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The Design of Seamless Steel Tube Ultrasonic Flaw Detection System

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Abstract: In recent years, ultrasonic nondestructive detection technology has definite application in seamless steel tube flaw detection. Seamless steel tube ultrasonic flaw detection system was designed in this paper. The constitution and function of relative machine system, electron test system and electron control system were elaborated. Some ultrasonic echo circuits were designed. They are first rank damping circuit of first rank attenuator, second rank damping circuit of first rank attenuator, first rank damping circuit of second rank attenuator, first rank amplification circuit, second rank amplification circuit and restraint circuit respectively. The feasibility of above circuits has been proven by engineering application. The research provides important references base for designing seamless steel tube ultrasonic flaw detection system, enhancing test process reliability and increasing test efficiency. *Copyright © 2013 IFSA.*

Keywords: Seamless steel tube, Ultrasonic flaw detection system, Machine system, Electron test system, Electron control system.

1. Introduction

The ultrasonic application on nondestructive detection is over 40 years. Now, longitudinal flaw, transverse flaw, inner flaw and external flaw such as contraction cavities, rip and impurity and so on can be tested accurately for the technology progress of ultrasonic test. Ultrasonic flaw detection has many advantages such as high test sensitivity, strong penetration force, good adaptability, agile use ability, light equipment, low cost, timely flaw detection result acquirement and innocuousness and so on. Ultrasonic flaw detection can work on various environments such as workshop, outdoors and under water. Running equipment can be tested and diagnosed by ultrasonic flaw detection. Ultrasonic flaw detection has been applied on many industry departments such as machine manufacture, metallurgy, electric power, petroleum, chemical industry and national defense. Ultrasonic flaw detection is important means to ensure product quality and equipment safety.

In recent years, many research works were made by researchers all over the world on seamless steel tube ultrasonic flaw detection test. Control system design of ultrasonic nondestructive flow detection was researched by Li Kaijun in Sichuan University in

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2008 [1]. The research of automation ultrasonic measurement on big diameter seamless steel tube layering fault was made by Gao Hongming, Chen Gui and Yu Qingbin in Yangzhou Chengde Steel Pipe Limited Company in 2010 [2]. The research of realization on ultrasonic automation measurement record system of steel tube was made by Lin Guangfeng in Guangdong Shantou Ultrasonic Electron Incorporated Company in 2010 [3]. The research of design and application on ultrasonic automation measurement flaw detection test system of welded steel tube was made by Chang Shaowen in Meng Feng Special Steel Limited Company in 2011 [4, 5]. The research of design and application on ultrasonic automation flaw detection control device of steel tube was made by Chang Shaowen and Yang Tong in Meng Feng Special Steel Limited Company in 2012 [6]. The application of ultrasonic nondestructive examination technology on steel tube detection was researched by Zhao Yi in Tianjin Steel Pipe Group Incorporated Company in 2012 [7]. The application of ultrasonic guided-wave technology to detection of small-sized seamless steel tube was researched by Tu Kui in Jiangxi Hongdu Steel Mill Limited Company in 2012 [8]. The application in deepwater gas heavy wall thickness pipeline of serial type ultrasonic test in China South Sea was researched by Lv Yudong, Cao Huayong and Gao Zhi in the Bohai Sea Petroleum Equipment Julong Steel Tube Company in 2013 [9]. Seamless steel tube ultrasonic flaw detection system was designed in this paper according to actual production.

2. The Constitution of Seamless Steel Tube Ultrasonic Flaw Detection System

Seamless steel tube ultrasonic flaw detection system mainly contains relative machine system, electron test system and electron control system. The functions of machine system are system connection, system transmission and test motion realization. The functions of electron test system are ultrasonic signals transmission, ultrasonic signals acceptance, acceptance signals pretreatment, steel tube fault judgement, test data transmission and test data storage. The functions of electron control system are monitoring machine system running condition and controlling machine system running process.

3. The Machine System of Seamless Steel Tube Ultrasonic Flaw Detection System

The machine system of seamless steel tube ultrasonic flaw detection system mainly contains gantry bracket, probe bracket, running vehicle, photoelectric bracket, pull roll system. It is shown in Fig. 1. Firstly, seamless steel tube was transmitted below gantry bracket by rollaway nests. Then, seamless steel tube was lifted by pull roll. Probes can move and touch steel tube surface driven by go up and down system installed on running vehicle. So, probe position was confirmed. Seamless steel tube may rotate uniformly driven by pull roll. Probe may move on straight line driven by running vehicle. Entire surfaces of seamless steel tube can be tested by combining above two movements. Jet and probe were installed on running vehicle. They move with running vehicle. The distance from jet to probe was decided by design. The probe scan area was decided by probe type and probe size. The movement speed of running vehicle is variable according to different seamless steel tube diameter. It can be tested by speed test card.

