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Study on Water Jet Cutting Quality Detector Section Based on Sensors

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Abstract: Because the upper ends of water jet cutting sections are smooth while the lower ends are rough, at the same time, the cutting sections have obvious conical degrees. On the base of the existing measuring instrument of surface roughness, a new type of water jet cutting quality detector based on sensor has been designed. The sensors, driving devices of sensors and the workbench of the existing measuring instrument of surface roughness have still been used, conditioning circuit of signals, processing and display circuits of parameters and relevant control circuits of the existing measuring instrument of surface roughness have been removed, the new hardware part and software part of the system have been designed. The hardware of system is mainly used to complete the related I/O control, processing of weak signal output by sensors and A/D conversion of signals. By programming, the software of the system is mainly used to realize human-computer dialogue, set test parameters, give corresponding control and measuring instructions, make users filter digital signals output by A/D and process parameters, complete the display and print of parameters and curves, generate and print detected forms for reporting statistics. The new designed water jet cutting quality detector will be used on universal microcomputers to complete the motion control of measurement process, data acquisition, data processing, data display, waveform display and print of relevant information. *Copyright © 2013 IFSA.*

Keywords: Water jet cutting, Section quality, Measuring instrument, Computer interface, Timely access.

1. Introduction

Water jet has been rapidly developed in recent years, water jet is a kind of soft tool. Hysteresis is one of the significant characteristics of water jet cutting. On the one hand when the nozzle moving at a cutting speed, because of the workpiece has certain thickness, so the jet exit the workpiece with respect to particle into workpiece has a time lag, resulting in delay, this lag makes the surface appear curved lines. On the other hand, because of high energy beam from the nozzle with scattering, and as the distance increases, the jet energy decay, so the abrasive jet cutting workpiece will produce obvious taper, at the same time, there are obvious differences in surface quality of the cutting section, the low and high roughness. When cutting thickness larger parts, this phenomenon is particularly prominent. When water jet cutting machine parts, it makes the tiny peak valley on parts of the surface, these tiny peak and valley′s height and spacing condition is called surface roughness. Surface roughness is important parameters describing machining the workpiece surface microscopic shape, surface roughness measuring which plays an important role in the development of the modern manufacturing industry. The design of the detector is based on the study of surface roughness measuring instrument, to design a kind of instrument which can detect water jet cutting quality. It is to analyze the section quality according to the quality problems existed in water jet cutting section.

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2. Design and Feasibility Analysis of the Overall Plan

2.1. The Overall Scheme Design

Water jet cutting quality tester of section, both have high test precision, friendly interface, convenient and fast test process, advanced performance, high cost performance and strong universality. The design of water jet cross cutting quality detecting instrument can be applied to the intelligent and automatic transformation of the various surface roughnesses measuring instrument. The overall structure of the system is shown in Fig. 1.

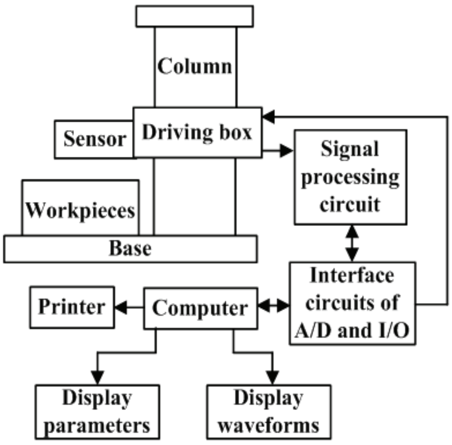

Fig. 1. The overall structure of the system.

The weak signal of the sensor output, after amplification, filtering, Xiang Min detector after processing, in order to get DC signal reflecting surface of the workpiece to be measured contour feature, then the A/D card to the DC signal is converted into digital quantity A/D, stored in the computer, then the software process the digital, to obtain the roughness parameters and waveform curve corresponding. The hardware of the system is shown in Fig. 2 diagram, is a complex circuit containing a modulation, amplification, demodulation, filtering and other processing of the sensor signal, the hardware part also includes an A/D conversion circuit of DC signal reflecting the surface contour features of the measured workpiece, and I/O control circuit. The detailed block diagram of hardware is shown in Fig. 2.

2.2. Feasibility Analysis

2.2.1. The Consideration of Test Accuracy

It is the first required precision to reach for the precision instruments with the purpose of measurement [1]. If there is no accuracy, the other design is impossible. The hardware and software to design the measurement system is composed of a set of new surface roughness measurement system. It will use the performance and high precision components in the hardware circuit design of the new, integrated operational amplifier and data acquisition card, again through the reasonable design, from hardware to ensure the accuracy of the system. At the same time, the design of data processing software will use digital filtering method and for the central line of reasonable algorithm, from the perspective of the software to ensure the accuracy of the system.

