BIOROW BIOMECHANICS OF ROWING **Rowing Biomechanics Newsletter** *No 167 2015 February*

Horizontal stretcher force

The stretcher force is not easy to measure and analyse because its direction and centre of application varies throughout the drive: at the catch, rowers push the stretcher with their toes and more vertically; during the second half of the drive, the force becomes more horizontal and located at the middle of the foot (Fig.1). It could be hypothesised that the line of the stretcher force action is related to the position of the rower's CM, but this has not been proved experimentally yet.

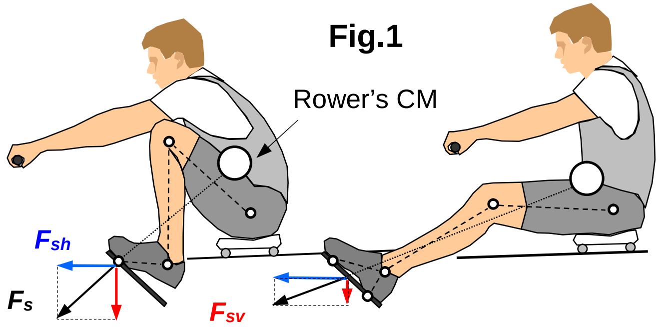
Fig.1

The stretcher force F_S could be decomposed into two components, which play very different roles in rowing biomechanics: horizontal component F_{SH} involved in the propulsion of the rower-boat system, but the vertical component F_{SV} affects "suspension" of the rower's weight (RBN 2013/09-10). Therefore, it is not enough to measure just the "stretcher force" F_S, but it is necessary either to define its direction as well, or measure horizontal and vertical components separately.

The horizontal stretcher force F_{SH} is a part of the balance of forces at the hull:

$$F_{PF} - F_{SH} = m_b a_b - F_D \qquad (1)$$

F_{PF} ($=F_P \cos(A)$) - forward component of the pin force (**A** – the gate angle), m_b is the active boat mass, a_b - boat acceleration, and F_D – is the drag force. From this equation, F_{SH} appeared to have a negative effect on the boat propulsion, as it is directed opposite to the boat's velocity and plays the same role as the drag force: the higher the stretcher force, the lower the boat acceleration. Quite often, rowers and coaches attempt to minimise "wrongly" directed stretcher force and maximise the handle force, which is applied in the "right" direction, transferred through the rigger to the pin force F_{PF} and accelerates the boat forward.

However, this is correct only in regards of the hull, which contributes about 15% of the total mass of the system. If the heaviest part of the system – the rower's mass m_R is considered, the balance of forces is:

$$F_{SH} - F_H = m_R a_R \qquad (2)$$

F_H - the handle force, a_R - acceleration of the rower's CM. This means the stretcher (reaction) force accelerates the rower's mass forward, but the handle force pulls it backwards.

Acceleration of a mass m increases its velocity v and kinetic energy $Ek=mv^2$. The higher kinetic energy accumulated by the rower-boat system during the drive means higher average speed of the system. As the rower contributes more than 80% of the system mass, acceleration of his own mass is the most important target of the rower's efforts during the drive. Early in the XX century, the great British-Australian coach and rowing methodologist Steve Fairbairn expressed it in the following way: "**Find out how to use your weight and you will have solved the problem of how to move the boat**". Therefore, maximizing the horizontal stretcher force during the drive is a very important part of the effective rowing technique, and many successful coaches set it is as the main target for the rower's efforts.

The pin/gate and horizontal stretcher forces have quite similar magnitude and pattern during the drive. The difference between them is the boat propulsive force, which is spent on overcoming drag F_D and boat inertia $m_b a_b$ forces (Eq.1), which are relatively lower. Fig.2 shows horizontal stretcher and gate forces measured using **BioRow™** system, and derived propulsive force in M1x at 32 str/min (the methods were given in RBN 2013/09).

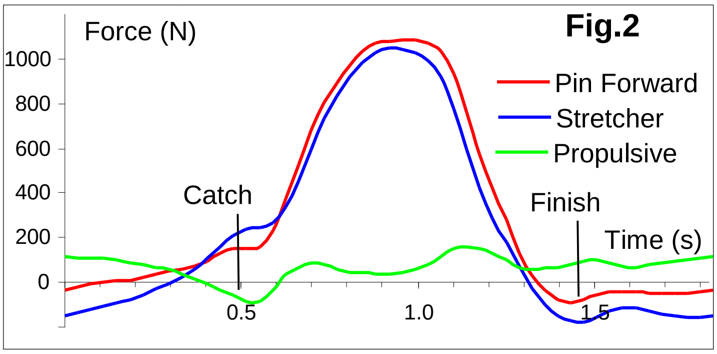
Fig.2

The boat inertia force could be derived from the measure boat acceleration and known active boat mass, so the drag force at the hull $F_D(F)$ could be calculated from the equation 1. For comparison, the drag force $F_D(V)$ was also derived from the boat velocity Vb and drag factor DF: $F_D(V) = DF*Vb^2$ (Fig.3).

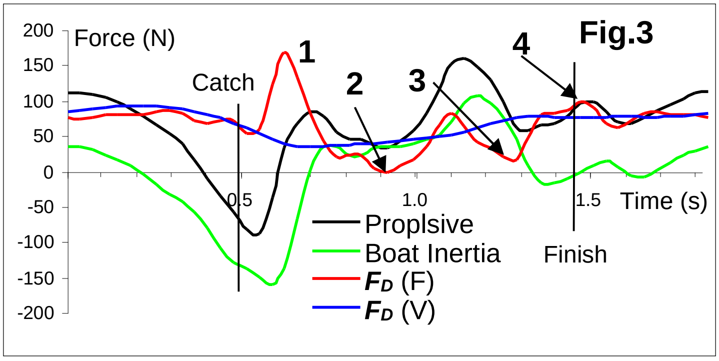
Fig.3

The average drag forces over the stroke cycle were quite similar: $F_D(V)$=68.2N, $Fd(F)$=66.9N. Their curves during recovery were also close, but during the drive they were very different. The highest $Fd(F)$ peak 1 after the catch coincides with the highest seat velocity and could be explained by the friction force at the wheels, which looks like increased drag force. The smaller peak 4 could be related to the highest vertical seat force, which pushed the boat down and increases drag force. The nature of the negative peaks 2 and 3 is not clear yet. One of possible reasons could be a small force at the rower's calves touching the hull, which is not measured, but affects the real balance of forces.