Snow removal device on top surface of inclined roof building

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Abstract. In view of the difficulty of snow removal in existing sloped-roof buildings in my country, a new type of snow removal device on the top surface of sloped-roof buildings is designed. The mechanical structure realizes snow removal at heights of sloped-roof buildings, reducing manpower and material resources, and solving the problem of existing devices Shortcomings in this area. Compared with the traditional building snow removal device, the device can be applied to a variety of building heights, with efficient snow removal, light weight, simple operation and easy to carry

1. Introduction
The problem of building snow is not only easy to damage the building, but also affect the daily life of residents. Every year when there is a snowstorm, the snow will bring huge losses to people's lives and property. Therefore, it is of great significance to design a snow removal device on the top surface of inclined-roof buildings that is more in line with people's daily life and is reasonable and convenient in combination with local climate and architectural design. After investigation, in view of the two major defects that the current snow removal device cannot handle the high-altitude snow accumulation and the inability to clean the slope snow, combined with people’s daily life requirements for snow removal safety, this project has designed a household snow removal device for sloped roof buildings to solve Snow removal on the top surface of high-rise buildings, reducing snow damage to houses and buildings and impact on people’s daily life.

2. Overall scenario
In order to achieve snow removal suitable for sloping roofs, the device is easy to operate and has a good treatment effect, and is suitable for different roof heights. This device requires snow shoveling and snow removal process, intermittent motion process, bracket expansion and contraction process, and horizontal movement process to realize the snow removal on the roof of the device, the back and forth movement of the push rod, the lifting of the bracket and the horizontal movement of the bottom, as shown in the following figure.
2.1. Putter motion module
The push rod motion module is composed of active slider, sleeve, winding wheel set and push rod.


2.1.1. *Intermittent motion structure design.* The push rod movement realizes force transmission through the crank slider mechanism. The active slider slides forward, and the active pawl drives the push rod forward. When the active pawl returns, the non-return pawl prevents the push rod from sliding down and completes a one-way movement. Repeat the above process to realize the one-way intermittent movement of the push rod.

![Figure 4](image-url)  
*Figure 4.* Schematic diagram of putter motion module.

![Figure 5](image-url)  
*Figure 5.* Internal structure diagram of active slider (left) and sleeve (right).

The intermittent motion structure part is located in the middle of the push rod. For the overall device, it needs to have light weight and a certain strength to ensure the overall stability of the device. At the same time, considering the difference in the width of the roof slope in different regions, the intermittent motion structure should also have the function of adjustable stroke size.

![Figure 6](image-url)  
*Figure 6.* Schematic diagram of intermittent motion structure.
After the device completes a snow removal work, the push rod needs to return to its original position to facilitate the next snow removal work. To solve this problem, the device is designed with a lock and a movable unlock key on the push rod. The upper lock piece is located at the bottom of the push rod, and the movable unlock key is located at the top of the push rod. When the push rod moves fast to the bottom, the check line in the sleeve can pull up the non-return pawl. When the upper locking member touches the active pawl, the upper locking member pushes the active pawl to move upward, and the active pawl is actively slipped. The magnet above the block is attracted and fixed, at this time the push rod can move freely and slide down. When the push rod slides down, the movable unlocking piece at the top hits the active pawl, which makes it free from the attraction of the magnet and returns to the starting position for the next snow removal work.

![Figure 7](image1.png)

**Figure 7.** The internal structure of the active slider when moving to the top (left) and bottom (right) of the push rod.

This device selects aluminum profile as the base of the push rod. Compared with other commonly used metals, aluminum profiles have the advantages of low density and light weight. The density is only 2.70 g/cm³, which is 1/3 of copper or iron. At the same time, the aluminum profile adopts two processes of heat and cold in the production process, which has strong corrosion resistance and long service life.

