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Measurement and Control System of Self-propelled Levelling Machine Based on Inclination Sensor and Laser

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Abstract: The measurement and control system of the self-propelled levelling machine adopts the software and hardware composing and the control mode based on inclination sensor and laser emitter. The system adopts the inclination sensor and laser emitter as the datum signal to form the datum plane. The separate time treatment avoids simultaneously adjusting inclination and laser signal to each other interfere. The hydraulic servo system controls the levelling part to work on the plane that parallels with the datum plane. The test result shows the measurement and control system satisfy with the request of the self-propelled levelling machine.

Keywords: Inclination sensor, Photo-electricity sensor, Laser, Levelling machine, Datum plane.

1. Introduction

Since the 80's of 20 centuries, Laser grader technology has attracted the wide attention from the scientific community and industry of china. Some large farms and enterprises imported the laser control grader to level the farmland [1].

Since the early 1990s, some schools and research institutions in China have also studied the laser grader. In 1996 Heilongjiang Academy of land reclamation sciences and Beijing Institute of Technology successfully developed agricultural laser grader of 1PTY-6. In 1997 aviation Industry Corporation of china completed the project of the laser calibration grader [2]. In 2003 Northeast Agricultural University designed and developed the laser grader of 1PJY-3.0 [3]. Research mainly focused on the flat shovel. In 2007 South China Agricultural University designed a laser land leveler for paddy [4]. Since the late 1990s China Agriculture University devoted oneself to design and develope the farmland grader. The system adopts laser and the hydraulic system to level [1, 2, 5].

In the nineteen seventies, The United States first applied the laser technology in agricultural grader, and had made the great economic benefits and the social benefits [6]. America spectral precision instrument company successfully designed and developed the first set of the laser knife plate [2]. Because the laser knife plate leveling system had many unique technique effect and economic benefit, it obtained the fast development. In the 80's many foreign enterprises producing the grader is equipped with the laser leveling system, such as America's DRESSR, America's Spectra-Physics company, America's TOPCON laser systems company, German Boukema company, The construction machinery company (Habaumag) and the Swiss firm Leica etc. In the 90's many developing countries also had used the laser land leveling technology, and achieved the good economic benefit, for example India, Turkey and Pakistan etc. [1]. At present the grader has

combined the advanced achievements in other fields in the developed industrial countries, led by the US, Europe and Japan. The advanced achievements include all wheel drive technology, laser automatic leveling device, electronic monitoring system etc.

With the development of the engineering technology, the precision request of the engineering construction and operation is higher and higher such as building engineering, farmland operation engineering, water conservancy, water and electricity engineering, railroad and highroad engineering etc. The method of the traditional measurement and construction hasn't satisfied the engineering operation request of the high quality. So the advanced technology means is applied to control and measure the operation quality [7]. Laser and inclination sensor is applied as signal source [8, 9]. The influence factors exist as follows: the levelling distance is long; the size is big.

Based on the surface levelling machine which was successfully developed by the research group of the author without the sundries cleaning function [10-13], the research group of the author studies and designs the self-propelled levelling machine that not only can level but also cleani sundries. In addition to the recent studies of the research group, domestic and foreign similar studies were the grader.

According to the request, this paper designs the measurement and control system of the self-propelled levelling machine based on inclination sensor and laser within 150 m distance. The self-propelled levelling machine is controlled to always run on a datum plane through the laser control device. When running the equipment stands the influence of the condition, the self-propelled levelling machine is able to incline toward a certain direction. So the levelling control system adopts the inclination sensor to measure the levelling part pose. The hydraulic servo system adjusts its pose in order to level the self-propelled levelling machine in the datum plane.

2. System Hardware

2.1. Hardware

The system hardware mainly includes inclination sensor, laser emitter, photo-electricity sensor, laser receiver, levelling control system and hydraulic servo system. The system hardware structure sees Fig. 1.

Two-axle inclination sensor adapts ZCT2XXMS which includes x and y direction and four direction output [14]. The central performance index is as follows: sensor angle response speed: 5per second; two-axle measurement range: ±60°; resolution ratio: ±0.02°; precision: less than ±0.3°; non-linear: ±1 %; recurrence rate: ±0.05°; temperature fluctuation: ±0.05 °/°C and working temperation:-20 - +80 °C.

