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# Wear Characteristic Study of the Flat Slipper of Shearer Considering Oblique Cutting

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***Abstract*—In order to investigate the wear characteristics of flat slippers of shearer, this study firstly built up the static model of the whole shearer machine. Basing on the static simulation research for the flat slipper by ANSYS, the maximum values of stress and strain of the flat slipper was obtained. Then the wear problem of the flat slipper considering oblique cutting was investigated via experimental method. The corresponding wear mass of the flat slipper considering oblique cutting was analyzed. This study can provide reliable theoretical basis for the design and manufacturing of walking mechanism of shearer.**

***Keywords-shear; flat slipper; experimental study; wear characteristics***

## I. INTRODUCTION

Flat slipper is one of the key parts for the walking machanism of a shearer, which is important for the failure-free operation of the shearer. In the state of oblique cutting, the working condition of the shearer is especially severe. Additionally, the shearer always works in the condition of slow speed and heavy load and during oblique cutting it bears impact load. Thus, the shearer frequently experiences faults such as excessive wear and fracture, which affects the working of the machine -- the mining output and efficiency of the shearer are severely affected. Therefore, the wear characteristic research of flat slipper of the shearer is very important. Zhao [1] improved the wear resistant ability of the guideway through various heat treatment processes; Wang [2] analyzed the wear situation of flat slippers of a large scale shearer, and concluded three factors bringing in severe wear of flat slippers -- excessive overload, long duration of idle loaded operation and high temperature on the friction surface. Inspired by static bearing principle, Liu [3] designed an air supported sliding guideway which can reduce the resistant force for the guideway during sliding so that the wear mass was decreased. Liu [4] analyzed the mechanical property of slippers by considering the leaning condition and the practical profile of the worn surface, and the results showed that a stable load bearing condition can be contained with certain elastic deformation and worn profile and that large wear mass can reduce the load bearing capacity of the slipper. Moreover, many other researchers gave their remarkable contributions on the wear characteristics of slippers of the shearer [5-7]. This study built the static model for the shearer to obtain the load condition of the flat slipper, and the load simulation of flat slipper was complemented by ANSYS. Then the wear characteristics of flat slipper considering oblique cutting was analyzed and researched by way of experimental study. This study can provide reliable theoretical basis for the design and manufacturing of walking mechanism of shearer. It can also provide references for the design and analysis of similar products.

## II. LOAD ANALYSIS OF THE FLAT SLIPPER DURING OBLIQUE CUTTING

As shown in Fig. 1, x axis is the walking direction of the shearer, y axis is the vertical direction of the conveyor and z axis is the axis direction of the roller. While a shearer is working in oblique cutting condition, the whole load situation is like Fig. 1.

Loads and symbols in the figure are: walking pull load -- $F_t$, loads for back roller -- $F_{gx1}$,$F_{gy1}$,$F_{gz1}$ and $M_{g1}$, loads for front roller --$F_{gx2}$, $F_{gy2}$, $F_{gz2}$ and $M_{g2}$, supporting load of front and back slippers -- $F_{hy1}$ and $F_{hy2}$, supporting load for front and back guide slippers -- $F_{dy1}$, $F_{dy2}$, $F_{dz1}$ and $F_{dz2}$, length of rolling arm -- R, rotation angle of front and back rolling arm, distance between hinged joint and the bottom surface of the machine -- T, distance between guide slipper and the center of the machine -- L, length of mining head -- O, distance between flat slipper and the center of the machine -- N, the distance between flat slipper and guide slipper in Z direction -- M, the distance between flat slipper and guide slipper in Y direction -- J, distance between the hinged joint of cutting arm and the center of the machine -- H, length of rolling arm

-- R, distance between gravity center of the machine and the line of two flat slippers -- F, depression angle of the conveyor -- δ, healing angle of the shearer -- η.

