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Welding Seam Turbulent Tracking Technique for Spiral Welded Pipe Ultrasonic Flaw Detection

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Abstract. In the process of spiral submerged-arc welding automatic flaw detection, the weld edge reflection echo is very close to the back edge of the detection gate (generally around 3Ls, is equal to steel transversal wave approximately 4.5mm); therefore once the detector approaches the welding seam, the edge refection echo will enter in the gate, which causes the false alarming. In the past, the mechanical cam tracking, approaching switches tracking and photograph tracking methods were applied, but the mechanical cam tracking and the approaching switches tracking method have low precision, the result is not good. Although photograph tracking method has high measure precision, because of the light scattering of the water flow on the surface of the steel pipe, which will affect the precision. Both photograph tracking and stepping motor-driven methods is commonly used national wide, the effect is not good. Base on the above situation, the electromagnetic welding seam tracking and servo control electromechanical system with functions of electromagnetic tracking and servo control is developed.

Principle

The servo motor drives the screw via 9:1 reducer, screw working length is ±200mm, both ends approach switches for limit protection. Working process is as follows: when tracking begins, the tracked probe should be located at the center of the screw to guarantee the ±200mm tracking range[1]. After the inspection of each steel pipe, the two reset switch on the probe shelf sent out the reset signal, the system is automatically reset to the center of the screw. The limit and the reset signal are all handled by the secondary control instruments of the electromagnetic sensors and sent to the servo motor driver. As shown in Figure 1.

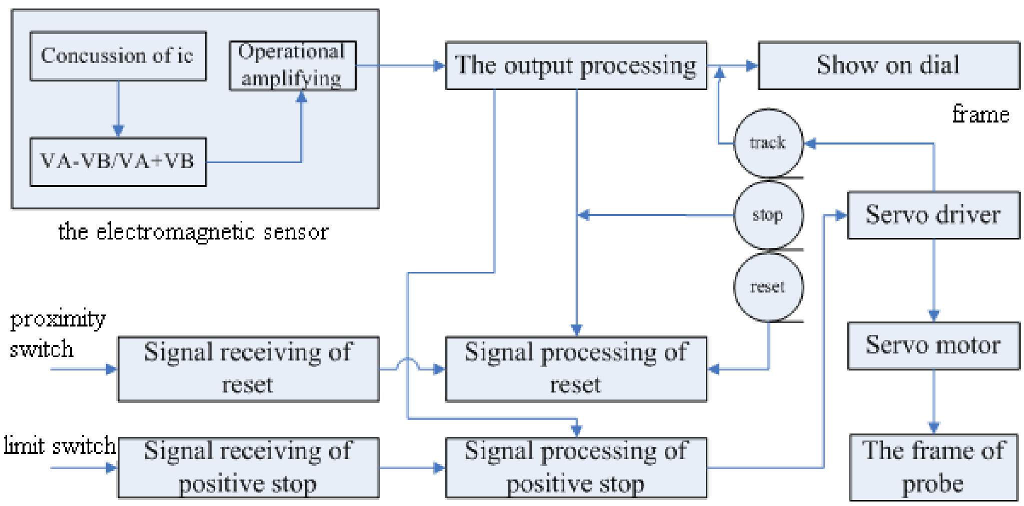
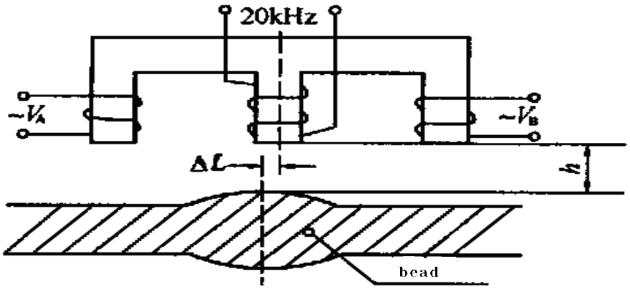


Fig.1 The block diagram of electromagnetic eddy track

Principle of electromagnetic turbulent sensor

As shown in Figure 2, the main coil core generates 20kHz uniform alternating magnetic field, while the induction amplitude and phase of the two secondary coil V_A and V_B are equal[2]. However, when the external ferromagnetic materials distribute unevenly, it can make the distribution of magnetic field lines within the core mutate, so $V_A \neq V_B$.



