A Design of Road Lifting Blind Device and Finite Element Analysis

Y Q Li¹, X C Lv² and J Dai³

¹,²,³ School of Mechanical and Power Engineering, Henan Polytechnic University, Jiaozuo, Henan, 454000, China
liyanqin@hpu.edu.cn, 1316040305@qq.com, dajun@hpu.edu.cn

Abstract. The visually impaired cannot identify the traffic signal lamp accurately in the existing road intersection, because there is no effective blind guidance system. In view of the problem, a new lifting blind device was designed in this paper, which contains device structure and control system. Three-dimensional modeling and stress situation of the device were analyzed through Solidworks, the results showed that the structure and material selection of the blind track lifting device could meet the requirements. Because the device is simple, reliable and efficient, it is conducive to popularize and apply.

1. Introduction
At present, there are more than 80 million disabled people in the country, of which the visually impaired accounts for about 15 percent. The comfortable, safe and rational barrier-free environment is not only important embodiment of urban humanistic care, but also strong guarantee for disable people to participate in social activities. As an important part of the barrier-free environment, the blind track can provide road guiding information for the visually impaired. The clarity and forerunner characters of guiding information are the overriding functions to guarantee in the blind track design [1]. At present, many urban intersections have blind tracks where there are overpasses and underground passageways in China, which bring great convenience to the blind. However, overpasses and underground passageways cannot be applied to all road intersections, thus crossing the street for the blind has become an urgent social problem to be solved [2].

To solve this problem, the existing solution at home and abroad is mainly setting up sound prompt system. For instance, Hong Kong and some cities in Japan and the United States took the lead in setting sound prompt system at intersections to indicate signal lights change to guide the blind to across the street [3]. In Hangzhou, Fuzhou and other cities in China, sound prompt system had also been set up at some intersections. However, it brought inconvenience to the visually impaired due to the disordered direction instructions [4]. There are other blind track recognition methods, such as visual images [5-6], to assist the blind to walk, but it is generally applicable to service robots. Based on the existing problem, a lifting blind device was designed for road intersections in order to improve the existing defects of blind tracks and provide a safer, more convenient and more practical way of crossing the street for the visually impaired.

2. Design scheme
In this paper, a lifting blind device for road intersections was designed to provide a safe and reliable way for the visually impaired to participate in traffic. The entire blind track was divided into two parts, lifting
blind track device part and fixed blind track part. The fixed blind track was located in the middle of the zebra crossing, as shown in Figure 1. The lifting blind track device, which could be lifted or dropped according to the current traffic light information, was located at the entrance and exit of the intersection. The entire blind track was connected with the blind sidewalks on both sides of the road to ensure the continuity in use. This design scheme could not only provide convenience for the visually impaired to cross the street, but also guarantee the traffic’s normal running at the intersections.

3. The Design of device structure and control system

3.1. The design of structure
The lifting blind track device was designed according to the national standard. The size was 250mm*250mm*4mm. The device contained lifting electromagnet, clamping electromagnet, detection mechanism, clamping slide block and spring, and mainly depended on lifting electromagnet to complete the lifting work. The system’s theory was shown in Figure 2. The detection mechanism was fixed by iron sheets on the bottom plane of the lifting part and the inner bottom plane of the shell. The detection mechanism would judge whether a specific unit was working normally or not through testing the circuit was closed or not within the specified time. If it was not working normally, the alarm would be given, and if large-scale failure occurred, the entire intersection device could be automatically stopped. In addition, in order to ensure that the entire lifting structure could bear more loads when the blind track bulged, the number of electromagnet coil and clamping slide blocks were equipped in the device. When the lifting structure was raised, the internal sliding block would extend the clamping electromagnets to provide supporting force for the whole lifting structure.

As the lifting blind track device was located on the road, it would be crushed by pedestrians and
vehicles, the shell should have sufficient strength and rigidity. Therefore, the device was made of Q235 steel, \([\sigma]=235\text{MPa}\), and end compressive strength \([\sigma_e]=325\text{MPa}\). Suppose that the maximum weight of a single unit was 10KN, the surface area of the bearing column \(A\) should be satisfied,
\[
A \geq \frac{F_N}{[\sigma_e]}, \text{ namely, } A \geq 30.7\text{mm}^2.
\]

The thickness of the outer border was 10mm, so the load bearing: \(S=250^2-230^2=9600\text{mm}^2 > A\), namely, the strength could meet the requirements.

Inside the lifting device, 4 sliding blocks made of Q235 steel were equipped, whose diameter was 10mm. The surface was strengthened by heat treatment. The length of the slider was 30mm. When a pedestrian step on the device, assuming his weight was 100 kg, the force exerted on each slide was
\[
F = \frac{kmg}{4} \text{ (}k\text{ is the safety coefficient, } k=1.5\text{), namely, } F=375\text{N. The extrusion stress on the slide was}
\]
\[
\sigma = \frac{F}{ul} = 1.25 \text{ MPa, the shearing stress was } \tau = \frac{F}{0.25\pi d^2} = 4.8\text{ MPa.}
\]
All the stresses were within the safe range, which proved Q235 steel could meet the requirements.

