299. Indoor rowing machine with training data analysis system

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Abstract. Indoor rowing machines and training facilities for rowing are developed to simulate movements performed during the on-water rowing aiming to get results as close as possible to real rowing. The paper presents the novel indoor rowing machine equipped with loading measuring devices and software for training parameters recording and analysis.

Keywords: indoor rowing machine, loading unit, software

Introduction

Indoor training machines are widely used for exercising in rowing. The analysis of quality and results of training by these facilities is as important as improving the facilities itself. There is a need of in-depth research in the field.

It is very important to improve mechanical constructions making them close to real conditions as well as to design training data registering systems and computer programs for processing results.

The loading closest to real conditions is reached when the muscle load during indoor rowing is similar to the load during the real rowing process and relevant loading units are to be developed.

Another problem of the research is the shortage of means and tools which could permit to get information about rowing motions from the rowing machine and to analyze this information. To be sure that the training equipment reaches the expected results, we need a system consisting of a physical analog/digital converter, a personal computer and analyzing software that can help us to evaluate, analyze the obtained parameters and present them graphically [1].

The aim of this study is to present a novel indoor rowing machine with hydraulically simulated loading and training data register as well as a system consisting of dynamo-graphical and processing equipment and software.

2. The rowing motion

The rowing stroke consists primarily of four phases: catch, drive, finish, and recovery. The way these four phases are sewn together determine the rhythm of the stroke. The catch is when the oar enters the water, the drive is when the rower applies force on the oar and the boat moves through the water, the finish is when the oar leaves the water, and recovery is when the oar returns to the catch position.

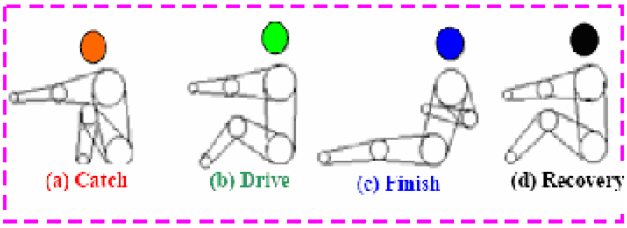


Fig. 1. Schematic diagram of rowing process

The schematic diagram of rowing process [2] showing the main sequential phases in a rowing stroke and the positions of the head, arm, and leg of the rower is shown in Figure 1.

These phases must flow from one into another to produce continuous movement. During the catch phase the hands are lifted, and the lower part of back is ridged. The catch movement includes shoulder flexion and stabilization of the back and hips. During the drive the knee and hip extend, the back remains firm, and the arms are drawn into the chest. The knee, hip, ankle, trunk, and shoulder joints extend during drive. The finish involves the final movements of the arm and trunk: back extension ceases, and the hands lower into the lap to extract the oar out of the water while the wrists flex. The recovery requires the hands to move away from the body back toward the stern of boat, as the hip, knee, ankle and shoulder joints flex.

The biomechanics of rowing is very complex, needing integration of the boat, oars and body motions [3], [4], [5].

3. Existing indoor rowing machine types and constructions.

There are the following basic components of an existing indoor rowing machine:

- a flywheel, to store the energy between strokes (simulating the boat momentum);
- a handle, attached to the flywheel via a chain and sprocket, or cable and pulley (simulating the oar);
- a damping mechanism on the flywheel (to simulate the water friction on the hull);
- a return mechanism (to simulate motion of the boat to front-stops).

The following models of rowing machines are popular:

Concept (also, *Concept UK*). This is an American mode (Fig. 2), which is mostly used as indoor training machine till now. Resistance in it is provided by air-damping. There are three types of the machines:

Fig. 2. Rowing machine *Concept*

Model A (1981). These have open bicycle wheel fitted with blades and load selected by putting chain around one of several gears. The main function of monitor is the indication of speed.

Model B (1986). Solid aluminum flywheel, load controlled by choice of *2* gears and damper setting. The monitor is much more sophisticated and calculates resistance dynamically by measuring deceleration of flywheel.