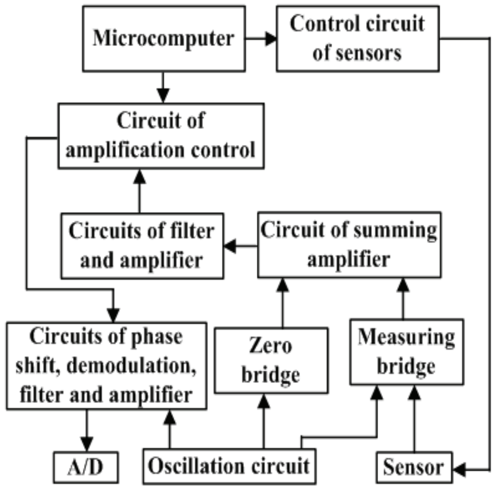

Fig. 2. The block diagram of hardware.

2.2.2. The Consideration of Test Efficiency

The operation process of the original system is complicated [2]. It is through the control button on the instrument panel to complete test set conditions, including vertical magnification selection, sampling length and stroke length selection. It is also through the control panel buttons to complete test whether to start, whether to automatically return control. The button on the panel has a multitude of names, different functions, the operation is not convenient [3]. And the parameters have a slow processing speed, reducing the efficiency of test. The newly designed system adopts the microcomputer 32, using the powerful computing ability of compute to process the parameters. It greatly improves the speed of data processing and the test accuracy. At the same time, it equips a certain peripherals such as high-speed laser print equipment. So it is more efficient and flexible for the printing of parameter and curve. And it can improve the efficiency of the whole testing process.

2.2.3. Economic Considerations

In the modern industrial system, economy is an important index to measure the performance of the system [4]. The newly designed system is the upgrading of existing equipment, in ensuring the accuracy, on the basis of efficiency improvement, it must be reduced the cost and have a good economy, this research can have the market prospect. After weighing the test accuracy and test efficiency and economy of the three aspects, to determine the surface roughness measuring instrument used for the original sensor, the sensor driving box and measuring workbench, removed the original electrical part of the instrument, and redesigned of the design project of hardware and software of the measurement system, as far as possible improve the system of price.

To sum up, through to the new design scheme of the analysis of the precision, efficiency and economy, that the new project can replace the original system which has feasibility, market prospects and operation.

3. The Hardware Design of the System

3.1. Design and Analysis of Longitudinal Driving Sensor Circuit

3.1.1. The Function of the Longitudinal Sensor Driving Circuit

Sensors in addition to the surface to be tested for the level of the lateral sliding movement, there are still in the longitudinal vertical movement [5]. Longitudinal movement is mainly motor drive the sensor and the drive box with rising and falling movement [6]. When measuring, through longitudinal motion sensor stylus adjustment degree of contact with the surface under test, a sensor coil armature is adjusted to near the center as well.

3.1.2. The composition of Longitudinal Sensor Driver Circuit Overview

The motion sensor longitudinal is driven by a DC motor [7]. The instrument is provided with three keys, an up key, a down arrow, an emergency stop button. By pressing the upward or downward buttons, the sensor will move upward or downward. If the emergency endangering the sensor or instrument appeared in the longitudinal movement process, you can press the emergency stop button to stop cutting power DC motor, stop sensor in longitudinal motion. The longitudinal driving circuit of the sensor is shown in Fig. 3. When the sensor along the longitudinal movement, the first is a very slow movement for 5 seconds, after 5 seconds, then increase the speed of movement. The purpose of this design is to prevent the sensor longitudinal motion because starting speed too fast and may cause the sensor and the measured workpiece collision, play a protective role.

