DESIGN AND DEVELOPMENT OF THE EMBEDDED CONTROL SYSTEM FOR INTELLIGENT BICYCLE TRAINER BASED ON ELECTROMAGNETIC BRAKING

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Abstract: Traditional bike trainer mostly use mechanical way to control resistance, it has the disadvantages of single function, complex resistance control, low intelligence and lack of fitness index, so that it can not meet the needs of the market. In view of the shortcomings of the traditional bicycle device, the electromagnetic brake principle is used to carry on the design and development of intelligent bicycle trainer based on the embedded control system. Firstly, the resistance braking device based on the principle of electromagnetic brake are designed to achieve no friction, no wear and no noise cycling resistance control; secondly, the hardware of the embedded control system for bicycle trainer is completed by designing resistance control circuits, sensor interface circuits, power circuits and other circuits, which select the ARM LPC1114 chip as the core. Then, the software system of the embedded control system for bicycle trainer is designed. Real-time operating system RTX is used as the main framework for program design, and multi-mission design methods are used to design and realize Bluetooth communication, brake drag control, acquisition and conversion of speed and other function modules. Finally the function and performance testing for the embedded control system for intelligent bicycle trainer are carried on and it turn out to be that the trainer can adjust the resistance in real-time and wirelessly, collect and calculate the heart rate, body-building time, real-time speed and riding distance. Therefore it can meet the requirements of design and the needs of various types of body-building of users, monitor and analysis the fitness motion data so as to allow users to access the data of fitness information. Compared to traditional bicycle trainer, the design increases the intelligence level to some extent.

Keywords: Electromagnetic braking; Intelligent bicycle trainer; Embedded control system; Continuously-variable resistance adjustment

1. Introduction

Bicycle trainer is a kind of indoor fitness equipment derived from outdoor bicycle. Almost all traditional bicycle trainers have no user controller or display interface, so it is inconvenient for the collection of motion signals [1], the quantification of training indexes [2], the access of proper training focuses. With resistance control system and inertial system [3], modern bicycle trainer can keep the running steps steady. It also increases the function of digital display for manifesting the motion data (such as velocity, time, distance, speed, etc.) in order to ensure scientific training. In addition, it can be added into debugging armrest and seat to meet the physiological index of people.

At present, the Chinese bicycle trainer market is mainly dominated by pedaled bicycle trainer [4-6], and its training posture varies from traditional vertical riding to horizontal riding. There also appears in the market the hand-operated bicycle trainer with alternating mode of movement, which uses both hands to drive so as to shift the exercise muscles from lower limb to upper limb [7,8].

The separate-type intelligent bicycle trainer is the main research object, whose users is relatively larger than others’, and the portable characteristic is suitable for family use. However, as the majority of Chinese enterprises is engineering works in low electronic level, China lags behind other nations in making bicycle trainer, whose resistance braking of bicycle trainer is simple mechanical adjustment, failing to achieve the interaction of fitness data between wireless control and PC or handheld devices, so it can only be called unintelligent bicycle trainer. In view of the above problems, the research on the design and development of the embedded system of portable bicycle trainer is carried on. The intelligent bicycle trainer is developed by combining multiple technologies such as mechanical design, motor control, embedded system, the electromagnetic brake, and the control algorithm.

2. Overall design scheme

The function indexes of the overall optimization design is based on the function of existing bicycle trainer, and the overall system framework includes body-
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The embedded bicycle trainer is studied emphatically. The structure of the control system of the embedded trainer is showed as figure 1:

![Fig.1 The structure of the control system of the embedded trainer](image1)

3. Hardware and software design

3.1 Resistance braking device

With electromagnetic brake device for main brake resistance mechanism, the bicycle trainer mainly utilize the magnetic field and its corresponding permanent magnetic field to generate the closed magnetic lines of force, then the eddying effect generated by inner metal plate in closed magnetic field hinder its rotation, resulting in braking effect [9,10]. As the bike speed increases, the speed for flywheel driving aluminum plate increases at the same time, thus the efficiency of cutting magnetic field becomes higher and creates large eddying current, which interacts with magnetic field can generate enhanced braking resistance.

Electromagnetic brake resistance structure is shown as figure 2, the magnetic control group mainly composes of an electromagnet, permanent magnet and aluminum plate. The staggered design of permanent magnet N-S can produce a large number of closed magnetic induction lines, and the corresponding electromagnetic can again increase the closure degree of magnetic field, and draw magnetic line [11].

![Fig.2 Electromagnetic braking resistance device](image2)

The aluminum disk in the research uses directly the plane structure, with the gap between the upper and lower magnetic field is only 2.5mm, making the maximum contact area of the closed magnetic field.

3.2 Hardware design of embedded system

The structure of hardware module of the embedded bicycle trainer is shown as Figure 3. The design of control board achieves docking with the supervisory controller, the wireless control of resistance and stepless adjustment. It can also improve the quality of fitness and experience effect of users through all kinds of sensors detecting the their-body-building situation, riding distance, and time.

(1) Master module

The structure of system control circuit for bicycle trainer based on electromagnetic braking is shown as figure 4. The bicycle trainer needs external power 36v, and all its peripherals are operating around the ARM minimum system.

