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A4_3 One, Two, Tree. Timber!

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Abstract

In the popular game Animal Crossing: New Horizons, the character is able to chop down any tree with just three hits. In this paper, we focus on the coconut palm tree, and calculate the force required to do this. We use the flexural strength relation, and found that each hit would have to equate to approximately $86,521N$ in order to chop down the tree. In order to achieve such a force, the impact velocity of the axe on the tree trunk would have to be around $240m/s$.

Introduction

Animal Crossing: New Horizons is a popular video game in which players can explore their island and interact with villagers. In the game, you play as a human character and can participate in many activities, such as fishing, catching bugs and hunting fossils. One possible activity is cutting down trees, and the character is able to chop down any tree with just three hits.

In this paper we will focus on coconut palm trees, investigating the amount of force required for such a feat. We will also look at the velocity required to generate such a force, and evaluate whether this might be possible in reality.

Theory

To calculate the amount of force required to chop down a tree, the flexural strength relation is used. This is shown by the equation [1]:

$$M_r = \frac{3FL}{2bd^2}, \tag{1}$$

Where M_r is the modulus of rupture, F is the force the tree is struck with, L is the height of the tree, b is the width of the tree and d depth of the tree. We must assume a square cross section to be able to use this calculation. This is justified by the simplistic nature of this paper. Therefore b is equal to d.

We can rearrange (1) to find the force, F, required to chop down the tree.

$$F = \frac{2M_r d^3}{3L} \tag{2}$$

This can then be divided by three, under the assumption that each hit by the character is equally forceful and that the tree has a constant density throughout.

If we assume that the axe stops just as it has cut through the entire diameter of the tree, and has a constant deceleration throughout, we can calculate the impact velocity required using of Newton's Second Law, $F = ma$, and the kinematic equation of motion:

$$u^2 = v^2 - 2ad, \tag{3}$$

Where u is the velocity on impact, v is the final velocity (equalling 0 due to our assumption), a is the deceleration of the axe through the wood and d is the width of the trunk.

Results

The Modulus of Rupture of a coconut palm tree is taken to be $120MPa$ [2]. The average height of the tree, L, is taken to be $30m$ and the depth of the trunk, d, as $0.46m$ [3]. These values can then be substituted into Eq.(2), giving the amount of force required to chop down the tree as $259,563N$. Over the three hits, this translates to a value of approximately $86,521N$ per hit.

Using an axe of mass $1.4kg$ [4], the deceleration of the axe in the wood is calculated using Newton's Second Law, and is found to be $61,800m/s^2$. Substituting our values into Eq.(3), the impact velocity required is found to be approximately $240m/s$ for each hit.

Discussion and Conclusion

Our calculations assume that the top of the tree remains motionless throughout this process – that is to say that it does not sway once hit. This has been done because it would incur additional forces, such as gravity, that may help with the toppling of the tree. Furthermore, this assumption means that all the force of the axe is directly applied into the cutting down of the tree. Whilst this may not be entirely realistic, it is a good approximation. Quantifying the effects that come from not using this assumption is outside the scope of this paper.

This calculation also assumes that the character is hitting the tree at the midpoint of its height every time. However, when looking at the Animal Crossing gameplay it is clear to see that the character is incredibly tall when compared to structures and trees within the game. Therefore this assumption is reasonable.

The Boeing 737-800 planes flown by many commercial airlines have a cruise speed of around $850km/h$ [5]. This is approximately equal to $236m/s$, showing us that the impact velocity required by the character in Animal Crossing: New Horizons is similar to that of an airplane. For a human, moving an arm quickly enough for the axe to reach such a speed would likely lead to many negative health effects, such as ripped tendons and muscles. Therefore we can conclude that the character is based off a better adapted being.

References

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[5] `https://corporate.ryanair.com/ryanair-fleet/` [Accessed 14 November 2021]