Variation of the boat velocity

There is an old and widely spread idea, that the variation of the boat velocity during the stroke cycle is the main factor of energy loss and must be reduced for efficient rowing. Its reasoning is the following: Energy losses due to drag resistance (drag power P_d) are proportional to the cube of boat velocity v:

$$P_d = DF\, v^3 \qquad (1)$$

where ***DF*** is the drag factor. The minimal P_d could be achieved at constant boat velocity. E.g., at typical for 1x v=5m/s and ***DF***=3, it would be P_d = 375W. However, if the boat speed would be 4m/s during half of the stroke cycle, and 6m/s in the other half (the same average speed 5m/s), then the average drag power would be P_d = (192+648)/2=420W, which requires 12.0% more energy production. If the rowing power remains the same 375W with similar velocity variation, then the average boat speed will be only 4.82m/s, or 3.7% of the speed would be lost.

Variation of the boat velocity in rowing has only two reasons:

1. Periodic nature of the propulsion. Blades produce propulsive force only during the drive phase - about half of the stroke cycle time. Therefore, the rower-boat system accelerates during the drive, and slowing down during recovery.
2. Significant movements of the rower's mass, which is much heavier (4-6 times) than the boat mass.

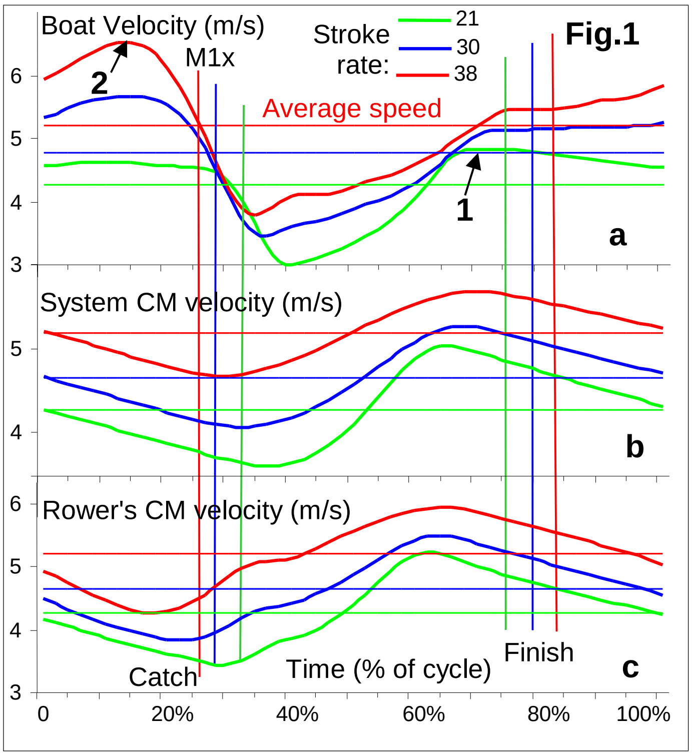

Fig.1

These two factors affect variation of the boat velocity in a different proportion, which vary with the stroke rate: **At lower stroke rates (below 24), the periodic propulsion dominates**, because recovery time is long and a rower moves to the catch slowly and pulls the stretcher easily. The maximal boat velocity is achieved at the finish (Fig.1a, 1), then, it decreases during recovery. **At higher stroke rates (above 24), the rower's movement dominates**: the recovery time shortens dramatically, so the rower must move faster and pull the stretcher harder. This force accelerates the boat, which achieves its maximum velocity just before catch (Fig.1a, 2), when the seat velocity is maximal and the rower switches from pulling to pushing the stretcher (moment M2, RBN 2013/07).

The coefficient of variation C_v was defined as the ratio of the standard deviation σ to the mean value of the variable, in this case, the average boat speed ***Vav***:

$$C_v = \sigma / Vav \qquad (2)$$

It was found that variation of the boat speed has a nearly functional relationship with energy losses E_l and speed losses V_l (R^2=0.996):

$$E_l = 2.5\, C_v^2 \;\text{ and }\; V_l = 0.9\, C_v^2 \qquad (3)$$

A large sample of telemetry measurements (n=5448) was analysed, and these values were found lower than in above example: C_v ranges 10-18%, E_l - 2.7-9.0%, and V_l – 0.9-3.0%.

To study the effect of above two factors, velocities of the rower's centre of mass ***Vrow*** and the whole system (rower+boat+oars) ***Vsys*** were derived (Kleshnev, 2010, Fig.1 b, c), as well as trends of their dependences on the stroke rate in different boat types (Fig.2). It was found that all variations were higher in smaller boats, and they depend on the stroke rate: the boat velocity variation increases with the stroke rate, but variations of the rower and system velocities– decrease.

