

# Creative Design and Manufacture of a New Type of Boating and Exercising Machine with Energy-Saving

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**Abstract:** It designs and manufactures a new boating and exercising machine, which uses a optimized four-bar mechanism as a active bar to simulate the boating movement, adopts the ratchet wheel to realize the continuous rotating of the resistance system, increases the output shaft's speed by the gear system, designs a flywheel to adjust speed fluctuation and energy store and release, transmits the energy generates from boating movement to the shaft of motor which linked with a storage batteries, thus realizes the energy-saving. This boating exercise machine operates convenient and reliable, which has the strengthen body function generates from boating movement and energy-saving function, so it worth market popularization and application.

**Keywords:** boating and exercising machine; drive system; reverse design; energy-saving

## 1. Investigation of Existed Boating and Exercising Machine in the Market

### 1.1. Analysis of Boating Movement

Boating movement, such as gigs, is the exercising items on the water. The athletes take the quant as lever in boating, so makes the gig moves back toward the athletes. When boating, each movement such as bend and extend of arms, can make about 90 percent muscle into practice, especially for the back side of body. At the same time, boating movement can prompts the body's heart and blood vessel and breathe system function, enhances the muscle energy, adjust the nerve system balance, so it does well for the bodies healthy.

The boating and exercising machine simulates the boating movement so that helps people exercise without go out.

### 1.2. Product Analysis in the Market



The boating machine is a new type exercising machine, there are several types boating machines. Most of them use the air pressure box to support the movement resistance, according to the number of air pressure box; it can be divided into single and double air pressure box boating machine. The performance analyses of existed products are listed in sheet 1.

After earnestly comparison and analyze for the above products, it can be draw that they have three main disadvantages:

- 1) The track of hand in exercising is arc, can't simulate the boating movement factually.
- 2) The force on the handle changes with the boating behavioral small, and can't reflect the real property of the boating---pull back with bigger force while push forward

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Practical and new type patent: 200920165008.8

Sheet 1. Performance analysis of existed product

Existed products	Performance analysis
	Double air pressure, slide bar, the height can't adjust, can withstand big push or pull force, long lifetime, the moving track is arc, the force in movement is static.
	Single air pressure, slide orbit, the height can't adjust; the moving track is arc, single construction, easy to transit and storage.

with little force.

- 3) The energy generates from the movement can't be callback.

## 2. Design Plan of Boating and Exercising Machine

### 2.1. Total Design Method

Based on the above investigation and analysis, designing and manufacturing a new type of boating and exercising machine, its construct is as figure 1.

Based on the characteristic of boating such as ellipse track, push forward with bigger force while pull back with little force, adopts reverse thought to determine each function realization of the boating system, adds the energy-saving part to it, the electrical machine not only provides resistant moment, but also save the electrical. Energy generated in boating movement to save energy. The overall design method of the system is as figure 2.



Figure 1. Configuration figure of boating and exercising machine with energy-saving

## 2.2. Optimum Design of the Active Mechanism

The boating movement can be divided into four procure:

into the water, thrash, out the water, back the oar. The track of hand when boating likes a declining, flat and Long ellipse, so it can be simulated and realized by a certain dimension four-bar mechanism. And the four-bar mechanism has the characteristic of fast-back, this tallies with the real boating characteristic which is slow in thrash while quick back, so here uses the four-bar mechanism as the active mechanism[1].

Designing a crank and rocker mechanism and making its output track are approximately a declining ellipse. Reference to the mechanism optimum method of machine and mechanism theory, it sets up the mechanism optimum model of a linkage mechanism which can trace the demanded track.

According to a common people's parameters such as height, weight and arm length, gets the 10 coordinates which must be accurately traced by the mechanism, as listed in sheet 2. (Unit:  $\varphi_{li}$ -radian,  $\bar{x}_i$ 、 $\bar{y}_i$ -mm).

