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Simulation of swimming posture based on CFD fluid

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Abstract

Swimming, as a regular sport with certain requirements for coordination, can not only play the role of exercise, but also a life-seeking skill when necessary. This paper mainly studies four basic swimming positions and draws the optimal swimming posture under different requirements, and establishes a model to provide pre-race guidance for athletes who take part in the freestyle competition by climbing.This paper establishes six degrees of freedom space to describe the position of motion, and use the DH parameters optimized Jacoby matrix to convert the motion into the power of the work of this parameter. Committed to find fastest in contrast and maximum thrust swimming posture, and based on an equivalent alternative to the maximum, the breaststroke thrust movement crawl fastest. In order to construct the climbing action guidance model for freestyle swimmers, the athlete model is established by using BJD-3D modeling method, and the resistance of the CFD technology is simulated in the fluid, the analysis concludes that the athlete should keep his five fingers close to his arms and palms when swimming.

Keywords

Jacoby Matrix; DH parameters; CFD; Ball-jointed Doll.

1. Introduction

Because swimming this sport requires athletes to complete the whole body multijoint collaboration, involving more variables, the following related content is introduced.

1.1. Jacoby Matrix

Jacoby matrix is a matrix conductor, in simulating joint motion, assuming that the rotation angle matrix of the joint is θ and the position matrix at the end of the joint is x,there is a functional relationship between the position parameter and the rotation parameter:

$$x = T(\theta)\theta \tag{1}$$

$$\dot{x} = J(\theta)\dot{\theta} \tag{2}$$

Where J(θ) is the Jacoby matrix, the Jacobean matrix can also be used for the inverse problem of the aesthetic problem.

1.2. Computational Fluid Dynamics(CFD) simulation

Computational Fluid Dynamics (CFD) simulation technology is applied to the process of calculating fluid mechanics, because it can approximate the integrals in the control equations in the control equations in fluid mechanics as discrete algetoric forms, and solve discrete equations through the computer, can clearly simulate the fluid flow details, momentum transfer and other processes, with low cost and high simulation accuracy advantages.

2. Models

2.1. Optimal swimming model

In this question, two optimal criteria are involved, the first focuses on speed and the second focuses on thrust, making the following models according to different qualification requirements.

2.1.1. The best speed model

(1) Parameter settings and relationships

The upper body joint of the athlete's torso is placed into six degrees of freedom space, with the athlete's center of gravity as the center, and the spatial vector of the athlete in the water is the largest C,The rotation parameters of the degree of freedom space are the angle θ of the athlete's water entry, the angle of the arm and torso, and the φ,distance is set to R.

Taking into account the impact of the athlete's track on the result, the distance from the athlete to the pool boundary is set to r, and the relationship between the parameters is estimated to be as follows, based on inverse motion to solve the simulated athlete's arm based on the Jacoby matrix:

$$\frac{c\theta_i}{r} = \frac{r^2 - c^2\theta_i^2}{2Rr} + \cos\varphi_i \ (i = 1,2 \dots M) \tag{3}$$

Where M is the number of subdivision intervals that simulate the rotation angle of the force arm in swimming.

(2) Work efficiency

In six degrees of freedom space, the upper is simplified by the numerical method of the DH parameter combined with the Jacobean matrix[1-2]:

$$^0_NT = \begin{bmatrix} n_e & o_e & a_e & p_e \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

On the basis of which the model of motion parameters is analyzed, and the formula obtained by the DH parameters is obtained to obtain the spatial force relationship of the athlete's body in the water:

$$K = \frac{1}{2}\sum_{i=0}^{M}[I_i\dot{q}_i^2 + m_i(\dot{x}_i^2 + \dot{z}_i^2)] \tag{5}$$

Among them, the dot letters are the result of the variable's movement distance within the slight change, and the whole system can be considered as the efficiency of the change.