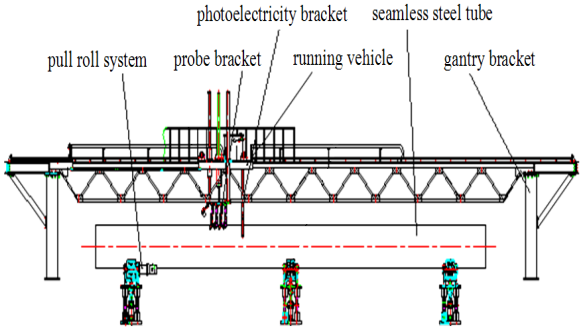

Fig. 1. The machine system of seamless steel tube ultrasonic flaw detection system.

3.1. Gantry Bracket

Gantry bracket is beam structure supported by four supports. The length, width and height of gantry bracket are 20 metres, 3.7 metres and 3.3 metres respectively. Light orbit was paved on gantry bracket beam. The length of light orbit is 18.7 metres. Probe bracket and photoelectric bracket can run on light orbit driven by running vehicle. Gantry bracket is shown in Fig. 2.

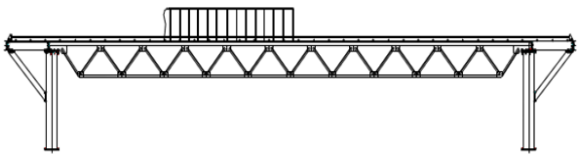

Fig. 2. Gantry bracket.

3.2. Probe Bracket

Probe bracket can be adjusted by go up and down speed reduction mechanism installed on running vehicle. Probe and jet mechanism were installed on probe bracket. After receiving control system signals, jet mechanism can sign axial position according to tested fault. Probe bracket is shown in Fig. 3.

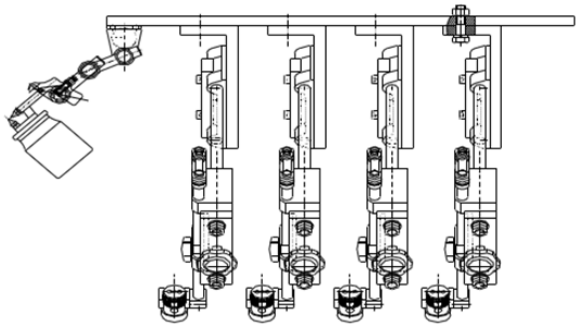

Fig. 3. Probe bracket.

3.3. Running Vehicle

The main function of running vehicle is driving seamless steel tube movement on axial direction. Ultrasonic test couplant is water. So, water box was installed on running vehicle. There are four wheels were placed on light orbits. Running vehicle was driven by four wheels roll. The go up and down system mainly contains electromotor, reducer, screw and cylinder. It was installed on running vehicle to adapt to test different seamless steel tube diameter. The maximum running vehicle speed is 7 m/min. Running vehicle is shown in Fig. 4.

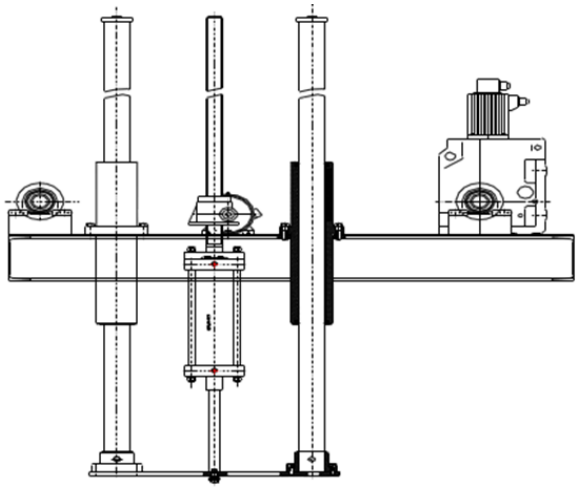

Fig. 4. Running vehicle.

