ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

ASPECTS REGARDING PADDLE KINEMATICS FOR A SKIFF IN ORDER TO IMPROVE THE SPORTS PERFORMANCE

[1] Marin Chirazi, [21] Emil Budescu and [2] Eugen Merticaru
[1] ”Al. I. Cuza” University of Iasi, Romania; email: mchirazi@yahoo.com
[2] ”Gh. Asachi” Technical University of Iasi, Romania; email: emil.budescu@gmail.com, emertica@yahoo.com

SUMMARY
The paper presents some kinematic aspects of the paddle motion from a skiff, in order to improve the sports performance at canoeing sports. Thus, using the mathematical relations expressing the trajectory of a point of paddle, there are emphasized the geometrical parameters, depending on either the skiff tuning, or the technical abilities of the sportsman, that influence the velocity of displacement of the craft at an active stroke of the paddle. Numerical solving of the equations defining the craft displacement at an active stroke of the paddle, for different values of the geometrical parameters, puts into evidence the possibilities to increase the sports performance.

INTRODUCTION
The sports performance at canoeing depends on the amplitude of the paddle stroke, the force and the cadence developed by the sportsman, so that the speed of the craft to be maximum. The skiff used for canoeing allows some tunings that may lead to obtain sports performance. Thus, the simple tunings (the rudder bar tuning, the height of the crutch and the attack angle of the paddle) and "fine" tunings (the tuning of the distance between the crutches, the tuning of internal lever, the tuning of the crossing of paddles) have as effect optimization of the trajectory of paddle and the attack surface of the paddle.
The angle of the circle arc of the active and passive strokes depends on the motion of the sportsman in the skiff, respectively the motion of legs (which determines the motion of the mobile seat) and motion of arms. The bigger is this circle arc, the bigger will be the span of the arc of the end of the paddle in water, resulting a bigger displacement of the craft for an active stroke of the paddle.

METHODS
The kinematic analysis of paddle motion uses the analytical method of expressing the coordinates of some points onto the paddle, function of some constant or variable parameters. Thus, considering the case of a simple skiff (Figure 1), there can be defined the cartesian coordinates of points A and E (Figure 2) with respect to reference system (xOyz) with origin in O into the joint between the paddle and crutch and, also, with respect to reference system ($x_1O_1y_1z_1$) with origin in O_1 into the shoulder joint of the sportsman. Between the coordinates of point A with respect the two reference systems there can be written the following relations, taking into account the distances “a”, “b” and “c” between the two coordinate systems [1, 2]:

$$\begin{cases} x_A = x_{1A} - a, \\ y_A = y_{1A} - b, \\ z_A = z_{1A} - c, \end{cases}$$

where: a = a (t), b = constant, c = constant.
The speed of the mobile seat pushed by the sportsman during the active and passive strokes is:

$$v_c = \frac{da}{dt},$$

depending on the type of the sportsman motion.

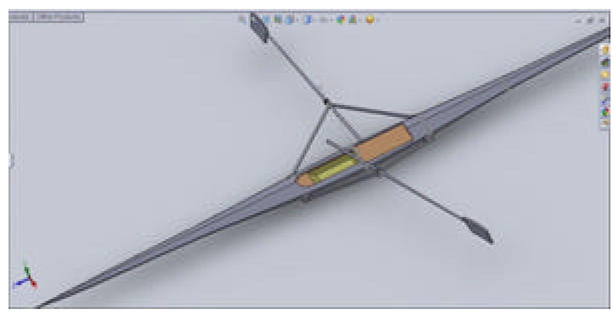

Figure 1: Virtual representation of a simple skiff

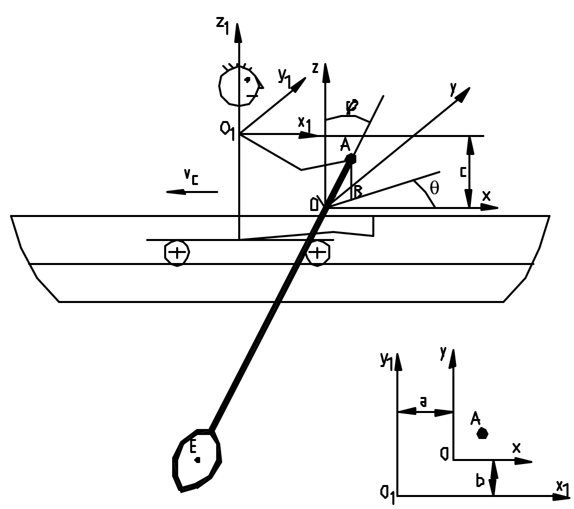

Figure 2: Definition of geometrical parameters

The coordinates of points A and E, written in spherical coordinates, are [2]:

$$\begin{cases} x_A = l_{OA}\cdot\sin\varphi\cdot\cos\theta \\ y_A = l_{OA}\cdot\sin\varphi\cdot\sin\theta \\ z_A = l_{OA}\cdot\cos\varphi \end{cases},\quad \begin{cases} x_E = -l_{OE}\cdot\sin\varphi\cdot\cos\theta \\ y_E = -l_{OE}\cdot\sin\varphi\cdot\sin\theta \\ z_E = -l_{OE}\cdot\cos\varphi \end{cases}$$

The angle "θ" defines the circle arc of the active stroke (identical with that of the passive stroke), and the angle "φ" defines the circle arc between the active and passive strokes (the angle under which the paddle, through point E, enters and exits from the water).