(3) Landscape comparison

Through the force arm movement of the four swimming positions, a comparison of the power at the four same speeds can be obtained, and the comparison results are as follows:

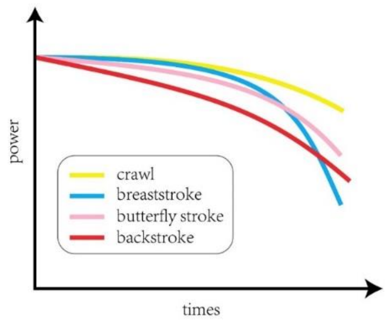

Figure 1: Power schematic at the same limit speed

According to the above illustration, it can be intuitively concluded that climbing has more power at the limit speed.

2.1.2. Thrust optimal model

(1) The determination of a position R

In the six degrees of freedom space established in the first question, according to the spatial planning of the simulated athlete's arm, the relationship between the momentum the therm and the momentum moment the theority can be obtained by moving the angle of the torso of the arm before and after movement.Through the upper integral, the movement direction R of the athlete can be obtained during a sports cycle R:

$$R = \frac{Mr^2 - c^2 \sum_{i=1}^{M} \theta_i^2}{2c \sum_{i=1}^{M} \theta_i^2} \tag{6}$$

(2) Compare results horizontally

Through the operation, in a cycle time, the four swimming positions get the moving direction R as follows:

Table 1: The moving distance of the four swimming positions in one cycle

	Backstroke	Breaststroke	Crawl	Butterfly
$R(m)$	1.84	2.92	2.52	2.66

Through the results show that the breaststroke is considered to be the most thrusting swim.

2.2. The establishment of the climbing simulation model

In order to further improve the athlete's posture to improve the speed, the overall state of the athlete's swimming position is described using the BJD model, and the resistance of the model in water is analyzed by CFD.

2.2.1. BJD-3D model

In order to complete the humanoid simulation, a female model with a height of 179cm, a weight of 63kg, a chest circumference of 84cm, a waist circumference of 61cm and a hip circumference of 90cm is constructed.

3D models are constructed in a variety of ways, because the model is close to human mechanics, the choice of BJD human simulation model.[3-4]The models based on the physical condition of the model are shown as follows:

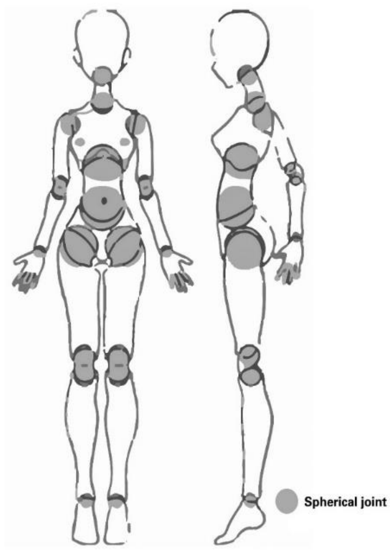

Figure 2: BJD builds a model diagram

Next, use the constructed model to describe the posture of the climb.

2.2.2. 3D model fluid mechanics analysis

(1) Grid division

In the process of simulating fluid motion, in order to analyze the fluid environment accurately, the space is divided precisely, the division should reflect the details of its own changes, but also can include enough molecules to reduce its uncertainty, the formation of the mesh covering the object itself. The division schematic is as follows:

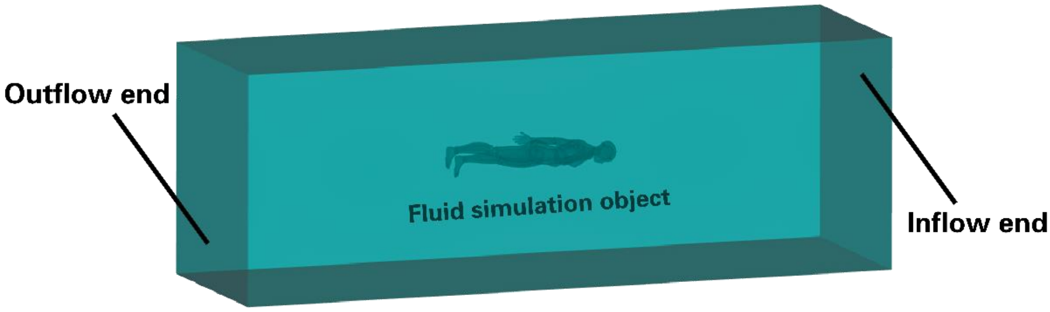

Figure 3: Grid division schematic

(2) Fluid mechanics is stressed

After the grid, the object can be described by many infinitesimal. Through each infinitesimal force of end resistance and can be integrated to the whole lift.

