Design of Small Lawn Garbage Sweeper

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Abstract. In view of the fact that the leaves and white garbage in the lawns are difficult to clean, this paper designed a small lawn garbage sweeper. The motor drives the cleaning roller and the traveling mechanism to realize the automatic cleaning and recycling of garbage. The author designed a filter compartment and a compacting mechanism in the recycling bin to complete the preliminary screening of the garbage. Finally, the static analysis of the rear axle was carried out by ANSYS software, showing that the axle can meet its stiffness requirements.

1 The introduction

With the continuous improvement of modern urban greening level, the number of urban greening vegetation is increasing. In some places, such as the campus, the park and the community where people live, the lawn is sometimes covered with a lot of fallen leaves and some household garbage, which is not only harmful to the growth of the grass itself, but also has a great impact on the beautification of schools, cities and communities. At present, most of the lawn cleaning work is mainly done by sanitation workers, which not only affects the health of workers, but also does not conform to the process of urbanization. Therefore, the future development direction must be toward the direction of mechanization, and finally replace the manual cleaning operation with professional cleaning equipment [1-2].

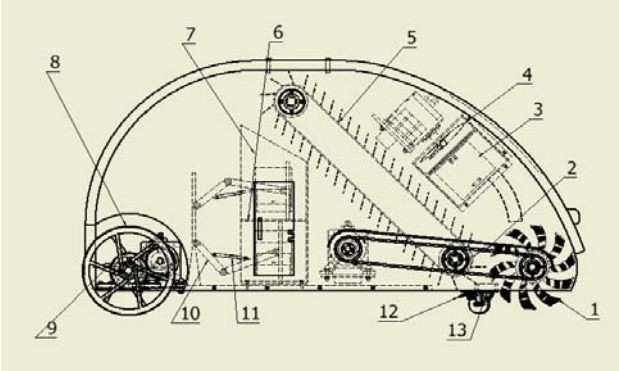
Since the 1940s, sweeping vehicles have been used in large quantities in developed countries such as the United Kingdom and the United States. The products are in the world's leading position. After years of development, technology has accumulated and the development is now quite mature [3]. The foreign road sweeper has the characteristics of multi-function, not only can be cleaned, but also can replace parts to complete snow removal, mowing, etc [4-6]. The development of sweeping vehicles in China started late. After years of hard work, the sweeping vehicles currently used in cities are mainly vacuum cleaners [7-9]. However, these sweeping vehicles are mainly used for large roads, and are bulky, costly, and have certain damage to the lawn, and are not suitable for lawn garbage cleaning. At present, most of the domestic and foreign lawn garbage cleaning vehicles use dust collection methods to clean up the collected grass clippings and fallen leaves, but they cannot complete some white garbage cleaning. For some small cleaning vehicles, they are mainly hand-pushing. The operator needs to determine the location of the garbage to complete the cleaning [10-11].

In order to realize the automation requirements of lawn garbage cleaning, the hands of the workers are completely liberated and the cleaning efficiency is improved. The author designed a small automatic garbage cleaning vehicle suitable for lawns. The sweeping vehicle has the function of vacuuming and cleaning, and can clean the garbage such as white garbage and leaves on the lawn.

2 Working principle

The lawn garbage sweeper adopted the dust-cleaning type [12-13], which combines the characteristics of pure sweep type and pure suction type sweepers [14].During operation, the motor drove the cleaning roller to rotate, and the garbage was smashed to a certain height by the mechanical kinetic energy of the roller brush. At the same time, the dust suction device on the inside of the enclosure was driven by the AC motor to form a partial vacuum, which was used to vacuum and help to get into the garbage. The collected garbage passed through the garbage transfer device, and the garbage thrown up by the roller brush was continuously caught and continues to enter the garbage can. In this way, when the brush was cleaned, it is not necessary to make the rubbish too high, thereby reducing the power required for the brush cleaning operation. The designed garbage collection device generated a certain airflow through the transmission of the scraper conveyor belt at the garbage entrance and the garbage collection system, so that when the roller brush picks up the garbage, if the flying dust rises, it could also flow in along with the airflow. The conveyor belt was transported to the garbage collection bin along with the drive belt to reduce dust pollution. A filter compartment was arranged inside the recycling bin to allow small-sized garbage to enter the lower layer. When the garbage reaches a certain amount, the

compacting mechanism of the upper and lower layers compacted the collected garbage, saving space in the recycling bin. When dumping the garbage, the operator opened the side door of the recycling bin and took out the garbage for dumping. The running mechanism is driven by the rear wheel, and the universal wheel of the front wheel is used for steering, and the steering is flexible. At the same time, the brake mechanism of the front wheel can control the stop and stop of the robot. Its specific structure is shown in Fig.1. The 3D model created using inventor is shown in Fig.2.



