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A4_7 A Crew-cial Race Start

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Abstract

In this paper we aim to investigate the practicalities of reaching the peak speed of a rowing race in one stroke of the oars from a standstill. The feasibility of such a start is evaluated by the velocity of water generated by the boat's movement and the force needed by each of the eight rowers. The velocity of water caused by this motion was found to be $143.58ms^{-1}$, creating significantly dangerous currents in the water. The force required of each rower was calculated as $1.78MN$, a force comparable to lifting around 182 tonnes. Therefore, a race start of this calibre is concluded to be unfeasible, dangerous and absurd to all those involved.

Introduction

In 2017, at the Rowing World Cup, the German men's eight took home both a gold medal and a new world record, completing a $2km$ race in a time of 5 minutes and 18.68 seconds [1]. Races in rowing start from a standstill, therefore the idealistic beginning to a crew's race is to achieve their race pace as quickly as possible. In this paper we will analyse the effort required for the German crew to achieve this in one stroke of the oars.

Within this paper we assume that the race is conducted under calm conditions on a lake, therefore there are no winds present or currents that could induce additional forces on the rowing boat. This is done to keep the nature of this paper simplistic. Additionally, each rower within the boat is assumed to exert the same force.

Theory

To analyse the proposed start, it is initially required to know how the water must be affected to get up to race pace. This is achieved through consideration of the conservation of momentum for the boat:

$$m_w v_w = m_b v_b = 0 \tag{1}$$

where m_w and v_w are the mass and velocity of the water, and m_b and v_b are the same parameters for the boat. This equation can then be rearranged for the velocity of water required to move the boat from standstill.

In order to find the mass of the water required, we considered the volume of water to be moved as the surface area of the blade part of a rowing oar, multiplied by $30cm$. The value of $30cm$ was assumed as it is not precisely known how much water is moved by a rowing stroke, and the value is within a reasonable estimate given the blade dimensions. Volume can then be converted to mass through the mass-volume-density relation.

To achieve this race start the rowers must exert a force equal to that of the resistive force acting on the boat. For simplicity, it is assumed the only resistive force, F_R, is due to the water flowing on the submerged hull of the boat. This is shown by [2]:

$$F_R = 0.5c\rho v_b^2 A \quad (2)$$

where c is the coefficient of hull resistance, ρ is the density of the water and A is the submerged surface area of the hull, assumed to be half the total surface area of a cylindrical model of the boat.

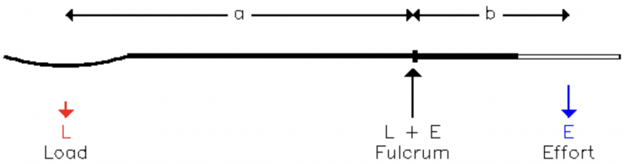

Figure 1: Diagram depicting the lever action on a rowing oar during a stroke [3]. With L = F_R and E = F_E

With the resistive force calculated, the force required to be exerted through the rowers, F_E, can be found through consideration of the lever action of the oar and analysis of Figure 1:

$$F_E = (F_R \times a)/b \quad (3)$$

where b is the inboard length of the oar and a is the outboard length of the oar, shown in Figure 1. This force can then be divided by 8 to find the force required of each rower.

Results

Using blade dimensions of a widely used Smoothie2 Vortex Edge Concept2 oar $25.5cm \times 54.5cm$ [4] and assuming a density of water of $997kgm^{-3}$, the total mass of water required to be moved was found to be $41.57kg$.

To calculate the velocity of water moved by the oars, the total mass of the boat was considered to be $951kg$. This takes into account eight rowers each weighing $100kg$, a $55kg$ coxswain, and a $96kg$ Emacher R86 boat [5]. The velocity of the boat was calculated using the velocity-time-distance relation. Therefore, the velocity of water caused by the one stroke start was found to be $143.58ms^{-1}$.

To find the resistive force on the boat, the coefficient of hull resistance was taken to be 10.50 [6]. By considering the dimensions of the Empacher hull [5], the submerged area was calculated to be $31.41m^2$. With these values, the resistive force against the boat's movement was calculated to be $6.48MN$.

Taking F_R, the length dimensions for a Concept2 oar [7] of $b = 117cm$ and $a = 258cm$ [8], F_E is found to be $14.24MN$. The force required by each rower to achieve peak speed in one stroke is therefore $1.78MN$

Discussion and Conclusion

It is clear from the values found that a race start of this calibre is wildly absurd, as the force required of each rower would be comparable to them lifting 181.96 tonnes. It would also create speeds in the water vastly greater than what is considered to be safe on the coasts [9].

In reality, rowers are required to gradually build to their race pace over the first $250m$ of the race with numerous strokes. The values calculated in this paper are, of course, highly simplistic by not taking into consideration numerous processes that may affect the boat's movement either positively or negatively, such as head or tail winds.

References

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