Optimization design of scraper angle based on orthogonal test

Can Wang[1,2], Yuanbin Fang[1,2,a], Song Huang[1,2], Guizhi Zhang[1,2], Qingyu Meng[1,2] and Xi Liu[1,2]

[1]Jiangsu XCMG Construction Machinery Research Institute Co., Ltd, Jiangsu Xuzhou, China
[2]State key Laboratory of Intelligent Manufacturing of Advanced Construction Machinery, XCMG Construction Machinery Co., Ltd, Jiangsu Xuzhou, China

Abstract. The scraper angle of milling machine has a direct effect on the milling efficiency. This research establishes the finite element model of scraper, and designs the cutting front angle and the cutting back angle as factor, impact force and the average force for orthogonal test of evaluation indexes. Through simulation analysis, the force is obtained at the different level. At the same time, the simulation results are verified by experiments. The results show that the simulation results of contact force in the X direction are close to the measured results, and prove the accuracy of the simulation results. The optimized scraper is that the cutting angle is 5.5°, and the cutting back angle is 9°. The impact force is minimum, and the resultant of average force and impact force is minimum. The optimization of scraper angle can effectively reduce the impact force and the average force, which provides guidance for the improvement of scraper.

1 Introduction

The scraper of milling machine takes waste together. It has indirect effect on throwing waste efficiency to collect waste quality. The scraper is impacted by abrasive wear and sharp corners at work. The clearances between roads and scrapers reduce the collecting waste and the throwing waste effect, which reduce the quality of milling pavement [1-3].

With the continuous ripening of the scraper structure design, the angle design and manufacturing process have become an effective means of improving the performance of the engineering application. Piccione E. et al., based on structural dynamics, established the finite element model and rotor blade model equations. By scanning morphology and angles, a new generation of helicopter blade structure was developed [4]. Valigi M. C. et al. optimized the mixing blades of concrete mixer. The wear resistance of blades was evaluated based on three-dimensional scanning method. The new blade geometry was increased the wear resistance and prolonged the service life [5]. Lee P.Y. et al. designed and manufactured of new material 316LN stainless steel, which were studied manufacturing cost, connection process brazing and its wear resistance improvement [6]. Yin Z. J. et al. used discrete element methods to simulate the particle flow on the elliptical vibrating screen. The effects of vibration direction, trajectory and throwing index on efficiency and speed were analyzed. [7]. Anwar W. et al. researched that the wings were kept at a high angle of attack. The change of structural dynamic characteristics affected the fatigue life of the structure [8]. The above research work highlights the importance of structural design for performance improvement. The influence of angle on force is also analyzed from single factor test. There is few prediction and scientific method in analyzing the influence of multiple factors on performance improvement.

In this research, through designing the cutting front angle and the cutting back angle of scraper, the orthogonal test is designed. By the dynamic analysis of milling machine scraper, the force is obtained. By the comparative analysis of the average force and impact force, the best angle of scraper is got.

2 Methodology

2.1 The establishment of mechanical model

To ensure the good toughness of the milling machine and maintain the wear resistance of the material, hard alloy in the front of scraper is designed. The material of the scraper is 345 steel, and the cemented carbide is WC-Co series. The angle between the bottom plane of the hard alloy and the road is defined as the cutting back angle. The design angle is 9°. The angle between the front surface of the scraper and the basal plane is defined as the cutting front angle, and the design angle is 6°. A schematic diagram of the scraper structure is shown in Figure 1.

A scraper and road surface model are established using PROE. The division of hexahedral element mesh is used to ensure the accuracy of analysis. To mesh uniform, scraper matrix mesh size is about 0.5mm, and the hard alloy mesh size is 0.2mm. There are a total of 39138 mesh nodes and 37026 elements. The road adopts the HJC constitutive model. The mesh size of the road is 0.5mm. There are 12400 mesh nodes and 10800

*Corresponding author: [a] fybflying@163.com

elements. The finite element model of scraper and road is obtained, as shown in Figure 2.

