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The Automatic Control System for The Touchdown Pressure of Disc Brush Based on Fuzzy Sensing Technology

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***Abstract*—In the daily cleaning process, the workload of the cleaning vehicle is large, leading to fast wear of the disc brush, so that the touchdown pressure of disc brush decreases. The staffs need to adjust the hydraulic oil cylinder by hand frequently according to the wear of the disc brush to compensate it. The operation of this process is comparatively complicated, it is unfavorable to improving the efficiency of the work. This study combines the structural characteristics of the cleaning vehicle and the application of sensor technology, making disc brush adjust the touchdown pressure autonomously to reduce the poor cleaning effect because of the lack of the touchdown pressure when it can't work normally due to a large change in the touchdown pressure and enhance the cleaning efficiency of cleaning vehicle. The result shows that the self-control of the touchdown pressure of disc brush system can greatly improve the cleaning efficiency of the cleaning vehicle when the continuous working time of the cleaning vehicle exceeds 4h.**

Keywords-disc brush, touchdown pressure, fuzzy control, self - control

I. INTRODUCTION

The cleaning vehicle has a long history, in more than a century of development, it has undergone many changes, and each time the function of the cleaning vehicle has been greatly improved. [1] the disc brush system is extremely important, it has the function of cleaning, collecting the road garbage and settling dust and so on. [4]

The cleaning performance of the disc brush system is closely related to the touchdown pressure of the disc brush bundle, which directly affects the cleaning efficiency of the cleaning vehicle. When the disc brush system works, the disc brush bundle needs to contact the ground with a large touchdown pressure to achieve the ideal cleaning effect. The bundle wears faster if the touchdown pressure of the disc brush is too large, and the life of disc brush is shortened; If the grounding pressure of the disc brush is too small, it can't effectively clean the road and reduce the quality of road cleaning. In the daily cleaning process, the disc brush wears quickly due to the heavy workload of the cleaning vehicle, and the relative height between the disc brush and the ground decreases, which leads to the poor cleaning effect of the road. The staff needs to adjust the hydraulic oil cylinder frequently according to the wear of the disc brush. The operation of this process is complicated, which is not conducive to improving the efficiency of work [2].

In this paper, we propose the automatic control system for the touchdown pressure of disc brush which is based on fuzzy sensing technology. If the relevant data are detected to exceed the set range during the disc brush working process, the touchdown pressure of the disc brush can be adjusted to Reduce abnormal phenomenon about the touchdown pressure, so as to improve the cleaning performance of the cleaning vehicle.

II. SYSTEM DESCRIPTION

A. Functional structure analysis of disc brush system

The disc brush system plays an important role in the cleaning process of cleaning vehicle. The study to the disc brush system is the core of this paper. The structure of disc brush is shown in the figure 1.

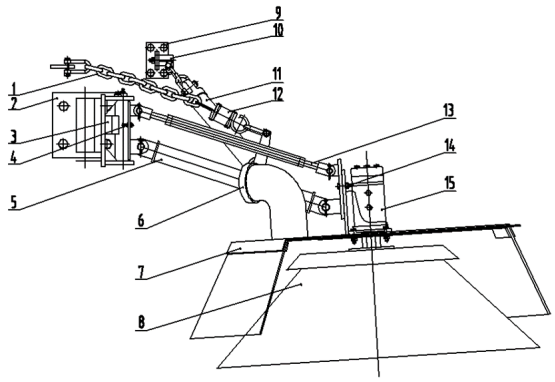

Figure 1. The basic structure of the disc brush system.

TABLE I. THE STRUCTURE OF FIGURE 1

The serial number	projects
1	chain
2	connecting rod support abutment
3	angle adjusting baffle
4	angle adjusting bolt
5	connecting rod
6	dust collection interface
7	dust shield
8	disc brush
9	Oil cylinder support abutment
10	Oil cylinder adjusting rod
11	electronic control hydraulic oil cylinder
12	spring

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13	screw adjusting rod
14	adjusting angle bolt
15	hydraulic motor

