A brief history of our developments in force measurement area

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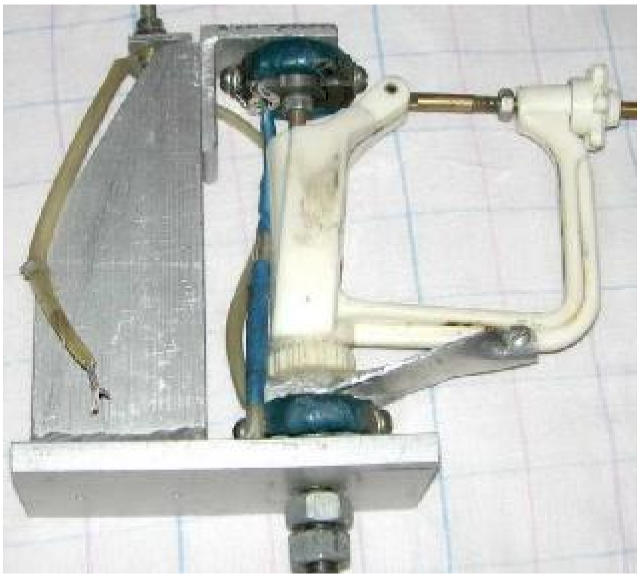
Prehistory

The history of biomechanical measurements in rowing in Saint-Petersdurg, Russia goes back to the end of 1940-s, when Georgy Krasnopevtsev measured force applied to the oars in a dinghy. In 1960-70 a telemetry system was developed, which measured force through the bent of the oar and used strain-gauges glued directly on the oar shaft. The signal was transmitted to a motor boat though a cable hanging on a sort of big fishing rod and recorded on photo-plotter. A large number of studies were done using this technology by scientists from Rowing department of Leningrad Sport Institute: Morzevikov N.V., Hohlov I.N, Dunaev A.F., Lazutkin V.M., Diakov S.E., Shliakov S.K., Sema A.A. and others. Some of these studies were referred in a review written by Zatsiorsky & Yakunin in 1991. As a sculler, I was tested in a single using this cable telemetry system in early 1970-s and then learned its principles, when finished an athlete carrier and entered the Sport Institute in 1986.

Below is a brief history of my developments in the area of force measurements in Rowing Biomechanics.

1987 Gate v.1



The first prototype of the instrumented gate was developed in the end of 1986. A standard gate was used and possibility of pitch adjustment was preserved. The gate rotated together with a pin, which was connected to a mounting bracket through two rings with strain gauges. The bracket can be mounted on a standard rigger and back stay can support its top.

Oar angle was measured using a potentiometer with an arm connected to the oar shaft. This potentiometer was mounted on top of the bracket (not shown here).

This prototype was quite heavy (0.7kg) and awkward. Only two experimental gates were made.

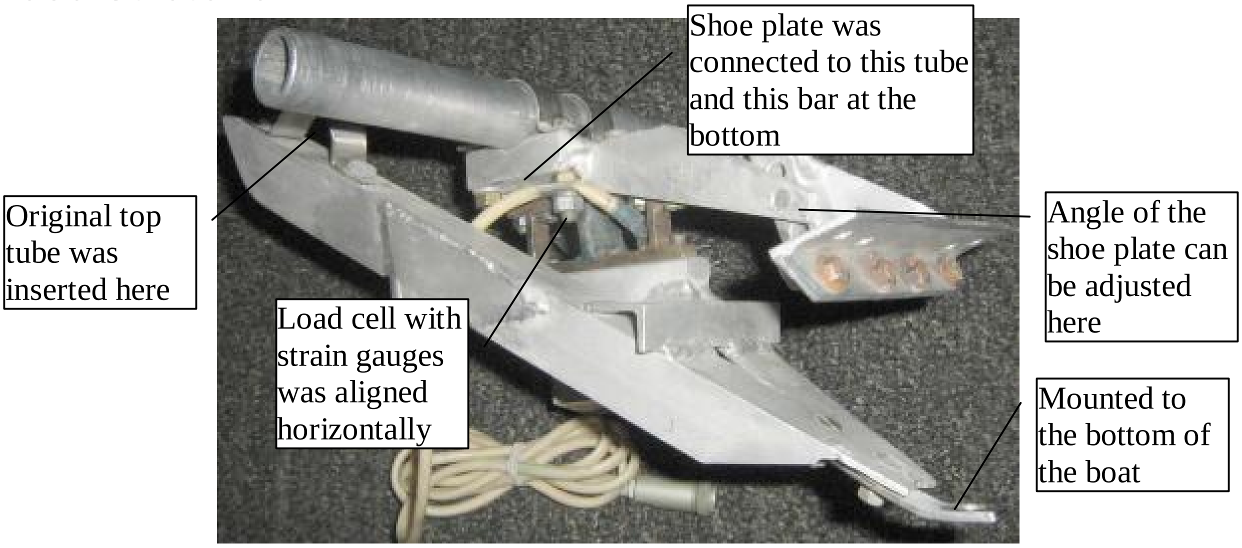
1988 Gate v.2

Quite complicated structure consisting of four rings was designed and made from stainless steel in 1988. The gate angle was measured with incorporated potentiometer. All mechanics was covered with a stainless steel protector, which made it quite heavy (0.5 kg). Pitch can be adjusted using various exchangeable load plates. A small series of 16 gates was manufactured. The data was collected on a portable tape recorder with a possibility to replay it after the session, input into PC DVK3 and provide a simple analysis.

