Structure design of small road snow remover

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\textbf{Abstract:} According to the characteristics and degree of snowfall in Northeast China and the compaction characteristics of ice and snow on urban traffic roads, the equipment is designed according to local conditions, which can be widely used in various small area snow removal operations. The cleaning power of the machine is mainly provided by the gasoline engine. The power is transmitted to the actual rotating cleaning parts through the reducer, transmission shaft and chain transmission to complete the task. This paper briefly introduces the scheme design, structure design and parameter design of the small road snow remover.

\section{1. Introduction}
Northeast China, North China and parts of Northeast Inner Mongolia are often experiencing large-scale and long-term snowfall weather. A large amount of snowfall is difficult to melt under low temperature, and it freezes after rolling by vehicles and pedestrians. How to remove the compacted ice and snow has been a problem for people, because it is related to pedestrian safety, traffic safety and environmental health to a large extent. In winter, snow and ice often cause serious traffic obstacles. In some road sections, such as ramps, turns, intersections, airport runways, snow and ice on the road surface often cause traffic accidents. Snow cover on the road in winter brings a lot of inconvenience to people's travel. The traditional manual snow removal method has high labor intensity and low efficiency. Northern cities often use professional large-scale snow remover to remove snow, but because of its high cost of purchase and use, large work width, it is often only suitable for urban road cleaning. The purpose of this design is to design a small low-cost snow removal equipment, which can be widely used in a variety of small area snow removal operations.

\section{2. Scheme design}
The small-scale snow removal equipment is mainly powered by the gasoline engine, and the power is transmitted to the actual rotating parts through the reducer, transmission shaft and chain transmission to complete the task. The main working principle of this snow cleaning machine is to provide power through the gasoline engine, and then transfer it to the rotating part, the auger, so that the snow can be transported back. With its thrust and the vacuum suction of the internal rotating blades, the snow can generate strong power and be sent to the elbow, and then it will collide with the elbow and throw out of the machine cavity, so as to achieve the purpose of removing snow.

The main components of the small snow removal equipment are shown in Figure 1. As can be seen from the figure, it mainly includes prime mover, frame, walking device, transmission device, snow device and snow throwing device. Its basic working principle is to provide the original power through the gasoline motor, and then transfer the transmission to the driving device through the reducer and chain drive. Snow and ice on the road can be cut up by rotating the cutting parts and absorbed into the
snow storage device. There are high-speed blades inside the snow remover, which can scatter the inhaled snow and other mixture through centrifugal force, and the high-pressure gas from the fan can blow out the snow. The walking device of the whole snow remover is designed from the perspective of equipment cost, so it can be easily realized, walking while cleaning, and the maintenance of this kind of equipment is more convenient.

3. Structural design

3.1. Main technical parameters
The basic technical parameters of this design are shown in Table 1.

| Parameter          | Value           |
|--------------------|-----------------|
| Deadweight (kg)    | 100             |
| Operation time (km/h) | 2~2.5          |
| Clearance rate (%) | 95              |
| Auger diameter (mm)| 360             |
| Dimension (l×w×h)  | 1200×1100×1100  |

The specific structure of the small snow removal equipment is shown in Figure 2, which is mainly composed of auger 1, snow shovel 2, snow throwing cylinder 3, transmission system 4, gasoline engine 5, operating device 6, wheel 7, frame 8, snow throwing wheel 9, etc.
3.2. Selection of transmission mode
The specific transmission mode of the snow removal equipment is: the driving motor and the transmission shaft can be connected by belt to complete the kinetic energy transmission. In addition, one side of the transmission shaft can be connected to the reducer through synchronous conveyor belt, and the snow throwing device is connected with the output shaft of the reducer through coupling; the other side of the transmission shaft is connected with the rotating auger part which works directly through ordinary hinge transmission. The specific walking part is the process of pushing the handle forward step by step.

3.3. Design of ice breaking structure
The core of small snow removal equipment is the ice breaking part, which is called spiral ice breaker, as shown in Figure 3 below. The spiral ice breaker is arranged at the front end of the whole equipment, and the two ice breaking parts rotate in opposite directions and are arranged left and right. Through its rotation, the shell of the ice layer on the road can be broken, and the broken ice can be gathered towards the middle part. Finally, the broken ice is sent to the throwing rotor for throwing through the transmission.

