Optimization design and analysis of the pavement planer scraper structure

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Abstract. By LS-DYNA, it establishes the finite element model of road milling machine scraper, and analyses the dynamic simulation. Through the optimization of the scraper structure and scraper angle, obtain the optimal structure of milling machine scraper. At the same time, the simulation results are verified. The results show that the scraper structure is improved that cemented carbide is located in the front part of the scraper substrate. Compared with the working resistance before improvement, it tends to be gentle and the peak value is smaller. The cutting front angle and the cutting back angle are optimized. The cutting front angle is 6 degrees and the cutting back angle is 9 degrees. The resultant of forces which contains the working resistance and the impact force is the least. It proves accuracy of the simulation results and provides guidance for further optimization work.

1. Introduction

Cold pavement milling machine is a kind of efficient equipment for road repair and maintenance. The pavement material is crushed into granular under the impact and extrusion of the milling cutter. The scraper at the bottom of the receiving plate of the rotor housing collects the waste materials, and throws the waste on the conveyor through the polishing plate. Then transfer it to the designated location and transport vehicle. The scraper is the key part by abrasive wear, sharp shock, and bump in waste collection process. After the wear, the gap between the feeding plate and the road surface becomes larger, which results in the difference of the feeding effect [1-3].

With the continuous maturity of the finite element method, the simulation and prediction technology has become an effective means of structural design in engineering applications. Ma Pengyu established the model of a cold milling machine system. The laws between the load and the work speed were investigated through simulation and experiment [4]. Li Qinghua designed a new type of scraper mechanism, and analyzed the scraper board to determine the best installation angle considering the force of the scraper [5]. Sujit M. analyzed the effect of scraper board, and found that zero pressure was reported to achieve by placing the scraper board at an optimal location [6]. These researches focus on the ability of milling road surface, but there is little research on the recycling milling waste efficiency, especially structure and cutting angle of cold pavement milling machine scraper influencing on the impact force and the working resistance.
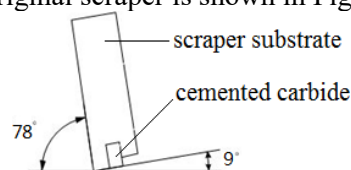
This research carries on the dynamic analysis through the work of the cold pavement milling machine scraper, and obtains the working resistance before and after improvement. At the same time, to study the influence of installation angle of cemented carbide on the working resistance, adjust the installation angle of cemented carbide, and change the angle of the comparative analysis of the working resistance and impact force. It obtains the best angle of the scraper.

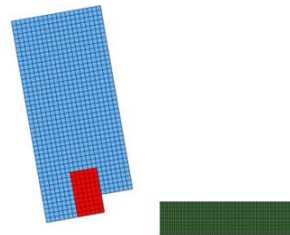## 2. Establishment the mechanical model and dynamic analysis of the original scraper

2.1. Establishment the mechanical model of the original scraper.

The scraper of milling machine is mainly composed of scraper substrate and cemented carbide inlaid in the scraper. The material of the scraper substrate is 345 steel, and the cemented carbide is WC-Co series. The angle of the cemented carbide and the bottom is 9 degrees, and the back angle of the scraper is 78 degrees. A diagram of the original scraper is shown in Figure 1.

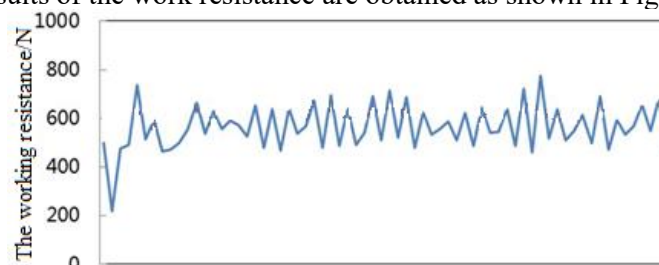**Figure 1.** A diagram of the original scraper

The grid of the scraper that belonged to solid 164 is divided of hexahedron. To ensure the accuracy, the grid is as far as possible used of small size and uniform grid, whose size is about 0.5mm. The nodes of the scraper are 318912, and units are 304413 as shown in figure 2.