(3) Resistance solution

During the analysis process of water resistance and speed during short-distance swimming, the force of athletes in water can be analyzed[5], the formula after decomposition is as follows:

$$D = \frac{1}{2} C_D \rho A v^2 \tag{7}$$

$$L = \frac{1}{2} C_L \rho A v^2 \tag{8}$$

The C_D and C_L in the decomposition formula are the water resistance coefficient and the lift coefficient, which add up the projection of the lift and the resistance in the forward direction, and the thrust of the swimming is known. By CFD technology, the resistance coefficient, which is difficult to determine through the simulated environment, is shown in the CFD simulation diagram of the model as a whole as follows:

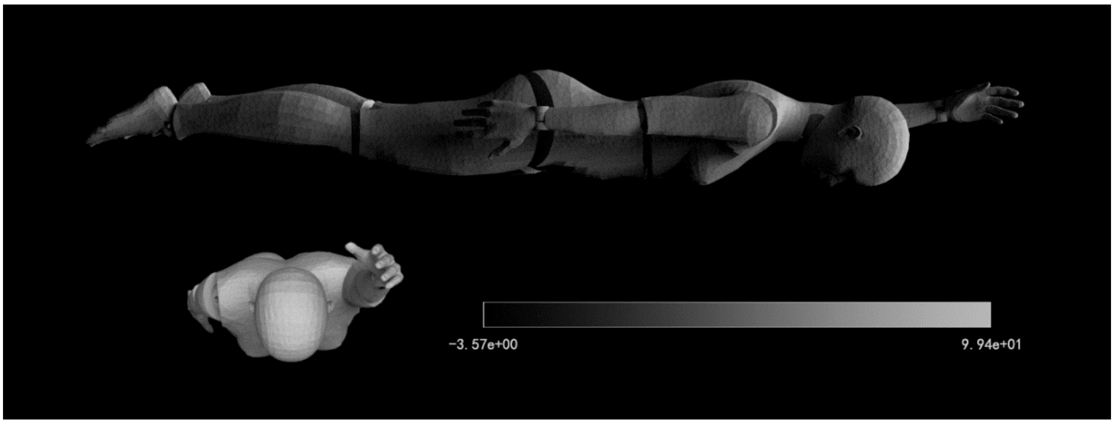

Figure 4: CFD simulation model diagram

Next from the body parts of the analysis, combined with the specific body form of the resistance to swimming, to get the minimum resistance when the body's form, and as a reference for athletes exercise.[6]

The palm of your hand

For the analysis of palm movements, refined to the angle of the argument, the angle of the corner can be from the following illustration.

