Design on Robot Electrometrical Control System

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Abstract. This paper uses robot as study object, implements development of overall design plan of this robot, designs software and hardware system of ARM controller, designs idea of software under LabVIEW environment, gives flow process chart of procedure operation, establishes electromechanical control system of the whole fatigue machine and simulation, analysis model. In addition, it simulates close-cycle control way on system under MATLAB environment, simulation result indicates that speed close-cycle control strategy is feasible, and design is reasonable.

1. Introduction

With the development of modern electronic and information technology, computer science, modern sense technology and control technology, robot can implement or assist in implementing more and more tasks[1.2,3] that completed by human. In fields such as building, manufacturing, military, transportation and medical treatment department etc, the traditional technology has profound changes under penetration by scientific technology, accompanies with the emergence of much more advanced production way. The electrometrical structure of robot may be the combination of multi-bit stepper motor, D C motor controlled by multi-bit PWM and motor of AC frequency conversion. As for control machine, the number of control equipment is too large. In the complicated task, motor(such as steppe motor, servo motor) use by robot usually requires high timing accuracy, for example, motor control may include advanced motion model, such as variable motion, timing motion, rotation of fixed angle as well as quick and accurate switch of these models.

This paper makes study and analysis on force transmission structure of spot-weld fatigue tester, it provides theory base for equipment model selection of fatigue tester and control system design. In the aspect of controller development, it designs software and hardware system of ARM controller, including hardware circuit, software design method etc, as well as introduces commissioning method of system software and hardware. This paper establishes simulation and analysis model for electrometrical control system of fatigue machine, makes simulation on open-cycle control and close-cycle control way of the whole fatigue machine as well as makes analysis on simulation result in details.

2. System Overall Design Plan

2.1 Flow chartof system structure

According to function division of spot-weld fatigue machine, system is mainly composed of 2 parts:

1）Control part: it mainly includes upper monitor, controller, motor driver etc. The upper monitor receives data transmitted from serial port by controller, at the same time sends control signal to controller. Motor driver transmits motor current and speed signal to controller, at the same time receives motor control signal of controller.

2）Motor part: it includes motor, reducer, ball screw etc. Motor provides force moment; reducer enlarges it and converts rotational motion into rectilinear motion moved upwards and downwards by screw ball. From physical pictures we know that screw moves downwards, it will push tension on welding spot, target of this control system is to control this tension and higher accuracy.

Flow chart of electrometrical control system for weld-spot fatigue machine is indicated by diagram 2.2

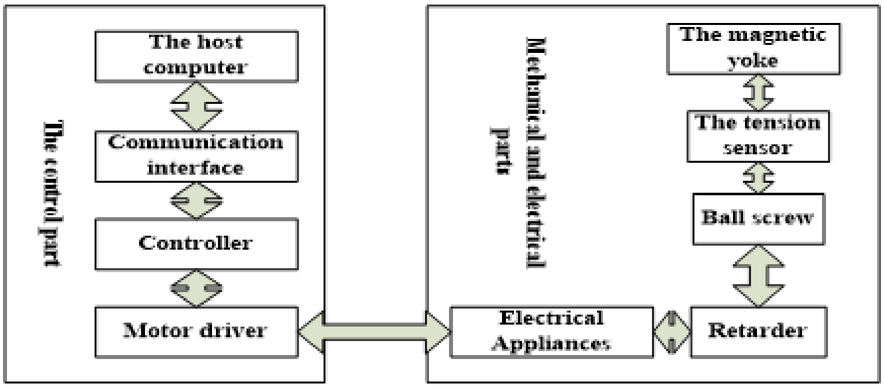


Diagram 1 Flow chart diagram of electrometrical control system

2.2 Hardware choice

Model selection of motor is considered from performance index of system, motor is the important part of fatigue machine control, system index requires output torque of fatigue machine is 100N, speed ratio of reducer designed by system is 4, suppose output force of ball screw is F, screw lead is L, output torque of reducer is T, reducer efficiency is , then we can get formula of output torque from power conservation:

$$T_m = FL/(2\pi i\eta\eta_1) \qquad (1)$$

In the designed system plan, screw lead is 2mm, then the efficiency of ball screw is relatively higher, suppose =0.95，transmission efficiency of reducer η_1=0.7, gets output torque of motor through calculation Tm=46.4 mN.m, so output torque of motor can be at least reduced to 46.40mN.m, under the operation state of motor, total torque of the current-carrying conductor on armature winding formed in magnetic field is regarded as magnetic torque of motor.

$$T = \frac{PN}{2\pi a}\phi Ia \qquad (2)$$

In the formula, ϕ is flux per pole，Ia is armature current，unit is A。N is the overall conductor number of armature winding, a is parallel branch number of motor, p is pole pair number of motor.