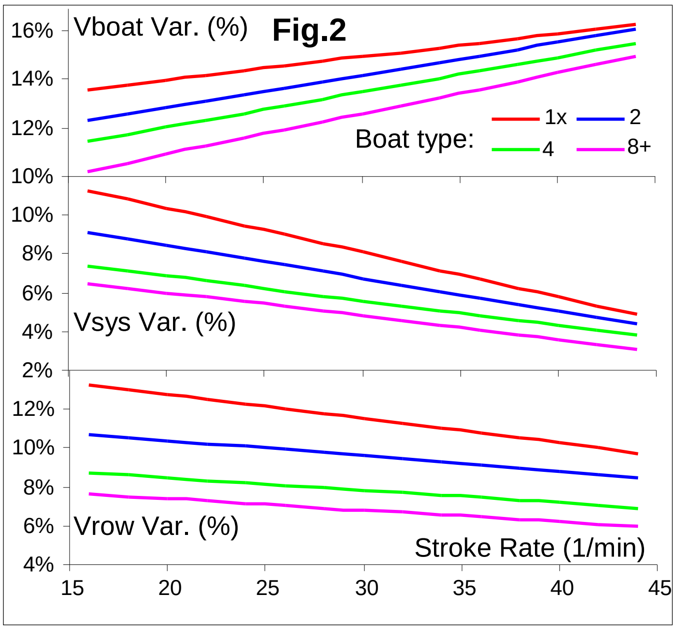

Fig.2

At low rates, 60-80% (depending on the boat type) of the boat velocity variation is provided by the system velocity variation, which depends on periodic propulsion only. At high rates, 70-80% of the boat velocity variation depends on the rower's movements – variation of rower's CM velocity.

For many years, an idea of asynchronous rowing was considered as a way to eliminate both above factors and achieve more efficient and faster rowing. Phase shift drive should make the propulsion constant; an opposite direction of the rowers’ motions should cancel their effect. Some efforts were spent to implement this idea (Fig.3, 4, Ref.3), but no practical results were achieved. This happened because of dramatically increased inertial energy losses. Instead of moving a light boat in normal rowing, rowers had to change direction of the movements of their heavier body mass, and also overcome boat accelerations created by countermovement of their teammates, which made it even less efficient than rowing in a stationary tank/erg rowing (RBN 2010/05). About 6-8% energy was saved due to less variation of the boat velocity, but instead the rowers had to spend 10-12% extra energy to overcome inertial forces. In other words, ***Vboat*** variation was decreased, but ***Vrow*** variation – increased (Fig.2), which was especially inefficient at high rates, so asynchronous boats were slower than normal ones.


Fig.3. Asynchronous eight at London rowing club, 1929.


Fig.4. 1979 World champions W4+ USSR. The boat was designed for asynchronous rowing, but rowed normally, because it was faster.

In rowing technique, an idea of faster rowing by means of more even boat velocity have created many unproductive outcomes, such as “do not “check” the boat at catch”, “pull the handle before you push the stretcher”, etc.

What could be really done in technique to minimise energy losses due to variation of the boat velocity? The two factors above dictate opposite solutions: increasing propulsion time requires longer drive phase and higher rhythm (ratio of the drive phase to the stroke cycle time). Contrarily, if rower’s movements need to be smoother, then recovery phase should be longer and the rhythm lower. As we are interested mainly in higher racing stroke rates, where the second factor dominates, it make sense to follow the second route. This was confirmed with the data: at rates above 30, the rhythm ***Rh*** significantly correlates with rate-normalised variation of the boat speed ***Cvr*** (r=0.63, ***Cvr=0.248 Rh + 0.019, Cvr*** was derived as a deviation from the rate-based trend line, to eliminate the effect of the stroke rate), so **the shorter the drive time and longer recovery, the more efficient the boat velocity**.

Not all methods are productive for shortening drive time: e.g., shortening drive length would decrease power and the speed. In general, maintaining the constant boat speed during the recovery should be emphasised, but not during the drive, because the boat speed is much higher on recovery, and creates the highest drag resistance. Here are a few things, which could be used effectively:

- **Avoid sharp jerky pulls of the stretcher during recovery. Try to spread stretcher pulling force evenly** to produce the most constant boat speed and minimise energy losses.
- **Use optimal gearing ratio according to weather conditions: shorter outboard at head wind. Avoid too heavy gearing, which makes drive too slow and requires rushing on recovery** to maintain the stroke rate. Shorter recovery time requires harder pulling the stretcher, which accelerates the boat more and increases variation of its velocity.
- For the same reason, **do not put the blade too deep during the drive, which may “break the force curve” and make drive time longer**.
- **“Front-loaded” drive with quick force increase after catch is the only way to accelerate the boat earlier during the drive and make its velocity more even**.

It is difficult to estimate numerically the effect of above methods, because it requires special experiments and/or complicated modelling. Some publications in this area (e.g. 4) suggest that the effect should not be huge: only a few seconds could be saved in 2km race by means of optimised recovery techniques.

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