1-spiral cleaning roller brush; 2-belt transmission;
3-dust box; 4-dusting fan; 5-step conveyor belt;
6-filtration compartment; 7-recycling box;
8-active rear wheel; 9-speed reduction mechanism;
10-link compaction mechanism; 11-cylinder;
12-front wheel brake mechanism; 13-universal wheel

Fig.1. The schematic diagram of the overall structure of the lawn garbage sweeper.

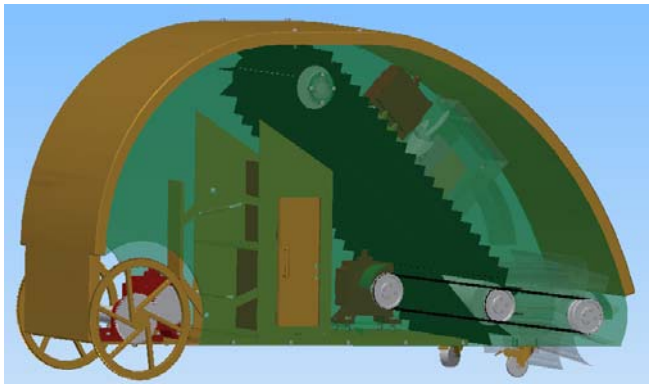


Fig. 2. The overall appearance of the lawn garbage sweeper.

3 Structural design

The lawn garbage sweeper mainly consists of cleaning and conveying part, recycling part and walking part.

3.1 Clean the vacuuming and conveying part

Cleaning and conveying part is divided into cleaning, vacuuming and conveying system. The roller brush and garbage conveyor are the main actuators of the sweeper. They are responsible for the final cleaning task and the transfer task of the garbage. It is the most important part of the sweeper and the main function of the sweeping robot. Its transmission process principle is shown in Fig. 3. The roller brush throws the garbage into the conveyor belt, which throws the garbage into the garbage collection box.

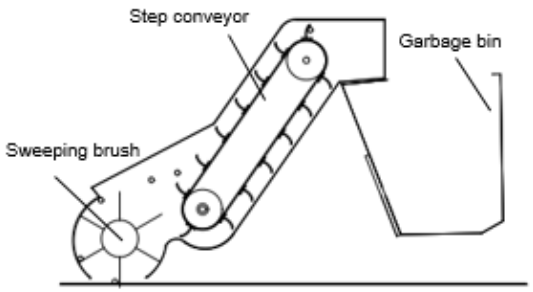


Fig. 3. The schematic diagram of garbage transportation process.

3.1.1 Cleaning system

The cleaning system usually consists of a disk brush or a roller brush, which is the actuator of the system. When working, the roller brush was in contact with the ground for garbage cleaning. The speed of the brush, the quality of the brush, and the type of roller brush directly affect the cleaning efficiency [15]. In order to better throw the garbage into the conveyor belt, this paper used a spiral cleaning roller brush. According to the diameter of the largest garbage plastic bottle is about 6 mm, the size of the blade was rationally designed. In order to reduce the air resistance to the blade and the loss of power during the rotation of the brush, small holes were formed in the blade. The roller cylinder has a diameter of 100 mm, a blade positioning dimension of 70 mm, a width of 50 mm, an inclination angle of 15°, and a roller brush length of 500 mm. Sweeping brush is shown in Fig. 4.

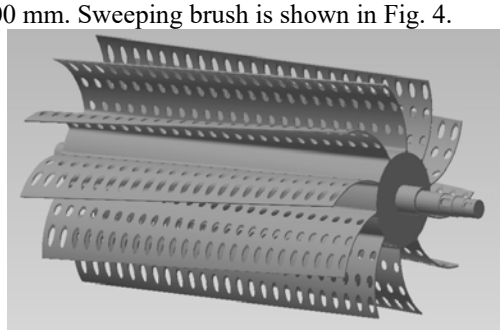


Fig. 4. The sweeping brush.

3.1.2 Vacuum system

The vacuum system is an auxiliary function part of the lawn garbage cleaning sweeper. It mainly assists in improving the efficiency of cleaning the roller into the garbage, and achieves a certain degree of vacuuming.

The vacuum system used an electric motor to drive the fan blades to rotate at a high speed, and a negative pressure was formed in the sealed casing to absorb external dust. Therefore, there are certain requirements for the curvature and size of the blade. In this way, the fan air volume can be guaranteed to have a certain vacuuming capacity.

Known wind volume calculation formula:

$$Q=VF \quad (1)$$

Where V is the Wind speed, it can be accurately measured with an anemometer; Q is the air volume; F is air duct cross-sectional area.

According to the design requirements, the maximum air volume is not less than 3000m3/h.

$$Q_{\max} \geq 3000 m^3 / h \quad (2)$$

Completion of fan blade design calculation according to formula (1) (2), the outer diameter of the fan blade is 180 mm and the rotation is 16 mm. Fan blade structure is shown in Fig. 5.

