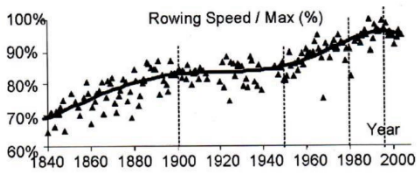
The application of physics in the progressive development of Rowing.

The sport of Rowing has drastically changed over its history and has had several impacts which influence its design, efficiency and the overall competitive edge. In this report, only single person rowing will be explained about (aka as single sculls).

The physics concepts that will be elaborated on are as follows:

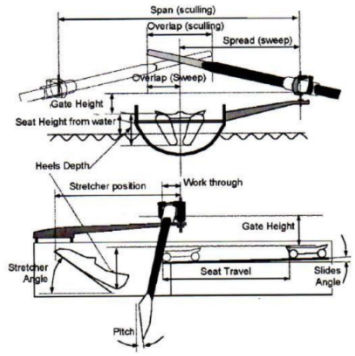
- Forces (in relation to Newtons Three Laws of Motion)
- Energy (kinetic energy)
- Torque

All of these concepts result in a change in the velocity of the boat and can either be better or worse from its initial stage in history.



Before 1900, there was a fast growth rate on which the speed of the rowing boats increased. The reason for this may be explained by the initial development of the equipment used in this sport such as timber boats, outriggers and the sliding seat and also the addition of different sport techniques and different training methods. This fast growth rate slowly decreased between 1900 and 1950 and then increased again between 1960 and 1980. The reason for this is the same as above except, the material used to improve the equipment has changed. Such as instead of timber boats, plastic boats were used, and the oar was changed with the introduction of the big blade. Meaning that the surface area of the end of the oar increased. Then between 1980 and 2000, the growth rate stabilised and the speed in which the boats were travelling has slowly come equal to one another. However, we can further speculate that the other reasons for further development of rowing in our present time are through biological development, such as doping and sociological factors. The above data is based on the Grand Challenge Cup of the Royal Henley Regatta.

Oar structure and boat structure in relation to Torque:



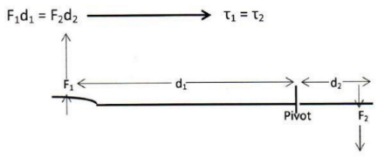
Before we look at the physics concepts behind rowing, we must first look at the structure of the boat and oar. It may look simple, but the mechanics involved aren't because we have to take into account the angle and the movement of the oar as it impacts the water and comes back out. This affects the vector of forces and velocities and hence, the efficiency/effectiveness of the rowing technique.

The diagram on the left shows the parts of the oar and the boat that allows the rower to make the boat accelerate and move forward. The basic maneuver of the oar is a 2-stroke cycle. The first stroke is when the oar impacts the water and the second stroke is when the oar comes out of the water and this 2 stroke cycle repeats. The seat within the boat moves in relation to the 2-stroke cycle of the oar. During the 1st stroke, the seat (human) moves forward while pulling the oar towards the person. During the second stroke, the seat (human) moves backward while pushing the oar away from the person. The oar has 1 centre point each which allows the oar to move along the plane of the boat and can move vertically but only a little. Hence, the physics principle of torque comes into play. Torque is a measure of how much force is acting on an object that causes it to rotate about the pivot point.

The formula for calculating torque is **τ=Fd**

Where τ is for torque, F is the force being applied to the object and d is the total distance between the pivot point and the end of the object.

For oars, there are two forces acting on the oar. When a person is pulling the oar, this end of the oar encounters pulling force while the other end of the oar has water resistance acting on it. When the person is pushing the oar away, this end of the oar encounters pushing force while the other end has water resistance acting on it as it comes out of the water. Therefore, now the formula to calculate the torque for each stroke is as follows;



This formula states that the torque (force) applied on one side on the oar, is equal to the torque (force) that is acting on the opposite side on the oar. The Torque applied is dependent upon the mass of the boat with the person and therefore, by using the formula above, we can calculate the force required by the person if we know the torque that is acting on the end of the oar by the water. E.g.:

$$F_1d_1 = F_2d_2 \longrightarrow 50N \times 1.5m = F_2 \times 0.5m$$
$$F_2 = (50N \times 1.5m)/0.5m = 150N$$