- The electronic control hydraulic oil cylinder mainly provides the lifting power of the disc brush to ensure that the disc brush has the lifting ability. By adjusting the lifting force of electronic control hydraulic oil cylinder to adjust the touchdown pressure of the disc brush, if abnormal tension of electronic control hydraulic oil cylinder is found in the working process, the lifting force of electronic control hydraulic oil cylinder will be adjusted. [7]
- The hydraulic motor mainly drives the rotation of the disk brush, which can be adjusted to meet the requirements of different speed of the disk brush under different working conditions.
- The disc brush is the main executing device in the cleaning process, cleaning the road by rotating.
- Oil cylinder adjusting rod, adjusting angle bolt, screw adjusting rod, connecting rod, angle adjusting bolt, angle adjusting baffle constitute the angle adjusting mechanism to make the disc brush have a certain Angle, generally 3° to 5°, to avoid the bottom of the disc brush overall contact with the ground, causing road garbage to move around to add to the chaos on the road.
- The chain and the spring act together constituting the avoidance device of the disc brush system, which makes the disk brush system has the function of avoiding in the work.

B. Basic Process of the System

Firstly, the tension sensor obtains the lifting force provided by electronic control hydraulic oil cylinder .Secondly, the touchdown pressure of the disc brush model is established .Thirdly, the fuzzy control model of touchdown pressure is established, and the control of lifting force is realized by using fuzzy sensing technology, so as to realize the constraint of touchdown pressure of disk brush. Finally, these models are synthetically combined to make the touchdown pressure of disc brush to be controlled automatically.

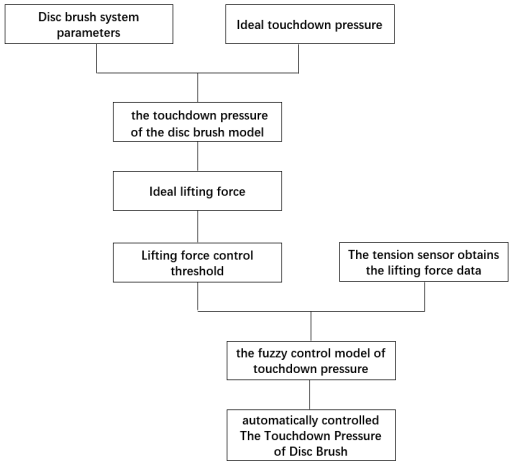

Figure 2. Basic process of system.

III. MODELING

A. The touchdown pressure of the disc brush model

When the cleaning vehicle is working, due to the weight of connecting rod, disc brush and hydraulic parts, the disc brush drops and touches the ground. It will generally cause the touchdown pressure too much large only by the weight of the above mechanisms, and the disc brush will wear quickly. It is necessary to connect the electric hydraulic oil cylinder to the disc brush to adjust the lifting force, so as to adjust the touchdown pressure of the disc brush. [1] The static analysis of the disk brush is performed, the force is shown in the figure 3 to figure 5.

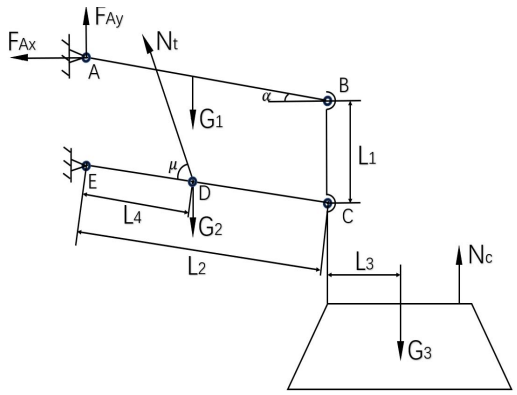

Figure 3. Analysis on force of disc brush connecting rod.

According to figure 3, the torque equilibrium equation is established at point E:

$$F_{Ax}L_1 + N_c(L_5 + L_2\cos\alpha) + N_t L_4 \sin\mu = \frac{1}{2}(G_1 + G_2)L_4\cos\alpha + G_3(L_3 + L_2\cos\alpha) \quad (1)$$

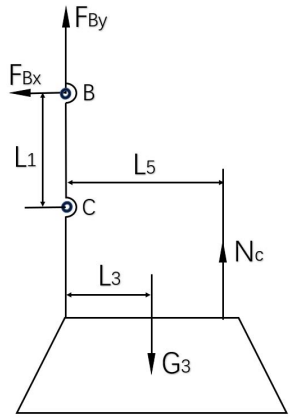

Figure 4. Analysis on force of disc brush and rod BC.