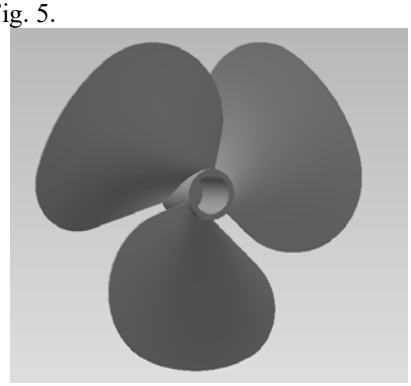


Fig. 5. The fan blade.

3.1.3 Conveying system

The rubbish that is swept by the sweeping brush was sent to the rubbish bin through the garbage conveyor. Therefore, the conveying device is mainly responsible for transporting the garbage from a low place to a high place, and then throwing it into a recycling box. In order to prevent the garbage from slipping due to vibration during the conveying process and effectively improve the transmission efficiency, a tilted conveyor with a scraper was selected. That is, a stepped conveyor. Its structure is shown in Fig.6.

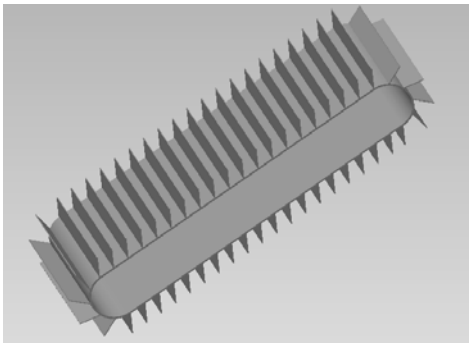


Fig. 6. The step conveyor.

3.2 recycling part

The recycling part is mainly composed of a recycling box and a connecting rod compacting mechanism.

3.2.1 Recycling bin

The recycling bin was divided into two parts. A filter compartment was arranged in the middle of the upper and lower layers, so that the smaller volume of the blade was dropped, the upper layer collected the bottle-shaped bulk garbage, and the lower layer collected the fallen leaves. The initial screening by geometry was more in line with the concept of garbage collection. Two garbage outlets were opened on one side of the garbage collection box, and the opening and closing of the garbage removal outlet was controlled by the telescopic sliding baffle. The recycling bin is shown in Fig. 7.

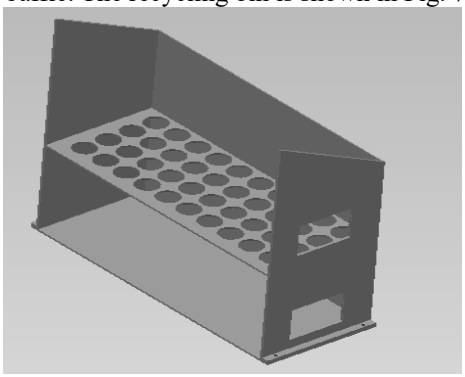


Fig. 7. The recycling bin.

3.2.2 Connecting rod compaction mechanism

The upper and lower parts of the recycling box were provided with a connecting rod compacting mechanism to compact the garbage accordingly, increasing the capacity of the recycling box. A schematic diagram of the mechanism of the connecting rod compacting mechanism in the upper recovery tank is shown in Fig. 8. The connecting rod BC was connected to the compacting plate in the recovery tank. Under the action of the cylinder, the crank AB performed a circular motion, and the compacting plate reciprocated left and right to compact the garbage. At the same time, the process of compacting garbage could also help some small-volume garbage to fall into the lower recycling bin.

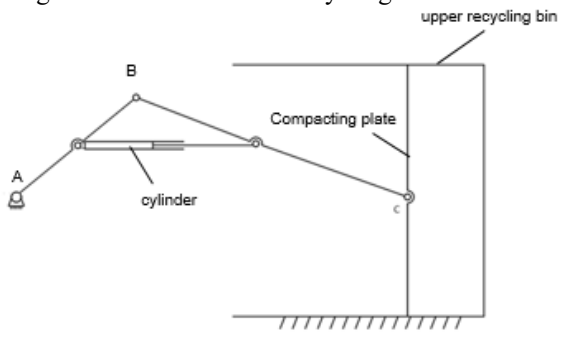


Fig. 8. The schematic diagram of the connecting rod compaction mechanism.

3.3 Walking part

The walking part of the lawn garbage weeper adopted a rear wheel drive front wheel steering mode. The front wheel selected the universal wheel with brake function, which makes the car body more flexible and avoids the generation of cleaning dead angles，as shown in Figure

9. The rear wheel is a driving wheel, which will have a certain friction with the ground when walking. In order to reduce the damage to the lawn, a groove was provided at the outer edge of the rear wheel, and a material that is less harmful to the lawn was selected, as shown in Fig. 10.