3.2. The design of control system
Because the internal parts were made of steel, accidental electrical leakage would inevitably occur in application. 36V direct current power was adopted for safety. By using the circuit of traffic signal lamp, the blind track was powered by changing alternate current into direct current, regulating voltage and filtering. Each unit block was powered to ensure whenever the device could normal work.

The system adopted the 51-series MCU through I/O pin to control the system. The signal control flow chart and circuit diagram were shown in Figure 3 and Figure 4. For instances, Port 00 read green light signal, Port 01 read red light signal, Port 10 connected the relay that controlled lifting electromagnet switch, Port 11 connected the relay that controls clamping electromagnet switch, and Port 12 identified input signal of detection system. When the red light was on, Port 01 was on high level, Port 00 was on low level, the microcontroller-controlled Port 10 and Port 11 output low level, the relay didn’t close, the lifting and clamping electromagnet were not energized, and the lifting blind track device was not raised. When the green light was on, the Port 00 was on high level, the Port 01 was on low level, the microcontroller-controlled Port 10 and Port 11 output high level, the relay closed, the lifting and clamping electromagnet were energized, and the lifting blind track device was raised. When Port 12 was high, the system worked normally; when Port 12 was low, the system broke down, Port 10 and Port 11 output low level, the relay was disconnected, and the signal was transmitted to the alarm system.
Start

Detecting traffic lights

Red/green

Red

Relay disconnect

Device fall

System test

Alarm system

Yes

Is it normal?

No

Green

Relay close

Device rise

Figure 3 The signal control flow chart.

The signal control circuit diagram.

The experimental model was shown in Figure 5. The system was consisted of microcontroller, relays, lifting module, and power supply, etc. The four states of stationary state, lifting state, clamping state and reset state of the blind lifting module were tested.

Figure 5 The experimental model.

Its working mode was as follows:

• Stationary state: as shown in Figure 6, neither the lifting electromagnet nor the clamping electromagnet was energized, and the spring remained its original state. And internal monitoring iron sheets contacted, monitoring circuit detected and output signals.

Figure 6 Stationary state.

Figure 7 Lifting state.
Figure 8 Clamping state.  
• Lifting state: as shown in Figure 7, when the green light was on, the lifting and clamping electromagnet were all energized. The lifting structure was raised by the effect of lifting electromagnet and the external blind track was in convex state. Monitoring iron sheets separated from each other, and monitoring circuit detected and output signals.

• Clamping state: as shown in Figure 8, the lifting electromagnet pulled the internal main body up to the working point, and at this time the clamping electromagnet could exactly pull the sliding block out and tighten it, so that maintain unchanged under pressure. The monitoring iron sheets were still separated, and the monitoring circuit detected and output signals.

• Reset state: as shown in Figure 9, when the red light was on, all moving components returned to the original position under the effect of spring tension and gravity of the device. The external blind track dropped simultaneously, monitoring iron sheets contacted, and monitoring circuit detected and output signals.

The experimental results showed that all four states could be implemented smoothly, which verified the feasibility of the scheme and provided the basis for practical application.

4. Finite element analysis of blind track device structure

4.1. Finite element model of blind track device

4.1.1. Node cell grid partitioning. The three-dimensional model of blind track device was divided into cell grids by Solidworks software, as shown in Figure 10.

4.1.2. The restraint of lifting device. Through the finite element simulation, the stress and deformation of the lifting mechanism were analyzed. When the pedestrians or vehicles passed, the constraint was jointly restrained by the shell and the clamping mechanism.

Figure 10 Grid model of blind track device.
4.1.3. The addition of load. Considering the force exerted by pedestrians when they stepped on the lifting mechanism, we supposed that the weight of the person was 100kg, and analyzed the situation of person one foot pressed on 2 bumps. In addition, considering that the lifting mechanism was pressed by the car, we supposed that the weight of the car was 1500kg, and analyzed the situation of the wheel pressed on 4 bumps.

4.2. Finite element analysis of blind track device

In order to analyze the stress situation of blind track device, the composite stress distribution cloud diagram and displacement diagram of the finite element model were shown in Figure 11-12.

| State | The maximum composite stress (N/m²) | The maximum displacement (mm) |
|-------|-----------------------------------|-------------------------------|
| State 1 | 7.983e+006                      | 9.156e-004                   |
| State 2 | 3.990e+007                      | 4.584e-003                   |

As shown in Table 1, the maximum composite stress in two cases was 3.990e+007 N/m², which was less than the extrusion strength of Q235 steel, and the maximum displacement was 4.584e-003mm, which would not affect the work of the mechanism and meet the design requirements.

5. Summary

In view of the problem of the visually impaired crossing the street, the lifting blind device for road intersections was designed in this study. The lifting mechanism was employed in order to judge the signal lamp accurately to cross the street safely for the visually impaired via sense of touch, avoiding
the faults of existing scheme, interference and ambiguous direction, which caused by voice information. In addition, three-dimensional modeling and stress situation of the mechanism were analyzed through Solidworks; the results showed that the structure and material selection of the blind track lifting device could meet the requirements. The design of the device could improve the safety for the visually impaired people to cross the street, and simultaneously due to its simplicity, high reliability, easy maintenance and low economic cost, it was conducive to popularization and application.

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