Comparative Analysis of the Snow Clearing Performance Test of the Concave Disc and Vertical Milling Prototype

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ABSTRACT: In the north of China, the road is covered with the solid ice-snow which seriously affects the traffic safety of the city, it is a problem that how to clear the solid ice-snow quickly and efficiently. The concave disc clearing machine and the vertical milling clearing machine have been developed respectively based on the thought of agricultural machinery concave disc and vertical milling principle. The concave disc clearing machine is the clearing plate passively cutting ice-snow, which can complete crushing, cutting, scraping, tilt and push five operations. The vertical milling clearing machine is the cutting knife actively cutting ice-snow with function of milling, crushing, copying, obstacle etc, which has a very strong crushing capacity for ice film like high density ice-snow. The comprehensive clearing snow performance test of the concave disc and vertical milling clearing machine were performed under three kinds of road conditions. The test results show that the concave disc machine and the vertical milling machine have good operation, high working efficiency and the clearing rate are all higher than 90%, parameters setting and all indexes can meet the requirements of snow clearing operations. The concave disc machine is suitable for the plate compacted ice-snow which density is lower than 550 kg/m$^3$ and thickness range from10 mm to 80 mm. The vertical milling machine is suitable for the plate and ice film ice-snow which density range from 300 to 750kg/m$^3$ and thickness is lower than 50mm, especially suitable for ice film freezing ice -snow, which density is higher than 550kg/m$^3$.

1 INSTRUCTIONS

In winter, the most northern regions of China has been plagued by clearing snow problems, snowfall in these areas has the characteristics of lasting a long period, a large amount of snow and a wide range. The snow without clearing in time forms a hard solid ice-snow with surface ice and containing impurities plate by the means of vehicles and pedestrians repeatedly rolling and temperature changing. The road covered solid ice-snow has not only caused great inconvenience to vehicles and people, but also increases the probability of traffic accidents. According to the survey results for the world's major cities by the relevant aspects, the traffic accidents caused by the area of the city icing roads are more than 20% of the total traffic accidents in winter, which has become the world recognized "white" urban hazards[1-2]. Therefore, the vertical milling clearing machine and the concave disc clearing machine has been developed respectively.

Road test is an important part of evaluating the working performance of the clearing snow prototype. The solid ice-snow has the characters of irregularity, seasonal etc, and has close relationship with the outside climate condition, the dust, the time history and so on, therefore, it is necessary to test the performance index of clearing snow work by clearing snow test[3]. Based on previous theoretical analysis and experimental optimization, the optimal parameters combination of the concave disc clearing machine and vertical milling clearing machine were obtained, adjusting the parameters to the optimal operating state, designing the performance test of the two kinds of snow removal machine[4-6].

2 TEST CONDITIONS AND METHODS

The snow clearing performance test was performed under three different road conditions in Jiamusi, Heilongjiang Province. Road one: Jiamusi City victory road, which is the city’s busy road, 15 days of vehicle rolling, melting ice-snow, the ice and
snow in this section due to the combined effect of tail gas, dust, mud, etc was formed a frozen ice film, with the ground in a solid, more difficult to remove, as Figure 1 (a) shown. Road two: Jiamusi City China Road, this section is a country road, snow cleaning is not timely, the snow time is 30 days, the snow, compacted by vehicle and pedestrian since the winter snowfall, in this section was formed a plate and ice film mixed ice-snow , as Figure 1 (b) shown. Road three: Jiamusi university road, the snow in this section has not been cleared since the winter snowfall, which was formed a thick plate solid ice-snow caused by the compaction of pedestrian, as Figure 1 (c) shown. Above three kinds of ice-snow conditions are the typical state of urban roads in northern winter, with strong representation.

The snow clearing performance test of concave disc clearing machine and vertical milling clearing machine were performed in those three different kinds road condition in Jiamusi on December 23, 26, 28, 2013. The length of the test area was 40m and divided into three segments in the experiment, 10m is used as a reserve buffer for each end of the two ends to ensure that the stable operation of the clearing machine snow, 20m middle section as the test area.

The ice-snow samples of the test area were sampled before the test, and the physical parameters were measured. The ice-snow were measured by the method of parallel quadrilateral sampling in the test area of snow clearing. The vertices of a parallel quadrilateral and diagonal intersection point are used as the sampling points[7]. The ice-snow sample site was measured after selecting, the measured parameters include: the average density of snow-ice, the average hardness of snow-ice and the average thickness of snow-ice. The first step in the test was measured the thickness of ice-snow, and then the area of 0.01m² snow was shoved, measured the quality of ice-snow with scale, and calculated the density of ice-snow. The solid degree of ice-snow was measured by using the T1SD-750-IV type soil measuring instrument. The relevant physical parameters of the test area are obtained by the test, as shown in Table 1. The average values of the parameters in the table are three times.

