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P3_12 More Star Wars? We are all Doonium-ed!

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Abstract
In our previous paper, we discussed which of our chosen materials was most similar to Doonium [1]. Here, we build upon this paper, using the suggested improvements to establish a more accurate picture. Using the iconic scene from The Phantom Menace, where Qui-Gon Jinn cuts through the door with his green lightsaber in 14s [2], we find that aluminium most closely resembles Doonium, taking 13.8s to cut through the door, compared to 29.8s for titanium and 39.6s for carbon steel.

Introduction

In our previous paper, we explored the scene with the Grand Inquisitor cutting through a door made of Doonium, a material used for building blast-resistant doors on starships. Here, we build upon this paper and explore the scene from The Phantom Menace , where Qui-Gon Jinn uses his green lightsaber to cut a semi-circular arc through the door [2], with the same blast-resistant materials explored in our previous paper. We will also account for the time taken to heat the material before it melts but not the final temperature, which will be negligible compared to the latent heat of fusion and the energy needed to melt the material.

Method and Results

Firstly, we will consider the energy needed to heat the material from room temperature to its melting point. As such, we will need to identify the temperature change for each material. Here, we will take room temperature as 20°C and the melting points as 660°C, 1670°C, and 1482°C for aluminium, titanium, and carbon steel [3]. This means the temperature changes, ΔT, for each material are 640°C, 1650°C, and 1462°C. To find the energy required, we first need to find the mass, m, of each material melted, and we can do this by using the following equation:

$$m = \rho V, \tag{1}$$

where ρ is the density and V is the volume. In the scene, we observe Qui-Gon Jinn cut a semi-circle through the door. The width of the lightsaber is 0.04m [**?**], and we compare the size of this cut to the height of the actor, who is around 1.9m tall [4]. He begins to cut around shoulder height and finishes this cut around 0.2m from the ground. As such, we estimate the diameter of this semi-circle as 1.5m, with an outer radius of R = 0.75m and an inner radius of r = 0.71m. We also estimate the depth, d, of the door to be 0.4m, in line with our previous paper [1].

Using the following equation, we find that the melted material's volume is 0.037m^3.

$$V = \pi d(\frac{R^2}{2} - \frac{r^2}{2}), \tag{2}$$

And finally, using the densities for aluminium

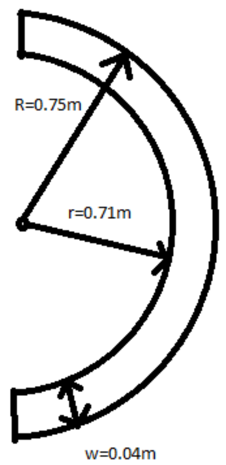

Figure 1: This diagram visualises the cut made by Qui-Gon Jinn.

(2710 kgm^{-3}), titanium (4506 kgm^{-3}), and carbon steel (7840 kgm^{-3}) [1], we find that the total mass melted for each material are 99.4kg, 165.3kg, and 287.7kg respectively.

We can find the time needed to melt through each material using the equation below.

$$t = \frac{E}{P} = \frac{mc\Delta T + mL_f}{P}, \tag{3}$$

Where P is the power of the lightsaber (6.96 MW), c is the specific heat capacity of each material (890 $Jkg^{-1}°C^{-1}$ for aluminium, 523 $Jkg^{-1}°C^{-1}$ for titanium, and 466 $Jkg^{-1}°C^{-1}$ for carbon steel [5]), and L_f is the latent heat of fusion for each material (3.96 $\times 10^5$ Jkg^{-1} for aluminium, 3.90 $\times 10^5$ Jkg^{-1} for titanium, and 2.76 $\times 10^5$ Jkg^{-1} for carbon steel [1]).

Substituting the relevant values for each material, we obtain 13.8s, 29.8s, and 39.6s for aluminium, titanium, and carbon steel.

Discussion and Conclusion

We find that aluminium is most similar to Doonium and not titanium, as concluded in previously. However, the aluminium estimate is more in line with the 14s we observe in this new scene. This could be due to taking the initial melting of the material into account, where aluminium needs less energy to heat the same volume due to a lower melting point and density.

Another paper, written by Luke Willcocks [?], uses a similar method to find the power of Qui-Gon Jinn's lightsaber, where they estimate the radius of the semi-circle as 0.5m and the depth as 0.15m. However, we believe this to be an underestimate. Additionally, they estimate the time taken to be 11s, but we found it to be 14s. Rearranging Eq. 3 for the power, and using values for aluminium, we find that the revised power is 6.86 MW, not too dissimilar to the 6.96 MW we quoted and used in our calculations, with just a 1.44% error in this value. This suggests that the energy needed to reach the melting point contributes more to the disparity in our results, rather than the inaccuracies in the power used.

In conclusion, we summarise that aluminium is most similar to Doonium, over titanium or carbon steel. We also find that potential inaccuracies in the power quoted are unlikely the cause of this disparity and that accounting for the energy needed to reach the material's melting point is more significant. Potential improvements to this paper would analyse multiple scenes and calculate the energy to reach a final temperature.

References

[1] Brewer, L., et. al (2022) "P3 8 Which Earth material is most similar to Doonium?", Journal of Physics Special Topics. [Accessed 5 December 2022]

[2] `https://www.youtube.com/watch?v=3RCYsON5Wsc` [Accessed 5 December 2022]

[3] `https://www.onlinemetals.com/en/melting-points` [Accessed 5 December 2022]

[4] `https://starwars.fandom.com/wiki/Qui-Gon_Jinn` [Accessed 5 December 2022]

[5] `https://gchem.cm.utexas.edu/data/section2.php?target=heat-capacities.php` [Accessed 5 December 2022]