Photo-electricity location sensor is two-dimensional sensor the model number of which is 2DPSD. The central performance parameter of silicon photocell is as follows: spectral range: 380 nm – 1100 nm; response time: less than 1 μs; working temperature: -20 °C - +60 °C; maximal incidence angle: more than 100°.

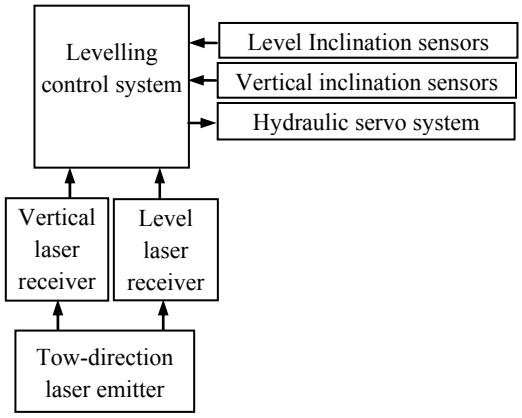


Fig. 1. The system hardware structure.

Laser signal source is a semiconductor laser emitter the model number of which is JP300. The central performance index of JP300 is as follows: red wave length: 635 nm; automation level adjusting range:±5°; level precision±10″; vertical precision: ±15″; working semi-diameter: 300 m; scan speed: 0-600 rps; scan frequency of laser emitter: 10 Hz and facula diameter: 10 mm. Photo-electricity location sensor is two-dimensional sensor the model number of which is 2DPSD. The central performance parameter of silicon photocell is as follows: spectral range: 380 nm – 1100 nm; response time: less than 1 μs; working temperature: -20 °C - +60 °C; maximal incidence angle: more than 100°. Laser receiver accepts the beam signal which is scanned by laser transmitter, and then transmits the location error signal to the controller. The receiving height and the scope of level adjustment are 20 mm. The effective receiving semi-diameter of laser signal is 300 mm, and the effective receiving angle is 360°. Photo-electricity location sensor width is 5 mm and laser beam approximately scans 1μs on the photo-electricity location sensor surface. Photo-electricity location sensor of the slim two-dimensional array is composed of the triangular model and the receiving angle of each array is 120°. According the system demand, the level direction and the vertical direction can respectively or together be selected.

The levelling control system adopts microprocessor of ARM the model number of which is LPC2102 and built-in control software. This chip has the rich inside and outside function for example very small 48 pin package, low power loss, multi-timer of 32 bit, 10 bit ADC of 8 channels and serial communication port of SPI etc. According to the system function request, controller exports the corresponding control signal to real-timely control the hydraulic servo system of the Self-propelled levelling Machine based on location deviation and leveling inclination signal that is transmitted by inclination sensor and laser receiver.

2.2. Inclination Sensor Signal Treatment

In the level and vertical direction inclination angle of x, y direction which is measured by inclination sensor exports the milli-voltage. After the milli-voltage is enlarged by amplifier, the amplifying voltage is imported to frequency transformer. And then through the photo-isolator the pulse is read by the levelling control system. After the upper treatment the data error which is induced by electromagnetic disturbance is effectively reduced.

2.3. Filter Treatment

The disturbing signal of natural light is stronger more than laser signal. So the light signal must carry through the filter treatment. Because laser transmission rate of 635 nm wave is strong, laser receiver adapts the big bandwidth filter chip. Considering the slope incidence of laser, the central wave of filter chip is 670 nm. When the slope incidence angle of laser beam is 45°, the central wavelength of filter chip changes from 670 nm to 600 nm and the peak transmission rate reduces a percentage of 10. So the semi-bandwidth of filter chip is 100 nm.

2.4. Laser Receiver

Laser receiver is an important composing part of levelling control system. When the system works, laser emitter scans and transmits laser beam to form a laser beam datum plane of level and uprightness above the operation plane. Laser receiver connects with the levelling control system and laser transmission and real-timely accepts the faint low-frequency. After it is treated, the location deviation is transmitted to levelling control system. Low-frequency laser signal is transformed to get the faint analog signal by photo-electricity sensor. The faint analog signal is carried through amplitude modulation. And then amplitude modulation signal passes low-noise pre-main amplifier, rectifier circuit and stretching circuit in turn. Last the levelling control system exports the control signal to the hydraulic servo system. The laser receiver system structure Sees Fig. 2.