Figure 2. The grid of the original scraper

2.2. Dynamic analysis of the original scraper.

At the working speed of milling machine scraper, waste will hinder effect in the horizontal direction of scraper, which is referred to as working resistance. The optimization of the scraper structure determines the wear resistance and the collection rate directly. It simulates the work of the scraper used of LS-DYNA, and the results of the work resistance are obtained as shown in Figure 3.
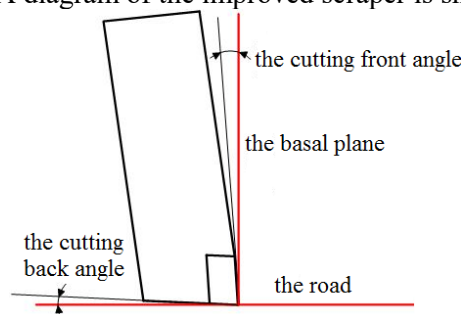

Figure 3. The working resistance of the original scraper

From figure 3, it is known that the working resistance of the original scraper is great, which seriously affects the wear resistance of the scraper. The cemented carbide is in the center of the scraper substrate, and the actual force of the cemented carbide is not considered. There are some disadvantages that the cemented carbide angle is not reasonable, and high working resistance causes vibra-

tion and impact force to make the scraper substrate and the cemented carbide wear, which is easy to make the scraper premature failure, seriously affect the production efficiency and economic cost. The installation position of the cemented carbide is not reasonable, which uses the cemented carbide less to result in wasting. The scraper substrate is contact with the road. The scraper substrate angle is unreasonable, which the back angle is contact with the road to cause the scraper substrate wear seriously. Therefore, the scraper structure is not reasonable, and it is necessary to improve the scraper structure.
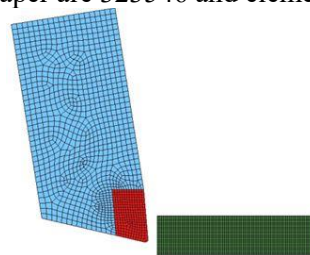
2.3. Establishment the mechanical model of the improved scraper.
The cemented carbide is the main part of the force, and the contact between the scraper substrate and the road should be avoided. So it is necessary to move forward the cemented carbide, and makes it contact with the road directly. Considering the effect of waste discharge, there should be a certain inclination angle of cemented carbide and the scraper substrate. The scraper fixed on the receiving plate is a certain angle between the receiving plate and the ground. Therefore, it is necessary to design the cutting front angle of the cemented carbide and the scraper substrate, and the cutting back angle of the scraper substrate and the road. A diagram of the improved scraper is shown in Figure 1.
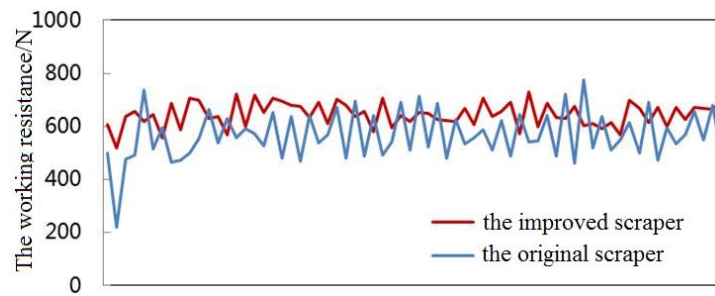

Figure 4. A diagram of the improved scraper

The cutting front angle mainly controls the most reasonable force, so that the cutting is carried out smoothly and the chip is easy to discharge. The cutting back angle is mainly to reduce the friction between the back surface and the road, and to ensure the rigidity of the scraper. To compare the working resistance of the original and improved scraper, the cutting front angle sets 10 degrees and the cutting back angle sets 10 degrees. Similarly, the grids of the improved scraper structure are meshed. The size is about 0.5 mm. The nodes of the scraper are 323546 and elements are 310957 as shown in Figure 5.

Figure 5. The grid of the improved scraper

It simulates the work of the scraper, and the results of the work resistance are obtained and compared with the original scraper as shown in Figure 6.

