Bulgarian Chemical Communications, Volume 49, Special Issue K1, (pp. 228 – 232) 2017

Double motor intelligent control system for industrial agitation based on Kingview and single chip microcomputer

Y.J. Wang[1*], K.Y. Wei, H.H. Liu

Department of Electronics Information Engineering, School of Electronics and Information Engineering, Liaoning University of Technology, Jinzhou, China

Received September 7, 2017, Accepted December 20, 2017

To overcome the uneven stirring problem of a conventional single motor and meet the high stability requirements in pulping process of semi-solid alloy slurry, a double motor intelligent control system based on Kingview and single chip microcomputer (SCM) is designed. The system mainly includes the motor and its driving circuit, the power circuit, speed and voltage current detection circuit, Kingview and SCM control system. The double motor operation can be controlled effectively so as to achieve precise control of the agitating speed. The proposed method is illustrated through the preparation of a semi-solid alloy slurry in the laboratory. The experimental results show that the system can precisely match the double-motor speed and achieve better results than a single motor stirring system.

Key words: Intelligent double motor control system, Pulping process of semi-solid alloy slurry, Kingview, Single chip microcomputer.

INTRODUCTION

The metal semi-solid processing technology in industrial stirring is to directly shape the solid-liquid slurry where the spherical primary solid phase is uniformly suspended in the liquid metal mother liquor. As an advanced metal processing technology in the 21st century, it is provided with the advantages of high efficiency, high energy saving and high molding performance. Extensive research has been conducted on the effects of external factors such as microgravity fields, electromagnetic fields, and ultrasonic fields on the microstructures during solidification [1-4]. Although the kind of agitation affects the microstructure and its rheological properties, these methods cannot make an ideal cracking effort on the dendrite fracture mechanism in fact. Some industrial agitation preparation technologies cannot meet the needs of industrial production in automation control system, stability and reliability. Considering the important role of intelligent control in industrialization and semi-solid processes, a double motor intelligent control compound agitation method is proposed. The method can greatly improve the stability, reliability and operability of automatic control in industrial production. The mixed slurry can be fully stirred to achieve an accurate control.

Based on the motor parameter detection, a double motor control system combining the Kingview interface with SCM is designed. The three-phase phase shift voltage regulator circuit is used to drive the rotation of a three-phase motor and a three-phase stator magnetic field. The lift control is realized by a DC motor [5-7]. The motor parameter detection and control system mainly includes computer configuration control, SCM control system, signal acquisition circuit and motor drive circuit. The motor drive circuit adopts H-bridge structure to control the steering, speed and other functions of the motor by receiving control commands given by the control system. The SCM control system uses STM32F103ZET as core microprocessor so as to realize the closed-loop control of the motor combining with PI algorithm. By connecting with the configuration software interface of the computer, the control of the motor parameters is achieved.

OVERALL DESIGN OF THE SYSTEM

The control system consists of a motor and its driving circuit, a power circuit, speed and voltage current detection circuit, Kingview and SCM control system. Since the controlled object in the agitation system usually has large inertia and hysteresis characteristics, the proportional plus derivative controller is used to improve the dynamic characteristics of the system in the process of adjustment. The speed of the motor can be measured by the infrared laser receiving module, the working voltage and current can be measured by the pressure flow detection module, and the measured physical quantity is fed back to the control module. The overall design scheme is shown in Figure 1.

*To whom all correspondence should be sent:
E-mail: wyj_lg@163.com

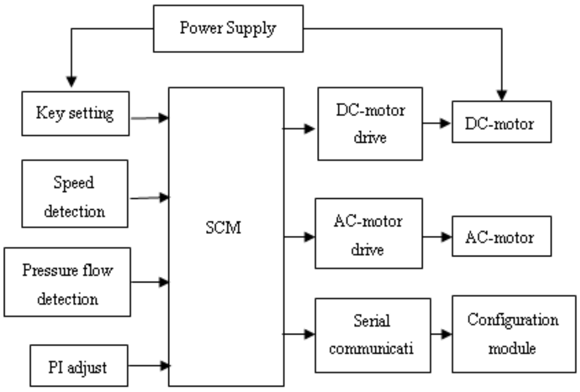


Fig. 1. Overall design block diagram.

HARDWARE DESIGN

Single-chip microcomputer system

Figure 2 shows the minimum system of a single chip microcomputer, in which the two capacitors connected to the 8 MHz crystal oscillator are ceramic capacitors, which is convenient for the oscillation of the crystal oscillator. Considering the noise problem, the SCM STM32F103ZET is contrary to the traditional C51 SCM [8-9], hence the low level reset is used.