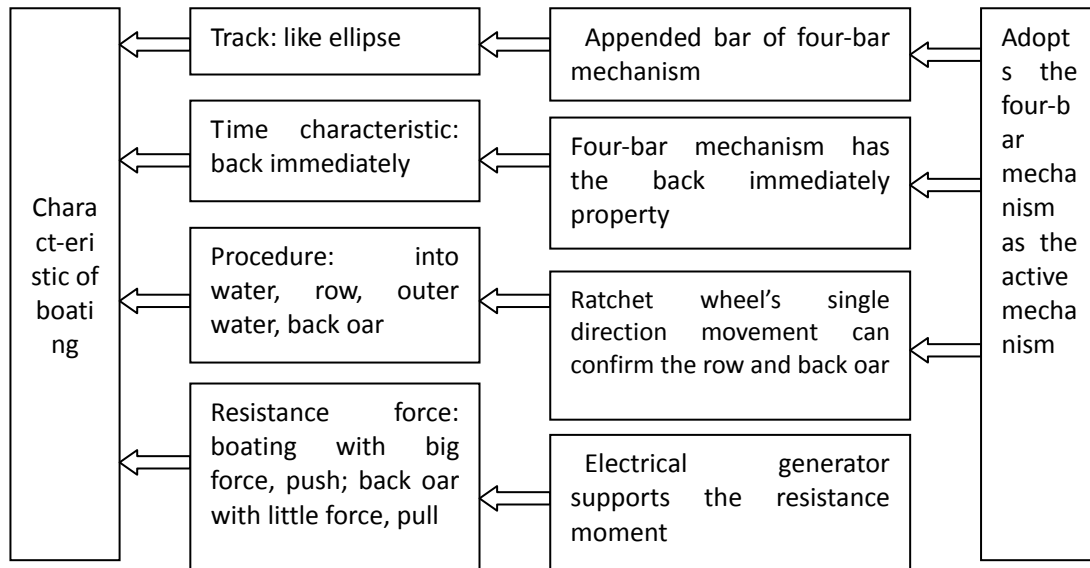


Figure 2. Integrated design of boating and exercising machine

Sheet 2. The 10 coordinates which looks like an ellipse and must be traced in moving

	1	2	3	4	5	6	7	8	9	10
$\varphi_{li}$	0.6283	1.256	1.885	2.513	3.141	3.769	4.398	5.026	5.654	6.283
	2	6		3	6	9	2	5	9	2
$\bar{x}_i$	642.71	492.7	307.2	157.2	100	157.2	307.2	492.7	642.7	700
		1	9	9		9	9	1	1	
$\bar{y}_i$	523.51	538.0	538.0	523.5	500	476.4	461.9	461.9	476.4	500
		4	4	1		9	6	6	9	

Design parameters:

$$X = [x_1, \dots, x_5]^T = [\varphi_{10}, b, c, d, \gamma]^T, \text{ in which,}$$

$\varphi_{10}$  is the angle of crank AB and horizontal line; while  $b, c, d$  is the length of linkage BC, rocker CD and

machine frame DA;  $\gamma$  is the angle of appended-bar and its linkage.

The aim function:

$$\begin{aligned} \text{Min} F(x) = & \sum_{i=1}^n [x_a + a \times \cos(\beta + x_1 + \varphi_{li}) \\ & + k \times \cos(\varphi_{2i} + x_5) - \bar{x}_i]^2 \\ & + \sum_{i=1}^n [y_a + a \times \sin(\beta + x_1 + \varphi_{li}) + k \times \sin(\varphi_{2i} + x_5) - \bar{y}_i]^2 \end{aligned}$$

In which,

$$R = \sqrt{a^2 + x_4^2 - 2ax_4 \cos(x_1 + \varphi_{li})}$$

$$\varphi = \arctan \left[ \frac{x_4 \sin \beta - a \sin(\beta + x_1 + \varphi_{li})}{x_4 \cos \beta - a \cos(\beta + x_1 + \varphi_{li})} \right]$$

$$\varphi_{2i} = \varphi + \arccos\left(\frac{x_2^2 + R^2 - x_3^2}{2x_2R}\right)$$

Restrain conditions:

$$\text{The condition with crank: } \begin{cases} a + x_4 \leq x_2 + x_3 \\ a + x_2 \leq x_3 + x_4 \\ a + x_3 \leq x_2 + x_4 \end{cases}$$

The boundary condition:

$$\begin{cases} 100 \leq x_2, x_3, x_4 \leq 1000 \\ 0 \leq x_1, x_5 \leq 2\pi \end{cases}$$

For the above math model, uses matlab optimize tools to get the results[2] by its constringency,  $X = [x_1, \dots, x_5]^T = [\varphi_{10}, b, c, d, \gamma]^T = [1.27, 603.40, 537.49, 520.37, 0.46]$ . Validates the simulation results and gets the mechanism which meets the design requirements. The four-bar mechanism is as figure 3.