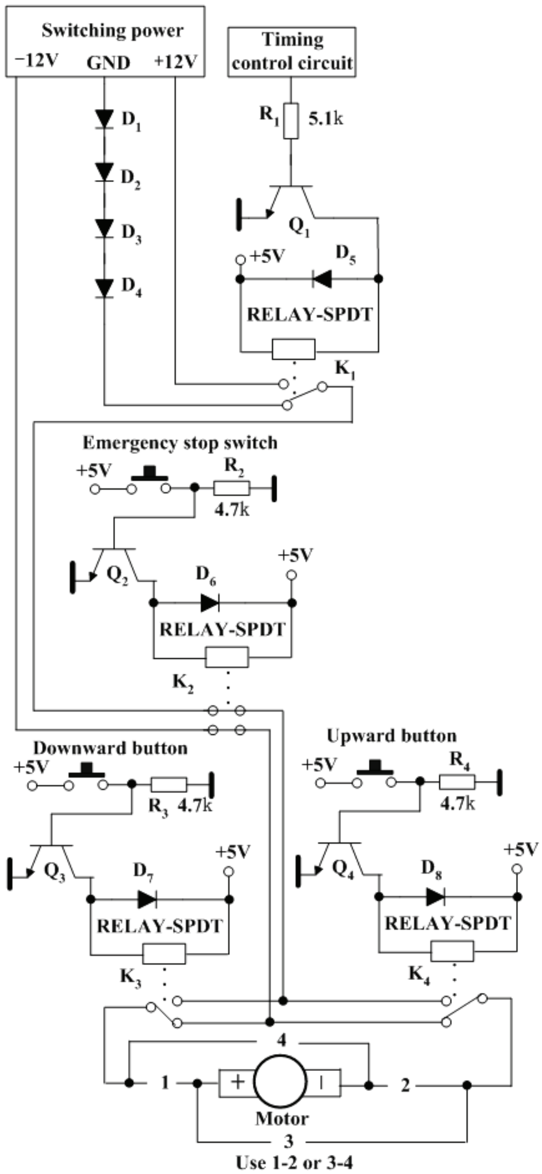

Fig. 3. The longitudinal driving circuit of sensor.

3.2. The Design of the Sensor Signal Conditioning Circuit

The surface roughness measuring instrument used by the sensor sensitivity is 0.036 mV/µm, and because of the general parts of the surface of the peak amplitude is relatively small, the sensor output signal is very weak, for amplification, filtering, detection and demodulation, signal conditioning circuit diagram is shown in Fig. 4.

3.2.1. Design of Oscillating Circuit

When the high frequency oscillator accesses to the oscillation circuit, it begins to oscillate, oscillation signals are sent into comparison circuit through frequency dividing circuit, and then the standard square wave signal with the frequency of

10 kHz can be gained. After the standard square wave signal goes through the stable sine signal after amplifier circuit and low pass filter, the stable sine signal with the amplitude 4 V, frequency of 10 kHz can be gotten. Sine signal can provide power to sensors and zero bridge by measuring bridge; it can also provide a reference voltage to the demodulation circuit by the phase shift circuit [8-10].

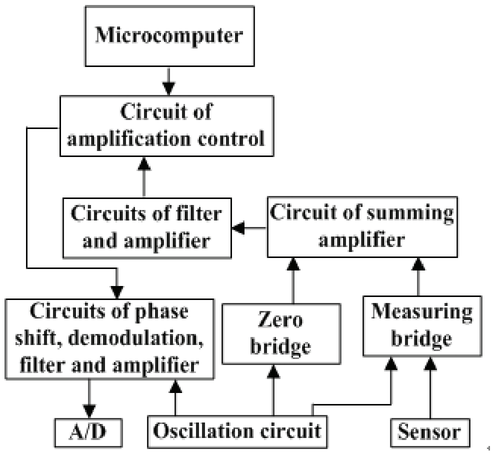

Fig. 4. The diagram of signal conditioning.

3.2.2. Design of Arithmetic Summation and Amplification Circuit

The effect of adding amplification circuit is to amplify the modulated carrier signal of the measured workpiece surface profile graph and the zero signals. Usually using the summation circuit, the measuring signal and the zero signal required for the operation of addition, seeking to meet and operation function, the summation circuit consists of integrated operational amplifier and resistor, a reverse input noninverting input and two connections. Because the reverse summation circuit than with the summation circuit adjustment is convenient, and the integrated operational amplifier noninverting input summation circuit in the common mode output voltage is higher, adding circuit measurement signals in the system with zero input signal select reverse summation circuit. The schematic of reverse summation is shown in Fig. 5.

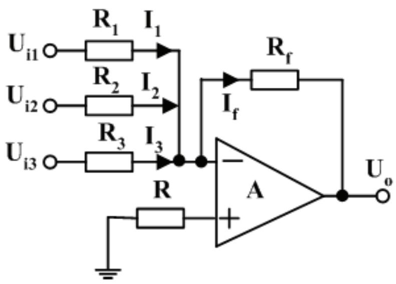

Fig. 5. The schematic of reverse summation.

3.2.3. Design of Band Pass Filter Circuit

The surface roughness measuring signal includes not only reflect the measuring signal roughness, also contain high frequency noise generated from the workpiece surface shape error and low frequency signal wave and the electrical interference [11]. In order to filter the high frequency and low frequency noise, the signals were bandpass filtered, so as to improve the signal to noise ratio. Feedback type second order band pass filter circuit infinite gain multiple in the design, the general form of the second order band pass filter transfer function is shown in following.

$$\mathrm{H}(\mathrm{s}) = \frac{\mathrm{K_p}(\omega_0 / Q)\ s}{s^2 + (\omega_0 / Q)s + \omega_0^2} \qquad (1)$$

Select America TI Company has developed production of low noise, high precision operational amplifier chip OP37 as the active element bandpass filter circuit [12]. According to the transfer function of the two order band pass filter, calculated in accordance with the traditional filter design, combined with the experimental circuit debugging, to choose the resistor R and capacitor C appropriate value, the second order band pass filter is shown in Fig. 6.