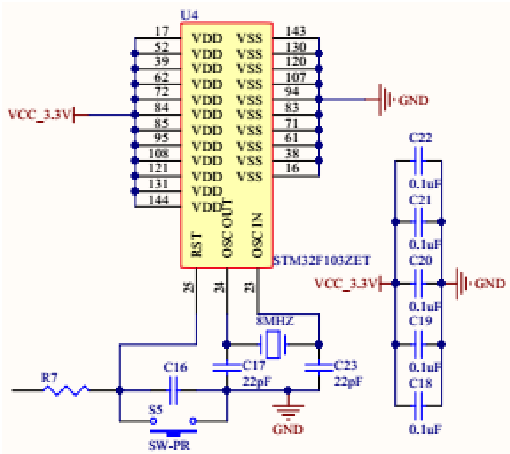


Fig. 2. SCM minimum system.

Three-phase AC voltage regulator principle

Three-phase AC voltage regulating circuit adopts wireless star connection mode, and the load is pure resistive load. Each phase must be connected with another phase in the conduction time. Hence, it is same as the three-phase bridge full-control rectifier circuit, there are two thyristors in the current flow path. Therefore, double pulse or wide pulse trigger should be used. The three-phase trigger pulse should be followed by a difference of 120 degrees in turn, and the trigger pulse of two anti-parallel thyristors in the same phase should be a difference of 180 degrees.

The phase shift angle is controlled by the potentiometer output voltage. Potentiometer output voltage is 0~5V. The corresponding three-phase voltage regulator circuit output voltage is 0~380V. Meanwhile, it is used to control the three-phase stator at the bottom of the agitator so that alternating magnetic field is generated with it, and by the corresponding control, the stirred object is in the opposite direction of the magnetic field generated by the three-phase stator at the bottom, so that it is fully stirred.

Figure 3 is a waveform diagram of the trigger pulse when the conduction angle of the upper and lower anti-parallel thyristors in the same phase is 60 degrees in the three-phase phase shift voltage regulator circuit, where the abscissa is time (sec), and the ordinate is signal output, high level is 1. Each thyristor turns on 120 degrees, and the two thyristors trigger pulses differ by 180 degrees.

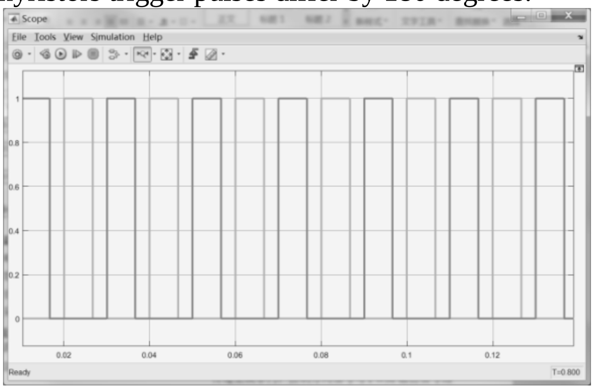


Fig. 3. Trigger pulse waveform.

The DC motor driving circuit

The control signal outputted by SCM is transmitted to the NOR gate through the high-speed optical coupler so as to control direction signal and PWM output signal to produce a certain logic output through the hardware. The logic signal is used to control the direction of the motor by controlling diodes D2, D6, and D3, D5, as shown in Figure 4.

The corresponding logic output signal timing diagram is presented in Figure 5. When DIR is low level, the corresponding waveform can be monitored at point A, while point B is low level. When DIR is high level, point B outputs the PWM waveform.