Fig. 3. Rowing machine *RowPerfect*

Model C (1993). Lighter and quieter than model B. Load controlled by lever position *1-10* (essentially a damper setting). Monitor works more precisely [6], [7].

RowPerfect a Dutch model (Fig. 3) is similar to Concept with one important difference: not only does the seat move back and forwards but so does in it the flywheel. This gives a better simulation of the rowing

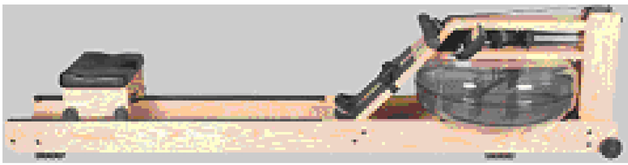


Fig. 4. Rowing machine WaterRower

stroke since the center of mass of the system remains in the same place. This also means that you get higher power scores and higher rate. Monitor works on the same general principle as the Concept.

WaterRower. A British model (Fig. 4) using a horizontal water-damped paddle which simulates the mass of rotating water constituting the flywheel rather than paddle itself.

Derrick Read *ROWEX* rowing machine from South Africa is a “sliding head” similar to *RowPerfec*t ergometer [8].

Gy-Ro - a British model, which differs from the other rowing machines by the application of electromagnetic damping, giving a different “feel” to air/fluid damping.

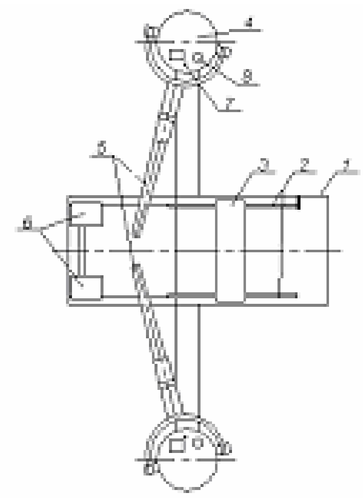
Kettler trademark have big variety of rowing machines. For example, *Kettler Cup* and the *Kettler Favorit* work by means of oar levers, while resistance is regulated by hydraulic cylinders. The *Kettler Kadett* operates with a characteristic outrigger design that simulates "real rowing" far more naturally than the basic machines. Hydraulic cylinders likewise produce resistance.

Comparing *Kettler Coach 2007* and the *Tunturi R 606*, as well as on the *R 610*, the *R 710* and the *Schwinn Windrigger*, rowing is done with a hand grip fixed to a cord. The movement performed on this indoor rowing machine is very similar to real one performed on water. The *Kettler Coach 2007* has a magnetic brake. *Tunturi R 610*, have an exclusive flywheel design and a magnetic brake that give one the feeling of real rowing. It is equipped with a *Polar* pulse receiver for telemetric pulse measurement [9], [10].

4. Novel rowing machine.

A novel indoor rowing machine is proposed which is different from the existing ones: rowing is simulated by handles, a hydraulic cylinder with two chambers to get a closer feeling of real rowing and its characteristics as well as a possibility to regulate resistance. The experimental rowing machine and its scheme are shown in Figure 5.

a



b

Fig. 5. a) photo b) scheme of indoor-rowing machine: *1*- frame fixed to floor; *2*- rail; *3*- movable seat; *4*- loading unit; *5*- handle; *6*-foot plate; *7*- screws to regulate resistance; *8*- manometer

The loading unit consists of fixed and movable plates. The latter is equipped with holes; one of which is for smooth regulation and the second one for rough. Diameters of the holes are regulated by screws *7*. Twisting-off screw *7* holes become bigger and lubricant can easier access from one chamber into another, hence resistance is decreasing and the rower can row easier. When the screws are screwed, the load is increased. The loading unit is shown in Figure 6.

