Speed and velocity in rowing

There are two words, which define how fast an object moves: speed and velocity. Speed defines quickness of the movement and has only magnitude, but no direction, so it is a scalar quantity. Velocity is the rate of change of the position of an object over time, so it is a vector and combines both magnitude (speed) and direction. With instantaneous velocity, its magnitude at each moment is equal to the speed. The same with average velocity at continuous linear motion: it is equal to the average speed. However, with curvilinear or recurring motion, it is more complicated. Average speed is equal to the average of its instant values, or to the travelled path divided by time. Average velocity is the ratio of displacement of the object to the time. At curvilinear motion the displacement is always shorter than the path, so the average velocity is lower than average speed. At recurring motion, when an object returns to its starting position, the displacement is zero, and so is average velocity, though the object may travel a long way and average speed could be high.

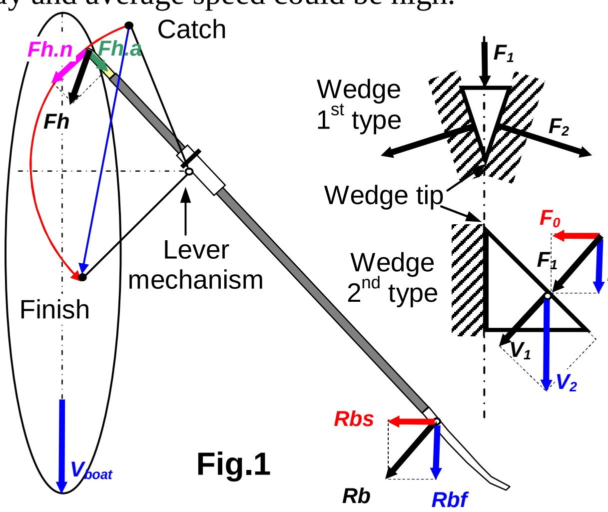

Fig.1

Fig.1 illustrates the difference between the speed and velocity for the motion of the oar handle. From catch to finish, the handle travels 1.71m (the length of the arc at the middle of the handle at 114° total angle and 0.88m inboard), but the displacement between these two points is only 1.44m, or 16% shorter. The same difference is between the average speed during the drive (1.90m/s with drive time 0.9s) and average velocity (1.60m/s). If the handle velocity is averaged over the whole stroke cycle, it is zero, because the handle returns to the same position relative to the boat. However, the average handle speed over the stroke cycle is not zero (2.05m/s in this case at 36str/min).

Performance in rowing is defined by average velocity of the boat, but not by average speed: the boat must arrive from point A Start to point B Finish in the shortest possible time. So, we are interested in the fastest displacement between these two points, but the length of the path travelled by the boat is not counted. Therefore, effective steering is a part of rowing performance and should provide the straightest path for the boat, which can be a complicated task in head races on curved rivers.

Power applied by a rower is the main factor of the boat speed and velocity. One of the components of the power is the velocity, but not the speed, because the direction of the movement relative to applied force is important. Therefore, power ***P*** is a scalar product of two vectors: force vector ***F*** and velocity vector ***v***:

$$P = F\, v \cos(\alpha) \qquad (1)$$

where α is the angle between these two vectors. When the force is applied perpendicularly to the velocity, the power is zero, because $\cos(90^o)=0$. E.g., the axial handle force ***Fh.a*** (Fig.1) does not produce power, because it is perpendicular to the instantaneous handle velocity by definition. Only normal handle force ***Fh.n*** produces power.

Speed and velocity can be easily converted with a simple lever mechanism, like an oar. Ratio of the input (handle) ***Vin*** to output (blade) ***Vout*** velocities is inversely proportional to the ratio of corresponding forces and defines the gearing ratio ***G***:

$$Vout / Vin = Fin / Fout = G \qquad (2)$$

Similar effect can be achieved, when a force is applied at an angle to the velocity. This defines another simple mechanism - a wedge, which can also convert velocity and force in two ways (Fig.1): 1) when force F_1 is directed towards its tip in axial plane – it magnifies lateral forces F_2 (used in wood splitting); in reverse 2) when lateral force F_1 is applied to a wedge slope, the output force F_2 is smaller, but the velocity in this direction V_2 is proportionally higher. The component of the blade reaction force ***Rbs***, perpendicular to the boat velocity, used to be considered as energy loss, which was one of the "myths" of rowing biomechanics for many years: "force application at steep catch and finish angles is ineffective". In fact, the side force produces zero power, because it is perpendicular to the boat velocity ***Vb***, so and energy losses are zero. Sharp catch angles work as a wedge of the 2nd type and make the gearing heavier (RBN 2006/06). This means the propulsive force ***Rbf*** is smaller than total blade reaction force ***Rb***, but it is applied at boat velocity V_{boat}, which is proportionally faster than the velocity of the propelling object - the blade. So, the propulsive power is the same and the only loss is a friction, which is small at the blade. Similar examples can be found in nature:

- A skater pushes his skate blade to the side, but moves forward much faster than a runner, which pushes the ground straight backwards.
- Sailing yacht moves much faster in a cross wind, than in a straight tail wind;
- In archery, a bow pulls the string to the sides, but the arrow flies forward much faster.

The total oar gearing is variable during the drive and equal to the sum of the lever and wedge effects. It must be optimal for each rower. (RBN 2007/03): heavier gearing helps to increase force quicker at catch, but may slow down handle velocity and decrease the stroke rate, and vice versa.