Analysis of the influence of the milling machine throw-out plate surfacing and structure design on throwing material

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Abstract. Material composition, hardness and wear properties of the throw-out plate improved are analysed on a road milling machine. At the same time, analyse the tissue and performance of Fe based alloy named Fe60 cladding layer using the plasma surfacing method. And the original and improved throw-out plates are analysed throwing material effect by the dynamic analysis. Then the throw-out plate samples are verified. The results show that Fe60 powder is selected as surface strengthening material. By the improved structure, the hardness of the throw-out plate increases from 14.6HRC to 57.5HRC, and the wear resistance increases from 0.452g\textsuperscript{-1} to 16.393g\textsuperscript{-1}. At the same time, it increases from 3263 to 3433 to fall into the collecting material number of milling machine. It provides important guidance for structure design and process design of the milling machine throw-out plate.

1. Introduction
Road milling machine is a kind of common asphalt pavement maintenance equipment. Through the design of the rotor tool, the depth and efficiency of the milling asphalt pavement are ensured. The waste material is thrown to the conveyor through the throw-out plate, and the effect of the throwing material affects the collecting efficiency. The scraper flattens the leftover waste and the wavy pavement of the milling surface, and collects it. Abrasive wear by in the process of collecting waste, surface sharp shock and bump will lead to failure of the scraper wear. The distance between the milling road and the scraper becomes large to result in material collecting effect becoming worse. At the same time, power consumption is large, and vibration intensifies. Pavement roughness is poor and the trimming performance is bad. Seriously affect the efficiency and performance [1,2]. Throwing material effect is very important to the fatigue life of the scraper. Therefore, improving structure and enhancing the wear resistance of the throw-out plate to improve the material receiving effect has a direct impact.

With the rotor scraper design of the milling machine continues to mature, milling depth and efficiency have greatly improved, which put forward higher requirements of throwing material efficiency. Gao Lu evaluated different texture pavement surfaces, which were tested in different milling drums, forward speeds and cutting depths. The forward speeds were positively associated with both skid resistance and macro texture [3]. Bae A. developed building information modeling to optimize milling
quantity and pavement quality, which enabled optimization of milling and paving options [4]. The structure of the throw-out plate that is attached to the spiral structure of the rotor scraper is mainly rectangle. The research on improving the wear resistance helps to improve the throwing material effect. Plasma surfacing uses compressed plasma arc as heat source to melt the filler material and some base metal that form the deposited layer. Compared with common surfacing methods such as manual arc and argon arc surfacing, the plasma surfacing has the advantages of high production efficiency, low dilution rate, good process stability, easy realization of automation, and stable quality of welding layer. Filled materials commonly used in powder, including iron based, nickel based, cobalt based, copper based, metal-ceramic composite materials, and so on. Each material has its own characteristics and scope of application. The mechanical properties of iron-based materials vary widely. The toughness and wear resistance can achieve a good match and meet the requirements of different work conditions, and the price is cheap. Shchitsyn Y. found that the plasma surfaced of steel under reverse polarity current was feasible, and the microstructure of the surfacing layer was studied [5]. Sidorov S. found the thickness of the surfacing layer was a factor affecting the service life of these components. Surfacing was the most effective way to react with the abrasive medium under working conditions. The composition had certain allowable value for the thickness of the surfacing layer [6]. More research is to study the surfacing, but there is little research on the application of technology and structure together, especially the analysis of the throw-out plate surfacing and structure design of throwing material.

Based on the wear resistance of the pavement milling machine throw-out plate are analyzed, it obtains the surfacing material. At the same time, the performance and microstructure of the surfacing layer are analyzed. Then, the influence of the original and improved structure on the throwing material effect is simulated by the dynamic simulation. Finally, the samples of the throw-out plate are verified.

2. Performance analysis of the original and improved plate

2.1. Performance analysis of the original plate.

The throw-out plate material is ordinary carbon steel. To study the hardness and wear resistance of the original throw-out plate shown in Figure 1, chemical composition of the throw-out plate is analysed using the ARL-3460 spark spectrometer. The results of the test are shown in table 1.

![Figure 1. A diagram of the original throw-out plate](image)

Table 1. The chemical composition of the throw-out plate.

| Chemical composition | C   | Si  | Mn  | P   | S   | Cr  | Ni  | Cu  |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Content              | 0.06| 0.47| 0.46| 0.905| 0.015| 0.51| 0.20| 0.30|

The hardness of the throw-out plate adopts THRP-150D digital display Rockwell hardness tester. The results of the test are shown in table 2.

Table 2. The hardness of the throw-out plate.

| The test sample | 1  | 2  | 3  | Average value |
|-----------------|----|----|----|---------------|
| Hardness value  | 14.2| 14.1| 15.5| 14.6          |

The wear resistance is used by pin-disc wear tester. The results of the test are shown in table 3. From table 2 and table 3, the original throw-out plate is low in hardness and poor in wear resistance. In the form of structure, the slotting in the center of the throw-out plate not only ensures the bolt assem-
bly, but also realizes the rule surface to ensure the effect of the throwing material. From the performance analysis, the hardness and wear amount are poor, and it needs other processes to be improved.

**Table 3.** The wear performance of the throw-out plate.

| The sample | Weigh before test (g) | Weigh after test (g) | difference (g) | loss (g) | Wear resistance (g⁻¹) |
|------------|-----------------------|----------------------|----------------|---------|-----------------------|
| 1          | 9.596                 | 7.403                | 2.193          | 2.213   | 0.452                 |
| 2          | 9.506                 | 7.273                | 2.233          | 2.213   | 0.452                 |

2.2. *Performance analysis of the improved throw-out plate.*

To increase the wear-resistance of the throw-out plate, the structure is improved as shown in Figure 2.