Fig. 6. Loading unit

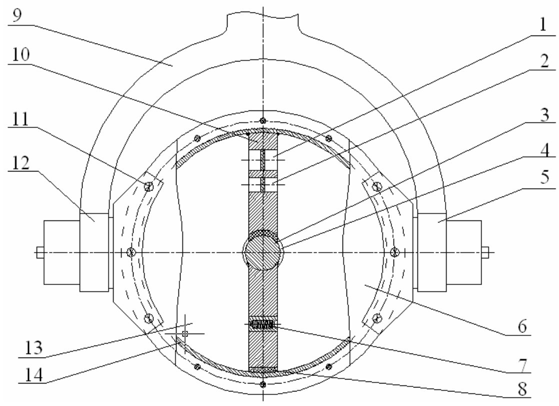


Fig. 7. Scheme of loading unit: *1*- rough regulation hole; *2*-smooth regulation hole; *3*- axle; *4*- bearing; *5*- bearing; *6*- frame; *7*- valve; *8*- gasket; *9*- handle; *10*- diaphragm; *11*- screw; *12*- bearing; *13*- oil; *14*- gasket

Tensometers and amplifiers were fastened to the loading unit and to the footplate of experimental rowing machine at points 4 and 6, and allowed us to get the data, listed in Table 1.

Table 1. Registered signals order and scale

Channel number	Signal designation	Scale
1.	Left hand force	1kG=50mV
2.	Right hand force	1kG=50mV
3.	Left leg force	1kG=25mV
4.	-	
5.	Seat force	1kG=10mV
6.	-	
7.	Left oar travel	1cm=5mV
8.	Right oar travel	1cm=5mV

The original computer program "Oars" is part of the rowing dynamo-graphical parameters research system. A full system scheme is shown in Figure 7.

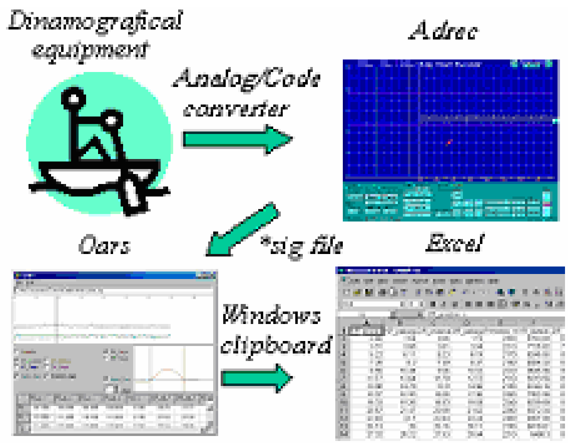


Fig. 7. General rowing dinamografical parameters research system structural scheme

The system consists of dynamo-graphical equipment, PC and mounted Analog/Digital converter. At rowing the dynamo-graphical data are registered, which with the help of the converter are saved into RAM. This is performed by *Adrec* program, which creates a special format data fail (conditional named *.sig type) on the hard disk. Therefore we use the original program "Oars", designated for rowing dynamo-graphical signal structural analysis and evaluation. The program allows us to receive the values of dynamo-graphical parameters, which can be transferred through *Windows* intermediate memory "Clipboard" into popular calculation programs (*Microsoft Excel*, *Sigma Plot* and etc.) to be summarized and analyzed.

The program requires a computer with *Intel Pentium*[tm] processor or higher, at least 20MB RAM and at least 6MB free space on hard disk. The program requires operational system *Windows 98*. Signals have to be registered as *Adrec* file format on eight channels, using Analog/Digital converter with sensitivity ± 5 V and discretisation frequency *100* Hz. Signals are registered into files arranged by order and scales as shown in Table *1*.

The program analyzes the structure of signals of registered oars, leg and seat forces, recognizes characteristic time moments (stroke start and finish) and measures dynamo-graphical parameters given in Table *2*.

Table 2

Serial Number	Parameter designation	Units
1.	Left hand stroke start	s.
2.	Left hand stroke end	s.
3.	Right hand stroke start	s.
4.	Right hand stroke end	s.
5.	Period	s.
6.	Max. left leg force	N.
7.	Max. seat force	N.
8.	Work performed by left hand	J.
9.	Work performed by right hand	J.
10.	Left hand power	W.
11.	Right hand power	W.

