Q&A

We have received positive feedback on the previous Newsletter and an interesting discussion with Marinus Van Holst about the choice of the frame of reference (FoR). He argued that FoR related to the ground of Earth should be used, but not FoR moving with the constant speed of rower-boat system. Being not able to convince each other, I've received another excellent comment from Martijn Weterings, a coach from Wageningen student rowing association Argo, Nederlands, which has resolved our discussion. Here it is with some abridgments:

"To determine internal kinetic energy fluctuations it is very common to use FoR, which is fixed to the CM of the system. Using FoR which moves with constant velocity absorbs the speed fluctuation of the system CM into the equations of the speed fluctuation of the rower and boat (V_{boat}-V_{rower}). However, the speed fluctuation of the CM of the system does not involve energy losses due to internal kinetic energy fluctuations. Therefore, the physical interpretation of the two representations is different. The one using kinetic energy as determined from the reference frame, which does not move with constant velocity, does more purely reflect internal kinetic energy losses. A way to connect the two different paradigms or representations is:

$$E_{kinetic\ total} = E_{rower} + E_{boat} = E_{sys} + E_{in} \quad (1)$$

$$E_{row} + E_{boat} = ½\, M_{row} V_{row}^2 + ½\, M_{boat} V_{boat}^2 \quad (2)$$

$$E_{sys} + E_{in} = ½\, M_{sys} V_{sys}^2 + ½\, M_{in} V_{in}^2 \quad (3)$$

The equations 2 and 3 are equal, if:

$$M_{sys} = M_{row} + M_{boat} \quad (4)$$

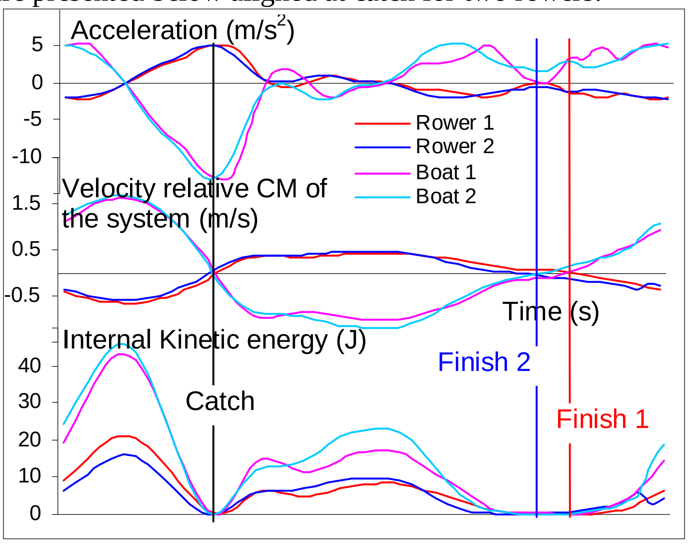
$$V_{sys} = V_{row} M_{row}/(M_{row}+M_{boat}) + V_{boat} M_{boat}/(M_{row}+M_{boat}) \quad (5)$$

$$M_{in} = M_{row} M_{boat} / (M_{row}+M_{boat}) \quad (6)$$

$$V_{in} = V_{row} - V_{boat} \quad (7)$$

Now the difference between the two representations is that E_{in} determines the internal fluctuation inside the rower-boat system and E_{sys} determines fluctuation.." of CM of the whole system in external environment.

We have made additional analysis and calculated velocities and kinetic energy relative to CM of the system, which are presented below aligned at catch for two rowers:



The Table below shows inertial losses associated with internal (variation of V_{row} and V_{boat}) and external kinetic energy (variation of V_{sys}):

	N	Rower's Inertia (W)	Inertia of the boat (W)	Total Inertia (W)	Energy Losses (%)
Internal	1	20.5	25.4	46.0	**6.4%**
Energy	2	17.9	25.5	43.4	**6.5%**
System	1	23.6	21.5	45.2	**5.6%**
Energy	2	35.6	15.1	50.7	**6.6%**
Total	1	44.2	47.0	91.1	**12.0%**
Energy	2	53.5	40.6	94.1	**13.1%**

The internal inertial losses were still lower in rower 1, but by a very small margin 0.1%. So, most of the difference in speed should be explained by other factors.

Internal and external inertial losses are split nearly equally in these two rowers. In fact, the second one is not "losses" by the nature: this is the amount of kinetic energy, which the system accumulates during the drive and spends during recovery to overcome the drag resistance. In this case, the choice of FoR does matter, because more power required to create propulsive force $\mathbf{F_{prop}}$ and increase kinetic energy at higher velocity $\mathbf{V_{prop}}$ relative to the environment:

$$P = F_{prop} V_{prop} = ½\, M_{sys} (V_{cm2}^2 - V_{cm1}^2)/dt \quad (8)$$

It is similar to the acceleration of a car, which requires more power of the engine at a higher speed. Therefore, **FoR based on the substance used to create propulsive force, the water in this case, should be chosen for the whole system. Internal inertial losses should be calculated relative to the CM of the system, which makes them very similar to ones on the ergo** (see RBN 2010/5).

Q: Martijn Weterings also asked: "Did you take into account effects of boat velocity variations on drag? I guess that rower 2 has a lower average of the cubed boat velocity. … I can imagine that the difference would be less pronounced when drag is taken into account."

A: We have found that indeed the difference between maximal and minimal boat velocity during the stroke cycle was lower in sculler 2: 1.34 m/s compare to 1.43 m/s in sculler 1. However, if we take a ratio of these values to the corresponding average boat speed, then sculler 1 had lower relative amplitude of the boat velocity variation: 24.7% compared to 25.2% in sculler 2. When energy losses were estimated, it was found that the boat velocity efficiency (RBN 2003/12) was also higher in sculler 1: 93.1% compared to 92.3% in sculler 2. This means that the first sculler loosing only 2.37% of the boat speed (8.2s over a 2k race) compared to his less efficient opponent, who is loosing 2.64% or 9.9s over 2k race.

We can conclude that **attempts to achieve a more even boat speed by using the upper body at the catch doesn't work**. Sculler 2 had higher variations of the boat velocity and has lost 0.28% more of the boat speed for this reason (1.2s over 2k race), which contributed to the total 8.3% difference in the speed between these two scullers.

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