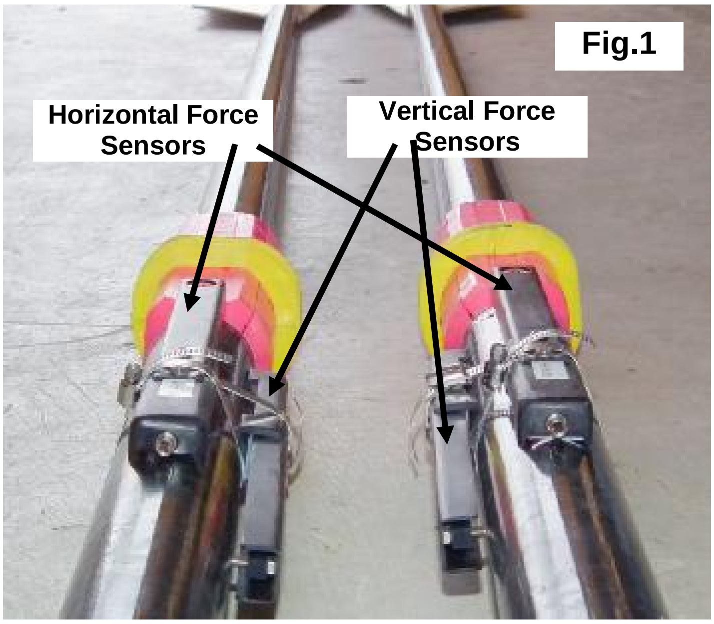
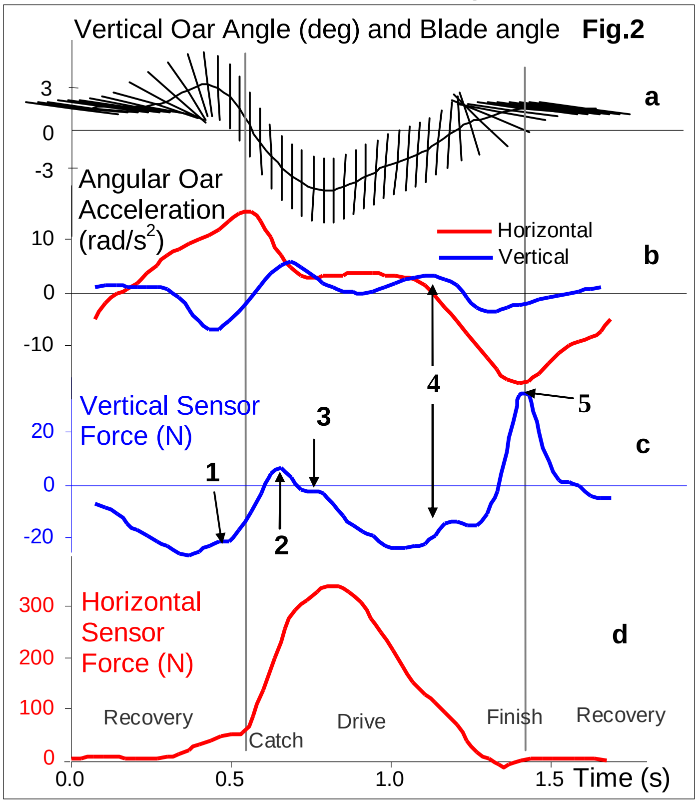
Vertical Handle Force

Last year, the first pilot study on the vertical oar forces was done with our ***BioRowTel*** system and now we will discuss the results. The vertical handle forces were measured with the same sensors as the horizontal forces, which were attached to the oar shaft at 90° to each other (Fig.1). These two sensors were positioned in two orthogonal planes and measured oar flex in horizontal and vertical directions.



The data of the right oar of a single sculler at the stroke rate 36 str/min is shown on Fig.2.



As the oar squared and feathered during the stroke cycle, the orientation of the sensors is changing relative to the horizon. Therefore, the oar roll was measured with ***BioRow*** 7D sensor (RBN 2012/10), so the orientation of the blade and sensors was determined (Fig.2, a). Angular oar accelerations (Fig.2, b) were derived by means of double differentiation of the oar angle in the horizontal and vertical planes, which were measured with ***BioRow*** 2D oar angle sensor. When the blade is in the air and the forces on it are negligible, the handle force ***Fh*** and angular oar acceleration ***a*** in each plane are related as follows:

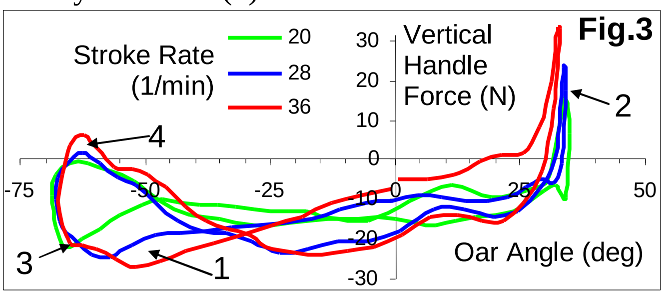
$$Fh = I\, a / Lin.a \qquad (1)$$

where ***I*** is the moment of inertia of the oar relative to the pins centre of rotation, ***Lin.a*** is the actual in-board from the pin to the middle of the handle. In this study and previous in-lab measurements ***I*** was found to be 3.4-3.6 kg·m^2 for a scull and 6.6-7.0 kg·m^2 for a sweep oar.

Before the catch, when the blade is already squared, but still in the air (Fig.2, 1), the sculler applies about 20N (2kgF) of negative (upwards) vertical handle force to insert the blade in the water. When the blade enters the water, the vertical force became slightly positive (2), which means the rower pulls the handle slightly down to stop the blade going deeper. At the deepest blade position, the vertical force is very close to zero that means the pull is horizontal (3).

It is interesting that during the second half of the drive (4) the vertical handle force again has a negative value of about -20N, but vertical angular acceleration became positive. This means the rower pulls the handle slightly upwards and tries to keep the blade deeper, but it moves out of the water. This fact could be explained only by the upwards force at the blade, which is related to a positive pitch angle (+6°). At ~200N horizontal handle force it creates ~20N of vertical force (sin(6°)=0.1). At the finish (5) the blade is already feathered, so significant positive force measured by the sensor is related to the horizontal acceleration of the oar.

At higher stroke rates (Fig.3), the higher negative forces were measured during recovery (1) and at finish (2), which is explained by higher horizontal accelerations. The upwards kick of the handle before catch stays nearly the same (3), but positive blade force after the entry increases (4).



Concluding, **vertical forces at the handle are quite small and even smaller at the blade (about 10N ~ 1kgF), so they do not really contribute to vertical movements of the rower-boat system**.

A significant part of the handle force is directed vertically: from 7% at pitch 4° up to 14% at 8°.

Variable (lateral) pitch could be recommended to minimize vertical forces and make the blade path in the water more horizontal. (RBN 2010/09)