This design was protected by a patent (2), which was referenced in 2004 patent of Peach Innovations Ltd. (3).

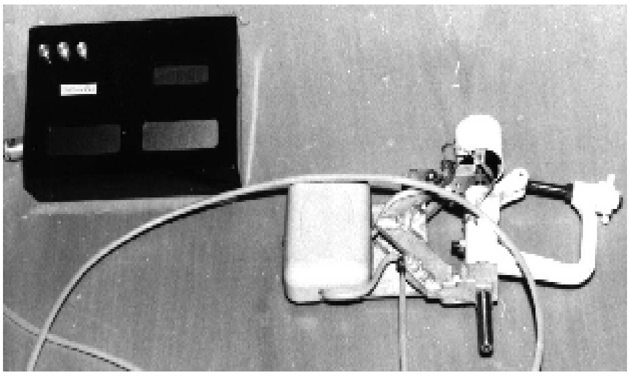
In 2009 one of these gates was presented to Chris Dodd, the most famous rowing historian, and stored now in Henley River & Rowing museum.

1989 Stretcher v.1



The first instrumented foot-stretcher was developed using the principle: all force is transferred and measured through one load cell. We were interested in horizontal component of the resultant force only, because the target was to derive a propulsive force for each rower. A special three-stay load cell was designed to be insensitive to vertical component of the force and torques and it worked surprisingly well. Installation was quite time consuming, because it required to disassemble an original stretcher, insert the top tube and shoes with plate into this construction, adjust position and angle of the shoe plate. Made from aluminium, this stretcher was not too heavy for its purpose: only 0.8 kg was added the mass of the original stretcher. Small series of eight stretches was manufactured.

1992 Gate v.3

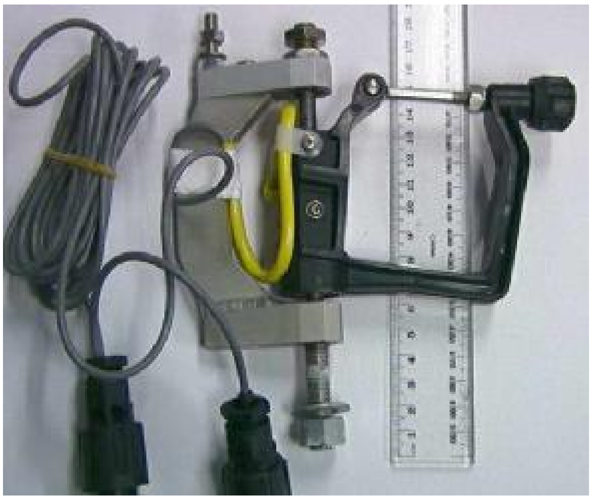
In this design, the strain gauges were applied to a pin, which rotates in a bracket together with a standard plastic swivel. This made whole design much more compact and light-weight (300g only). The angle of the gate was measured with a potentiometer connected to the pin and mounted on top of the bracket. The pitch can be adjusted using two bolts, which connect the swivel with the pin and affect alignment of the swivel. The second potentiometer could be mounted on the swivel (left photo), connected to the oar shaft with an arm and measured the vertical oar angle.

The box mounted on the bracket contains a circuit board with an amplifier and other components. In 1993 an electronics unit was made (right photo), which worked with this gate and was able to give an immediate feedback about angles, forces and rowing power.

1998 Handle-Force v.1


In 1997 I got a job of rowing biomechanist in Australian Institute of Sport and moved to Canberra with my family in 1998. I found there a radio-telemetry system, which used a proximity sensor mounted on the oar shaft (left photo). This sensor was very heavy (0.5 kg), bulky and unstable and affected oar balance and rower's feelings. Very soon I've developed a small, light (70g) and reliable sensor of the oar bent with strain gauges (right photo), which principles are used in the current sensors of handle force.

2001 Gate v.3.5 and Stretcher v.2



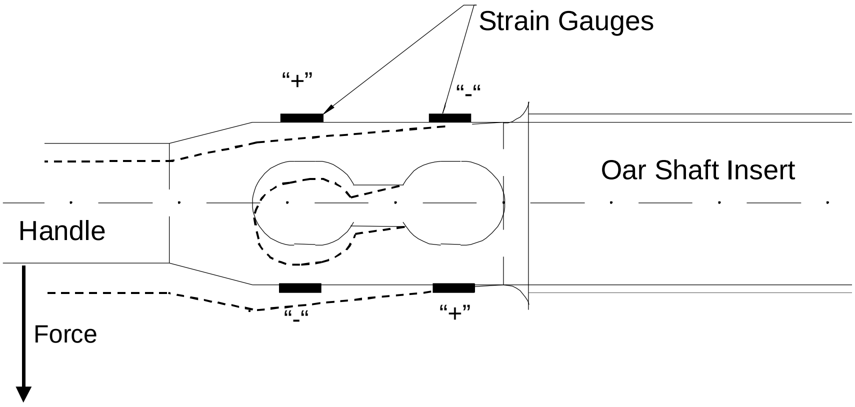

Design of 1992 v.3 gate force sensor was reproduced in Australia in 2001 (left photo).

