Design and modelling of the self-propelled hedge trimmer

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Abstract

Highway hedges need seasonal and periodic trimming and the trimming work is labor-intensive and dangerous. In order to improve the trimming efficiency and ensure the operation safety, a self-propelled hedge trimmer was proposed in this paper, which had the functions of walking and trimming along the central isolation belt in highway. The mechanical structure design and control system design was introduced, and modularized structure was adopted in the design of control system. During the automatic control process, the sensors could collect the environment information in real time, and further determine whether each mechanism worked or not. The proposed self-propelled hedge trimmer is especially suitable for the trimming work in highway, and it can satisfy the requirements in the trimming work.

Keywords: Hedge Trimmer; Self-propelled; Automatic control

1 Introduction

As an important equipment of highway, the central isolation belt plays an important role in the security of vehicles, and its major function is to protect drivers from dazzle light. There are commonly two measures in dazzle light protection, including anti-glare fence and anti-glare hedge. With comprehensive consideration of cost, environment protection and beautifying environment, hedges have been widely used in the protection of dazzle light [1]. However, the trimming work of hedges is seasonal and periodic. Besides, with the improvement of highway construction, the requirements of hedge trimming are continuously increasing [2]. Due to the high labor consumption, inefficiency and dangerousness to operations staffs, the traditional manual trimming cannot satisfy the requirements of the current trimming work in highway [3]. Therefore, it is necessary to design a more efficient and safer automatic trimmer for the trimming work in highway.

Hedge trimmers can be divided into two kinds, i.e., stand-alone hedge trimmers and tractor-mounted hedge trimmers. The power source of stand-alone hedge trimmers can be human power, gasoline or electricity, and typical manufacturers of stand-alone hedge trimmers such as Komatsu of Japan and STIHL of Germany have been producing these trimmers for many years. In contrast, tractor-mounted and tractor-driven hedge trimmers are not so commonly popularized. These machines consist of a moveable arm with a large hedge trimmer attachment at its end [4], and their common width is 1.2-1.5 m. The machines are always installed on a tractor or automobile, so that they can induce greater efficiency [5-6]. Unfortunately, it is likely to cause traffic accidents when using tractor-mounted hedge trimmers to do the trimming work in highway.

Considering the above reasons, a self-propelled hedge trimmer of 1 m wide is proposed in this paper, and it can finish the trimming work by automatically controlled programs. In the agricultural production, many self-propelled robots have been used in picking fruits or vegetables [7-9]. For these robots, the operation staffer only needs to input the parameters before the trimming work, and the power of the self-propelled hedge trimmer can be transmit during the trimming work by a flexible shaft which rises and falls like a string trimmer. Because of the small width of the self-propelled hedge trimmer, the highway lanes are almost not occupied by the trimmers, which can reduce the risk of traffic accidents in highway. Besides, the trimmer is controlled by AVR in a high automation degree, thus reducing the labor intensity. As a result, this self-propelled hedge trimmer is very suitable for the trimming work in highway.

2 Structure design

2.1 GENERAL STRUCTURE

Figure 1 shows the schematic sketch of the self-propelled hedge trimmer. It consists of a walking mechanism, a lifting mechanism, a rotating mechanism and a trimming mechanism. The whole hedge trimmer weight about 90 kg. The rated power of XY1P64F gasoline engine in the hedge trimmer is 2.7 kw, and the rated speed of the engine is 3600 r/min. The power from the engine is transferred to the rear axle with a reduction ratio of 20:1.

The modularized structure is used in the design of the self-propelled hedge trimmer, which not only reduces the design complexity, but also benefits the group work. The walking mechanism is responsible for the movement of the hedge trimmer, so that it must be able to effectively sashay, swerve etc. According to the specific requirements of trimming work, the lifting structure can adjust the height of the hedge trimmer, and the trimming mechanism can finish the hedge trimming work. After the work, the rotating mechanism can rotate the trimming mechanism back to ensure the safety of the operation staff.