If the coordinates (x_{1A}, y_{1A}, z_{1A}) are known, then the angles f and ? have the expression:

$$\varphi = \arccos\left(\frac{z_{1A}-c}{l_{OA}}\right),\quad \theta = \mathrm{arctg}\left(\frac{y_{1A}-b}{x_{1A}-a}\right).$$

Derivating with respect to time the expressions of angles φ and θ, there can be obtained the frequencies of the motion during the active and passive strokes and, respectively, of extracting and inserting the paddle into the water:

$$\frac{d\varphi}{dt} = -\frac{v_{A_{z1}}}{l_{OA}\cdot\sin\varphi},$$

$$\frac{d\theta}{dt} = \frac{l_{OA}\cdot\frac{d\varphi}{dt}\cdot\cos\varphi\cdot\cos\theta - v_{A_{x1}} + v_c}{l_{OA}\cdot\sin\varphi\cdot\sin\theta},$$

where $v_{A_{x1}}$ and $v_{A_{z1}}$ represent the components of the speed of point A along the axes (O_1x_1) and respectively (O_1z_1) in the reference system ($x_1O_1y_1z_1$), and v_c represents the speed of the mobile seat.

RESULTS AND DISCUSSION

The sports performance was defined as the displacement of the craft for an active stroke, respectively the magnitude of the span (E_1E_2) corresponding to the arc described by point E during the active stroke of the paddle (Figure 3).

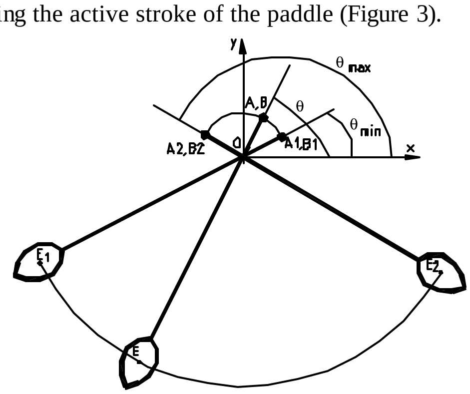

Figure 3: Defining the displacement of the skiff

Due to the possibility to choose a paddle with total length equal to 2.98 [m], 3.0 [m] and respectively 3.02 [m], the length l_{OE} was considered to be variable, with the extreme values 2.11 [m] and respectively 2.15 [m]. The values of the angle φ calculated for the position of point E into water, at the active stroke, is 85^0, and the angle θ is varying between 30^0 and 150^0, thus being defined the active stroke with an angular amplitude of 120^0.

The span (E_1E_2) is calculated with the relation:

$$E_1E_2 = x_{E_2} - x_{E_1},$$

where: $x_{E_2} = -l_{OE}\cdot\sin\varphi\cdot\cos\theta_{max}$,

$x_{E_1} = -l_{OE}\cdot\sin\varphi\cdot\cos\theta_{min}$.

For the values: $l_{OE_{min}} = 2.11$ [m], $l_{OE_{max}} = 2.15$ [m], $\varphi = 85^0$, $\theta_{min} = 30^\circ$, $\theta_{max} = 150^\circ$, the results for the span (E_1E_2) are given in table 1.

Comparing the results for length (E_1E_2) for the two values (OE_{min}) and (OE_{max}), given in table 1, there can be observed that the variable length of the paddle has, from kinematic point of view, a very small influence on the displacement of the craft during an active stroke, the value being of approximately 7 [cm]. But, if the frequency of motion of the paddle is taken into account, then the 7 [cm] are multiplied in a unit time, resulting an increase of sports performance.

CONCLUSIONS

From kinematic point of view, the parameters influencing the paddle kinematics and the sports performance are: the angles φ and θ, the lengths l_{OA} and l_{OE} for positioning the paddle into the joint O, the motion of mobile seat, given by a = a(t) and the constant dimensions "b" and "c", depending on the sportsman height. The detailed analysis of the influence of each parameter on the motion of craft, aiming to improve the performance, has effect on the sportsman training, through the modification of parameters "φ", "θ" and "a", sportsmen selection through parameters "b" and "c" and setting some position dimensions for the paddle, through parameters "l_{OA}", "b_E", "b" and "c".

Using the above analytical considerations, the trainer can analyze and intervene on the all mentioned parameters, to increase the sports performance.

REFERENCES

1. Budescu E., Iacob I., *Fundamentals of Biomechanics in Sports*, Sedcom Libris Publishing House, Iasi, Romania, 2005.
2. Ripianu A., et al., *Mecanica Tehnica*, Editura Didactica si Pedagogica, Bucuresti, Romania, 1982.

Table 1: The length of the span of the circle arc which defines the displacement of the craft.

l_{OE} [m]	f [°]	θ_{min} [°]	θ_{max} [°]	Length (E_1E_2) [m]
2.11	85	30	150	3.64072
2.15	85	30	150	3.709739