According to figure 4, the torque equilibrium equation is established at point C:

$$F_{Bx}L_1 + N_c L_5 = G_3 L_3 \quad (2)$$

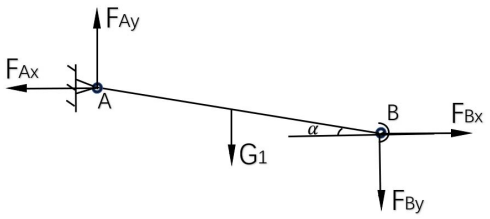

Figure 5. Analysis on force of rod AB.

According to figure 5, the force balance equation is established:

$$F_{Ax} = F_{Bx} \quad (3)$$

From equations (1), (2) and (3), we can obtain:

$$N_c = \frac{1}{2}(G_1 + G_2) + G_3 - \frac{L_4 sin\mu}{L_2 \cos\alpha} N_t \quad (4)$$

$$N_t = \frac{(G_1 + G_2 + 2G_3 - 2N_c)L_2 \cos\alpha}{2L_4 sin\mu} \quad (5)$$

In practice ,if the Disc brush radius R_m ,Brush bristle diameter d ,brush bristle free length L, blastic modulus of brush bristles E, The moment of inertia of brush bristles J, The amount of brush bristle deformation h, disc brush rotation rate n, disc brush line speed v_m, number of working brush bristles C_B are known , we can calculate the ideal touchdown pressure N_C^t in reality by type (6) : [2]

$$N_C^t = 5.3 * 10^3 d \left(\frac{Ej}{L}\right)^2 h^{\frac{1}{2}} C_B [1 + 0.18(v_m - 2)] \cos^{-1}\left(1 - \frac{h}{R_m}\right) \quad (6)$$

Comprehensive above, the relationship between the ideal lifting force N_t^t and the pressure N_C^t can be obtained.

$$N_t' = \frac{(G_1 + G_2 + 2G_3 - 2N_C')L_2 \cos\alpha}{2L_4 sin\mu} \quad (7)$$

It can be seen from the above equation, due to the wear of the disc brush, the gravity of the brush G_3 decreases, The Angle α between the connecting rod and the horizontal direction increases, while the Angle μ between the lifting force and the CE rod decreases, leading to actual lift N_t^t decreases.

B. *The fuzzy control model of touchdown pressure*

In practice, although the controlled object can be represented by a mathematical model, sometimes it is not as good as an experienced operator's manual control in the operation process, because the human brain can recognize and judge fuzzy things. For this kind of problem, the fuzzy control system and fuzzy control algorithm can be constructed by single chip microcomputer to solve it [8]. In the actual cleaning process, due to the influence of the surrounding environment and other factors, there is not a standard linear relationship between the lifting force and the touchdown pressure, and the lifting force and touchdown pressure can't be expressed by an accurate mathematical relation. Based on the fuzzy deduction of lifting force, the lifting force is closed-loop fuzzy controlled to improve the control precision of the touchdown pressure. [5]

When the tension sensor senses that the lifting force exceeds the predetermined threshold, it can adjust the touchdown pressure of the disk brush to a reasonable value by controlling the lifting force to change to the range. [6] The control of the touchdown pressure of the disc brush is the control of the lifting force of the electronic control hydraulic oil cylinder. This system adopts the valve control mode to the electronic control hydraulic oil cylinder, which is adjusting the load flow to control the lifting force by changing the valve opening size. In order to meet the requirements of single-chip microcomputer control circuit, digital throttle valve driven by stepper motor is adopted to control. The Control program block diagram is shown in figure 6.

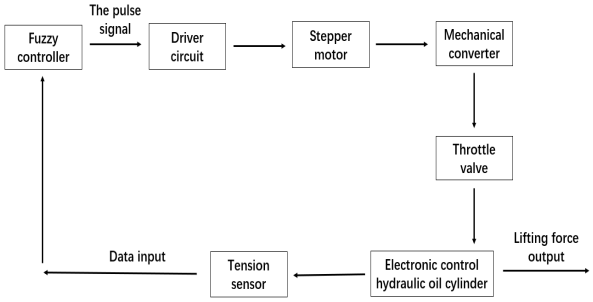

Figure 6. Control program block diagram.

IV. ANALYZE

A. *3D modeling of disc brush*

On the basis of corresponding parameters, the corresponding 3D model of the disk brush system is established through the 3D software SOLIDWORKS. The 3D model is shown in figure 7.