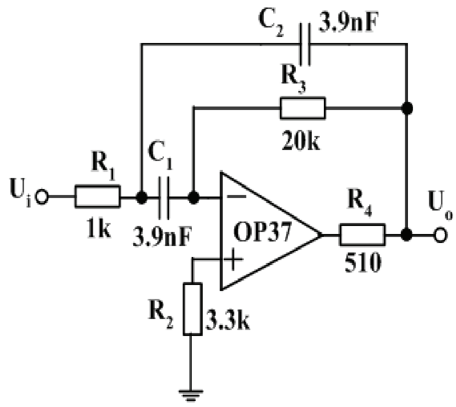

Fig. 6. The second order band pass filter.

4. Software Design of the System

4.1. The Main Program Flow Chart of System

The software needed to complete the parameter surface roughness measurement setup, sensor motion control, parameter processing and display, file and print output function. According to the measurement of surface roughness of function, the main program flow chart design is shown in Fig. 7.

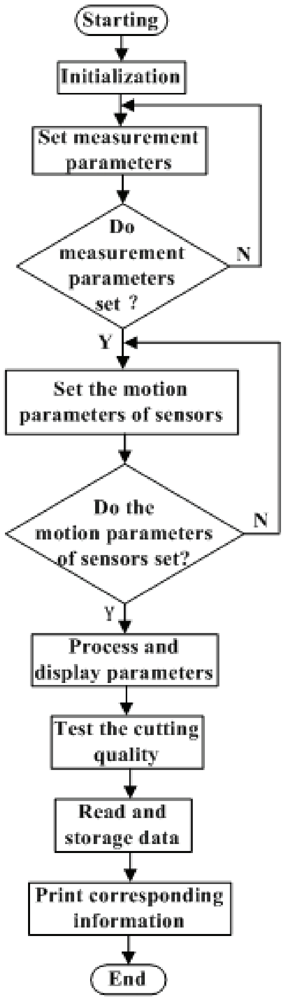

Fig. 7. The main program flow chart.

4.2. The Part of the Program Implementation of Data Acquisition

```
BYTE interrupt Sign;
WORD Based _Address=Oxc400;
BYTE Low_Byte, High_Byte;
WORD*Data=new WORD[30000000];
BYTE status;
The write port function is shown in the following.
void outPort (WORD port, BYTE value)
{
    _asm
{
mov dx, port
mov al, value
out dx, al
}
}
```

5. Test and Analysis of the System

A group of multiline roughness standard template, in the corresponding range and sampling length respectively for measurement. All measurements on 3 different positions on the sample in the work area for the 3 time, take the average, according to the following formula of relative error of indication instrument. Parts of the test data is shown in Table 1.

$$\delta_{\mathrm{Ra}} = (\mathrm{R_a}\text{-}\mathrm{R_{a0}}) / R_{a0} \times 100\%, \quad (2)$$

where δ_{Ra} is the relative error of indication, R_a is the reading average, R_{a0} is the test values of the multi-engraved line roughness standard model.

Table 1. Part of the test data.

Measuring conditions				
Item		**Sampling length (mm)**	**Evaluation length (mm)**	**The standard model R_{a0} (μm)**
Position 1		0.25	1.25	0.40
Position 2		0.80	4.00	0.82
Position 3		2.50	7.50	2.40
Position	No.	R_a / μm		
1	1	0.4002	0.8221	2.4241
	2	0.4024	0.8221	2.4251
	3	0.4024	0.8221	2.4046
2	1	0.4002	0.8228	2.4091
	2	0.4011	0.8228	2.4286
	3	0.4016	0.8230	2.4004
3	1	0.4010	0.8211	2.4156
	2	0.4011	0.8218	2.3989
	3	0.4002	0.8224	2.4069
The average/μm		0.40113	0.82224	2.41148
The relative error of indication		0.283 %	0.273 %	0.478 %

6. Conclusions

Surface technology development and application of sensor technology, single chip technology, A/D conversion technology, image processing and other rough value degree detector has higher, greatly improves the traditional rough surface defect inspection device, not only realize the automatic measurement, fast, but also to meet the provisions of the new national standard in multiple surface roughness measurement required parameter, by measuring the actual experiment, that can achieve satisfactory precision, has been widely used in metrology management, production, scientific research, laboratory and other fields.

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