H - The distance from electromagnetic sensor to bead

$\triangle L$ - The migration distance from the corner of electromagnetic sensor to corner of bead

Fig.2 The schematic of the electromagnetic sensor

Magnetic tracking circuit design

Electromagnetic tracking sensors are composed of the vibration winding and displacement testing composed integrated circuit MAX412, shown in Figure 3. Vibration winding includes the 6mm×6mm×26mm E type ferrite core, a primary coil and two secondary coils. Primary coil and MAX412 together generate 20kHz frequency sinusoidal oscillation signal, which is amplified and loaded into the main electromagnetic coil after reshaping [3]. The EMF V_A and V_B of the two secondary windings is connected to the differential signal input of the MAX412 to calculate and amplify output. Using the different output values of V_A and V_B, we can control the servo driver to conduct the output adjustment in different directions.

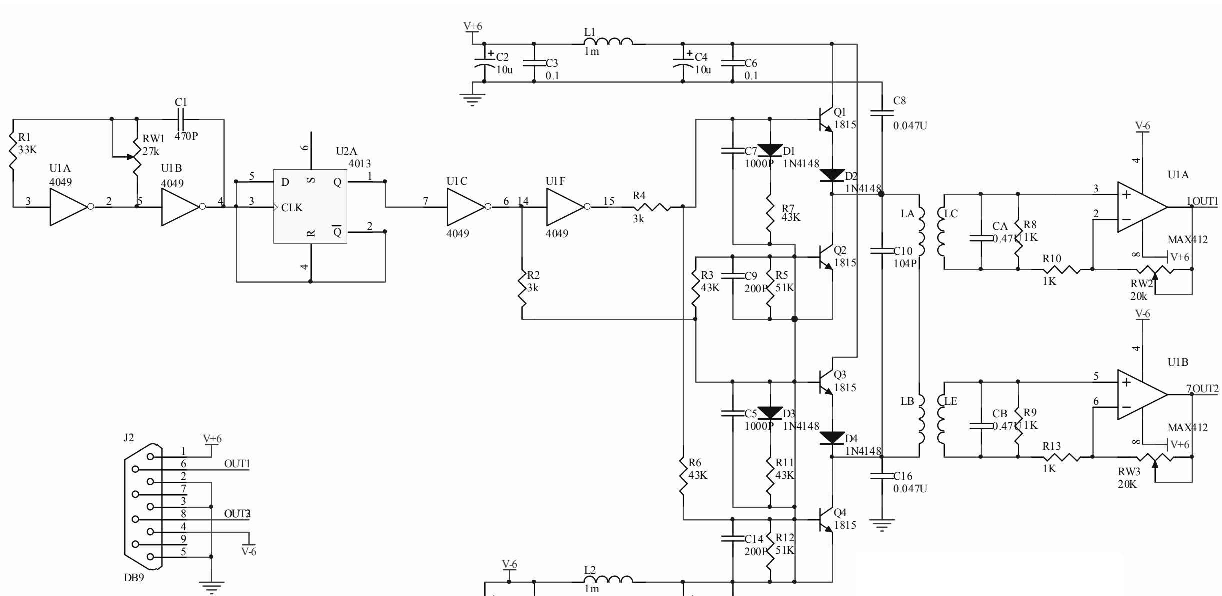


Fig.3 The circuit schematic of the eddy track probe

Core, MAX412 and amplifiers are packaged in a Φ30mm×100mm non-ferromagnetic housing, composed of electromagnetic tracking sensors. The sensor not only has enough high detection precision to the small deviation of the welding bead, but also has enough wide tracking range, which is very suitable for the automated weld inspection probe tracking control.