**Figure 2.** A diagram of the improved throw-out plate

According to the working condition of the throw-out plate and the characteristics of the iron base material, the plasma surfacing is adopted. Fe60 powder is selected as the surface strengthening material. The above-mentioned analysis method is used to analyze the composition, hardness and wear resistance of the surfacing layer. The chemical composition of the surfacing layer is shown in table 4.

**Table 4.** The chemical composition of the surfacing layer.

| Chemical composition | Fe | C  | Mn | Si  | P  | S  | Ni | Cr | Cu | Mo | V  | Co |
|----------------------|----|----|----|-----|----|----|----|----|----|----|----|----|
| Content              | 81.68 | 0.33 | 0.54 | 1.46 | 0.04 | 0.01 | 0.86 | 14.10 | 0.04 | 0.18 | 0.13 | 0.11 |

The hardness of the surfacing layer is shown in table 5.

**Table 5.** The hardness of the surfacing layer.

| Fe60 | Nominal hardness | Actual hardness |
|------|------------------|-----------------|
|      | Hardness value (HRC) | 60 | 57.5 |

The wear performance of the surfacing layer is shown in table 6.

**Table 6.** The wear performance of the surfacing layer.

| The sample | Weigh before test (g) | Weigh after test (g) | difference (g) | loss (g) | Wear resistance (g⁻¹) |
|------------|-----------------------|----------------------|----------------|---------|-----------------------|
| 1          | 11.213                | 11.154               | 0.059          | 0.061   | 16.393                |
| 2          | 11.125                | 11.062               | 0.063          |         |                       |

From table 5 and table 6, it is known that the wear resistance of the improved throw-out plate is raised from 14.6HRC to 57.5HRC, and the wear resistance has been greatly improved.

To study the microstructure of iron base alloy powder deposited layer, metallographic preparation is made. Metallographic grinding surface is made up of cross section of surfacing layer. The corrosion agent is selected by ferric chloride, hydrochloric acid, and alcohol solution, and the corrosion time is about 10-20s. The microstructure of the metallographic microscope is observed by DMI5000M inverted metallographic microscope after the preparation of the sample. The results are shown in Figure 3.

From Figure 3, the Fe60 powder surfacing layer contains more Cr and B elements, and the hard phase is mainly chromium carbide and boron carbide. The surfacing layer is mainly dendrite structure. The hardness is 57.5HRC, and wear resistance is good.
3. Result analysis and discussion

3.1. Comparison and analysis of the throwing material effect.
To investigate the influences of the throw-out plate structure design of throwing material effect on milling machine, the throwing material effect of the original and improved throw-out plate is simulated by the dynamic analysis. The same size discrete element is adopted to simulate the road surface. The angle of the throw-out plate is in conformity with the actual situation, and the angle with the milling drum is 90 degrees. The rotation speed of the milling drum matches the actual situation. The effect of the throwing material is evaluated by calculating the number of pavement materials falling into the simulated collecting orifice. Select the shed, detachment and completely out of three times into collecting quantities of materials to obtain the results as shown in figure 4, and n is defined as the quantity of material.

From figure 4, the throwing material effect of the improved throw-out plate is better. The quantity of material is 3433, and the original is 3263. Without considering the material size, the adhesion conditions between the material and the throw-out plate, under the existing conditions, the aggregate number is similar, and the material spilled in the shape of the air distribution are basically the same, but the throw-out plate is still a small amount of material the adhesion in the groove in the run-up to
the above. Therefore, the surface shape of the throw-out plate is not the key factor that affects the throwing material effect, but the improved structure can improve the throwing material effect.

3.2. Test verification.

On the above research results, the process parameters are used to test the sample of the throw-out plate shown in Table 7. The samples of the throw-out plate are shown in Figure 5. The plasma spray welding equipment is used to fix the throw-out plate on the turntable by using the tooling. After setting the turntable rotation speed and the surfacing process parameters, the automatic process is carried out.

Table 7. The process parameters of the plasma spray welding.

| Ionized gas (L/H) | Non-arc current (A) | Arc voltage (V) | Oscillating speed (mm/min) | Left stay (s) |
|------------------|---------------------|-----------------|-----------------------------|--------------|
| 0.3              | 36                  | 26              | 1400                        | 0.3          |

| Powder gas (L/H) | Non-arc current (A) | Arc voltage (V) | Rotational speed (mm/min) | Right stay (s) |
|------------------|---------------------|-----------------|---------------------------|---------------|
| 0.2              | 21                  | 22              | 6                         | 0.3           |

| Protection gas (L/H) | Speed (mm/min) | Supply (g/min) | Distance (mm) | Width (mm) |
|----------------------|----------------|---------------|---------------|------------|
| 0.75                 | 3.5            | 27            | 300           | 20         |

Figure 5. The samples of the throw-out plate

4. Conclusions

Based on a road milling machine original and improved throw-out plate, material composition, hardness and wear properties are analyzed. Using the method of plasma surfacing, material composition, surfacing layer hardness, wear properties and microstructure of the improved throw-out plate are analyzed. The throwing material effect of the original and improved plate is simulated and analyzed. The conclusions are as follows. The throwing material surface adopts the plasma surfacing, and Fe60 powder is as surface hardening material. Both hardness and wear resistance greatly improve. At the same time, the improved structure of the throw-out plate is conducive to enhance the throwing material effect of the milling machine. In this study, there is no comparative study on other iron based materials and materials which are cheap and can improve the wear resistance, when surface hardening materials are used. Only Fe60 is analyzed. Therefore, it is necessary to further optimize and analyze the surfacing materials of the throw-out plate.

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