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Abstract

In "*The Adventures of Tintin*" a float plane is used to fly across the desert, however, it runs low on fuel. In this paper, we use a similar model plane (Piper PA-18) to determine the plane's overall energy efficiency given that it was refueled using a belch. We found the efficiency of the plane engine to be 28.1 % with only 0.280 kg of ethanol vapour being the fuel, which produced an energy of 2.30×10^6 J to keep the plane flying for a short period of time.

Introduction

"*The Adventures of Tintin*" follows Tintin and Captain Haddock in search of treasure from a ship called the "*Unicorn*", during which, they commandeer a float plane (with two passengers) and are flying through the desert, when it runs low on fuel. Tintin asks Haddock to use the bottle of alcohol to refuel the engine. As he had already drank it, he instead belches into the engine to fuel it and maintain flight.

Theory

To determine the usefulness of fuel, which in this case is ethanol vapour, we calculate the energy released from combustion with

$$C_5H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + \Delta H \quad (1)$$

where this equation represents the complete combustion process of ethanol (all components are in the vapour state), and ΔH is the heat energy (enthalpy) released, which is 29017 kJ/kg[1].

Assuming all the energy produced from the belch goes through complete combustion and is converted into the kinetic energy of the plane engine and propeller:

$$E_k = \frac{1}{2} m_0 v^2 \quad (2)$$

where E_k is the kinetic energy, m_0 is the initial mass of the Piper PA-18 plane (794 kg[2]), the four people (each with mass 80.5 kg[3]) and fuel, and v is the velocity of the plane.

From this, multiplying the velocity with the flight time period, t (1 minute[4] movie time), we can determine the distance travelled. The power of the fuel being consumed is defined as:

$$\dot{W}_f = \dot{M}_f HHV \quad \text{and} \quad \dot{M}_f = \frac{\Delta H m_f}{t \times HHV} \quad (3)$$

where $\dot{W}_f$ is the power, m_f is the mass of the fuel, $\dot{M}_f$ is the mass rate of flow of fuel and HHV is the high heat value of the fuel, which for ethanol is 29.7 MJ/kg[5], which determines the whether the plane will be able to produce enough thrust to continue flying or not.

For simplicity purposes, we modelled the plane's exhaust velocity as a rocket, which is as follows:

$$v = v_{ex} ln \frac{m_0}{m_r} \quad (4)$$

where v_{ex} is the exhaust velocity and m_r is the mass of the plane and people, hence the thrust, T, of the the plane can be determined from:

$$T = v_{ex}\dot{M} \qquad \text{where} \qquad \dot{M} = \frac{\dot{M}_f}{p} \tag{5}$$

where $\dot{M}$ is the mass flow rate of air and p is the fuel-air compression ratio given as 7:1[2]. This, along with Equation (3) can be used to calculate the overall thermal efficiency of the plane as:

$$\eta_{\theta-t} = \frac{\dot{W}_t}{\dot{W}_f} \qquad \text{where} \qquad \dot{W}_t = Tv \tag{6}$$

where $\dot{W}_t$ is the thrust power. This value can be used to determine the actual amount of energy produced from the fuel.

Results

Haddock's favourite drink is *Loch Lomond* whiskey, and here we use that he drank a 700 ml bottle[6] of the whiskey. The alcohol content is 40 %[7] giving the fuel mass as 0.280 kg, and as he belched into the engine, we assumed that ethanol vapour provided the energy.

The energy released from combustion is calculated as 8.12×10^6 J (determined from multiplying the mass with enthalpy). Using the initial mass (m_0) of 1116.28 kg and Equation (2), the velocity of the plane was determined as 121 m/s, leading to a distance of 7.26 km travelled.

We calculated the exhaust velocity from Equation (4) as 482×10^3 m/s. We then use Equation (3) to calculate the mass rate of fuel flow as 4.56×10^{-3} kg/s. Therefore, with the compression ratio we calculated the thrust of the plane, from Equation (5), to be 314 N.

Finally, using Equation (6), the overall efficiency of the engine is 28.1 %. Including this efficiency value in the energy produced by combustion, the actual energy from combustion is 2.30×10^6 J, showing that the engine is somewhat efficient.

Conclusion

Although an interesting means of refuelling a plane mid-flight, it does not seem nearly as effective as using the correct plane fuel. Our calculations show that the overall efficiency of the plane is relatively low, which is expected given only a small amount of ethanol was used, in comparison to the amount of fuel a plane would usually take.

References

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