Measure and Control Technology Based on DSP for HighPrecision Scanning Motor

Institute of Physics Publishing Journal of Physics: Conference Series **48** (2006) 269–273
doi:10.1088/1742-6596/48/1/050 International Symposium on Instrumentation Science and Technology

Measure and Control Technology Based on DSP for High Precision Scanning Motor

N Yang, X Y Yang, B Wu and S H Ye

State Key Lab of Precision Measuring Technology & Instruments of Tianjin University, Tianjin, China, 300072

E-mail: stefan_821215@hotmail.com

Abstract. A welding seam tracking visual sensor based on laser scanning is designed to solve the problems, such as indistinct image, difficulty in processing image etc., caused by serious arc light interference during welding. This visual sensor is mainly composed of a scanning motor, a linear-array CCD, a scanning rotating mirror and a semiconductor laser. Because the sensor measurement precision relies dramatically on the rotate speed stability of the scanning motor, the crux in the sensor design is to control the rotate speed of the scanning motor. Selecting a brushless direct current motor as the scanning motor and using TMS320F2812 DSP to drive it, we adopted fuzzy algorithm to control the motor rotate speed and made the steadiness error of the rotate speed less than 0.5%, which guarantees the sensor measurement precision and is of great importance for enhancing the welding quality of the industry welding robot.

1. Introduction

Owing to the existence of lots of intense interference during welding, such as arc light, arc heat, splash, smog etc., each visual sensor needs to settle those issues [1]. During the welding the classical structured-light three-dimensional visual sensor has many drawbacks, such as arc light interference, low precision and reliability, poor performance for real-time control, and therefore an original visual measure technology based on laser scanning is put forward, which uses one dimension visual sensor scanning method to realize 3D measurement of the welding seams [2,3].

As fig.1 shows, the visual sensor is largely made up of a semiconductor laser, a scanning motor, a scanning rotating mirror and a linear-array CCD. Firstly, a work piece is illuminated by the laser beam reflected by the scanning rotating mirror, and then the reflected light is received by a lens through the scanning rotating mirror, and at last image is formed on the linear-array CCD. The rotating mirror driven by the scanning motor rotates rapidly and continuously, which makes the laser beam scan across the welding seam. According to one-to-one correspondence between the image location on the CCD and the welding seam depth, the welding seam depth can be worked out [4]. Meanwhile the light-spot position in the cross direction of the welding seam is determined by the rotate speed of the scanning motor. Therefore the coordinates of all the spots on the welding seam cross-section can be obtained. Simultaneously the robot drives the visual sensor to move along the weld joint, and 3D description of the welding seam is reconstructed from several sections.

Compared with the structured-light sensor, the laser scanning sensor uses point-source light, so the illumination of the laser scanning sensor on the work piece is much more intensive than that of the structured-light sensor. Thus the laser scanning sensor has a great deal of merits, such as fine image definition, good signal-to-noise performance, high accuracy and better real-time performance [5].

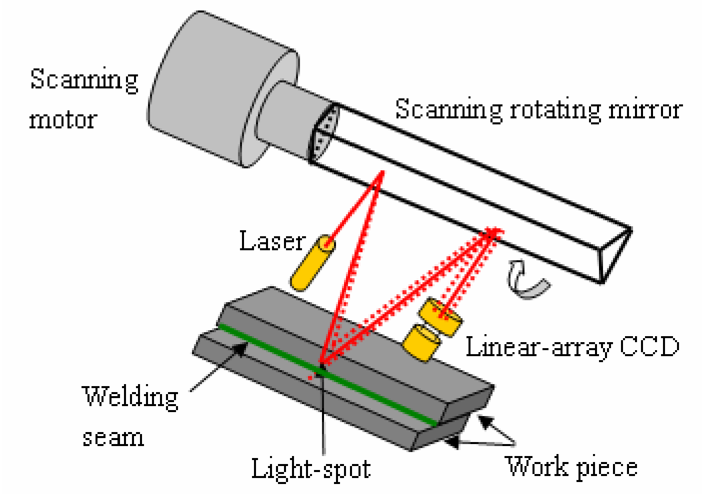

Figure 1. Welding seam tracking visual sensor based on laser scanning.

2. The DSP control principle of scanning motor

In order to trail the welding seam precisely, the welding robot must attain the cross section form and dimension of the seam groove. Thereby we must get the three-dimensional coordinates of every light-spot on the groove. The three-dimensional coordinates of the welding seams lie in the locomotion equation of the welding robot, the rotate speed of the scanning motor and the image position on the linear-array CCD respectively. Thus it can be seen that the stability of the motor rotate speed directly affects the sensor measurement precision and that the drive and rotate speed control of the scanning motor are crucial for sensor design.