So it uses DC brush motor of RE30 series in Switzerland Maxon company，this motor adopts coil rotor and high-performance permanent magnet material as well as rare metal brush, motor diameter is 30mm, power is 15W. It has big torque coefficient and higher reliability.

Driver choice is chosen and calculated according to formula (3), the voltage is 14V, and this system adopts switch power of 24 V.

$$Vcc \geq [\frac{Un}{n0}(n+\frac{\Delta n}{\Delta M})\frac{1}{0.98}]1 \qquad (3)$$

Model selection of controller chooses ARM chip of STM32F207VGT model as system controller, under CPU frequency as high as 120MHz, when program is operated in the Flash memorizer, it can realize operation performance equivalent to zero waiting state. It has already sued CoreMark basic test to make demonstration on this performance, this system adopts SH 6 2R ball screw of Switzerland SKF Company, its nominal diameter is 6mm, and lead is 2mm.

3. Control Design of Upper Monitor and Lower Monitor of System

3.1 Circuit design of controller hardware

STM32F2 series processor has 3 12 simulation ADC and 2 simulation DAC, of which ACD1 and ACD2 have as many as 16 external sampling channels, these 2 external set with strong functions can reduce hardware design load of system, the system adopts ARM of STM32F207 model as controller. The circuit of voltage conversion and DAC circuit are indicated by diagram 2 and diagram 3.

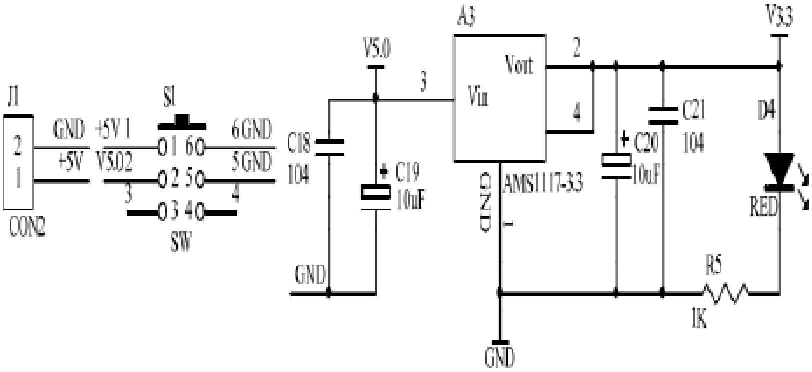


Diagram 2 Voltage conversion circuit

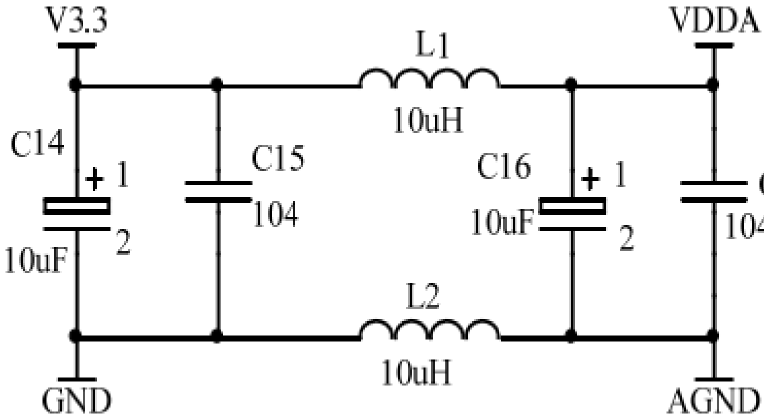


Diagram 3 Voltage conversion circuit of digital simulation

In the diagram 2, J1 is power switch connector, S1 is power switch, after power is on, and super-digits are lighted. It uses AMS 1117-3.3 chip to convert power of 5V voltage into digital voltage of 3.3V. Diagram 3 uses filter circuit of pi model to convert digital voltage of 3.3V to simulated voltage of 3.3V. Electric capacity of 10uF is used to reduce frequency noise.

The circuit of serial port converts to USB protocol is indicated by diagram 4: we use PL2303HX chip to convert serial port protocol to USB protocol. The effect of D5 is to prevent USB from supplying power with AMS1117-3.3 to switch power at the same time.