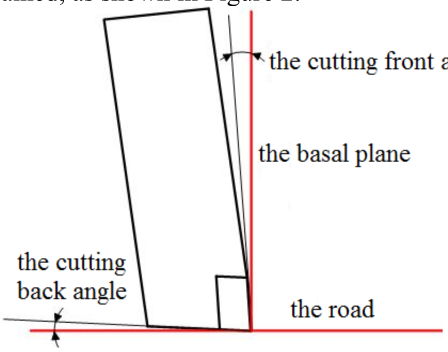


Figure 1. A schematic diagram of the scraper

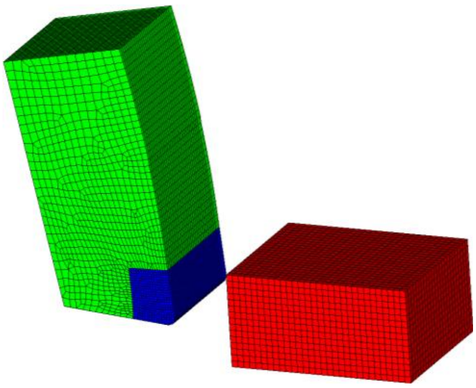


Figure 2. The grid of the scraper and road

As the milling machine scraper working, waste will impact effect in the horizontal direction of the scraper referred to as impact force. The failure criteria of subgrade materials are defined by the keyword *MAT_ADD_EROSION. The contact resistance is extracted with the keyword *DATABASE_RCFORC. The moving speed of the scraper is 11.6mm/s, and the calculation time is 1.5s.

2.2 The orthogonal test design of the scraper angle

The angle controls the most reasonable force state of the scraper, which ensures both the cutting of the road surface and the discharge of the asphalt particles, while reducing the friction between the scraper and the road surface and ensuring the rigidity of the scraper. The factors affecting the force of the scraper are determined as the cutting front angle and the cutting back angle. From the angle design and the installation error of the scraper, the minimum degree of resolution increases to 0.5°, and the cutting front angle takes 5°, 5.5°, 6°, 6.5°, and 7°. Because the cutting back angle is not directly affected by the impact force, the cutting back angle takes 7°, 8°, 9°, 10°, and 11°. The orthogonal test scheme of 2 factors and 5 levels is designed. The 1~5 scheme is that the corresponding front angle is 5°, and corresponding to the cutting back angle of each angle, and so on. There are a total of 25 groups. The test design is shown in table 1.

Table 1. The orthogonal test design.

Scheme	The cutting front angle (°)	The cutting back angle (°)
1	5	7
2	5	8
3	5	9
4	5	10
5	5	11
6	5.5	7
7	5.5	8
8	5.5	9
9	5.5	10
10	5.5	11
11	6	7
12	6	8
13	6	9
14	6	10
15	6	11
16	6.5	7
17	6.5	8
18	6.5	9
19	6.5	10
20	6.5	11
21	7	7
22	7	8
23	7	9
24	7	10
25	7	11

The dynamic simulation is used to simulate and analyse the working condition of the scraper, and the results of the force are obtained.

3 Result analysis and discussion

3.1. Finite element model verification and analysis

Through the simulation analysis, the force of the scraper cutting the road is obtained that the cutting front angle is 6° and the cutting back angle is 9°. From the feasibility of the test data comparison, the component and the resultant force of the contact resistance of the scraper are extracted in the three directions of X, Y, Z.

According to the transmission principle of force, the four strain gauges are pasted on the front and back sides of the scraper at the same position. The strain components in the X direction are taken, and the contact reaction force is calculated according to the strain components. The data contrast result is shown in Figure 3.

From Figure 3, the simulation results of the contact reaction in the X direction are close to the measured results, and the correctness of the finite element model is verified.

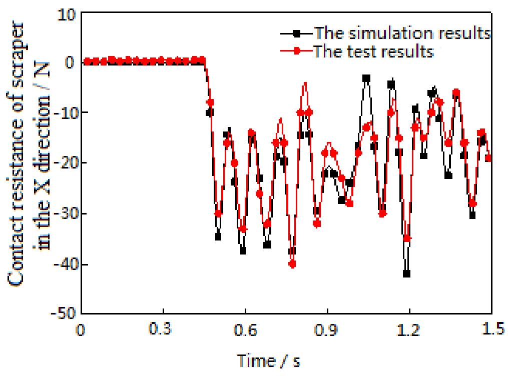


Figure 3. The finite element model of the improved scraper

3.2 Optimization and analysis of scraper angle

To study the force of different scraper angles, the simulation results are calculated and extracted. As the results of the simulation analysis, the results of the data arrangement are shown in Table 2.