Table 1 Output voltage and deviation distance proportion

h	output voltage $\frac{V_{out}/V}{\triangle L/mm}$										
$\triangle l$	0	0.5	1.0	1.5	2.0	2.5	3.0	5.0	10	15	20
3	0	2.2	3.8	4.2	4.2	4.2	4.2	4.2	4.2	4.2	22
4	0	2.0	3.0	4.0	4.2	4.2	4.2	4.2	4.2	4.0	20
5	0	0.8	1.3	2.0	2.6	3.2	3.8	4.2	4.0	3.8	18

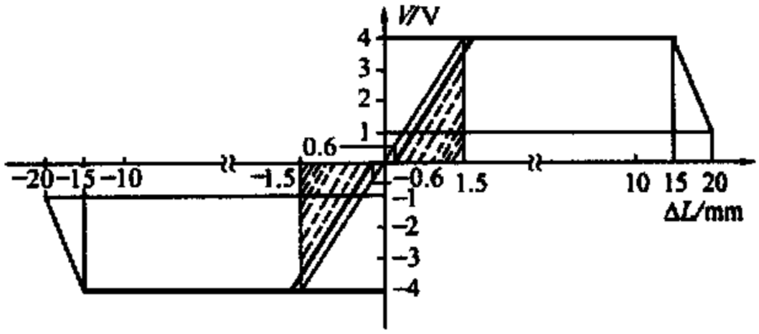


Fig.4 The features chart of the output voltage

Table 1 only shows the results of the $\triangle L$ positive deviation, while Figure 4 shows the $\triangle L$ positive and negative deviation of the output characteristics; the results show that the positive and negative output characteristics are almost the same. The oblique dotted line in Figure 4 is the actual tracking work zone, which is equivalent to ±*1.5mm*. In the range of ±20mm, the sensor output is still evident. That is, when a sudden abnormal situation happens, as long as the probe deviation is within ±1.5mm work zone, the system can automatically resume and enter into the work area. Especially when the probe had just landed on both sides of spiral weld pipe, it can not guarantee just to enter the work area, but as long as it is not more than ±20mm range, the system will automatically and quickly adjust to enter the work area.[4] This creates a flexible operating range for the actual detection operation

Servo motor gain control and speed adjustment

The output voltage within ±4V range of the electromagnetic tracking sensor can directly control the clockwise and counter clockwise rotation of the servo motor. We use Panasonic's MNAS series MSM022A1 servo motor and MSD023AIX drive, the rated output power is 200w, the maximum speed is 5000r/min. Drive has the speed, position and torque, three basic control methods, the system uses the speed control method. In the speed control method, the motor’s clockwise and counter clockwise speed is proportional to the positive and negative voltage of the analog speed command and is also proportional to the magnetic sensor output voltage, its proportion coefficient can be set by the user (setting range is 10 ~ 2600). The large the setting value, the higher speed gain is. Set x can be obtained by the following formula.

$$x = \frac{0.075 \times 6}{V} n \tag{1}$$

Where, V is the order voltage corresponding with demand speed. n is the demand speed.

Meanwhile, if the magnetic sensor output voltage is ±2V, then the speed is ±2000r/min; if the voltage is ±6V, then the speed is ±6000r/min. In order to avoid the motor speeding, the speed limit should be set. The system set the speed limit to 4500r/min, which is lower than the maximum speed of 5000r/min, to ensure the safe operation of the motor.

As shown by the simple calculation: If the set value is 600, the 3V voltage corresponds to 4000r/min, set the value to 900, the 2V voltage corresponds to 4000r/min, change the set value to 1800, the 1V voltage corresponds to 4000r/min. It shows the servo motors have strong speed gain adjustment ability.

The system setting value is only 4V, that is, 4 voltages corresponds to 4000r/min, there are a lot of gain residual is not used. Only this gain setting, when the bead offset $ L is ±1.5mm, the speed command voltage has reached ±4.2V, the motor speed can reach ±4200r/min. In this high-speed control, just enter into ±1.5mm of the work area, the tracking servo motor can be a powerful tracking regulator. That is, the system only swings in the ±1.5mm range in the work area but not departs from the work zone, to achieve the tracking purpose [5].

Motor can utilize the speed control, position control, torque control of three forms of control, which can be chosen according to the needs of users, here is to control the motor by using the speed control. By internal computation and comparison to obtain the specific value and then by judging the clockwise and counter clockwise rotation of the motor and parameters such as speed, to drive motor work. Motor drives lead screw to rotate so that ultrasound probe can track the weld seam, to achieve the real time tracking welding bead purpose, which ensures the accuracy of detection and higher reliability.

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