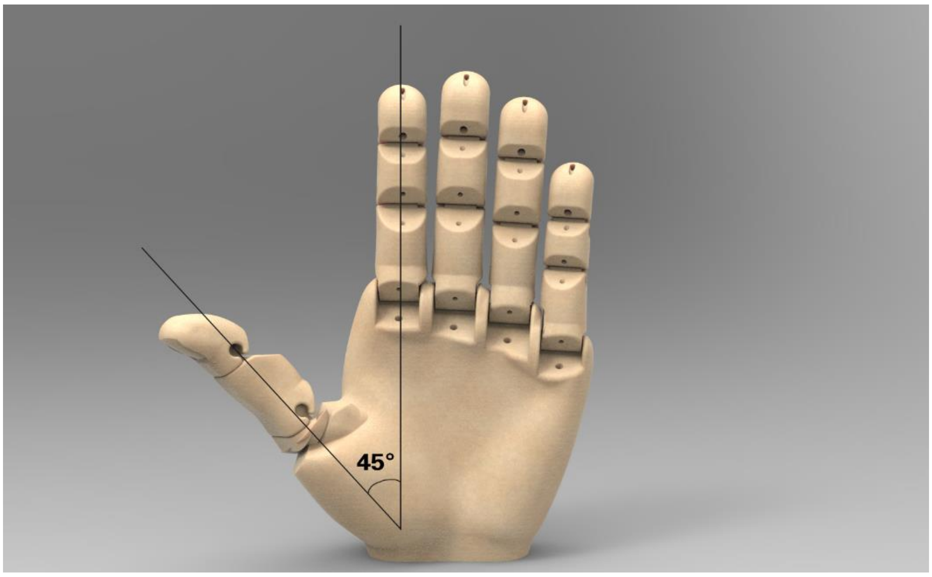

Figure 5: Palm models and angled signs

Take the angle of the welcome, respectively,0°, 30°, 45°, 60° and 90°, to obtain the corresponding resistance, lift parameters, for the different angle parameters.It is concluded by the model that when the angle is close to 0 degrees, the resistance is minimal and can be considered as a standard climbing position.

Arm

For the analysis of arm movements, refined to the parameter of rotation angle, the rotation angle can be represented from the following illustration.

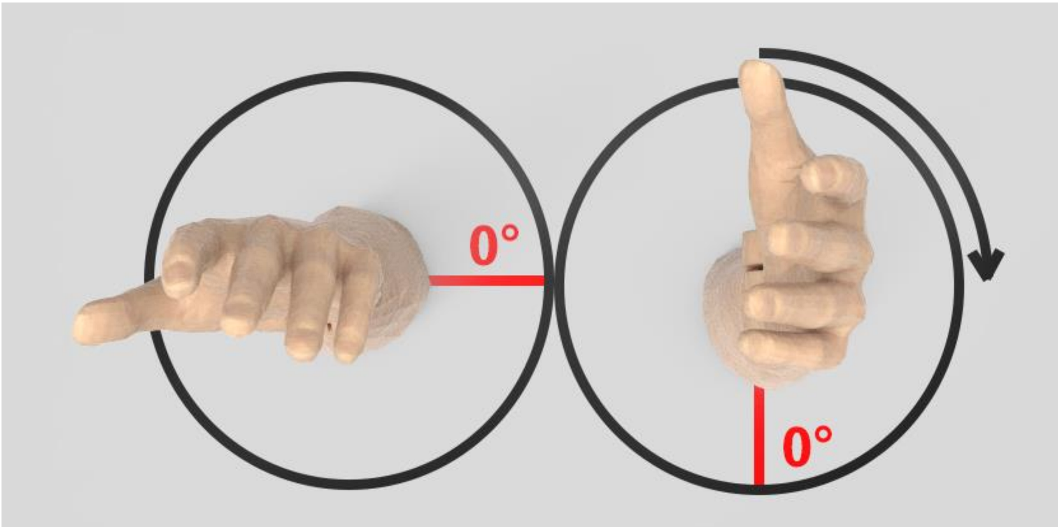

Figure 6: A diagram of the rotation angle of the arm

Take the rotation angles of 0, 30, 45, 60 and 90 degrees, respectively, to obtain the corresponding resistance, lift parameters, for the different angle parameters.It is concluded from the model that when the rotation angle is close to 0 degrees, the resistance is minimal and can be considered as a standard climbing position.

3. Conclusion

3.1. The fastest swim

At the highest limit speed, the most stable position of power change is climbing.

3.2. The swimming position with the greatest thrust

In a sports cycle, so that athletes produce the largest change in spatial vector swimming posture for breaststroke, combined with breaststroke action can be further verified, because of its long water stroke time, so the storage time is more full.

3.3. Guidance on the training of athletes for freestyle

Climbing as the fastest swimming posture, suitable for freestyle racing, in the pre-race training should pay attention to the body parts of the standard degree of movement:

The thumbs should be close to the other four fingers.

The arm tries to avoid rotating the word itself and remains at the same angle as the palm of the hand.

The torso should be close to the flow type, pay attention to control the shoulders, hips and other joints prone to angle changes.

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