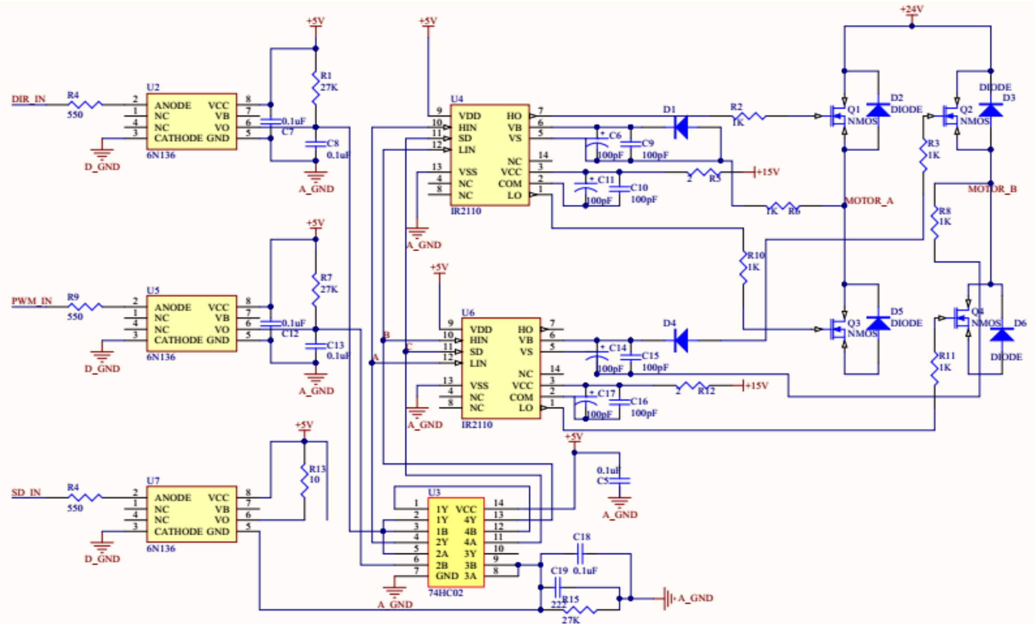


Fig. 4. DC motor driving circuit.

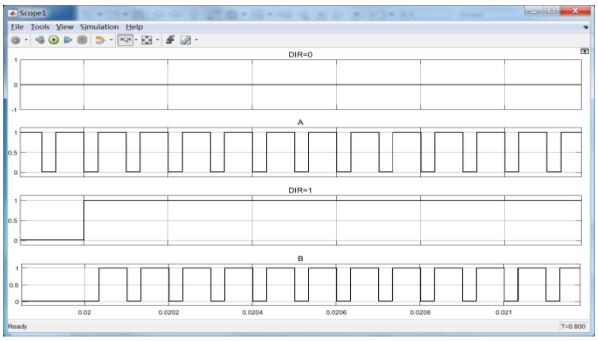


Fig. 5. Timing diagram.

Speed and pressure flow detection principle

The speed detection is measured by the reflective photoelectric sensor KM15/16. In the case of accurate positioning, the symmetrical installation of multiple reflective pieces or reflective stickers on the measured parts will acquire better measurement results. When the reflective sticker on the rotating part passes through the photoelectric sensor, the output of the photoelectric sensor output will change once, and the speed can be got by measuring the change frequency. The pressure flow detection uses the bidirectional and high-precision current sensor ACS712 in which there is a high precision linear hall sensor circuit. The current is linear with its output voltage, and the response is extremely fast. The pressure flow detection circuit is shown in Figure 6. The current is sent to pin 3 and 4 of the ACS712. The sine wave outputting from the seventh pin is filtered through the half-wave rectifier filter which can output the DC voltage signal. Since the input impedance of the A/D detection side of STM32F103ZET is low, the voltage signal after rectifying and filtering will have a large fluctuation, which has a great influence on the detection accuracy, hence, the voltage follower is added at the A/D input terminal.

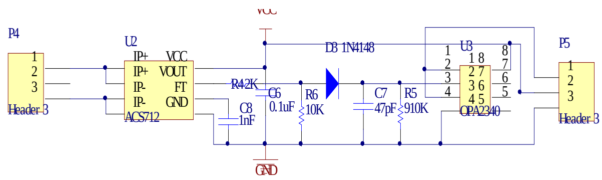


Fig. 6. Pressure flow detection circuit.

SOFTWARE DESIGN

Programmable controller (PC) design

Production control ability can be improved by using Kingview software monitoring system. The communication parameters of Kingview should be consistent with the SCM [10]. The monitoring interface is shown in Figure 7, the corresponding control information can be outputted through the button on the interface, and the serial port transmits the information to SCM. The actual operation of each part is controlled through the processing. The parameter settings of Kingview and SCM must be matched. The PC on the read and write operations sends different instructions to the SCM by using serial port communication. The lower-computer receives the instructions and returns to the PC according to the corresponding read and write command format.

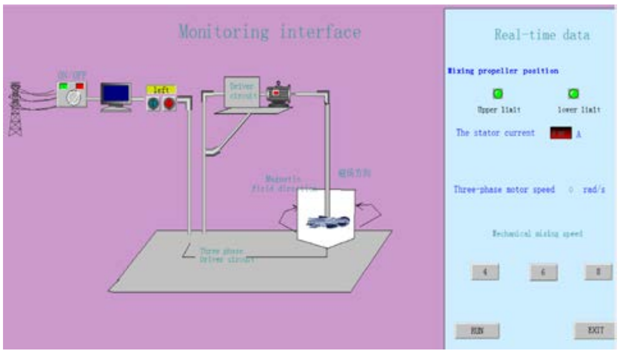


Fig. 7. Monitoring interface.