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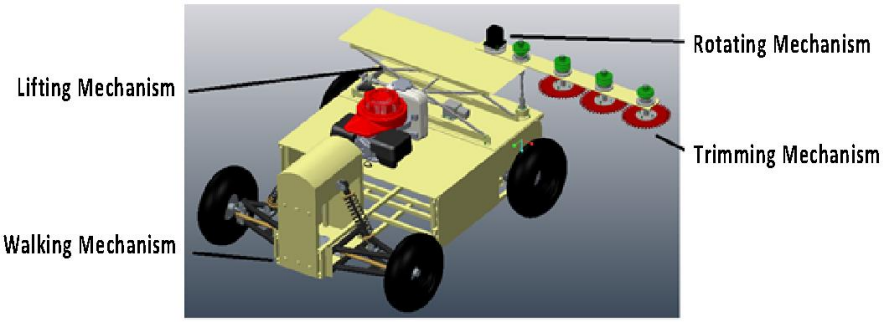

FIGURE 1 The self-propelled hedge trimmer

2.2 WORKING PRINCIPLE

Gasoline and electricity are two main power sources of the self-propelled hedge trimmer. Considering the characteristics of highway, the walking mechanism and trimming mechanism are both powered by gasoline to guarantee a day long work. In order to improve the control precision, the detection and trimming height of hedge trimmer are powered by electricity. The whole working process can be divided into three steps as follows.

Firstly, the self-propelled hedge trimmer walks to the specified location and adjusts the height of the trimming mechanism according to the inputs or settings in AVR.

Secondly, the trimmer walks along the central isolation belt in highway, and the sensors detect the environment conditions and the height of hedge. According to the detection information, it determines to extend or retract the trimming mechanism.

Finally, the trimmer stops walking and trimming at a given position after the trimming work is finished.

During the walking process, the sensors keep on working to collect the environment information in order to evade objects and track the route.

2.3 WALKING MECHANISM

The walking mechanism consists of a gasoline engine, a gearbox, a rear axle, a DC motor and the walking control system. During a hedge trimming operation, the walking mechanism moves along the central isolation belt in highway, and gains stability by the front independent suspension. In the trimming work, the walking speed of the hedge trimmer is 5 km/h, and the biggest climbing angle is 40°. Clutch and brake of the walking mechanism are controlled by the CDE2S5AA electromagnetic clutch and the CDI2S5AA electromagnetic brake respectively, and the swerve action is controlled by the GW82120-38 DC motor.

2.4 LIFTING MECHANISM

Scissors mechanism is used to raise and lower the trimming mechanism. The power source of the lifting mechanism is from the step motor with a step angle of 1.8°. The step motor rolls the ball-screw pair at 750 r/min, and the speed of the screw nut is 3 m/min. Here, the maximum stroke of the ball-screw pair is 300 mm.

As shown in Figure 2, the angle of the scissors mechanism can be changed from 20° to 55°. Accordingly, the trimming mechanism can be raised and lowered between 1 m and 1.3 m along with the angle change. Notably, the trimming mechanism needs to be kept level during the change process.

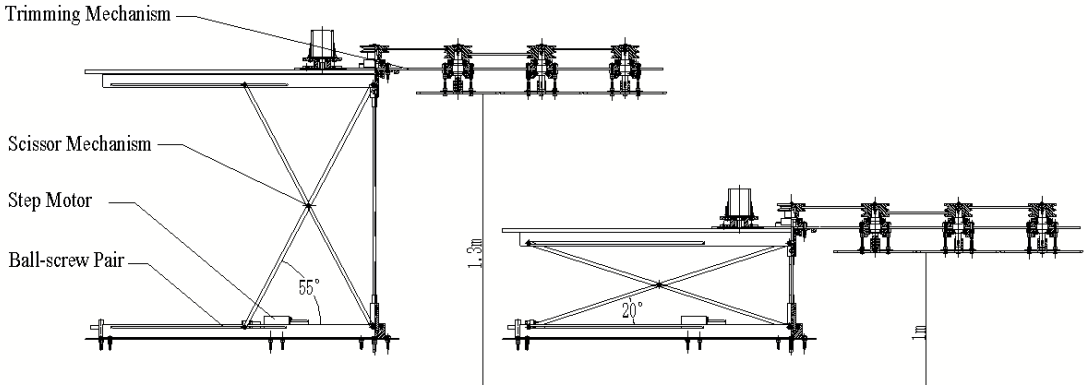

FIGURE 2 The lifting mechanism

2.5 ROTATING MECHANISM

The rotating mechanism is powered by a DC motor to achieve the rotation between 0° and 180°. The rated speed and torque of this DC motor are 30 r/min and 3 Nm, respectively. The rotating mechanism can extend the trimming mechanism in the trimming work and retract the mechanism after the work, thus ensuring the traffic safety.