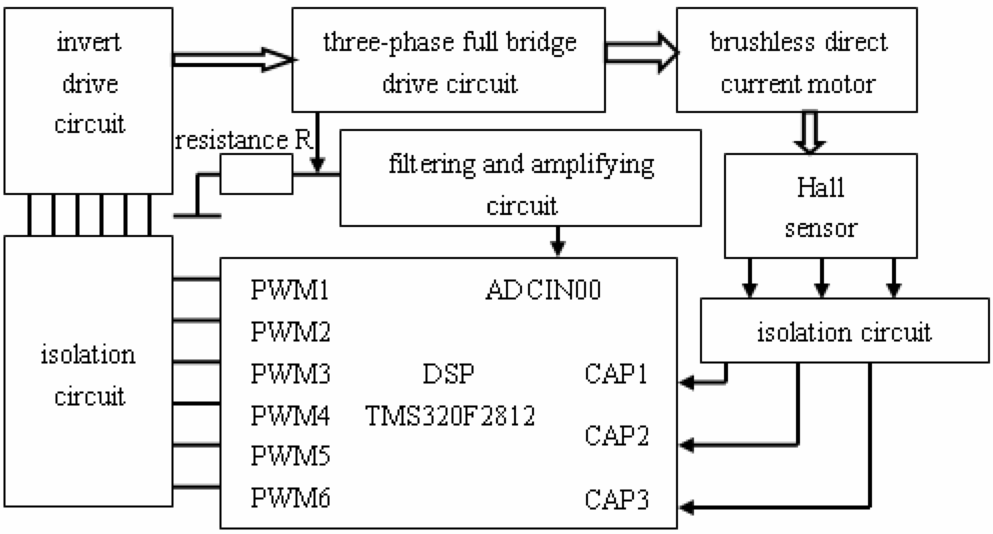

Figure 2. Control and drive circuit based on DSP.

As rotate speed of the scanning motor needs regulating accurately, a three-phase brushless direct current motor is selected as the scanning motor and the DSP TMS320F2812 is used in the driving circuit to adjust the rotate speed. As fig.2 shows, outputs of the hall sensors are connected to three capture pins respectively via a shaping isolation circuit in order that phase conversion time as well as the location information are ascertained through the capture interrupt [6].

By using a precise resistance as an electric current sensor which is placed between power supply and ground, the current feedback is achieved. Through a filter amplifier the current is sampled by the AD converter during each PWM cycle and the rotate speed is controlled by PWM.

The DSP pins PWM1～PWM6 are linked to six transistors through an invert drive circuit to implement fixed-frequency PWM and phase conversion.

3. The position detection and speed control

3.1. Position detection

Using position signal to convert phase and reckon the rotate speed indicates the significance of position detection.

According to the control principle of the three-phase brushless direct current motor, we must incessantly convert the phase of the motor to guarantee the constant torque. To convert the phase at the right time can abate the torque fluctuation and stabilize the rotate speed.

The phase conversion is ascertained by the position signal from the Hall sensors. Each output signal from the Hall sensor has a 180° pulse width, and the phase difference between the signals is 120°. Accordingly there are 6 rising or trailing edges per round, just corresponding to 6 phase conversion moments. By using DSP's capture interrupt function to detect both edges, the six moments can be got. However, in order to convert the phase correctly, we still have to determine which phase to convert besides the phase conversion moments. By configuring the capture ports as the I/O ports and detecting their electrical level, the relevant Hall sensor and corresponding edge triggering the capture interrupt are ascertained. The electrical level of the capture ports is called phase conversion control word. Thus in the capture interruption subroutine the phase can be converted correctly based on the phase conversion control word.

Position signal is also used to calculate the rotate speed of the motor. The phase changes 6 times per round, that is to say, when the rotor rotates 60° , the phase will switch once. Hence the average rotate speed can be figured out according to the interval between two successive phase conversions.

3.2. Speed control

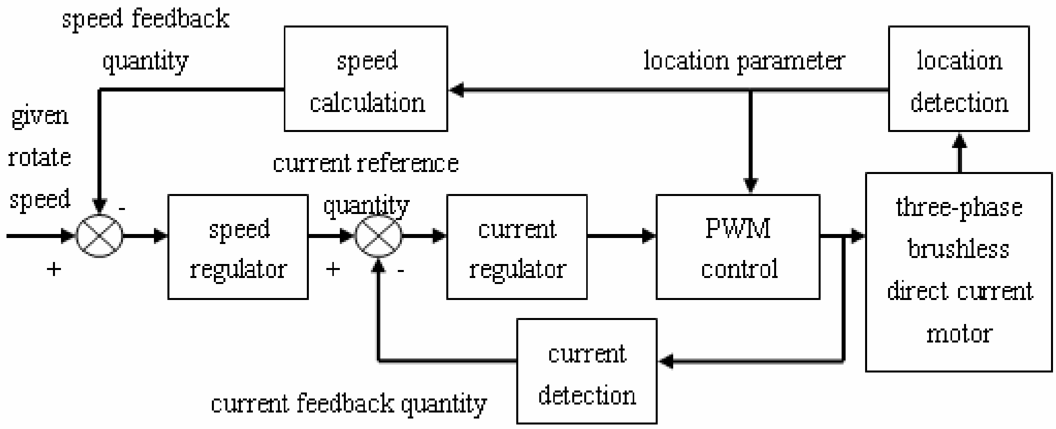

Figure 3. Rotate speed control block diagram for the three-phase brushless direct current motor.