The registered rowing dynamo-graphical signals and characteristic points of their structures are given in Fig. 8.

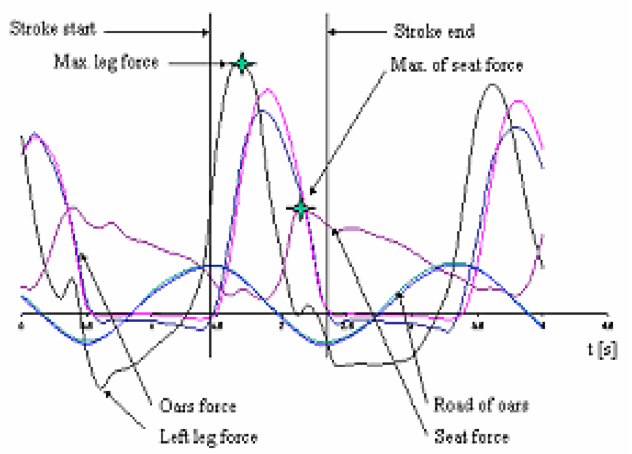


Fig. 8. Rowing dynamo-graphical signals and characteristic points of their structures

The program's window example is shown in Figure 9. With the help of *Open* function in *File* main menu we can select the signal's file and the program automatically executes the signal's structural analysis and evaluates parameters of all automatically found strokes. The results are given in the table shown in the lower part of the program's window. The changes in values of the evaluated parameters during the recording time are being presented graphically in the upper part of the program's window. The signal structural analysis quality can be controlled by the signal fragment, which can be found on the right side of the program, and correspond to one stroke. A particular stroke selection can be executed by a mouse click on the needed stroke parameter in the table row.

The obtained data allow us to determine the rower's personal parameters such as hand stroke, leg force etc. what is very important for defining compatibility of persons in rowing sweep. Also these data can help to organize personal training programs, to calculate the rower's load during training, to calculate different muscles group work during rowing, etc.

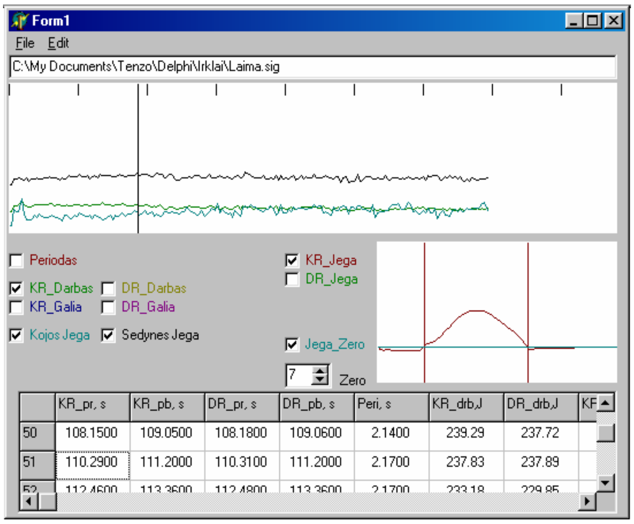


Fig. 9. Program "Oars" window: *1,2* – main menu points; *3* – currently considered file name and place; *4* – chosen parameter mark; *5*- time mark every minute; *6* – descriptive parameters choice; *7* – evaluated parameters table; *8* – zero signal setting; *9* - considerate stroke signal visualization choice; *10* – signal segment corresponded stroke

Conclusions

1. A novel rowing machine is suggested which is different from the existing ones by oar simulated handles, a hydraulic cylinder with two chambers and a possibility to regulate resistance.
2. The original dynamo-graphical and electronic equipment together with software *Adrec* and *Oars* permit to analyze the characteristics and parameters of the simulated rowing motions providing the information on stroke, period, force and performed work.

3. The use of PC is easily adaptable for the collection of the data on the motions of rowing machines and can be widely applied for the training of rowers and for medical research in the field of sport medicine.

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