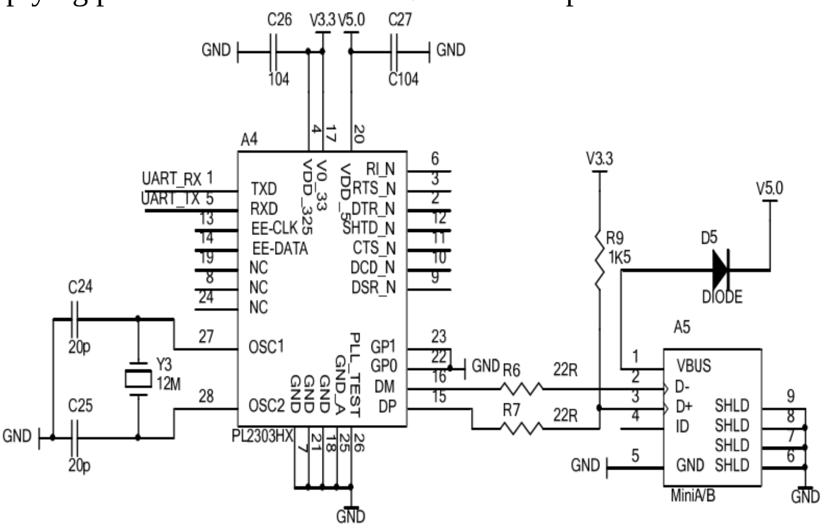


Diagram 4 Circuit diagram of serial port converts to USB

3.2 Design of controller program

Function of ARM controller mainly has 2 aspects: the first is main program design, including signal collection, control signal output and other auxiliary program. The second is design controller as well as communication protocol of upper monitor and corresponding program. Operation flow chart of ARM program is indicated by diagram 5.

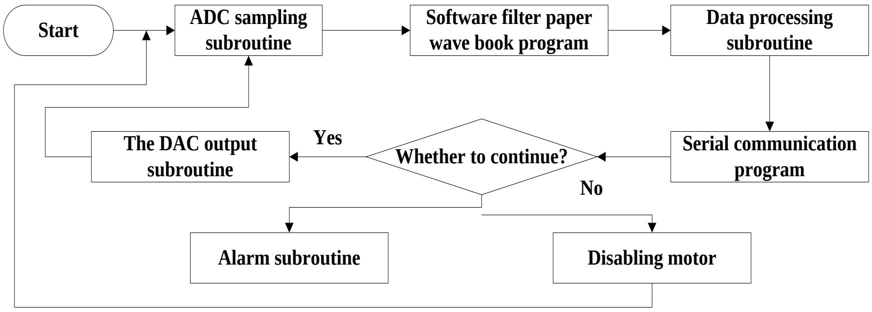


Diagram 5 Flow chart diagram of ARM main program

Communication module of serial port is responsible for serial port communication of RS232 between controller and upper monitor, it is operated under full duplex to complete data receive of serial port, data transmission of serial port. The lower machine needs to transmit the collected signal to upper monitor, when signal collection is completed, ARM will make package of collected signal according to given communication protocol and transmit to upper monitor. It establishes buffer area of 12 bytes in the controller and variable with length of 16, storage of variable value is speed value of binary system, it will be filled into buffer area after converting it to speed value of decimal system according to form of sending data packet, then uses printf function of redirection to input character of this buffer area into serial port, transfer UART SendDta function to send to upper monitor. Its flow chart diagram is indicated by diagram 6.

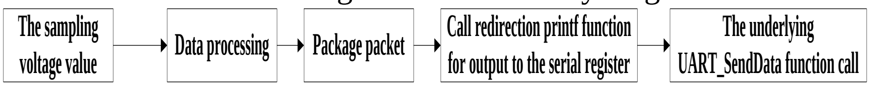


Diagram 6 Flow chart diagram of data sending

3.3 Overall deisgn principle chart of upper monitor

The overall design principle chart of upper monitor is indicated by diagram 7:

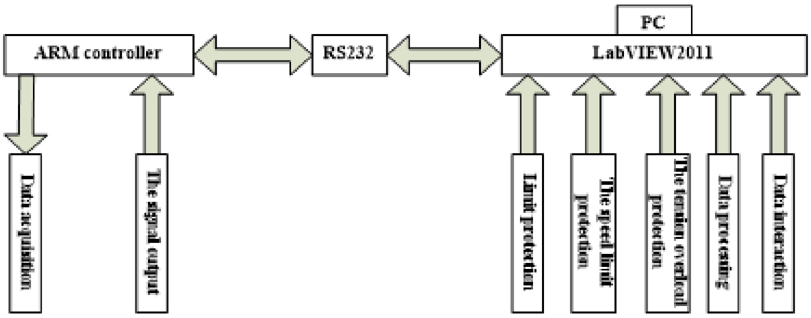


Diagram 7 Overall principle chart of system software design

When using LabVIEW Real-Time module to make software programming, we can realize cyclic code enforcement by using Timed Loop and simple configuration. Timed Loop can set plenty of cyclic enforcement priorities; in addition, users can choose kHz, mHz or self-defined external time to be used as the base time of cyclic timing. It just needs to establish one Shift Register in the timing cyclic module, its effect is to store position signal of motor and has accumulation function, and the initial setting of Shift Register is as follows:

4. Modeling Design and Simulation of Electrometrical Control System

4.1 Modeling of electromechnical control system

In modelling of this chapter, we consider quality and friction of motor rotator, reducer and ball screw together, so it can establish one quality-damp model. The modelling of the whole electrometrical system is indicated by diagram 8: of which, U is control voltage of motor, the rotating inertia of the whole motor is Jm, rotating inertia of big gear is J, speed ratio of reducer is n s. Quality of quality-damp system is M, friction is f. The vertical height of towline is h, serial stiffness of grillagebeam between towline and tension sensor is K.

According kinetic energy equivalent and speed ratio of reducer, speed of ball screw, quality of ball screw etc, it can get the following load quality of kinetic energy:

$$M = \frac{J_m n_s^2 + J}{r_0^2 \tan^2 \alpha} + m \qquad (4)$$

The system adopts typical static friction+Coulomb friction model:

$$f = \begin{cases} F_m + W - kx & ((F_m + \mathrm{W - kx})) \le \mathrm{f_{max}};\, x = 0 \\ sign(F_m + W - kx) \bullet f_{\max} & ((F_m + \mathrm{W - kx})) > \mathrm{f_{max}};\, x = 0 \\ -\mathrm{sgn}(x)[f_x + (f_{\max} - f_x)e^{-\frac{|\dot{x}|}{v_0}}] & |x| > 0 \end{cases} \qquad (5)$$

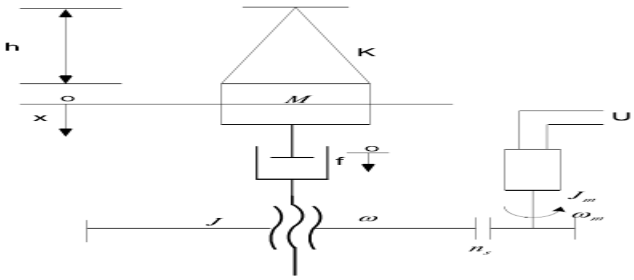


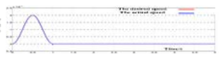
Diagram 8 System model chart

4.2 System simulation

Because this system is non-linear system, this paper has not used analysis method of frequency domain, but adopted analysis method of time domain; it can get the following close-cycle control model of PID:

$$Mx + f + kx = W + \frac{n_x}{r_0 \tan \alpha}\varphi(at^2 + bt + c) \qquad (5)$$

$$L_m i + \varphi\omega_m + Ri = P(v - x) + I(\bar{v} - \bar{x}) + D(\bar{x} - x) \qquad (6)$$

Suppose simulation parameter , A=Vmax/2, f max=10N，t 1=1s。After PID parameter undergoes commissioning for several times, when P=100000，I=200，D=5, speed response curve of system is indicated by diagram 9: from diagram 9 we can see that actual speed curve and expected speed curve are almost overlap, the error is very little, so dynamic response of system is better. Diagram 10 is current and control voltage curve of motor, it is equal to control voltage on the right of equation. The electromagnetic torque is equal to current multiplies torque constant, so driving force of motor is in proportion to motor current.