### 2.1.2. Structure design of winding wheel group.

The power source structure is composed of hand wheel, driven wheel, steel wire and bolt. The position of the module in the device is shown in the figure. The snow removal device on the top surface of the inclined roof building relies on manpower as a power source and does not rely on electricity at all. Therefore, the overall device is light and easy to move, and is suitable for outdoor snow removal with inconvenient power supply.

![Figure 8](image2.png)

**Figure 8.** The structure diagram and model of the wire wheel group.

The left and right sides of the reel are symmetrical, a steel wire is divided into two different directions (No. 1, No. 2) and the bottom pulley is wound and connected. No. 1 steel wire is wound around the front moving wheel, and No. 2 steel wire is wound around the rear moving wheel. The two wheels are
synchronously fixed by bolts during operation. When the driving wheel is rotating forward, the No. 1 steel wire is tightened to drive the upper driven wheel to rotate forward. After the No. 1 steel wire is completely wound on the driving wheel, the No. 2 steel wire is tightened when the driving wheel is reversed to drive the driven wheel to reverse. After the wire is completely wound on the driving wheel, repeat the previous steps to realize the forward and reverse driving of the driving wheel, thereby realizing the intermittent movement of the push rod. Through the design of the winding wheel group, it can be realized that both forward and reverse rotation can drive the push rod to move upward.

2.2. Bracket telescopic module
The double wire wheel structure includes a pin and a wire wheel. The pin is used to fix or separate the two wire wheels. When adjusting the height, remove the pin. After adjusting the height, turn the driving wheel appropriately to realize the tightness of the steel wire. The specific work flow is when adjusting the height of the stand, open the latch to ensure that the wire wheel can rotate freely, open the adjustment knob, and adjust the height of the stand.

2.3. Snow removal module
The snow removal module is mainly composed of snow shovel and rolling cloth. The snow shovel is used to cut snow blocks, and the rolling cloth is used to guide the snow blocks to slide down.

![Figure 9. Snow removal and snow removal module.](image)

The snow shovel can be applied to various snow thicknesses. Considering that there are still a large number of brick houses in our country, the front end of the snow shovel is equipped with two rollers to cushion the snow shovel, and the treatment of brick roofs can be tested.

2.4. Horizontal movement module
The horizontal movement module is located at the bottom of the device. It consists of a horizontal sled board structure, composed of pedals, ball hinges, etc. The horizontal sled enables the device to slide parallel to the eaves direction when working, and the ball hinge can facilitate the user to store the device, and the user can step on the pedal to strengthen Device stability.

![Figure 10. Horizontal movement module.](image)
3. Institutional design and verification

3.1. Crank slider

The operator rotates the compound two-hand wheel, the lower hand wheel drives the upper hand wheel to rotate, and the upper hand wheel rotates while driving the slider to reciprocate, and the push rod moves forward during the reciprocating motion of the slider. It should be the special nature of the crank slider. If the operator turns the hand wheel in the opposite direction to achieve the same effect, the stroke of the slider will not change, so the law of driving the push rod remains unchanged. Can keep the putter in a stable state of motion. However, because the center of the crank is not on the motion track of the slider, the transmission angle of the crank forward and reverse is inconsistent, and the extreme angle is not zero. Both the transmission angle and the extreme included angle have an impact on the transmission efficiency, so it is necessary to analyze the transmission angle and extreme included angle and design and calculate the size of the crank and connecting rod.

In the case of little crank eccentricity, twice the length of the crank is similar to the stroke of the slider, taking into account the distance between the manual crank and the lift of each push rod, and considering the items that are suitable as cranks on the market, the crank length The eccentricity is fixed at 32mm due to the limitation of crank installation conditions.

In a general four-bar linkage mechanism, the larger the transmission angle, the stronger the force transmission to the mechanism. In order to make the crank slider have relatively better force transmission performance, it is more important to design the connecting rod size.

![Figure 11. Crank slider diagram 1.](image1)

As shown in the figure, the rotation direction of the crank is positive. According to the conditions, the transmission angle is 75°. The position of the minimum transmission angle in this rotation direction is shown in the figure. The measured connecting rod length is 431mm.