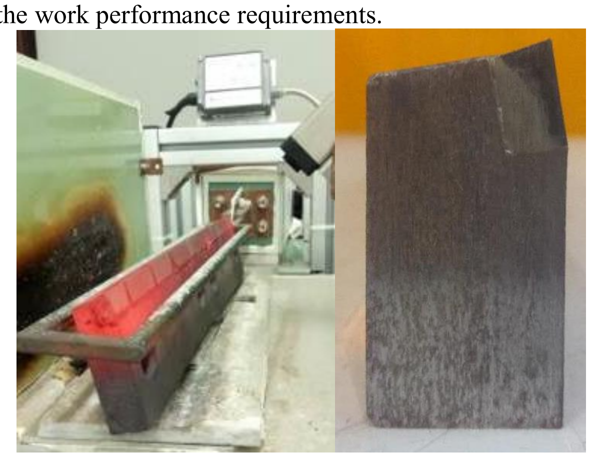
Table 2. The working force of the scraper.

Scheme	The average force (N)	The impact force (N)
1	610	121
2	603	173
3	587	165
4	576	204
5	584	191
6	621	67
7	617	63
8	608	51
9	613	55
10	627	61
11	635	58
12	629	63
13	629	53
14	629	68
15	630	67
16	631	138
17	637	127
18	628	115
19	636	121
20	642	108
21	637	154
22	617	164
23	629	186
24	640	196
25	645	177

From table 2, the impact force of scraper is minimum in the scheme 8, and the minimum value is 51N. The resultant of average force and impact force that is 659N is minimum, and the scheme is that the cutting front angle is 5.5°, and the cutting back angle is 9°. Through the analysis, the original scheme 13 is that the cutting scraper angle is 6°, and the cutting back angle is 9°. The impact force is 53N, and the average force is 682N. The cutting angle optimization can effectively reduce the impact force and the average force. The reduction of the impact force can effectively reduce the wear of the hard alloy in the cutting front angle of the scraper and improve the service life of the scraper.

3.3 Test verification

As the structure design requirements of the optimized scraper, the test sample of the scraper is processed. The induction brazing method is adopted in the welding of scraper, and the scraper sample is assembled. The parameters of induction heating are set up, and welding is carried out. Heat treatment after welding is done. The trial production of sample is shown in Figure 4. After the completion of the test process, the preliminary test meets the work performance requirements.



(a) The brazing process

(b) The scraper sample

Figure 4. The scraper sample

4 Conclusions

Through the dynamic analysis of the working force of a pavement milling machine scraper, this research design scraper angle as the factor, impact force and the average force for orthogonal test evaluation index, and optimize the scraper cutting front angle and the cutting back angle. The following conclusions can be drawn through the research. The correctness of the finite element model is verified by comparing the contact force in the X direction. The optimization of cutting angle can effectively reduce the impact force and the average force resultant force, and minimize the impact force after optimization, which helps to improve the fatigue life of scrapers. In this research, the process is not studied in the scraper angle optimization design, and the wear resistance of the scraper should continue to be studied.

Acknowledgments

This work was financially supported by National Science and Technology Support Program (2015BAF07B02).

References

1. T. Haga, H. Tsuge, T. Ishihara, S. Kumai, H. Watari, Key Eng. Mater. **611-612** (2014)
2. Y. Hao, H.F. Yu, Z. Liu, Y.L. Zhou, X.M. Mu, Coal Sci. Technol. **42,** 11 (2014)
3. Y.B Hu, X.G. Liu, F.F. Liu, J. Chang'an Univ. :Nat. Sci. Ed. **31,** 2 (2011)
4. E. Piccione, G. Bernardini, M. Gennaretti, Aircr. Eng. Aerosp. Tec. **84,** 6 (2012)
5. M.C. Valigi, S. Logozzo, M. Rinchi, J. Mech. Sci. Technol. **103** (2016)
6. P.Y. Lee, B.L. Hou, C.J. Pan, Z.Q. Cheng, K.W. Huai, F. Savary, Y.K. Fu, R. Gallix, Fusion Eng. Des. **85,** 7-9 (2010)
7. Z. J. Yin, T. Han, H. Zhang, Powder Technol. **302** (2016)
8. W. Anwar, K.M. Zubair, A. Israr, S. Mehmood, N. Anjum, Aerosp. Sci. Technol. (2017)