(1)

The relationship between torque, force and distance is that torque is inversely proportional to the distance between the pivot and the person. So, by extending the distance between the pivot and the person, the total torque (force) applied on this end of the oar is decreased significantly. Meaning, that the person now can apply less force but still gain the same velocity and in fact, will be able to gain greater velocity as the person now can oar more efficiently using less energy and less force. (1)

However, this alone is not enough to improve the velocity of the boat. The other physics concept that influences the velocity of the boat is Kinetic energy. Energy is defined as the potential to do work, hence giving us two different forms of energy;

Oar structure and boat structure in relation to Potential Energy and Kinetic/Work Energy.

The reason why only kinetic/work energy influences the torque required to row the boat is because of the boats centre of mass. The boats centre of mass changes as the person moves back and forward on the moving seat. This causes the boat to not be a solid body moving through water. It shakes with the movement of the person.

To improve rowing performance, one method is by reducing the difference in centre of mass during oar strokes which leads to less force acting on the oar and the boat will move faster. The total mass of the system is a constant but the individual masses of boat, oars, and the rower move most of the time relative to each other. The movement of the rower's mass generates an internal force in the system. Rowing best practice is to try to minimize both the distance and speed of movement of the rower to reduce this internal force. The amount the centre of mass changes can be changed by changing the material used to build the boat and the mass of the person. By reducing the difference in centre of mass, the kinetic energy used to move the centre of mass has also decreased and along with it, the force used to row the boat will also decrease.

The result of changing the centre of mass will allow the rower to use less force on the oar which allows the boat to move at a faster velocity. As (2) mentioned in the beginning of the report, the boats have been transformed from wood material to plastic and now fibre glass material. With each transformation of different materials, the physical properties change as well. Wood is a very dense and heavy material, so by having a human in it, it will still float because of the support force of the water but will not be able to move as fast as plastic. The density for plastic is less of that of wood so the likeliness of the boat travelling at a greater velocity than wood is higher. Fibre glass is the current and most modern material that is used for making the rowing boats. It has less density than plastic and has a high tensile strength meaning that of it encounters damage, the chances for major damages is low.

Newton's laws of Motion:

Basically, majority of the information above is related to Newton's Laws of Motion. They are:

1. A body will continue in its current motion unless an external force is applied - The boat will keep moving forward unless an external force is applied, which is the force of water. If the force of the water is greater than the forward force by the boat, then the boat will eventually slow down. Hence, by reducing the mass, the boat is able to travel faster and overcome the water resistance but not completely. The remaining force also has to come from the individual their self.
2. The rate of momentum is directly proportional to the force applied - When the torque is applied on one end of the oar (closest to the person), the other end of the oar (in the water) will have an equal amount of torque. Hence, when the torque (force) applied increases, the total momentums of the boat will also increase. The result will also be that the velocity of the boat increases.
3. Every action has an equal and opposite reaction - as explained for Newton's law number 1, the forward force of the boat will have an equal and opposite force which is water resistance. That is why the forward force of the boat has to be greater than the water resistance in order to gain significant speed.

All of these three laws enable the boat to gain efficiency and hence gain greater velocity during competition. To give rowing the competitive edge, the idea of velocity has to improve in some way shape or form. So, in conclusion, this velocity can be improved in many ways. A few major methods are named in the above report, but in brief summary, these major methods are:

1. Extending the oar between the pivot and the person will allow less torque to be applied and will therefore use less energy and gain greater velocity.
2. Reducing the change in the centre of mass of the boat between strokes.

There are many smaller minor methods that were implemented over the history of rowing as a competitive sport but these are mostly due to biomechanical means. Like, different training techniques and style, different positioning of the oars, etc. These major improvements allowed people all over the world to enhance the sport of rowing and give it the competitive edge.

References:

1. http://www.coachesinfo.com/index.php7option-com content&view-article&id=10139:rowingbiomechanics
2. http://www.atm.ox.ac.Uk/rowing/physics/basics.html#contents
3. http://www.issm.ore/vol7/n4/10/v7n4-10pdf.pdf

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