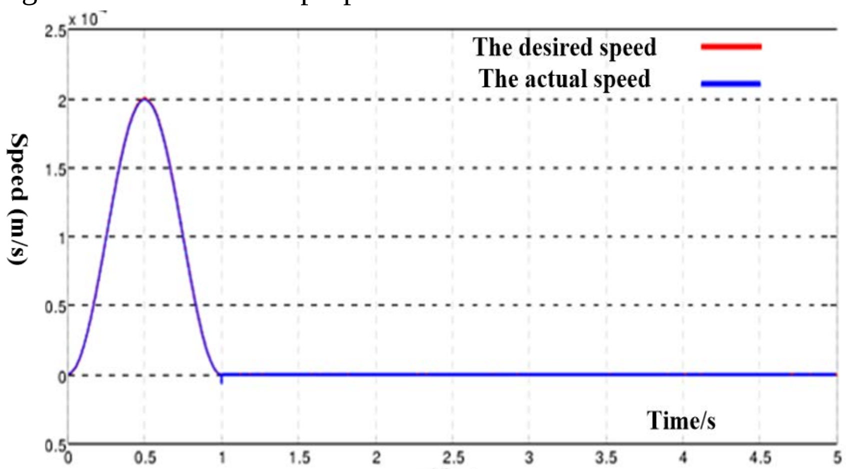


Diagram 9 Chart of speed response curve

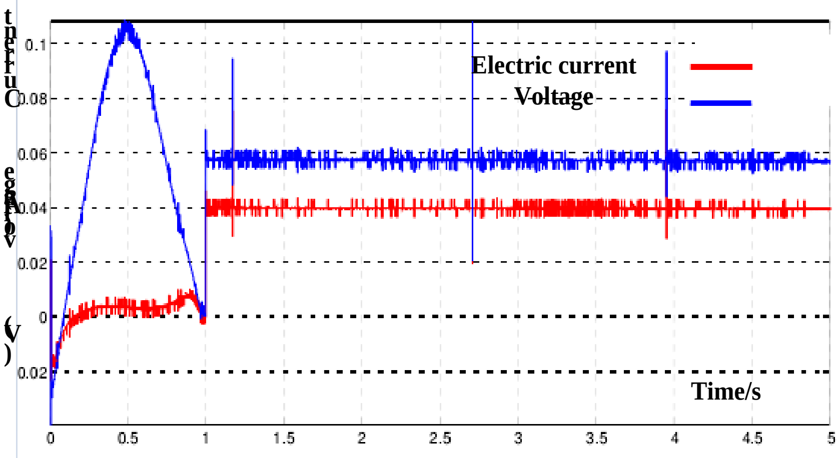


Diagram 10 Curve chart of current and voltage

5. Conclusions

This paper develops lower machine control system of fatigue machine, completes operation of control panel. Firstly, it designs external hardware circuit of ARM controller in details, completes software procedure design of controller and software design of upper machine, introduces procedure design idea and flow chart diagram of program operation. According to function division of software, it completes modularization design of software, gives close-cycle control strategy of speed, establishes simulation and analysis model of fatigue machine control system, and completes programming and simulation analysis under MATLAB software. The simulation result indicates that speed close-cycle control strategy is feasible, rationality of control strategy conforms to design requirement.

References

[1] Wang Guangzhi, Ren Yupeng, Ji Linhong etc. Study State on Recovery of Robot Auxiliary Neural Activity [J].Robot Technology and Application.2004,4: 9-14.

[2] Yuan Kui, Lu Peng, Zou Wei. Study and Development State on Visual Information and Procession Technology of Self-movement Robot [J].Hi-tech Communication.2008, 18(l):104-l10。

[3] Chen Boshi. Automatic Control System by Power Drag-Motion Control System [M].Beijing：Mechanic Industry Press，2009.8.

[4] Tian Yu．Design of Servo and Motion Control System [M].Beijing: People's Posts and Telecommunications Press，2010.

[5] Liu Longjiang．Mechanotronics Technology [M．Beijing：Beijing Institute of Technology Press，2012．

[6] Liu Zhiqiang. Analysis on Control Way of Electrometrical Control System [J]. Coal Technology，2009．28 (8) ：1-3．.

[7] Li Bo, Chen Anjun. Kinesiology Analysis on PCR Parallel Structure [J].Mechanic Design and Study, 2009, 25(5):31-34

[8] Shu Yinhui. Kinesiology Modelling and Control of Plain Parallel Structure [J].Mechanic Design and Manufacturing 2005(8):9-11

[9] Wu Jianxin. Coupling Kinesiology Simulation of Parallel Structure and Electrometrical [J]. System Simulation Journal, 2007, 19(19):4599-4603

[10] Gu Weijun, Peng Yigong. Intelligent Control Technology and Application [J]. Aoutomatic Instrument, 2006, 27:101-104.