AS figure 3 shows, firstly according to the deviation between the given speed and the measured speed, a current reference quantity is obtained through speed regulation, and then based on the deviation between the current reference quantity and the current feedback quantity, and through current regulation the controlled variable to adjust the duty cycle of the PWM is gained to control the motor speed. This paper implements all-digital double-closed-loop speed control by software [7]. Inner loop is a current ring, achieved by a current regulator of proportional regulation. Its primary function is to limit the maximal current, to offer sufficient dynamic torque and to guarantee the steady operation. Outer loop is a speed ring, carried out by a speed regulator of fuzzy control. Its main function is to enhance the ability against load disturbance, to diminish speed fluctuation and to ensure the static and dynamic performance.

3.2.1. *Current regulation.* Proportional control is used to regulate the current, namely:

$$COMP_k = COMP_{k-1} + e_{IK} K \tag{1}$$

COMP is the next compare value for PWM; e_{IK} is the current deviation: K is proportion coefficient, related to the motor parameters. We make K equal to 1 in the paper.

Additionally, the controlled variable COMP should be in a limit range, from 0 to 500.

3.2.2. *Speed regulation.* Fuzzy control is used to regulate the speed to improve system robust and quick-response performance.

Depending on the deviation E between the given speed and measured speed and its change rate EC, Fuzzy controller makes a synthetic decision [8]. Table 1 is the fuzzy decision table.

Table 1. Fuzzy decision table.

E \ EC	NB	NM	NS	ZE	PS	PM	PB
NB	**PB**	**PB**	**PM**	**PM**	**PS**	**PS**	NM
NM	**PB**	**PM**	**PS**	**PS**	**PS**	**ZE**	NM
NS	**PB**	**PM**	**PS**	**PS**	**ZE**	**NS**	NB
ZE	**PB**	**PS**	**PS**	**ZE**	**NS**	**NS**	NB
PS	**PB**	**PS**	**ZE**	**NS**	**NS**	**NM**	NB
PM	**PM**	**ZE**	**ZE**	**NS**	**NS**	**NB**	NB
PB	PM	NS	NS	NM	NM	NB	NB

4. Experiment and conclusion

According to welding procedure, the rotate speed of the scanning mirror should range from 500 r/m to 5000 r/m. The rotate speed can't be too low, otherwise the speed stability is poor, and at the same time the rotate speed can't be too high, otherwise the selected linear-array CCD must have a very high driving frequency. So the given rotate speed of the brushless motor is specified at 2000 round/minute during the experiment.

Table 2. The rotate speed measurement of the brushless motor.

Time (s)	Measured speed(r/m)	Time (s)	Measured speed(r/m)
t=2	2006	t=12	1998
t=4	2000	t=14	2000
t=6	2000	t=16	1995
t=8	2003	t=18	2000
t=10	1998	t=20	2003

Table 2 shows that the relative error between the given rotate speed and the measurement of speed is less than 0.5%, which can fulfill the sensor measurement accuracy completely, and that the speed regulation within the range of rotate speed is precise.

References

[1] Lin S Y and Chen S B 2000 *Welding Robot and Its Application*(Beijing:China Machine Press)

[2] Huang S S, Wang X Y and Gao X D 2000 Seam Tracking System Control during Hidden Arc Welding and Its Development *J. Welding* **15** 8−11

[3] Wang X J, Li C X and Ma Y Z 1998 Seam Tracking System Control during Fine Wire Hidden Arc Welding *J. Transaction of Gansu Industry University* **24** 1−4
[4] Chen Q and Sun Z G 2001 The Application of Computer Visual Sensing Technique in Welding *J. Transaction of Welding* **22** 83−90
[5] Chen W Z, Zhang X D 2002 Visual Sensor and Welding Seam Tracking *J. Modern Manufacture* **18** 58−60
[6] Wang X M and Wang L 2004 *The DSP Control of Motor*(Beijing: Beihang University Press)
[7] Xia C L, Guo P J and Shi T N 2005 Control of Brushless DC Motor Using Genetic Algorithm Based on Fuzzy Controller *J. Transaction of Chinese Electric Engineering* **25** 129−133
[8] Rong Y L 1995 *Fuzzy Control Principle and Application*(Beijing: Beihang University Press)