![Figure 3 Schematic diagram of screw auger](image)

The spiral ice breaker is arranged at the front end of the whole equipment, and the two ice breaking parts rotate in opposite directions and are arranged left and right. Through its rotation, the shell of the ice layer on the road can be broken, and the broken ice can be gathered towards the middle part. Finally, the broken ice is sent to the throwing rotor for throwing through the transmission. In fact, the working principle of the rotor casting ice can be compared with that of the blower. The crushed ice is fine particles, which can be easily sent to the front of the rotor by the spiral conveyor. The high-speed rotor rotation can cause different high-speed flow pressure difference in the air flow inside the rotor, which can force the fine ice to fill the whole rotor cavity.

![Figure 4 Schematic diagram of ice throwing rotor](image)

At the same time, under the action of rotating centrifugal force, the small ice entering the rotor will move along the blade end of the rotating blade, and then gather on the inner arc surface of the rotor cavity, that is, it can rotate together with the high-speed rotor blade until it reaches the throwing mouth and is thrown out. The speed at which the broken ice is thrown out is the tangential speed at the top of the high-speed rotating blade, and the absolute speed is actually the total vector sum of the tangential speed at the top of the blade and the radial speed at the exit. The main parameters of ejection are the outer radius $R$ of the rotating blade, the working length $l_g$, the unloading angle of the rotating blade $\phi_x$, the distance $L$ of ejecting ice and the energy $Q_t$ of ejecting ice of the whole rotor, as shown in Figure 4.
3.4. Design of snow collection device
The snow collecting device of the snow remover is mainly used to collect and gather ice and snow. In order to have a better cutting effect on the hard ice layer, we designed the ice breaking blade with double bolts. This design can not only cut the ice layer more efficiently, but also dredge the cutting position without blocking. The specific structure is shown in Figure 5.

![Figure 5 Diagram of ribbon spiral icebreaker](image)

The design of the auger blade can integrate the functions of cutting ice, breaking ice and transporting ice, and has high work efficiency. Figure 5 shows that the double helix of the auger is distributed to the left and right. This design can effectively gather the broken ice in the middle of the auger rotor, and then transport it to the narrow ejection chamber.

4. Parameter design
In the whole snow removal equipment, the design of the transmission shaft is actually a key point, because it plays a connecting role. The power output by the prime mover is transmitted to the transmission shaft through the sprocket drive. At this time, the transmission shaft can drive the parts on it to rotate at high speed, and transmit the power to the worm. The movement of worm gear and worm can realize the change of transmission direction and power transmission of the whole device.

Therefore, we choose solid shaft as transmission shaft, 45 steel as material, and normalize and temper process for heat treatment. The hardness of the transmission shaft shall be 230 MPa, and its tensile strength shall be 600 MPa.

4.1. Parameter design of transmission shaft
The shaft is made of 45 steel with hardness of 317 ~ 255HBS. The diameter of the whole transmission shaft is calculated according to the specific output torque. Taking \( C = 118 \), \( d_1 \) is 11.256mm. The specific calculation is as follows:

\[
d_1 \geq C \frac{P}{n_1} = 118 \times \frac{2.17}{2500} = 11.256mm
\]

Determine the diameter and length of each shaft section according to the design requirements. The whole transmission shaft is divided into 5 sections, with a total length of 775mm. Then the shaft diameter and length of each part of the 5 section are shown in table 2.

| Serial number | Length (mm) | Diameter (mm) | Purpose |
|---------------|-------------|---------------|---------|
| 1             | 30.0        | 20.0          | Assembling deep groove ball bearing |
| 2             | 191.0       | 34.0          | Shaft shoulder |
| 3             | 76.0        | 26.0          | Assembling sprocket |
| 4             | 243.0       | 20.0          | Assembling deep groove ball bearing |
| 5             | 235.0       | 14.0          | Connecting propeller |

4.2. Parameter design of worm
Because the movement characteristic of worm gear and worm can realize the change of transmission direction and power transmission of the whole equipment, this device is adopted. This device can be
compared with a reducer. In the actual design, we take the worm as the input end of force transmission, and the transmission shaft transmits it here. It should be installed above the turbine. The material selection of the worm gear transmission system is as follows: the worm gear is ZCuSn10Pb1, which is directly cast by metal mold; the worm gear is 45 steel, and the surface hardness is required to be 45 ~ 50HRC.