Figure 6. The working resistance of the original and improved scraper

From figure 6, it is known that the improved working resistance tends to be slow and the peak value is smaller. But the cutting front angle and the cutting back angle are not optimized, so it is necessary to optimize the two angles.
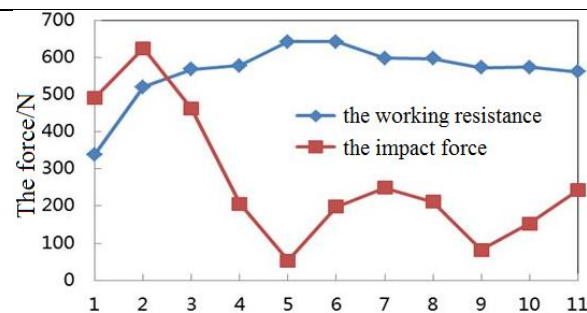
3. Result analysis and discussion

3.1. Optimization and analysis of the cutting front angle.

To study the influence of the cutting front angle of cemented carbide on the force of the structure, adjust the cutting posture of the scraper from 2 to 12 degrees, and extract the calculation results. The cutting front angle of 10 degrees is the initial angle. According to the simulation analysis, the results of the data are shown in Table 1. The force contrast in the cutting front angle is shown in Figure 7.

Table 1. The force analysis of the cutting front angle.

The cutting front angle (°)	2	3	4	5	6	7	8	9	10	11	12
The average force (N)	336	518	566	576	640	640	596	594	580	571	559
The impact force (N)	488	622	460	204	51	196	247	210	120	151	241

Figure 7. The force contrast in the cutting front angle

From table 1 and figure 7, when the angle is 6 degrees, the impact force of the scraper is minimum, and the minimum value is 51N. The resultant force is the smallest and the force is 691N. When the angle is 10 degrees, the resistance and impact force are greater than that of 6 degrees. The decrease of the impact force reduces the wear of the cemented carbide and improves the fatigue life of the cemented carbide.

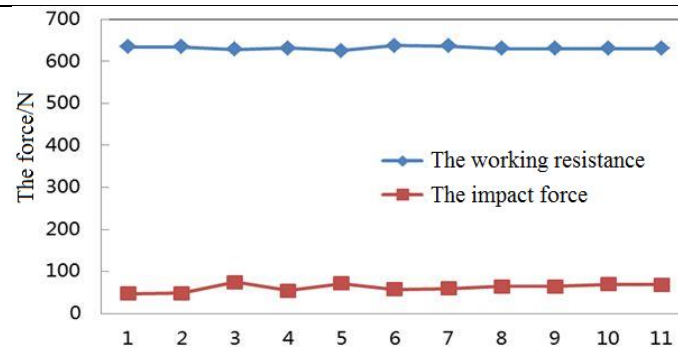### 3.2. Optimization and analysis of the cutting back angle.

The cuttings front angle of the scraper is defined as 5 degrees, and the angle of the cutting back angle is adjusted from 1 to 11 degrees, and the calculation results are extracted. The cutting back angle of 10 degrees is the initial angle. According to the simulation analysis, the results of the data are shown in Table 2. The force contrast in the cutting back angle is shown in Figure 8.

From table 2 and figure 8, when the angle is 9 degrees, the resultant force is the smallest and the force is 682N. When the angle is 10 degrees, the resistance and impact force are greater than that of 9

degrees. The decrease of the impact force reduces the wear of the cemented carbide and improves the fatigue life of the cemented carbide. The cutting back angle has little influence on the force. The size of the cutting back angle depends on the shape of the cemented carbide, and it also affects the strength of the scraper. Therefore, considering the strength and the shape of the cemented carbide, the cutting back angle is 9 degrees.

Table 2. The force analysis of the cutting back angle.

The cutting back angle (°)	1	2	3	4	5	6	7	8	9	10	11
The average force (N)	640	633	627	630	624	636	635	629	629	629	630
The impact force (N)	52	57	73	54	71	57	58	63	53	68	67

Figure 8. The force contrast in the cutting back angle

According to the size requirement of the improved scraper, the test sample of scraper is processed, and the reasonable welding and assembly process is designed. The test sample of scraper is shown in Figure 9. Then the machine assembly test is carried out. The test meets the performance requirement.

Figure 9. The test sample of scraper

4. Conclusions

This paper analyzes the working resistance of a cold pavement milling machine scraper by LS-DYNA, and compares with the working resistance of the improved scraper. At the same time, optimize the cutting front and back angle scraper. The following conclusion is drawn: the scraper structure is improved that cemented carbide is located in the front part of the scraper substrate. The cutting front angle is 6 degrees, and the cutting back angle is 9 degrees. After the improvement, the working resistance tends to be slow and the peak value is smaller. At the same time, the impact force is the smallest. This research does not study the process of the scraper, only improves the effect of waste collection. To guarantee the wear resistance of the scraper, it is necessary to further optimize the components of cemented carbide.

References

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