2.6 TRIMMING MECHANISM

The trimming mechanism is shown in Figure 3, which mainly consist of circular saw plates, flexible shaft, transmission shafts and pulleys. The diameter of the circular saw plate is 200 mm and the teeth number of the circular saw plate is 60.

As shown in Figure 3, three circular saw plates are distributed in a straight line, which can move along the

horizontal direction to adjust the tension of the belts. The power from the engine is transmitted to these circular saw plates by flexible shaft, transmission shafts and pulleys, and the flexible shaft can realize power transmission when the spatial position of the trimming mechanism changes.

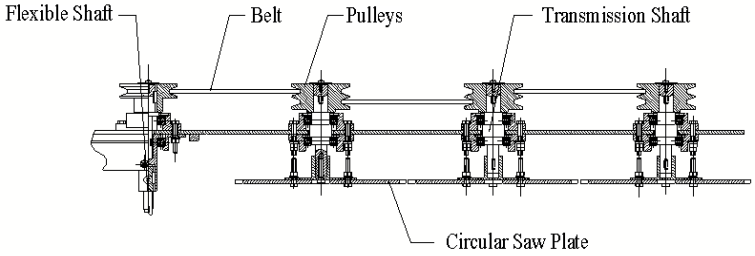

FIGURE 3 The trimming mechanism

3 Control system hardware

3.1 CONTROL SYSTEM STRUCTURE

As shown in Figure 4, the control system structure contains the following three parts: the main control circuit module, the DC motor drive module, and the input and output module.

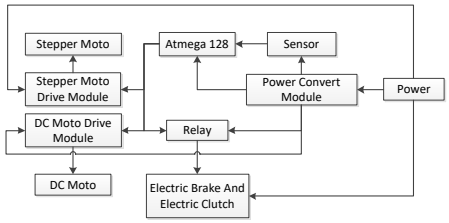

FIGURE 4 The structure of control system

3.2 POWER CONVERSION MODULE

As shown in Figure 5, the power conversion module uses LM2596 to convert 24 V into 5 V low-potential electric power supply.

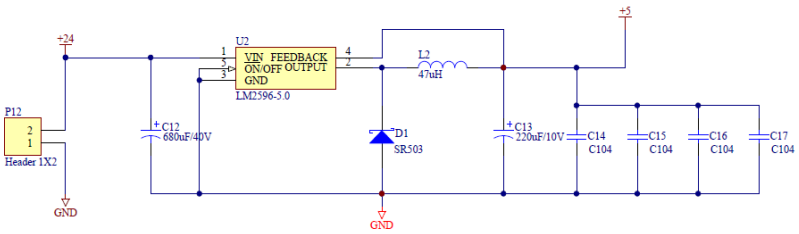

FIGURE 5 The power conversion module

3.3 AVR MODULE

Figure 6 shows the main circuit control module, which consists of the ATmega128 chip minimizing system, the work indication circuit and the peripheral circuit.

