) and the mass of a small rabbit [3] of 1.5 kg, the total mass

of the cargo is approximately 2.77×10^9 kg.

Buoyancy - The shipping containers have a total volume (V) of N_c times the external length, width and height of a shipping container. From the values in table (1), we get an approximate volume of 40.1×10^6 m^3. Dividing the total cargo mass by this, we find the effective cargo density ρ_{eff} to be 69.1 kg m^{-1}. Using Archimedes principle and the dimensions shown in figure (1), we can derive an equation for y, the depth the cargo is submerged:

$$F_g = F_B \tag{3}$$
$$gHA\rho_{eff} = gyA\rho_l \tag{4}$$
$$y = H\frac{\rho_{eff}}{\rho_l} \tag{5}$$

We will approximate the cargo as a cuboid with length, L, twice the width, W. The height is therefore $\frac{1}{2}V^{1/3}$, where V is the volume. This gives us a height, H of 171 m. If the density of the sea, ρ_l, is 1030 kg m^{-3} [4], we calculate the submerged height of the cargo, y, to be 11.5 m.

Power - We can now calculate the power required to move the cargo through the water. For simplicity, we will only consider the drag forces as a consequence of the submerged part of the cargo. If the cross sectional area of the submerged cargo perpendicular to the direction of motion is ($yV^{\frac{1}{3}}$), then the drag D is calculated:

$$D = \frac{1}{2}C_D\rho_l v^2 yV^{\frac{1}{3}} \tag{6}$$

Where the drag coefficient, C_D, in our case is 2.1 [5]. We will use a velocity, v, of 9.0 ms^{-1} - comparable to that of the one of today's largest container transportation vessels [6]. Using these values, we find that the drag force which must be balanced by forward thrust in order to maintain a constant velocity is 350×10^6 N. We multiply the thrust required by the velocity, to yield a power of 3.1×10^9 W.

Conclusion

We conclude that the power required to move the army of rabbits in water in this configuration is colossal. If we consider all drag forces on the cargo, the power required would increase.
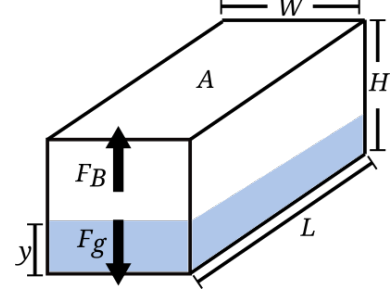

Figure 1: Dimensions of cargo

We suggest further investigation in order to optimise the cargo and thereby decrease the required power. This could include using a shape with a better coefficient of drag, or to use a method of transportation alternate to storage containers that would amount to less cargo mass.

References

[1] https://www.shippingcontainersuk.com/info/shipping_and_storage_container_dimension_charts.php [Accessed 15 October 2018]

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