3.4. Photoelectric Bracket

Photoelectric bracket was installed on running vehicle front. Two photoelectric sensors were installed on photoelectric bracket with same centre line. One photoelectric sensor was used to transmit light wave. Another photoelectric sensor was used to receive light wave. When seamless steel tube was moved to appointed position, the light wave transmitted from one photoelectric sensor was sheltered by seamless steel tube. So, light wave can not be received by another photoelectric sensor normally. System begins test simultaneously. Photoelectric bracket is shown in Fig. 5.

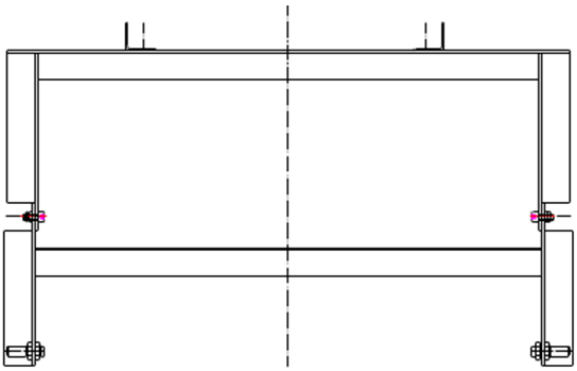

Fig. 5. Photoelectric bracket.

3.5. Pull Roll System

Pull roll system mainly contains servo motor and pull roll mechanism. Pull roll mechanism mainly contains base plate, top plate, link rod, cylinder and rubber wheel. Predesigned different steel tube rotation line speed can be obtained by adjusting servo motor rotation rate. The center distance between two rubber wheels can be adjusted by hand wheel so as to adapt to different steel tube diameter test. Pull roll can move up and down within certain range to lift steel tube to designated position. Three pull roll mechanisms were designed in this paper to ensure stable steel tube rotation during test process. One is initiative pull roll mechanism. The other two are passive roll mechanisms. The distance between two roll mechanisms is 5 metres. Pull roll mechanism is shown in Fig. 6.

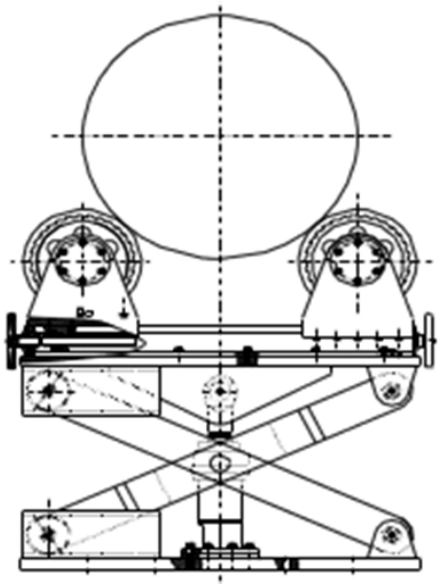

Fig. 6. Pull roll mechanism.

4. The Electron Test System of Seamless Steel Tube Ultrasonic Flaw Detection System

Electron test system is the core of ultrasonic test. It mainly contains current source, probe, transmission circuit, synchronous circuit, alarm circuit, alarm output, sign delay, time base circuit, depth compensation, prepositive receiver circuit, attenuator, prepositive amplification circuit, high frequency amplification circuit, interface circuit, inferior computer, superior computer and display device. It is shown in Fig. 7.

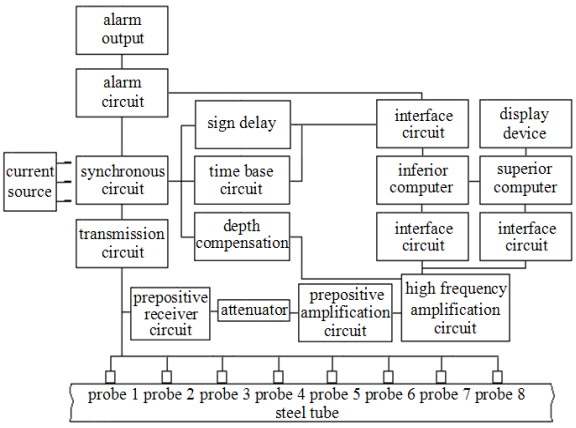

Fig. 7. Electron test system sketch.

4.1. Transmission Circuit

Big high frequency electric pulse produced by transmission circuit under the trigger of synchronous pulse signal was sent to probe. Pulse ultrasonics with same center frequency sent by probe under the trigger of high frequency electric pulse were transmitted to test material.