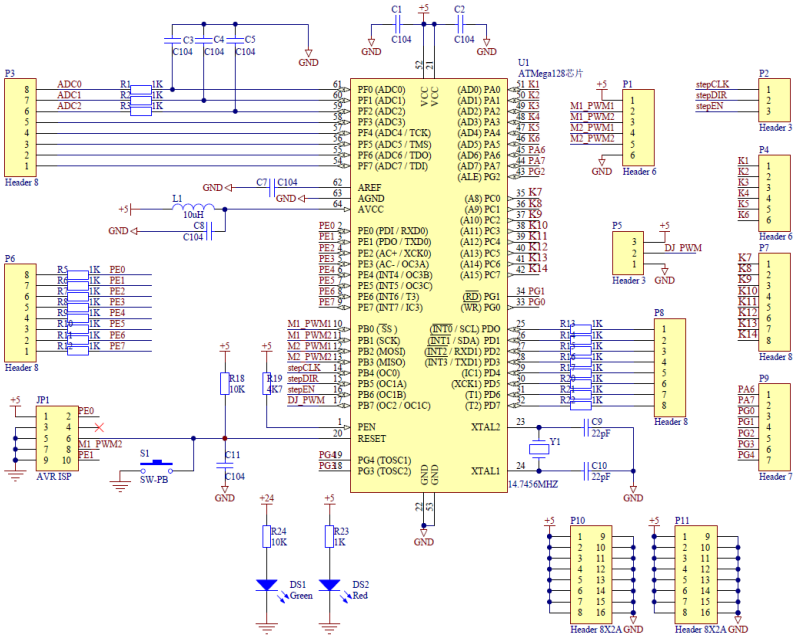

FIGURE 6 The AVR module

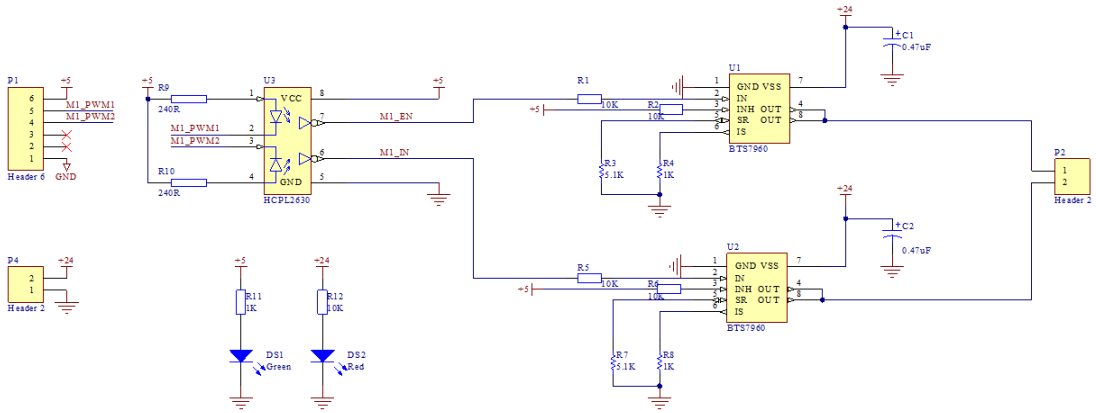

FIGURE 7 The drive module

3.4 DRIVE MODULE

As the mechanism, the GW82120-38 DC motor requires a current of 8 A under normal working conditions. As shown in Figure 7, the drive module uses the BTS7960 chip as the driver chip of DC motor, and the HCPL2630 as the signal photocoupler isolator.

3.5 INPUT AND OUTPUT MODULE

Input and output module is shown in Figure 8. The electromagnetic clutch and brake are controlled by relays, which is simple, reliable and easy to control. The executing elements are controlled by the on-off time of the relays.