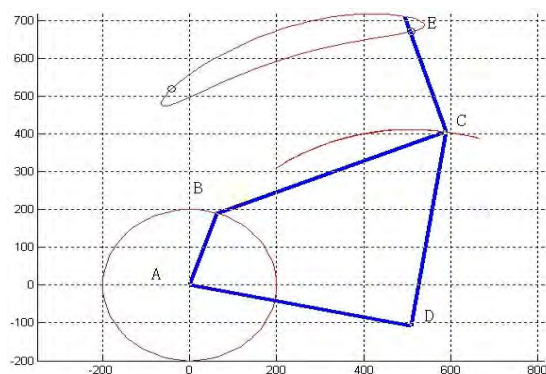


Figure 3 Final design figure of four-bar mechanism

The dimensions of four-bar mechanism are listed in sheet 4. (The mechanism unit is mm)

Sheet 3. Dimension of four-bar mechanism

parameter	AB	BC	CD	DA	$L_{CE}$	$\angle BCE$	The angle of bar AD and horizontal line
value	200	570	520	520	320	95°	-12°

In which, bar CE is appended-bar and fixed with bar BC; the thin curve is the track of the hand in movement. Because there will be dead center position in four-bar movement, this problem can be solved by add moment of inertia on the axis which connects the crank and the inertia will overcome it.

### 2.3. Design of Drive System

After selecting the drive mechanism, according to the design method, designs three grade gear system as the

drive system, as in figure 4.

Sets up a ratchet wheel on the small gear of the first grade, for the force appended by the hand in boating makes the rocker reciprocating swing, but the ratchet wheel can only moving in one direction, so uses the ratchet wheel to distinguish the pull procedure and push procedure. In pull procedure the pull force drive the chain wheel and chain bar to rotate the resistant mechanism, while in push procedure, because of the effect of ratchet wheel, the resistant mechanism can't move. This plan realizes the resistant mechanism continuous and single direction moving, so to make the direct-current motor generate electricity, and at the same time accords with the characteristic of boating movement.

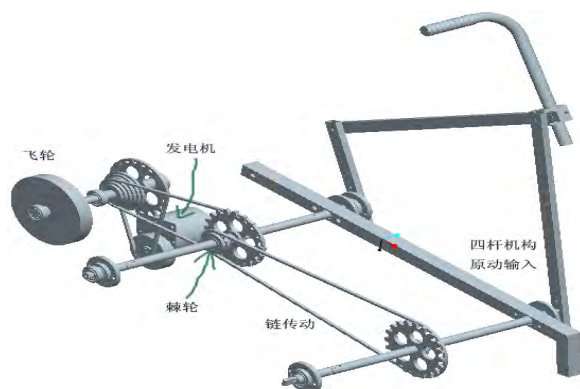


Figure 4 Design plan of drive and effector mechanism

Designing a fly-wheel on the small axis of the second grand gear, aims to adjust the speed fluctuation generates from the four-bar mechanism's reciprocating swing, and also can save and release the system energy.

In the third gear drive, small gear makes the motor spindle rotating, the resistant force generates from the motor electromagnetism moment, so the pull force overcomes the resistant force by drive mechanism to produce energy, so the user can exercise his body.

### 2.4. The Design of Energy-Saving

In the end of boating machine drive system, adopts direct-current motor to support electromagnetism resistant moment. In boating and exercising, the drive system works and makes motor rotating, so generates the electrical energy. Here designs an energy-saving apparatus, transits the energy into electricity-storage. The electrical energy stored can not only used on display of the boating and exercising machine, but also can be used in other cases, so as to save energy.

### 2.5. Setup of the System

In the design it uses the Pro/E software in modeling, and finishes its movement simulation to assure no interference in moving. In assembling the part strength

should be ensured. The practical operation is robust and reliable, proves the design plan is reasonable.

### 3. Result

Based on the existed boating and exercising machines in the market, do some creative designs on it: 1)Adopts four-bar mechanism as active mechanism to simulate the track of the real boating movement; 2) uses ratchet wheel and multi-rank gear system to realize the system continuous moving and electrical energy generating; 3) designs flying wheel to balance the speed fluctuation and kinetic energy save and release of the whole system; 4)at last realize the energy callback of the exercising, and

finish the model manufacturing.

The boating and exercising machine not only realizes the boating and body exercising function, but also has the function of energy-saving. In practical, it has the characteristics of easy operation, high robust and low cost, so it worth popularization in market

### Reference

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- [2] Liu Weiguo. Matlab program design. Chinese Water Conservancy and Water Electricity Publication. 2006.1.