2.5. Weak Electricity Treatment

When laser emitter works, it exports continuous laser beam. After being reflected by pentprism, laser beam diverts 90°. As the same time, motor whose speed is 600 rpm drags pentprism to circumrotate and scan laser beam. So the signal laser receiver accepts is the 10 Hz pulse.

After being filtered, laser signal translates analogy signal through the Photo-electricity sensor. Because analogy signal contains the noise of photo-electricity sensor and amplifier etc, its signal-to-noise ratio is very low. And it is a slow and faint signal of low-frequency. So the low and faint signal of low-frequency is carried through amplifying, filter and shaping treatment.

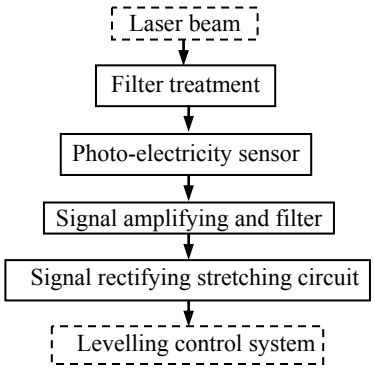


Fig. 2. Laser receiver system structure.

In faint detection system, the output port of sensor connects with a low-noise prefix amplifier. The function is as follows: a low-noise prefix amplifier amplifies the faint electricity signal that is exported by photo-electricity sensor and makes photo-electricity sensor offset and match with impedance. The request of prefix amplifier is as follows: low-noise, high-gain, low-output impedance, sufficient signal bandwidth and load driving power, linear zone width and strong anti-interference capability. In the structure, the request of prefix amplifier is as follows: compactness, close sensor, nicer ground and shield. Adopting high gain amplification circuit furthermore amplifies the faint signal. Band filter is designed for eliminating the diversified interference signal. Comparator circuit transforms the analogy signal into the regular pulse signal. And then pulse signal is treated by pulse spreading circuit. Last pulse spreading signal is imported to the levelling control system.

3. System Software

According to the signal of inclination sensors and laser, the levelling control system respectively exports the control signal to the hydraulic servo system to control the levelling part to work on the plane that parallels with the datum plane. Based on the different location deviation signal of the different inclination signal of inclination sensor and laser scan location, the leveling control system exports the two control signal every 0.1 s according to the control rule of the prior location and next inclination angle. The control program flow chart sees Fig. 3.

4. Work Process

Inclination sensor measures inclination angle on the plane. When inclination angle deviates 0.05 degree from the balance position, the levelling control system controls the hydraulic servo system by time measure to drive the levelling part to adjust the

horizontal direction angle in order to make self-propelled levelling machine level. Laser receiver receives the datum plane signal that is emitted and formed by the laser emitter.

The levelling control system judges the deviation direction of the self-propelled levelling machine, and controls the hydraulic servo system by the time measure to drive the leveling part to up and down in vertical direction. The structure figure of the self-propelled levelling machine sees Fig. 4.

5. Leveling Effect

After electing the original foundation and artificially leveling a datum plane, the self-propelled levelling machine levels the surface. The sampling area is 100 m×100 m. The sampling data sees Table 1. The Geomorphologic map after leveling test sees Fig. 5. As shown in Fig. 5, error variance is less than ±2.5 mm in 100 m length.