Figure 7. The 3D model of disc brush.

B. *Effectiveness analysis on the Automatic Control System for The Touchdown Pressure*

The experiment was carried out by the experimental cleaning vehicle carrying the experimental device under normal working conditions, Fuzzy controller threshold is set between maximum lifting force -100 and +100, Input the data from tension sensor into MATLAB to obtain figure 8:

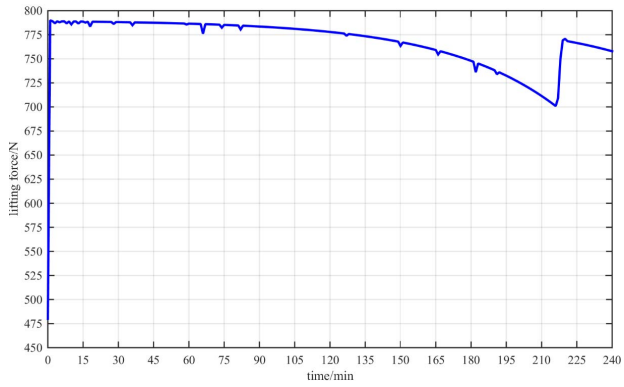

Figure 8. The lifting force changes with time

As we can see, the disc brush keeps wearing with the extension of the working time of the disc brush. When the threshold value of the fuzzy controller is not exceeded, the lifting force slowly decreases; After the preset threshold value is exceeded, the fuzzy controller controls the lifting force through the driving circuit, stepper motor and other devices, so as to change the touchdown pressure of the disk brush , which significantly improves the cleaning effect of continuous operation.

The effectiveness of the system also needs to check the performance of the system, so the concept of cleaning efficiency is introduced. Cleaning efficiency refers to the ratio of the amount of road garbage removed under specified test conditions to the amount of road garbage before operation.[4]

$$\mu = \frac{W_0 - W_1}{W_0} \quad (8)$$

μ----- Cleaning efficiency，$\%$;

W_0-----Amount of road garbage before cleaning，g/m^2;

W_1----- Amount of road garbage after cleaning，g/m^2;

The experimental vehicle is same with the reference vehicle except that the experimental vehicle is equipped with the ground pressure control system. The area to be cleaned remains consistent, and the relationship between cleaning efficiency and working time is shown in figure 9:

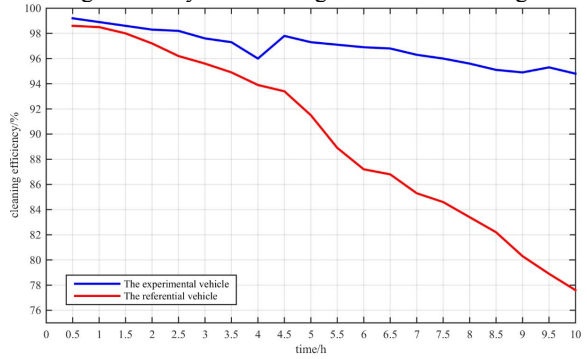

Figure 9. Changes of cleaning efficiency with time.

As we can see from the figure, under the condition that the touchdown pressure control system is not used, cleaning efficiency decreases significantly after working exceeding 4 hours. After the use of the system, the cleaning efficiency will be controlled at about 96%, which can effectively avoid the decline in cleaning efficiency, to ensure the cleaning effect of the cleaning vehicle.

V. CONCLUSION

Based on the basic driving theory of cleaning vehicles, this paper establishes the touchdown pressure of disc brush model. With the basic structure of the disc brush as the constraint condition, SOLIDWORKS simulation and MATLAB simulation are used to calculate cleaning efficiency of the different working duration of the corresponding vehicle. The calculated results are reasonable and can prove that the touchdown pressure control system of the disc brush can effectively improve the cleaning efficiency. If the continuous working time less than 4h, the system does not have much practical effect because the disk brush wear is small. When the continuous working time exceeds 4h, the cleaning efficiency begins to decline sharply due to the great change in the amount of disk brush wear. Therefore, the use of this system can effectively reduce the decline in cleaning efficiency when the continuous working time is long. And this kind of situation is common in real life, the system can be applied to a larger area. Above all, when the continuous working time of the cleaning vehicle exceeds 4h, the touchdown pressure control system of the disc brush is of great significance, which can effectively improve the cleaning efficiency of the cleaning vehicle.

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