A new stretcher sensor was designed, which was much lighter (only 200g added) less time consuming in installation than v.1. Two binocular-shape load cells were inserted into the original tube instead of plastic inserts (right photo). The bottom of the stretcher was mounted to the boat through a linear bearing. Therefore, it measured the horizontal force only, but it was possible to define which foot apply more or less force.

WEBA instrumented gate was made under our licence (left) and sell it as a part RowX Outdoor system.

Peach Innovations Ltd. has made a very tidy gate with a reference to our v.2 design (right), but it measures the force relative to the pin, not the gate and oar.

2002 Handle and blade force v.2



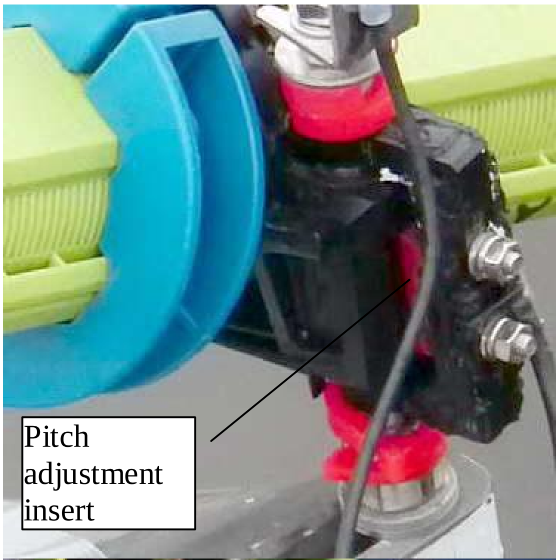
A special design of a sensor of the handle and blade forces was made for research purposes. The target was to investigate positions of the force application at the handle and blade, so these sensors measured force (not torque) and were insensitive to the lever. Also, torques at the handle and stretcher were measured with v.1 sensors and comparison of these two variables allowed to define the point of the resultant force application at the handle and blade.

A study with these sensors was presented in RBN 2003/08 (4).

2002 Seat force v.1

Sensor of the vertical seat force was designed and made using similar principle as stretcher v.2 sensor. A study with these sensors was presented in RBN 2002/05 (4).

2005 Gate v.4 and Stretcher v.3



Disadvantage of the previous gate v.3 design was necessity to remove the original pin during the installation, which is time consuming and may affect the gate settings. Also, it was not possible to use v.3 with new types of riggers with C-shaped mount of the pin.

This design v.4 can use the original pin on any rigger type, still able to adjust the pitch and measures 2D force: perpendicular and parallel to the oar shaft.

Disadvantage of the previous v.2 design of the stretcher was necessity to remove the inserts in the tube, which was not always possible.

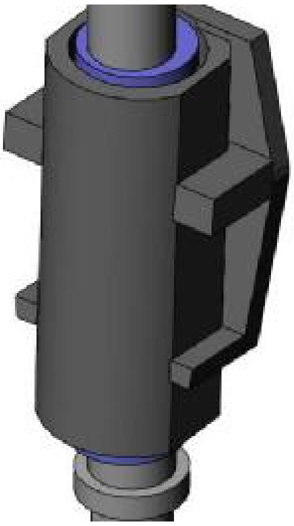
This is not required in this v.3 design, which makes installation much quicker. Three identical load cells measure 2D forces at three mounting points of the stretcher, so it is possible to define left-right, top-bottom and horizontal-vertical components of the stretcher force.

2009 Handle force v.3

This design is similar to v.2, but contains an amplifier inside the sensor body and has a connector instead of a cable, which is more convenient for rowers.

German FES design on the handle force sensor is very similar, but requires two clamps.

2011 Handle force v.4 and Gate v.5



Recently, we have developed a new v.4 wireless design of the handle force sensor. This makes it much more convenient to use and allows using it in other sports such as canoeing.

We plan to supply these sensors after exhaustive testing in the end of 2011.

A new v.5 design of the instrumented gate is also planned to be ready by the end of 2011. It is more compact than v.4, still allows pitch adjustment and measure 2D force relative the oar shaft. It can be used either with the standard 2D oar angle sensor or can have inbuilt gate angle sensor for more rower's convenience.

We also planning to redesign and rebuild the stretcher sensor and vertical seat force sensor. Please contact us on kleval@btinternet.com if you require more information.

References

1. Zatsiorsky, V.M., & Yakunin, N. (1991). Mechanics and biomechanics of rowing: a review. International Journal of Sport Biomechanics, 7(3), 229-281.
2. Kleshnev, V. (1988). Device for force measurement in rowing. USSR Patent 1650171
3. Haines, P. (2004). Force-sensing system. US Patent 7114398
4. Rowing Biomechanics Newsletters www.biorow.com