### Table 1. Ice conditions and related parameters of the test site.

<table>
<thead>
<tr>
<th>Ice conditions</th>
<th>Road one</th>
<th>Road two</th>
<th>Road three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frozen snow with a thickness</td>
<td>The surface contain 1mm thickness</td>
<td>Compacted plate</td>
<td></td>
</tr>
<tr>
<td>greater than 1mm</td>
<td>ice film, the deep layer as plate</td>
<td>ice-snow</td>
<td></td>
</tr>
<tr>
<td>Average temperature on test</td>
<td>-18</td>
<td>-21</td>
<td>-20</td>
</tr>
<tr>
<td>day(℃)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average humidity on test day</td>
<td>52</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>(% )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average density on test site</td>
<td>712</td>
<td>574</td>
<td>380</td>
</tr>
<tr>
<td>(kg.m⁻³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average thickness(mm)</td>
<td>25</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Average compactibility(MPa)</td>
<td>6.92</td>
<td>3.58</td>
<td>2.15</td>
</tr>
</tbody>
</table>

### 3 TEST EQUIPMENT AND APPARATUS

John Deal 5-804 main wheeled tractor as the supporting power in the test of concave disc machine and vertical milling clearing machine, the concave disc is the rear suspension, and the vertical milling is the front suspension. Other test equipment and tools: Soil hardness measuring instrument, scale, ruler, tape, shovel, tool etc.

In the snow clearing performance test, adjusted the parameters of the prototype to the optimal value, other parameters were set according to the theoretical analysis and experimental analysis, in order to study the performance and effect of the concave disc machine and the vertical machine. The main structural parameters of the concave disc machine and the vertical machine are shown in Table 2 and 3.

### Table 2. Main structural parameters of concave disc machine.

<table>
<thead>
<tr>
<th>Disk diameter (mm)</th>
<th>Disc thickness (mm)</th>
<th>Disc radius (mm)</th>
<th>Disc edge angle (°)</th>
<th>The angle between the concave plate and the moving direction (°)</th>
<th>Disk spacing (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>3.5</td>
<td>650</td>
<td>20</td>
<td>13</td>
<td>15</td>
</tr>
</tbody>
</table>
4 TEST RESULT AND ANALYSIS

The vertical milling type and the concave disc type snow removing prototype parameters are adjusted to the corresponding numerical value, carry out safety inspection of all the moving parts to ensure the reliability and safety of the operation. In the selected three kinds of road conditions were carried out clearing the snow performance test, three trips were measured on each road, data to take the average of the three operations.

### Efficiency analysis of snow clearing

The efficiency of snow clearing was defined as clearing the volume of ice-snow every hour by machine under the premise that the ice-snow removal rate was greater than 90%. Figure 2 shows the comparison of the snow clearing efficiency of the concave disc machine and the vertical milling machine.

![Figure 2. Operating efficiency comparison of concave disc machine and vertical milling machine.](image)

The test results shows that the snow clearing efficiency of the vertical milling machine was 33% greater than concave disc machine on road one, this is due to on the road one condition, ice-snow texture is hard and the concave disc is difficult to cut into the snow, but the vertical milling machine is active clearing operations, which can be completed quickly.

According to figure 2, the efficiencies of two machines on road one are all lower than road two and three. In which the efficiency of concave disc machine on road one is 60% lower than road two and 68% lower than road three, but the efficiency on road two is 19% lower than road three: the efficiency of vertical milling machine on road one is 33% lower than road two and 42% lower than road three, the efficiency on road two is 13% lower than road three. The main reason of the low clearing efficiency under the condition of road one is due to the high density and high hardness of ice-snow, and the ice-snow is difficult to clear, due to the relatively large snow thickness on road three, which leads to the efficiency on road two lower than road three.

The above results show that the ice-snow characteristics factors have influence on the prototype of snow removing performance, which is more significant than snow thickness.