If the operation is abnormal, the lower-computer should send corresponding instructions, hence it is clear that the operation of the whole system can be observed through the PC.

SCM system software design

First, each module is initialized. According to the initial speed and direction, determine whether the speed reaches the predetermined value, and use the PI algorithm to achieve a constant speed. Then call the subroutines to determine whether the current exceeds the rated value so as to protect the motor and the circuit. The main program flow diagram is shown in Figure 8(a). Figure 8 (b) shows the speed flow diagram. I/O interface initialization and module configuration are implemented. The main program will call the speed detection subroutine at regular intervals. In order to achieve high accuracy, the multi-measurement average method can be used.

PI algorithm

Using the digital PI control, the expression is:

$$u(k) = K_p \times \left\{ e(k) + \frac{T}{T_i} \times \sum_0^k e(j) + \frac{T_d}{T} \times \left[e(k) - e(k-1) \right] \right\} \qquad (1)$$

With the increment PI, the output value at the (k-1) sampling time is:

$$u(k) = K_p \times \left\{ e(k-1) + \frac{T}{T_i} \times \sum_0^{k-1} e(j) + \frac{T_d}{T} \times \left[e(k-1) - e(k-2) \right] \right\} \qquad (2)$$

Equation (3) is obtained by subtracting equation (1) from equation (2).

$$\triangle uk = K_p \times [e(k) - e(k-1) + \frac{T}{T_i} \times e(k) + \frac{T_d}{T} \times [e(k) - 2e(k-1) + e(k-2)]] \qquad (3)$$

The equation (3) is simplified

$$\triangle uk = A \times e(k) + B \times e(k-1) + C \times e(k-2) \qquad (4)$$

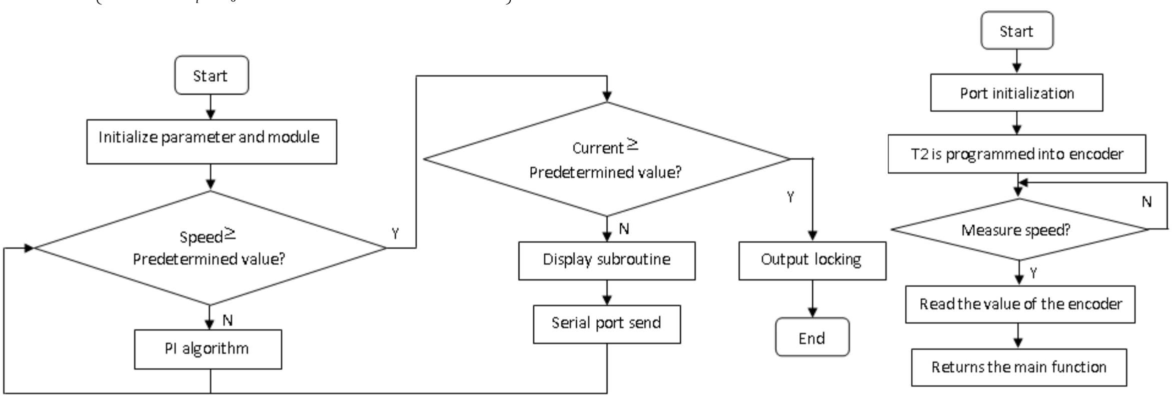
From the equations listed above, if the sampling period is given, once A, B, and C are determined, the amount of control can be obtained as long as the deviation value of the three measurements. Since A, B and C are determined by the load, their values are determined by the specific conditions in different load conditions.

EXPERIMENTAL RESULTS

The DC motor driving circuit requires that the output voltage should be always stable at 24V. In actual measurement, the power supply circuit can output 24V stably no matter whether the output is connected to the load, and the design requirements are satisfied. Meanwhile, the drain-source voltage of MOSFET is measured. The bus voltage is 350V, the reset voltage is 120V, the peak voltage is 120V, and the peak voltage of drain-source is 584V, all of which are within the voltage range of the MOSFET, it meets the design requirements.

The control system is used in the preparation of A356 semi-solid alloy slurry in the laboratory. Motor speed test results: when the current is 2-3A, the speed can reach 180-300 rpm; when the current is 3-4A, the speed can reach 300-700 rpm, which meets the design requirements of 300-500 rpm in preparation.