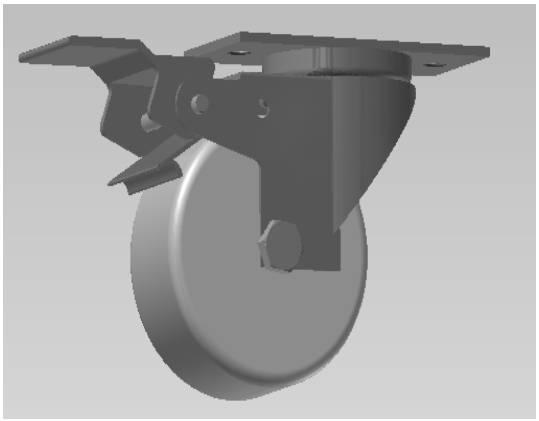


Fig. 9. The universal wheel.

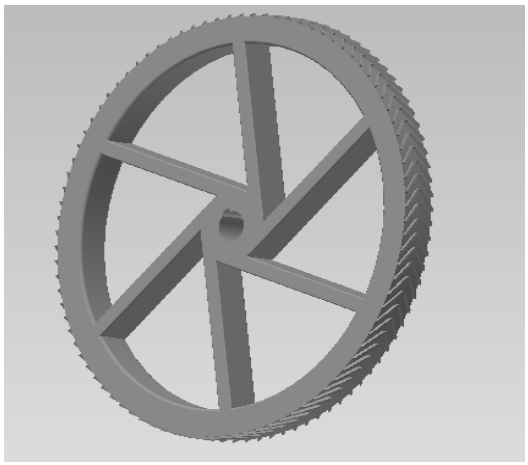


Fig. 10. The rear wheel.

4 Finite element analysis

The rear wheel is a drive wheel. The axle is mainly subjected to torque from the motor, and is easily deformed due to its large span. Whether the reliability meets the conditions directly affects the work of the sweeper. Therefore, this paper performed static analysis on the rear axle.

The design length of the rear axle is 590mm. The parts on the axle have bearings, spur gears, sleeves and other components. The electric motor transmitted torque to the spur gears, while the spur gears were mainly subjected to radial and circumferential force. The material of the axle is 45 steel, and its material properties are shown in Table 1 [16].

Table 1. material properties of #45 steel.

material	E/Pa	μ	ρ/ ($Kg \cdot m^{-3}$)	$[\sigma_{-1}]_b$/ (Mpa)
45	2.09×10^{9}	0.31	7890	55

Before the analysis, the necessary simplification of the model was performed, and the undercuts and chamfers on the axle were ignored. The finite element model was built by ANSYS software. After meshing, the finite element model had 7409 common units and 14153 nodes. Considering the force of the axle, applied radial and axial constraints at the bearing connecting shaft section. A circumferential force of 1910 N was applied to the side of the keyway at the gear connection, and a radial force of 695 N was applied to the surface of the shaft section. After solving, the equivalent stress cloud map was obtained, as shown in the Fig.11.

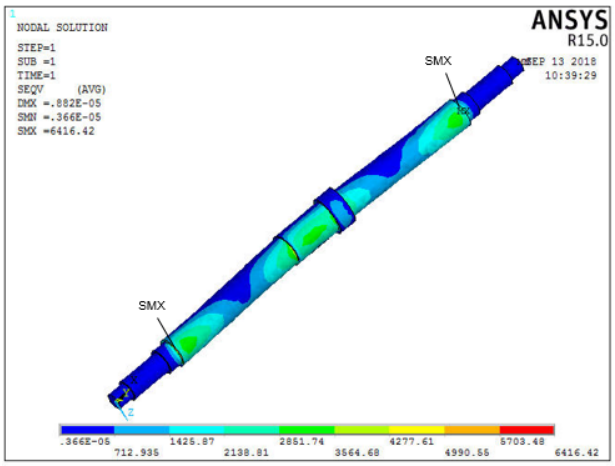


Fig. 11. The equivalent stress cloud diagram of the rear axle.

As can be seen from the equivalent stress cloud map, the maximum value of the total equivalent stress is 0.64mpa, which is less than the allowable value of the axis. The maximum value appeared at the bearing joint. The maximum displacement occurs in the middle of the axle, and the maximum deformation was 0.000882 mm, which is much smaller than the maximum bending deformation value allowed by the spindle of 0.025 mm. Therefore, the design meets the requirements.

5 Conclusion

This paper designed a lawn garbage sweeper that can automatically clean up the garbage on the lawn and reduce the damage to the lawn. The author established the three-dimensional model of the lawn garbage sweeper by inventor software, and analyzed the force of the rear axle of the main working part with ANSYS. Through the above analysis, the lawn garbage cleaning sweeper meets the functional requirements and has a simple structure.

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