### Fuel consumption analysis
The fuel consumption was defined as the fuel consumption per hour machine under the same operating condition, the unit was L/h. Figure 3 shows the comparison of the fuel consumption of the concave disc machine and the vertical milling machine, the results showed that the fuel consumption of the vertical milling machine was higher than the concave disc machine in three kinds of road conditions, due to the vertical milling machine was active cutting, a portion of the fuel consumption was used to provide a torque to the main shaft. The fuel consumption of two machines under the road one condition are all higher than road two and road three, the consumption of concave disc machine was 10.3L/h and vertical milling is 12.4L/h, under road one condition, the thickness of ice-snow was more than 1mm of ice film which has characteristic of hard texture, broken difficult, so that a significant increase in fuel consumption. The fuel consumption of concave disc under road three condition was significantly decreased, 7.2% lower than road one, because the ice-snow in road three was plate compacted snow, which density was relatively small and low power consumption, so the fuel consumption fell. Working on the road three conditions, the fuel consumption of concave disc machine was 5.6% lower than vertical milling machine, which showed that the concave disc machine was more suitable for the road condition.

Figure 3. Fuel consumption comparison of concave disc machine and vertical milling machine.

4.3 Net rate analysis

(a) Road one condition

(b) Road two conditions

(c) Road three conditions

Figure 4. The clearing rate comparison under three conditions.
The clearing rate contrast analysis chart of two machines at different operating speed under three road conditions is shown Figure 4. When the concave disc machine working on the road one condition, concave disc cutting into ice-snow was relative difficulty due to the ice-snow on this road was high density, hard and bonded with the road surface firmly, which clearing rate was overall lower than vertical milling machine. When the working speed was higher than 7km/h, the clearing rate of concave disc decline rapidly, the lowest clearing rate was only 90.1%.

Under the same condition of road two, the clearing rate of concave disc machine and vertical milling machine were all better than road one condition. Because the hardness and density of ice and snow under this road condition were relatively lower, the ice-snow under road one condition was broken easily. The clearing effect of vertical milling machine was better than that under road one and road three conditions, the clearing rate can reach 99.0%. When the marching speed reach 3km/h~4km/h under road two condition, the clearing rate of concave disc machine was better than vertical milling machine, and when the marching speed was more than 4.5km/h, the clearing rate of vertical milling machine was significantly better than concave disc machine, which can up to 2.8%, it explained that the vertical milling machine can ensure higher working efficiency and clearing rate under road two condition.

4.4 Analysis on the effect of clearing snow

Concave snow removal operations effect as Figure 5 shown. In Figure 5(a), the removal of ice-snow for the plate compaction of ice-snow, the disc can quickly burst, cut into the ice-snow, make ice-snow and the road stripped. The experiment found that the installation of multi group snow concave plate can be very good to complete the ice-snow of the broken. The concave disc snow removal key part of the rear was connected with a supporting scraping skis, scraping the skis unilateral tilted 30 degrees, will have already broken the ice-snow road side in order to facilitate transfer removal, as Figure 5 (b) shown. According to the analysis of snow clearing test of concave disc machine found that the concave disc machine was applicable to plate compacted ice-snow, under the same marching speed condition, the ice-snow thickness of 46mm and 54mm, concave disc clearance effect is not very different.

(a) Ice-snow breaking effect

(b) Ice-snow clearing effect

Figure 5. Concave snow removal operations effect chart.

The working effect of vertical milling machine was shown as Figure 6 (a), (b). It can be seen that the ice-snow was broken quickly to bulk and crumb by vertical milling machine. The test result showed that the vertical milling type snow removing machine was better than the concave disc type snow removing machine to remove the ice and snow which is more than 550 kg/m^3. The vertical milling machine has good adaptability for the frozen snow with high density and high hardness.

5 CONCLUSIONS

Two kinds of snow removal effect comparison analysis found that concave disc and marching direction had 13 degrees angle when concave disc type snow removing machine work, while plate compacted ice-snow with the characteristics of
viscous brittleness, which make the ice-snow exist a phenomenon of block bond, reflects the "lift" effect. When the density of the solid ice on the road was lower than 550kg/m$^3$, the snow resistance in snow clearing working was small, the two kinds of key components can cut into ice-snow and complete clearing working quickly, the clearing effect of concave disc machine better than vertical milling machine.

When the density of the solid ice on the road was greater than 550kg/m$^3$, the ice and snow was hardness and bond firmly with road surface, the snow resistance of key components was increasing, working speed inclined, and the clearing rate also inclined, the clearing effect of vertical milling machine was better than concave disc machine. according to the snow clearing performance test result of two machines found that the impact of ice-snow density to the snow clearing performance of vertical milling machine was not obvious, this machine can complete the clearing working of the solid ice and snow that density was 300~750 kg/m$^3$, but the impact of ice-snow thickness to the now clearing performance of vertical milling machine was obvious, when the snow thickness lower than 50mm, the clearing effect was better.

6 ACKNOWLEDGEMENTS

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REFERENCES