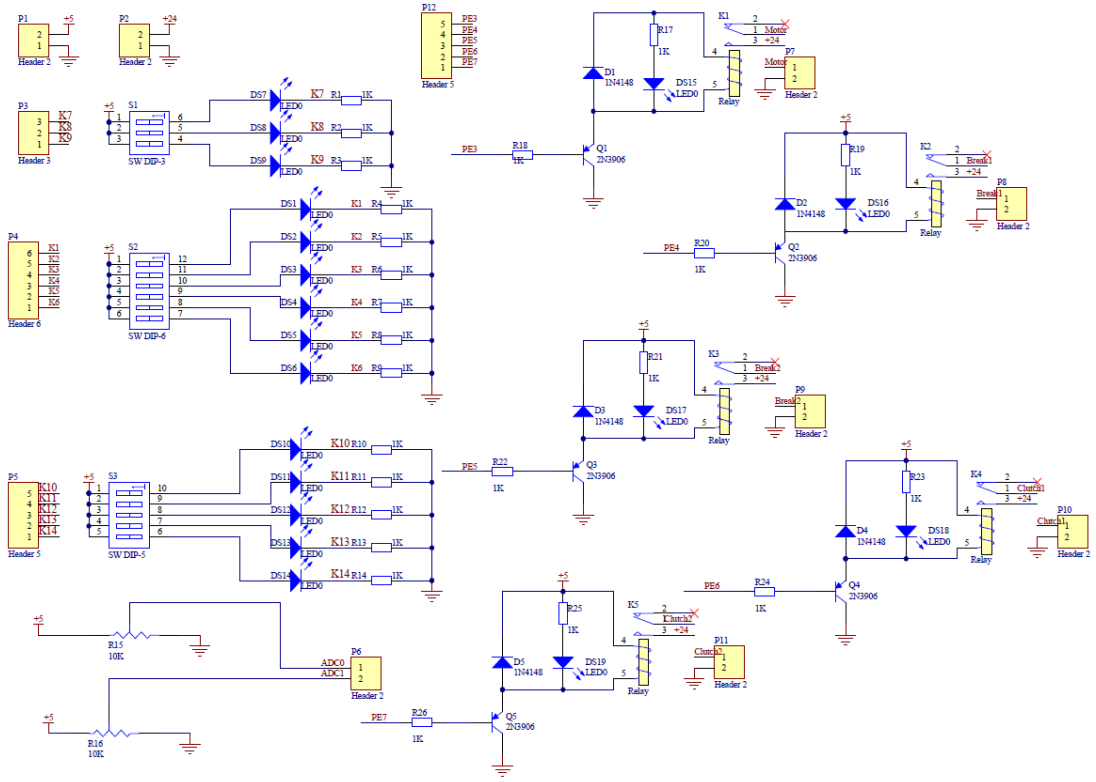

FIGURE 8 The input and output module

4 Control system software

4.1 SOFTWARE DESIGN

The software can be divided into four parts: information collection layer, information processing layer, decision layer and execution layer. The information collection layer is responsible for the environmental information collection, the information processing layer is for environmental information analysis and processing, the decision layer is for directing the movement of the self-propelled hedge trimmer, and the execution layer is for executing the movement. According to the control requirements, the general design of the software can be summarized as follows.

Firstly, systematic initialization of the control system module is executed. That is, the electromagnetic clutch of the walking mechanism should be separated to ensure the trimming mechanism and the walking mechanism disengaged.

Secondly, once the start button is pressed, the self-

propelled hedge trimmer switches to the auto-control status through three steps as: adjusting the height of the trimming mechanism and extending the trimming mechanism; adjusting the valve angle of the gasoline engine by the steering engine; controlling the electromagnetic clutch, the electromagnetic brake and DC motor according to the environment conditions detected by the sensors to make the self-propelled hedge trimmer finish the trimming work.

Finally, when the stop button is pressed, the self-propelled hedge trimmer stops walking and trimming, and the trimming mechanism is retracted to the safe mode. Under some specific conditions such as the end position of the trimming work, the self-propelled trimmer will be in the same situation.

4.2 THE FLOW CHART OF THE SOFTWARE

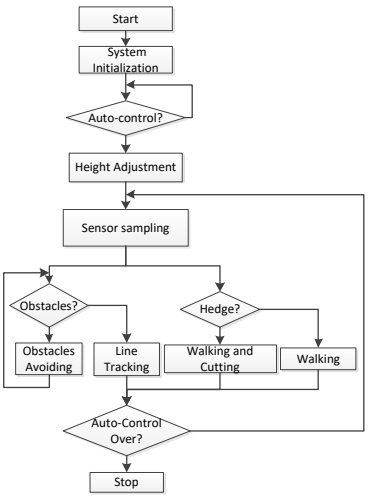

FIGURE 9 The flow chart of the software

During the walking process of the self-propelled hedge trimmer, sensors are used to dynamically inspect environmental parameters to determine whether the trimming mechanism works or not. The auto-control can be started or stopped by a switch. The software flow chart of the self-propelled hedge trimmer is shown in Figure 9.

5 Conclusion

The mechanical structure design and control system design of the self-propelled hedge trimmer are introduced in this paper. The trimmer has simple structure and reliable system with intelligent control, and the control of the walking mechanism adopts the combination of line-tracking and distance detection to ensure the stability during the trimmer walking. In this way, the trimmer can finish the trimming work only by inputting correlative parameters before the work, so that labor intensity and dangerousness of the operation staffs can be reduced simultaneously. In conclusion, this paper not only puts forward a new structure of hedge trimmer, but also designs an automatic system for trimming work according to the characteristics of central isolation belt in highway. In the future, further work will be concentrated on improving the trimming mechanism to satisfy the requirements of trimming hedges with different shapes.

Acknowledgement

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