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A2_3 A Nice Flight... TO HELL!!!

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Abstract

In this paper we look into the effects of drag on paper aeroplanes, specifically how much it heats it up. This could potentially be an issue if you make an aircraft out of a flammable material such as paper. By using a purely theoretical approach, we found that to set a paper aeroplane on fire just from the effect of drag it would have to be thrown at a velocity of $5725ms^{-1}$.

Introduction

A paper dart is often taught as the standard paper aeroplane. This is because it is simple to make and has favorable aerodynamic properties that allow for fast flight. One thing that a paper plane has to deal with is drag. An effect of drag is to heat up a moving object and, since paper has a relatively low auto ignition temperature (the temperature that an object must reach for it to set alight), we decided to find out if it would be possible to set fire to a paper aeroplane by drag alone. We decided to use a simplistic model of the paper aeroplane to discover whether or not an experimental test of this would be feasible.

Theory

Firstly we had to find out how much work had to be done on the paper plane in order for it to reach its auto ignition temperature of $233°C$[1]. To do this we used the specific heat capacity equation,

$$Q = mc\Delta t \tag{1}$$

where Q is the work, C is the specific heat capacity, m is the mass and Δt is the change in temperature. The mass of paper is often expressed in grammage which is the density of the paper. Since standard office paper has a grammage of 80g/m we could calculate that a single sheet of A4 paper has a mass of $0.005kg$ [2]. We found Δt by taking standard lab temperature ($20°C$) from the previously mentioned auto ignition temperature. Also we used a value of $1400Jkg^{-1}K^{-1}$[3] for the specific heat capacity. From these values we determined that the work required to ignite the paper was 1491J.

By assuming that the plane would ignite within a distance of $1m$, we used the work equation

$$W = Fs \tag{2}$$

where W is the work done, F is the force and s is the distance traveled, we could say the force applied to the plane is equal to the work done giving us a value of $1491N$.

Next we assumed that all the frictional force done to the paper dart would only be converted into thermal energy and that it was a rigid body. Doing this allowed us to use the drag equation to determine the velocity the plane would have to be traveling at.

$$F_D = C_D \frac{\rho v^2}{2} A \quad (3)$$

In the equation F_D is the drag force, C_D is the drag coefficient, ρ is the air density, v is the velocity of the object and A is the reference area. Reference area is the area of an object that is facing the direction of travel. We next measured the reference area of a paper dart by hand using a ruler, making the assumption that the wings are too thin to provide significant drag and found that it has a value of $0.00247m^2$.

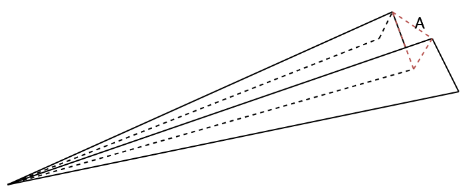

Figure 1: This is a diagram of a paper dart with the approximate reference area, A, marked on it in red.

By using a value of 0.03 for C_D [4], $1.225kgm^{-3}$ for the air density, the measured value for A and the previously calculated value for F_D we rearranged the drag formula and calculated the velocity of the plane.

$$v = (\frac{2F_D}{\rho A C_D})^{\frac{1}{2}} \quad (4)$$

Results and Discussion

Our final value was a velocity $5725ms^{-1}$, over 10 times the speed of sound. This is unsurprisingly impractical as no human would be able to do this by hand. Another problem with attempting to recreate this practically is that we assumed that the paper plane can be modeled as a rigid body and that all the work done by drag gets expressed as heat. In reality this is not the case and if you were to launch a paper plane with such a high velocity it would crumple and slow down rapidly meaning that a higher velocity would be required to reach the auto ignition temperature. An experiment would not be feasible as even in our best case scenario the speed required would be far too high.

Conclusion

The speed needed to ignite the paper was extremely high, at $5725ms^{-1}$. This, and other issues with paper aeroplanes, makes an experiment to verify this impossible. However, since the fastest passenger plane has a top speed of $675ms^{-1}$, you could make this plane (Tupolev TU 144) out of paper if you made it very small, and it still wouldn't ignite.

References

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