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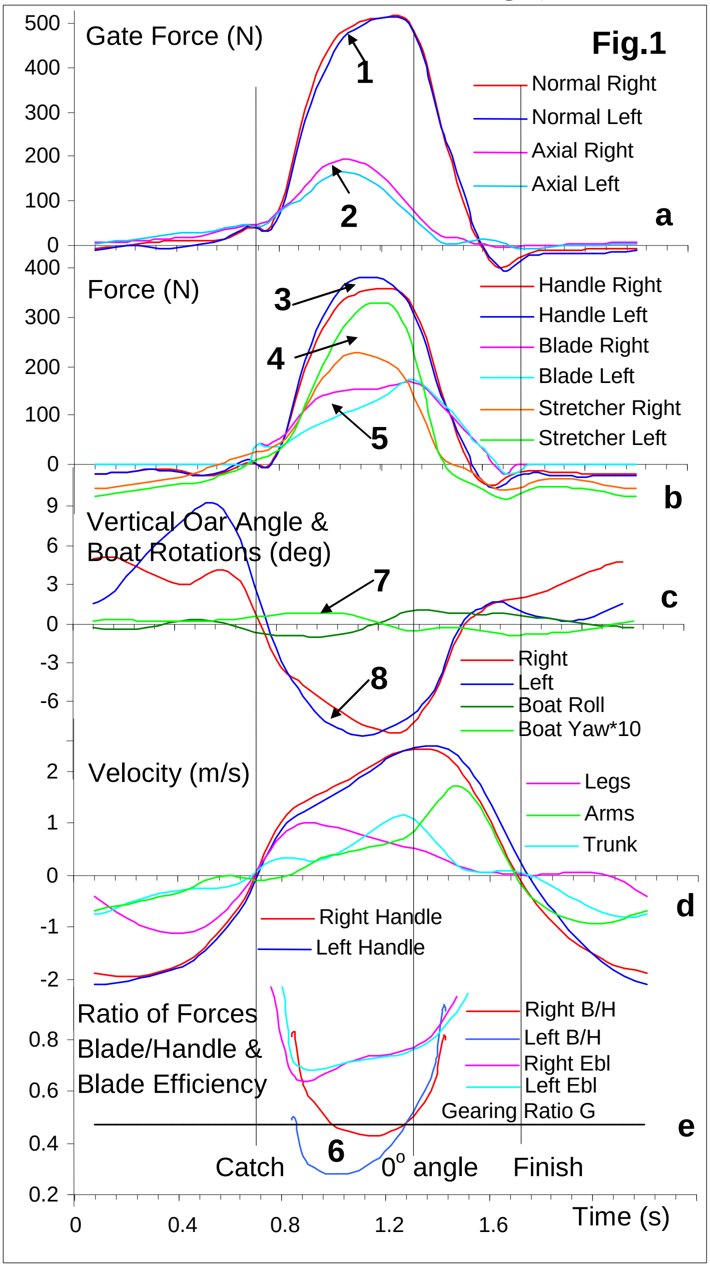
Ratio of the blade and handle forces

Recently, a new interesting phenomenon was discovered in analysis of the data in M1x at 32 str/min (the same measurements as in RBN 2013/08), which was also found in other rowers at various stroke rates. Handle forces were measured together with normal and axial gate forces (Fig.1, a). Horizontal components of the stretcher force were measured at three points (Fig.1, b shows top right and left components). Also, were measured: horizontal and vertical oar angles and boat rotation (c), velocities of legs and trunk (d, handle velocities were derived from the oar angle).



Blade forces ***Fb*** were derived (Fig.1,b) as a difference between normal gate ***Fg*** and handle ***Fh*** forces, neglecting small oar inertia forces:

$$Fb = Fg - Fh \qquad (1)$$

Fig.1,e shows blade efficiency (RBN 2007/12) and the ratio ***Rb/h*** of the blade ***Fb*** and handle ***Fh*** forces, which should have equal gearing ratio ***G*** derived geometrically from actual outboard ***Lout*** to inboard ***Lin*** (from the pin to the centre of the blade and handle):

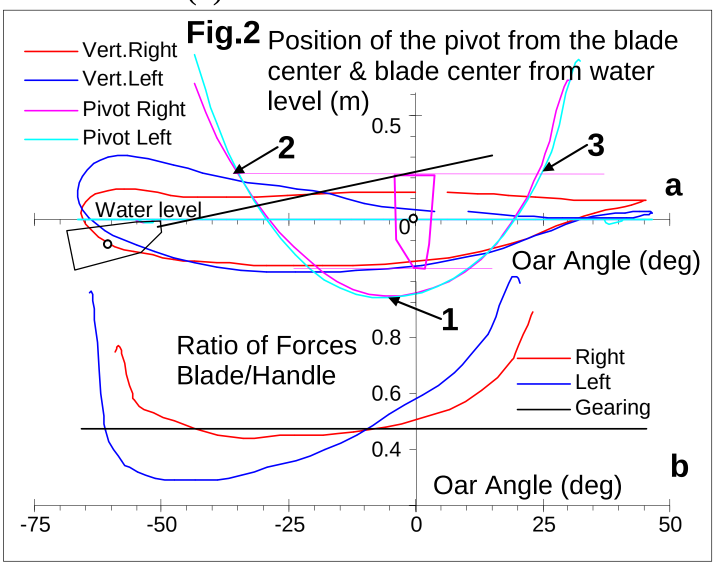
$$Rb/h = Fb/Fh = Lout/Lin = G \qquad (2)$$

It was found that, during the first half of the drive, the left and right normal gate forces were quite similar (1), right axial gate (2) and handle (3) forces were slightly lower than left ones and right stretcher force was significantly lower than left one (4). However, right blade force was significantly higher than the left (5), so the ratio of forces ***Rb/h*** was significantly higher for the right (port) oar (6), which is confirmed by the data of boat yaw to the starboard (7). Relatively lower left blade force corresponds with deeper placement of the left blade into the water (8). Also, ***Rb/h*** is higher at catch and finish, when the blade is shallower. This allows us to raise a hypothesis that **the depth of the blade could be related to the ratio of the blade-to-handle forces: the deeper the blade, the lower the blade force at the same handle force**.

The first guess to the reason of this phenomenon was the effect of negative force acting on the inner area of the blade and oar shaft: when the blade rotates in the water, its outer parts move faster backwards and create propulsive force, while the inner parts and shaft move slower, could be dragged forward together with the boat and create braking force. To make it clear, the position of the pivot (stationary) point of the oar ***Lpiv*** was derived relative to the blade centre:

$$Lpiv = Vb / (\omega \cos(\alpha)) - Lout \qquad (3)$$

where ***Vb*** boat velocity, ***ω*** oar angular velocity (rad/s), ***α*** oar angle. Fig.2 shows these positions together with vertical position of the blade centre (a) and the ratio ***Rb/h*** (b).



At the middle of the drive, the oar pivot is located on the shaft at 15-20cm from the inner edge of the blade (1), which means any deeper placement of the blade drags the shaft forward in the water and creates extra resistance. However, at the catch and finish the pivot moves much further away from the pin: it is located on the outer edge of the blade at a 35° catch (2) and a 25° finish oar angle (3); at sharper oar angles the virtual pivot moves outside the blade, which means the whole blade is dragged forward. Further analysis is required to make this area clearer. Any ideas?