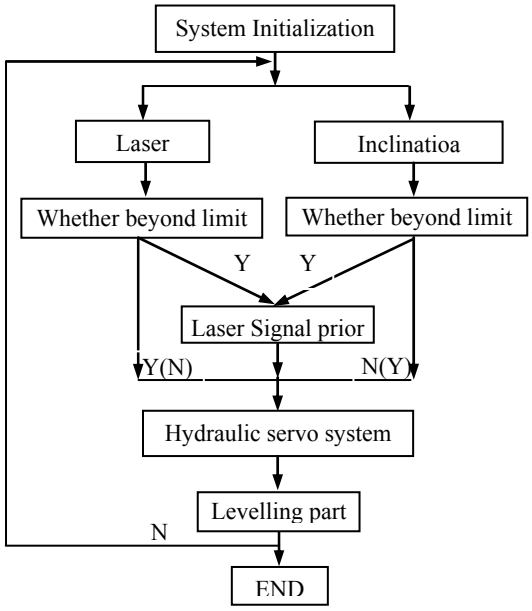
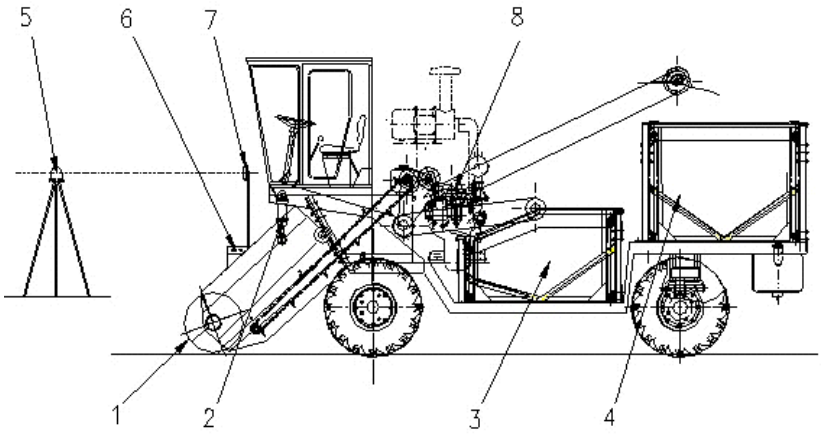


Fig. 3. The control program flow chart.



1. Levelling part; 2. Hydraulic cylinder; 3. Soil box; 4. Glove box;
5. Laser emitter; 6. Inclination sensor; 7. Laser receiver; 8. Debris provoking device.

Fig. 4. The structure figure of the self-propelled levelling machine.

Table 1. Leveling test sampling data (unit: mm).

Hij	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11
i=1	15.5	2.0	12.1	15.0	14.5	14.6	13.8	14.5	14.1	13.5	13.9
i=2	12.9	12.0	10	14.5	13.2	13.2	14.1	15.0	14.9	15.1	10.1
i=3	12.8	14.8	12.0	14.9	13.8	12.4	14.9	13.3	14.70	15.1	11.0
i=4	14.9	14.2	9.3	15.1	13.0	9.8	13.0	13.2	14.1	14.6	14.8
i=5	13.6	13.0	11.0	13.2	11.9	11.2	13.3	14.8	15.2	14.5	13.3
i=6	14.5	12.8	11.1	12.5	13.0	10.3	12.3	11.30	10.0	12.8	10.1
i=7	12.1	12.0	9.5	14.9	13.1	9.8	10.2	9.6	8.5	10.1	15.1
i=8	14.2	11.0	9.0	13.1	13.8	12.4	15.0	8.9	10.3	12.2	8.0
i=9	13.1	13.2	9.5	13.5	12.1	10.3	13.2	12.8	11.0	13.0	14.0
i=10	13.5	11.8	11.0	12.0	11.5	9.5	14.1	15.2	13.6	15.0	11.0
i=11	12.0	11.1	8.2	10.1	10.3	8.2	15.1	14.2	13.2	13.0	10.8

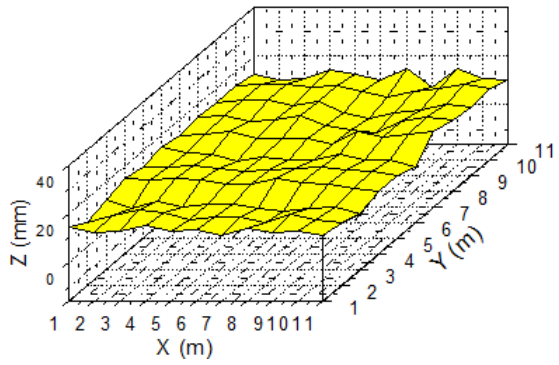


Fig. 5. Geomorphologic map after leveling test.

6. Conclusions

The self-propelled levelling machine adopts two-way laser emitter the model of which is JP300 as signal source. After received, filtered, amplified and modulated, the emitted signal is used for the leveling or vertical control signal. The balance of the self-propelled levelling machine adopts inclination sensor as signal source. Inclination sensor real-timely measures the leveling or vertical pose in order to make the levelling machine balance. The system realizes the united control and measurement of inclination sensor and laser. This system is already applied by trench-leveling Machine also. The test result shows that the system is satisfied with the levelling request.

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