![Fig. 3 The structure of hardware module design of the embedded bicycle trainer](image3)

![Fig. 4 Structure of system control circuit](image4)

From the above analysis it can be seen that the master module chip in this study chooses the single chip from ARM series and LPC1114 chip from Cortex-M0 series. The minimum system based on LPC1114 chip mainly controlling the circuit is one of the core circuits of the design, and the microprocessor controls the function of resistance braking module and Bluetooth communication data transmission and etc.

The main control program of the research is carried out in the Keil uVision3.0 platform, so we need a interface circuit to upload the the host computer program to the minimum system. As the JLINK interface elements have existed, and the JTAG normally needs 20 pins, while the JLINK SWD requires only 4 pins, so we selected SWD serial communication to save pins.

(2) Bluetooth module

The CC2541 Bluetooth module based on Bluetooth...
protocol 4.0[12] (see Figure 5) is selected in the research, compared with the traditional Bluetooth, it has greater data transmission rate and transmission distance and lower power consumption. CC2541 chip can make the whole system run correctly at a low power consumption, and the dormant state of extra-low power consumption is available on this basis.

![Fig. 5 CC2541 chip based on Bluetooth 4.0](image)

(3) Velocity test module

Hall sensor is most popularized for velocity test in bicycle field, whose testing precision can fully meet the requirements [13]. The sensor is placed within the bicycle trainer in the research, so we can embed a permanent magnet in the rotating flywheel, above which the Hall sensor will be installed in the corresponding location.

The magnetic field will be cut when the sensor near a magnet, then the output will be high, otherwise the output will be low[14,15]. The wheel rotation velocity can be calculated through the time and number of processing pulses appearing in single-chip microcomputer. However, the rotate speed of central spindle is relatively quick in the actual process of riding, so too small set number of laps may cause large errors. In order to improve the accuracy of research, we set up a calculation formula of 10 turns, the calculation formula is shown as below:

\[
 v = \frac{s}{t} = \frac{2\pi R \times n \times 10^2}{t} \times 3.6
\]

R represents the bicycle spindle radius, t represents clock timing and n represents the number of laps, of which 3.6 represents the coefficient when the velocity unit is converted to Km/h.

(4) Resistance control module

The resistance of the bicycle trainer is regulated by the output of the PWM of master module, as the single chip microcomputer can not directly control the circuit on-off [16], the switch drive circuit is designed instead. The switch drive circuit makes use of the on-off action of power transistor, resulting in large current but small pressure drop when the device is on, and low current but big pressure drop when the device is off, thus leading to smaller power consumption and higher efficiency. The control circuit is shown as Figure 6 and Figure 7.

![Fig. 6 Relay control circuit](image)
Except for above functional modules, the power management module and other expansion modules would not be described here.

### 3.3 Software design

The software development environment is in Keil uVision3.0 platform (software interface shown in Figure 8), mainly realizing wireless communication between supervisory controller and single chip, and the collection, conversion and transfer of the data such as velocity, temperature and other information. The software system adopts the RTX system as the main framework, utilizing the system clock and extra system timer to design the allocation and interrupt of priorities of task in system.

Assigning properties of system task: the system timer defaults to the highest priority, the next is the serial communication task and braking control task, and the last is other remaining tasks.

4. The realization and test of the bicycle trainer

After designing the hardware of bicycle trainer, we need draw the control panel. The schematic diagram is drawn by using the design tools of the software principle diagram, then generating the corresponding grid table. If the components to be used did exist in original standard principle gallery, you can draw the principle diagram by yourself according to the pin and size of required component. After that, we will lead the diagram into the PCB environment and sent to the manufacturer for the plate making, then according to the corresponding element for the welding. The effect of the embedded control board is shown as in figure 9. We will burn the designed program into the SCM and Bluetooth chip for performance test. In order to ensure the signal effect of Bluetooth, we will choose the contact pin to overhead the Bluetooth chip.
The test bench is composed of dynamometer and trainer, the function of the former is to test the output power supplied for bicycle trainer, and the latter include esembedded bicycle trainer and bicycle. Road bike is the best choice, for the friction between its small tire and the trainer is not too large, so as to allow users to experience more resistance change effect. After many tests, the data obtained is shown in table 1:

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<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
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From the data in Table 1, the low speed PWM gear and the output power were divided equally into basic consistent, showing a linear distribution. With the increasing riding speed of users, however, the braking resistance represents non-linear growth, thus the absolute average could not meet the requirements for the resistance, so the design should not only divide equally the brake resistance within the normal speed range of body-building of most users, but also consider the gear options of riding resistance. After continuous debugging, the bicycle trainer based on the electromagnetic brake achieves a more stable system control, the stable Bluetooth connection and communication, the uniform distribution of braking resistance gear and etc, thus improving the intelligence of the bicycle trainer.

5. Conclusion

The main design is the indoor training platform of the embedded bicycle trainer, and its low cost and easy fixation can meet the needs of different users and improve the intelligence of bicycle trainers. The whole system realizes continuously - variable resistance adjustment in detailed way, allowing users to access the data of fitness information and comfort of the experience effect. Moreover, some problems of design appearing in the process of debugging, such as hardware defects leading to system instability, the distribution of brake resistance gear and etc. After continuous debugging, the entire system becomes stable.

6. References


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