When the crank rotation direction is reverse, it is obvious that the minimum transmission angle is greater than 75°, so a rod with a rod length of 431mm is selected to meet the design requirements.

![Figure 12. Crank slider diagram 2.](image2)
Used as a graph method to measure the extreme angle of 1.66°. The stroke of the slider is 162.464mm. Therefore, when the connecting rod length is 431mm, the crank slider has the best transmission effect, and the connecting rod length of this length will not interfere with the device itself. The angle between the extreme positions calculated according to the conditions is 1.66°. The quick return characteristic of the crank-slider mechanism is weak, and the load of the device is relatively even, which is beneficial to the stable work of the mechanism. The stroke of the slider is 162.464mm effective.

3.2. Bearing design at the rotating part
It is known that the low-speed environment, the load is stable, there is no vibration phenomenon, the bearing is radially stressed, so the deep groove ball bearing is selected, and its nominal contact angle \( \alpha = 0^\circ \), and the design is designed for its static load.

Radial force:
\[
F_R = G = 30N
\]  
(1)

Radial force of the largest bearing rolling element:
\[
F = \frac{5}{Z} F_R
\]  
(2)

In order to limit the excessive plastic deformation of rolling bearings under static load and impact load, static load calculations are required. The static load calculation formula for controlling the plastic deformation of the bearing is:
\[
\frac{Cor}{Por} \geq S_o
\]  
(3)

Because the bearing type is a deep groove ball bearing with a nominal contact angle \( \alpha = 0^\circ \), we can get: \( Por = F \)

Look up the table:
\[
S_o = 0.5
\]  
(4)

\[
C_{OR} = 4200MPa
\]  
(5)

Integrated:
\[
Z \geq \frac{5S_o G}{C_{Or}} \approx 0
\]  
(6)

In summary, deep groove ball bearings with a number of rolling elements greater than or equal to one meet the requirements, so the deep groove ball bearing code 6200 is selected.

4. Conclusions
The snow removal device on the top surface of the inclined-roof building solves the problem of difficult snow removal in the existing inclined-roof building. The snow removal device of the inclined roof building achieves the purpose of snow removal at the height of the inclined roof building through the transmission between the machines, and does not consume energy and can adjust the height. The device provides a new solution to the snow removal problem on the top surface of the inclined roof building, improves the snow removal efficiency, and has broad application prospects.
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References
[1] Tan Yiqiu, Xu Huining, Zhang Chi, Fu Yongkang. Old methods and new technologies for snow removal [J]. China Highway, 2018(03): 59-63.
[2] Zhang Zhifu, Xi Shuang, Liu Na, Yu Yu, Fan Shaohua, Feng Mingnong. Analysis of the characteristics of the temporal and spatial changes of snowfall in China from 1961 to 2012[J]. Resources Science, 2015, 37(09): 1765-1773.
[3] Yao Jiwei, Sun Kuan. Current status and development trend of road snow removal machinery[J]. Construction Machinery, 2013(11): 68-73.
[4] Wang Chunxue, Li Dongliang. The temporal and spatial variation of snow cover days and maximum snow depth in China in the past 50 years[J]. Glaciology and Geocryology, 2012, 34(02): 247-256.
[5] Hu Haiying. Discussion on domestic snow removal methods and the development trend of snow removal machinery [J]. Forestry Machinery and Woodworking Equipment, 2011, 39(05): 8-9+22.
[6] Ai Zhihao. Dynamic modeling and parameter estimation of crank-slider mechanism[D]. Hunan University of Technology, 2008.
[7] Li Xingkui. Research on Residential Building Design Code [D]. Tianjin University, 2006.
[8] Wang Wenzhi. A new type of automatic tensioning device with pulley transmission[J]. Modern Manufacturing Engineering, 2006(02):126.