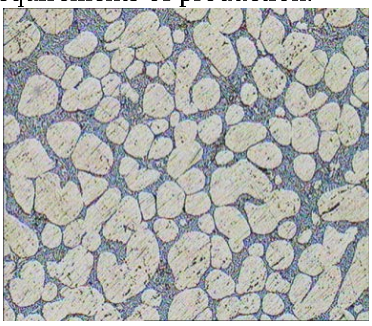
The A356 alloy melt with temperature of 650ºC is poured into the pulp chamber with a temperature of 400 ºC .The direction of rotating magnetic field produced by electromagnetic stirrer is opposite to that of homogeneous stirring rod.



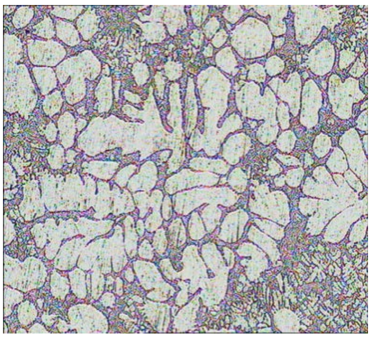
(a) Main program flow diagram (b) Speed flow diagram

Fig. 8. Software flow diagram.

The input power of the electromagnetic stirrer is 2.5 Kw, the frequency is 20Hz, and the rotation speed of the homogeneous stirring rod is 400 r/min. When preparing the slurry, the stirring direction of electromagnetic stirrer and homogeneous stirring rod is changed periodically at 5-15 sec intervals. The semi-solid slurry of A356 alloy is obtained until the alloy melt temperature reached 600 ºC, and the preparation time is 5 min. Finally, the semi-solid A356 alloy ingot is used as the raw material of the thixotropic shape. The prepared slurry water quenching microstructure is shown in Figure 9(a), qualified grain microstructure is obtained, which can be directly put into the die casting machine, extruder machine or forging machine for direct forming, and can also be cooled to get the semi-solid A356 alloy ingot as a thixotropic forming raw material. The slurry water quenching organization by using a single mechanical stirring is shown in Figure 9(b), which is composed of a large irregular near spherical primary phase and scattered but still directional dendritic crystal. In practice, it does not meet the requirements of production.



(a) Water quenching microstructure of double motor agitated slurry.



(b) Water quenching microstructure of single mechanical agitated slurry.

Fig. 9. Water quenching microstructure of slurry.

CONCLUSIONS

The double motor intelligent control system can realize strong and uniform agitation, and the monitoring interface can display the agitating speed, working current and commutation conditions in real time. The PC monitoring interface, SCM control system and motor driving circuit can effectively coordinate the operation, and can realize the accurate control of motor rotation speed and the accurate matching of speed between the two motors.

The agitation control system is suitable for the preparation of aluminum-based alloy and its composite semi-solid slurry or ingot. It is also suitable for the preparation of other non-ferrous metals and their composite materials, as well as ferrous metals and their composite semi-solid slurries or ingots.

Acknowledgements: *This work was supported by National Natural Science Foundation of China (No.61503169) and the Natural Science Foundation of Liaoning province (No. 2015020102).*

REFERENCES

1. B. Yucel, *Mater. Sci. Engin. A*, **528**, 5636 (2011).
2. J.E. Felix, U. Joachim, *Chem. Engin. Technol.*, **39** (7), 1251, (2016).
3. R. Ortega, A. Van Der Schaft, F. Castanos, A., Astolf, *IEEE Trans. Automat. Contr.*, **53** (11), 2527 (2008).
4. A.J. Hugo, Agitation and Fluid Mixing Technology. Chemical Reactor Modeling, Springer International Publishing Switzerland, Springer, Cham, 2014.
5. D. Casadei, M. Mengoni, G. Serra, A. Tani, L. Zarri, *IEEE Trans. Ind. Appl.*, **46** (4), 1436, (2010).
6. A.A.E. Abdulrahman, B.M. Rosbi, *Procedia Engin.*, **41**, 420, (2012).
7. M. Rahul, K. Tejbeer, *Int. J. Advan. Engin. Sci. Technol.*, **8** (2), 291, (2011).
8. M. Liu, J. Yu, H. Liang, *Instrum. Techn. Sens.*, **5**, 95, (2010).
9. G. Peng, Z.Q. Qin, Application practice of embedded microcontroller based on ARM Cortex-M3 STM32 series. Beijing: Electronic Industry Press, China, 2011.
10. L.F. Yang, J. Yuan, W. Liu,, X.M. Nie, X.L. Pei, *Appl. Mech. Mater.*, **121**, 3195, (2012).