4.3. parameter design of auger shaft
The auger shaft is the key axis which supports the stirrer used for rotary removal. It mainly realizes the cleaning function by connecting the worm system and the cylinder with high speed rotating blade. The turbine is fixed in the middle of the shaft. Both sides are fixed on the shell by bearing and connected with the rotating cylinder by supporting to ensure the smooth operation of the whole device. The whole process of the auger shaft to be processed is relatively simple, but in the process of turning, we must grasp the dimension precision and position precision of the machining. A rough shaft with diameter of 25mm and length of 670mm can be turned, and then the two ends of the shaft can be turned to 17mm. During this process, attention should be paid to the dimension and accuracy requirements of each processing. Finally, the spline groove can be milled out at the assembly of the shaft. The total length of the shaft is 590mm, the number of sections of the shaft is 6, and the diameter and length of each section are shown in Table 3.

| Serial number | Length (mm) | Diameter (mm) | Purpose               |
|---------------|-------------|---------------|-----------------------|
| 1             | 30.0        | 17.0          | Assemble the bearing  |
| 2             | 252.5       | 19.2          | Assembling auger drum |
| 3             | 15.0        | 20.0          | Assemble the bearing  |
| 4             | 10.0        | 24.0          | Shaft shoulder        |
| 5             | 252.5       | 19.2          | Assembling the auger bearing |
| 6             | 30.0        | 17.0          | Assemble the bearing  |

4.4. parameter design of spiral blade
The double spiral blade of the auger is also the core part of the whole snow removal device, because it is the main force and cutting parts, which can directly affect the work efficiency and effect. Because of its unique double helix characteristics, it is inconvenient to design and manufacture. Because the power input part is at the middle end of the auger, the blades of the auger can gather the broken ice in the middle and send it out by its double spiral rotation, so the rotation direction of the blades of the auger is divided into left and right. The parameters of each part of the auger blade, such as blade pitch $P$, the inner diameter and outer diameter of the blade are $d$ and $D$ respectively.

Pitch $P$: the blade pitch here refers to the distance between the same position points on each adjacent blade; The inner diameter of the blade $D$: it is equal to the outer diameter of the whole cylinder and can be obtained directly from the drum; Outer diameter of blade $D$: it needs to be designed according to the specific inner cavity space of the whole device.

In the normal operation process, generally speaking, the auger is a relatively easy damaged part, and the blade on it is a more easy worn part. At the beginning of the operation, the blade of the blade is often rapidly worn, but this is a normal working state, which does not affect its continuous work in the next step. With the continuous work, the external diameter of blade blade will become smaller and smaller, until the task of cutting and transporting broken ice cannot be completed, which seriously
restricts the work efficiency. In a word, its wear state is in line with the Archard wear model, and the wear curve is in line with the bathtub curve. At the same time, the wear rate of multiple blades on the same rotating axis is also different, because the surface state they contact is time-varying and uncertain. This kind of disordered contact can cause different degrees of blade wear, especially in the overload state or after repeated use for many times, the wear will be more obvious. According to experience, if about three to five blades on a rotating shaft are seriously worn, then we must stop the machine and replace the worn blades in real time instead of directly replacing the whole rotating shaft. This is not appropriate from the perspective of cost. Then, through calculation, we can get the nominal sizes of the whole spiral blade, which are set as follows:

\[ L = \sqrt{(\pi D)^2 + P^2} = \sqrt{(3.14 \times 360)^2 + 120^2} = 1136.75\text{ (mm)} \]

\[ l = \sqrt{(\pi d)^2 + P^2} = \sqrt{(3.14 \times 110)^2 + 120^2} = 365.65\text{ (mm)} \]

\[ h = \frac{1}{2} (D - d) = 125\text{ (mm)} \]

\[ \gamma = \frac{lh}{L - l} = 59.27\text{ (mm)} \]

\[ \alpha = 360^\circ \times \left[ 1 - \frac{L}{2\pi(\gamma + h)} \right] = 7.2^\circ \]

\[ C = 2(\gamma + h)\sin \frac{\alpha}{2} = 23.14\text{ (mm)} \]

Where: \( L \) is the real length of the outer helix (mm); \( l \) is the real length of the inner helix (mm); \( h \) is the blade height (mm); \( r \) is the radius of the expanded blade (mm); \( \alpha \) is the notch angle (degree); \( C \) is the notch chord length (mm); \( P \) is the pitch (mm).

5. Conclusion

This paper, through the design of small road snow remover, determines the overall layout and transmission mode of snow remover, and introduces the structure and parameters of ice breaking device and snow collecting device in detail. In addition, the key parts of the machine, such as transmission shaft, worm, auger shaft, spiral blade, are designed.

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