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P1_7 Row, Let's Row Away

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Abstract

This paper investigates the energy difference between flying to a destination, compared to rowing to it i.e. the energy burned per passenger on an airplane, compared to a person rowing across the sea to the destination. The destinations we consider are from London Heathrow to New York JFK airport, and we found that for a Boeing 747 and an Airbus A380, the energy used is 6069.1 MJ and 5677.8 MJ respectively. The amount of energy to row the distance in a single lightweight scull was found to be 128.67 MJ; in comparison to the Airbus the rower uses approximately 98% less energy.

Introduction

For years, members of the public have attempted to cross the English Channel by rowing boat. We investigate using a rowing boat to instead cross the Atlantic Ocean to America, in particular the popular tourist destination New York, to determine the difference in energy used.

Discussion

Rowing to any location, including the specific case of America, presents a couple of real world issues. To obtain estimates for the energy differences to see the potential saving we shall overlook these in this investigation. Firstly, the airports are on land. Thus, the distance rowed is shorter from the actual coast where rowing could begin. The distance that would be travelled over land is negligible compared to the distance travelled over the ocean. Therefore, this change in distance will produce a negligible change to the end results, bearing in mind the other assumptions made and the total distance travelled. The other major factor is the sea and its volatile nature. Even small vessels are discouraged from attempting to cross the Atlantic Ocean. For the paper we will use the approximation that the Atlantic Ocean offers no more wave amplitude than seen in an Olympic rowing venue, allowing for constant moderate rowing.

The energy used per passenger to transport them in the two aircraft are calculated and this is then compared to the energy burnt by a non-stop rower. This has then been used to determine the percentage of energy that could be saved for a person per km by rowing rather than flying.

By Flight

The two aircraft being used are the Boeing 747-400 and the more modern aircraft the Airbus A380-800. As both are commonly used aircraft both have been included in the investigation. The energy in a fuel can be determined by

$$E = UV, \qquad (1)$$

where E is the energy, U is the energy density and V is the volume, which in the case of an aircraft's fuel is in litres. The energy density of the fuel used, Jet A fuel, is 35.3 MJ L^{-1} [1]. The Boeing 747-400 and the Airbus A380-800 have a fuel efficiency of 3.1 L per passenger over $100\text{x}10^3$m [2] and 2.9 L per passenger over $100\text{x}10^3$m respectively [3]. Using the specific case of London Heathrow to New York's JFK Airport the distance travelled by an aircraft is approximately $5546.3\text{x}10^3$m [4]. From the above data we can calculate the total fuel burnt per passenger, for each aircraft, for the entire flight.

By Boat

In this model, we do not consider the effects of the drag on the person in the air, currents and waves in the ocean, energy lost due to heat generation, and feasibility of such a feat. Firstly, consider a single light-weight scull 8m long and roughly 265x10^{-3} m wide [5], the drag surface area we model will be half that of a cone i.e.

$$A_d = \frac{\pi r\sqrt{r^2+h^2}}{2}, \quad (2)$$

where A_d is the drag surface area, r is the radius (0.5 x 265x10^{-3} m) and h is the height (4m). The drag surface area then becomes 0.835 m^2. With this, we can find the force of drag for the scull in order to find the force exerted by the rower.

$$F_d = \frac{1}{2}\rho v^2 c_d A_d, \quad (3)$$

where F_d is the force of drag, ρ is the mass density of the fluid, v is the velocity of the object and c_d is the coefficient of drag. We assume a constant velocity, throughout the entire journey, so therefore the force of drag is equal to the force exerted by the rower. With that in mind, we can then calculate the work done by the rower using:

$$W = \int F \cdot ds, \quad (4)$$

where W is the work done, F is the force exerted and ds is the change in distance.

Results

The fuel burnt per passenger on the Boeing aircraft is 171.9 L and on the Airbus is 160.8 L. Using equation (1) we can determine the energy used per person for the whole flight on average to be 6069.1 MJ for the Boeing aircraft and 5677.8 MJ for the Airbus.

For a rower rowing across the Atlantic Ocean we need to consider equation (3). Taking ρ = 1000 kg m^{-3} [6], v = 4.75 m s^{-1} [7], c_d = 2.459 x 10^{-3} [8] and A_d = 0.835 m^2. The result obtained was 23.2N. This value can be substituted into equation (4) where ds = 5546.3 x10^{3}m. The final result for work done is 128.67 MJ.

By dividing the total energy used by the total distance travelled the energy per km for all three methods of transport can be obtained. We found these to be:

$E_{Rower} = 2.30 \times 10^4 J\ km^{-1}$
$E_{Boeing} = 1.09 \times 10^6 J\ km^{-1}$
$E_{Airbus} = 1.02 \times 10^6 J\ km^{-1}$

In terms of fuel for the human rower, the energy comes from food, which is regularly measured in kCal instead of joules. Converting gives a value of 30752.8 kCal of food that would have to be consumed for the rower to make the journey. This is approximately 15 times the average daily intake of calories (2000 kCal) [9].

Analysis

The difference between the two aircraft is as expected due to the Airbus A380 being newer and more efficient.

It can be seen from the above energies per kilometre that rowing is ~98% more efficient, in terms of energy used, than flying across the Atlantic Ocean in either aircraft.

Conclusion

The numbers obtained in this investigation are subject to many constraints that further studies could account for. Consideration of tidal effects and currents that could affect the boats crossing could produce more realistic and accurate results. It is also possible to consider other aircraft, such as a helicopter.

References

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