4.2. Synchronous Circuit

The function of synchronous circuit is to produce periodic synchronous pulse signal so as to trigger each part circuit of ultrasonic flaw detection device. It amounts to control center.

4.3. Attenuator

Attenuator can compare the strength of receiver signal. Attenuator can estimate ultrasonic damping quantificationally. Attenuator mainly contains first rank attenuator and second rank attenuator. First rank attenuator mainly contains first rank damping circuit and second rank damping circuit. First rank damping circuit of first rank attenuator is shown in Fig. 8. Second rank damping circuit of first rank attenuator is shown in Fig. 9. Second rank attenuator mainly contains first rank damping circuit. The damping of two damping circuits of first rank attenuator is 1 dB to 5 dB. The damping of first rank damping circuit of second rank attenuator is 6 dB to 24 dB. Second rank damping circuit of first rank attenuator is shown in Fig. 10.

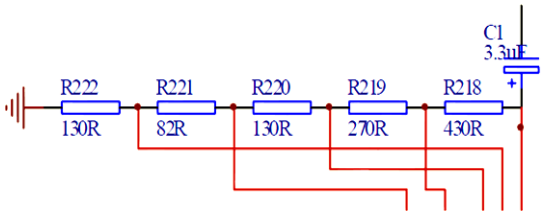

Fig. 8. First rank damping circuit of first rank attenuator.

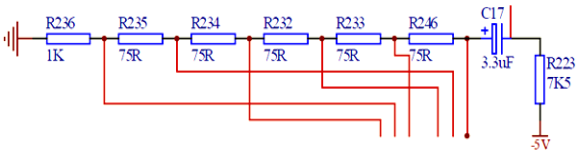

Fig. 9. Second rank damping circuit of first rank attenuator.

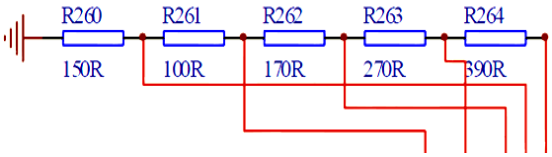

Fig. 10. Second rank damping circuit of first rank attenuator.

4.4. Ultrasonic Amplification

The function of receiver circuit is to amplify echo signal. Receiver circuit mainly contains first rank amplification circuit and second rank amplification circuit. First rank amplification circuit is between first rank damping circuit and second rank damping circuit. It is shown in Fig. 11. Second rank amplification circuit is between second rank damping circuit and restraint circuit. It is shown in Fig. 12.

4.5. Restraint Circuit

Some ultrasonic clutter unrelated with flaw detection can be restrained by restraint circuit. Restraint circuit is shown in Fig. 13.

4.6. Inferior Computer

The function of inferior computer is to receive superior computer information. Information extractions were made by inferior computer on received ultrasonic signals simultaneously. Then, steel tube fault was judged. Relative test information was transmitted to superior computer.

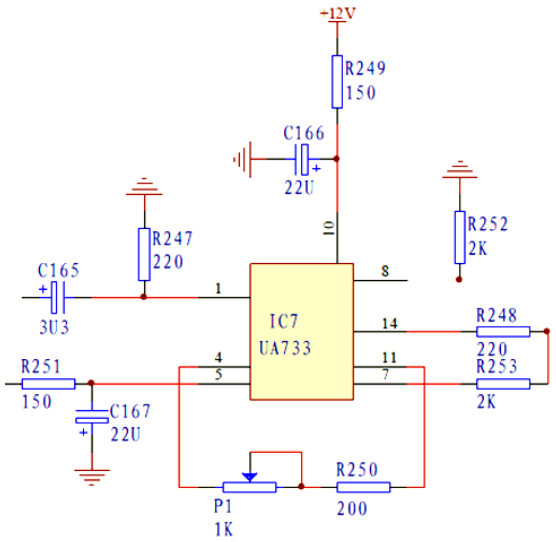

Fig. 11. First rank amplification circuit.

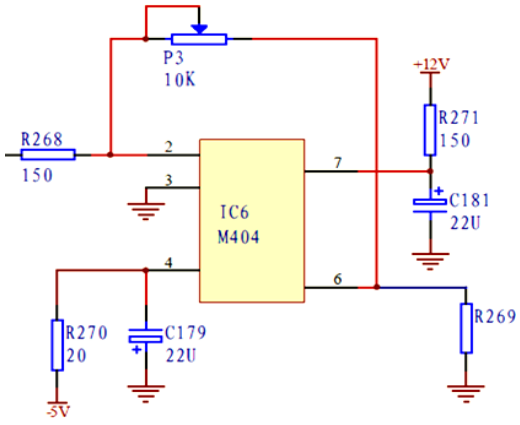

Fig. 12. Second rank amplification circuit.

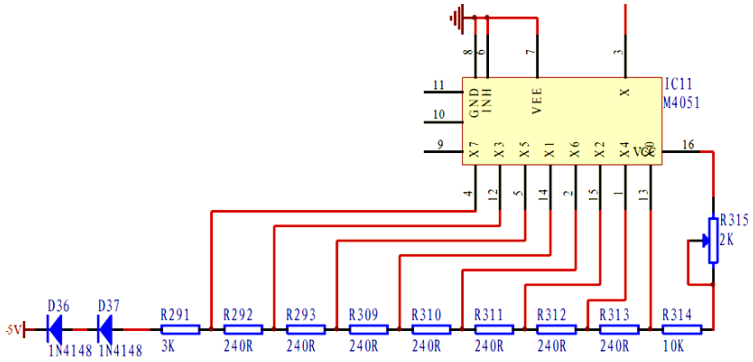

Fig. 13. Restraint circuit.

4.7. Superior Computer

The function of superior computer is to realize the monitoring and setting on seamless steel tube ultrasonic flaw detection system. Relative test parameters were set to inferior computer by superior computer according to the differences of diameter and test standard of seamless steel tube.

5. The Electron Test System of Seamless Steel Tube Ultrasonic Flaw Detection System

The functions of electron control system are monitoring machine system running condition and controlling machine system running process. When seamless steel tube was moved to flaw detection area front, photoelectric switch was opened. Steel tube test position was judged by PLC. When seamless steel tube head enters into flaw detection area, the condition of test switch DIL1 installed on flaw detection area entrance changes from 0 to 1. Then flaw detection programs were started. Spray water valve was opened. Spray begins. Probe bracket was driven by servo motor. Probe bracket and steel tube were aligned. Flaw detection probe 1 and 2 that is GD11 and GD12 were descended to detect flaw. After time delay T, flaw detection probe 3 and 4 that is GD21 and GD22 were descended to detect flaw. After time delay T, flaw detection probe 5 and 6 that is GD31 and GD32 were descended to detect flaw. After time delay T, flaw detection probe 7 and 8 that is GD41 and GD42 were descended to detect flaw. When seamless steel tube end enters into flaw detection area, the condition of test switch DIL1 installed on flaw detection area entrance changes from 1 to 0. Every part of flaw detection equipment returns to original position successively with time interval T. Then, flaw detections were accomplished. Steel tube was send to next area. The schematic diagram of electron test system is shown in Fig. 14.

6. Conclusions

Seamless steel tube ultrasonic flaw detection system was designed in this paper. The constitution and function of relative machine system, electron test system and electron control system were elaborated.

The constitution and function of gantry bracket, probe bracket, running vehicle, photoelectric bracket and pull roll system of relative machine system were elaborated. The constitution and function of transmission circuit, synchronous circuit, attenuator, ultrasonic amplification, ultrasonic restraint, inferior computer and superior computer of relative electron test system were elaborated. The principle of relative electron control system was elaborated. The damping circuit, amplification circuit and restraint circuit of ultrasonic echo were designed. The feasibility of above circuits has been proven by engineering application. Echo signal can achieve satisfying effect by above treatments so as to ensure seamless steel tube ultrasonic flaw detection demand.

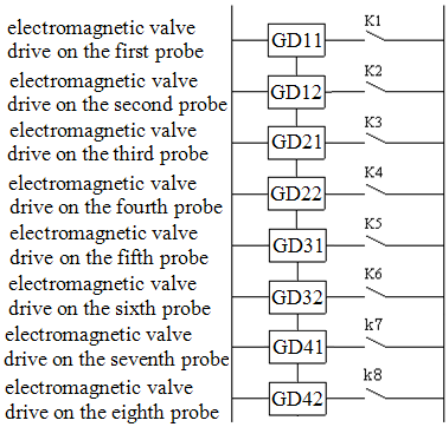

Fig. 14. The schematic diagram of electron test system.

Acknowledgements

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