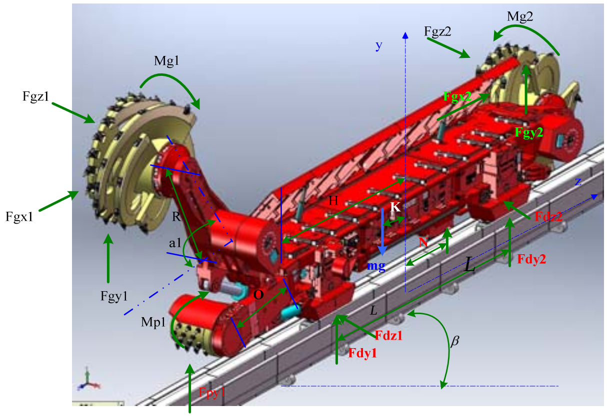


Figure 1. The force situation of the shearer when oblique cutting feeding

Thus, the mechanical balance equations of whole machine in x, y and z directions are: $\sum F_x=0$, $\sum F_y=0$, $\sum F_z=0$; Taking the flat slippers as constraint, the balance torque equations are: $\sum m_x=0$, $\sum m_y=0$ and $\sum m_z=0$, so that:

From $\sum F_x=0$,

$$F_{gz1}+F_{gz2}-(|F_{dy1}|+|F_{dy2}|+|F_{dz1}|+|F_{dz2}|+F_{hy1}+F_{hy2})u-F_t=0$$

which can be transformed to:

$$(|F_{dy1}|+|F_{dy2}|+|F_{dz1}|+|F_{dz2}|+F_{hy1}+F_{hy2})u_t=F_{gx1}+F_{gx2}-F_t \quad (1)$$

From $\sum F_y=0$,

$$F_{dy1}+F_{dy2}+F_{hy1}+F_{hy2}=mg\cos\delta\bullet\cos\eta-F_{gy1}-F_{gy2}-F_{gp1}-F_{gp} \quad (2)$$

From $\sum F_z=0$,

$$(|F_{dy1}|+|F_{dy2}|+F_{hy1}+F_{hy2})u+F_{dz1}+F_{dz2}-mg\sin\eta\bullet\sin\delta=F_{gz1}+F_{gz2} \quad (3)$$

Taking the flat slippers as constraint, the three balance torque equations are:

From $\sum m_x=0$,

$$(F_{dy1}+F_{dy2})M+(F_{dz1}+F_{dz2})J=mg\cos\eta\bullet\cos\delta F+F_{gz1}(T+R\sin\alpha_1+F_{gz2}T+R\sin\alpha_2+(F_{gy1}+F_{gy2})D-(F_{py1}+F_{py2})E \quad (4)$$

From $\sum m_y=0$,

$$(F_{dy1}+F_{dy2})\mu L+(F_{dz1}-F_{dz2})L+(F_{hy1}+F_{hy2})\mu N=(-F_{gx1}+F_{gx2})D+F_{gz1}(H+R\cos(\alpha_1))-F_{gz2}(H+R\cos(\alpha_2)) \quad (5)$$

From $\sum m_z=0$,

$$(F_{dy1}+F_{dy2})L+(F_{hy1}+F_{hy2})N=-F_{gy1}(H+R\cos\alpha_1)+F_{gy2}(H+R\cos\alpha_2)-F_{py1}(H+O\cos\beta_1)+F_{pgy2}(H+O\cos\beta_2)-F_{gx1}(T+R\cos\alpha_1)-F_{gx2}(T+R\cos\alpha_2)+mg\cos\mu\bullet\cos\delta \quad (6)$$

## III. LOAD SIMULATION OF THE FLAT SLIPPER OF THE SHEARER DURING OBLIQUE CUTTING

The static analysis of the flat slipper was studied using ANSYS. The 3D model built by 3D software was imported into ANSYS. The stiffness, strength and safety coefficient of pin rail was analyzed and checked according to working requirements. By that analysis, the maximum stress value and its location were obtained, which can provide theoretical basis for further research.

The deformation nephogram, strain nephogram and stress nephogram of the state of maximum load during oblique cutting for the flat slipper is represented in Fig. 2, Fig. 3 and Fig. 4.

From the analysis of Fig. 2, the deformation values of two ends are larger. As the location is closer to the pin axis hole, the deformation is smaller. The max value is 0.319mm. From the strain nephogram (Fig. 3), strain is larger as the location is closer to the pin axis hole and the max value is 0.0014mm. Strain values of two ends are small. The max stress locates at the pin axis hole -- 313.4MPa -- which is smaller than the yield stress of the material (Fig. 4). Results showed that the design of flat slippers is sufficient to the requirements.

This study is based on the wear situation of flat slippers of MG500/1180-WD shearer during oblique cutting. The contact area of flat slippers to pin rails is $4.2\times10^4$mm$^2$. The bearing loads of front and back flat slippers are 35KN and 125KN, respectively. The bearing load of both flat slippers under idle loaded condition is 180KN.

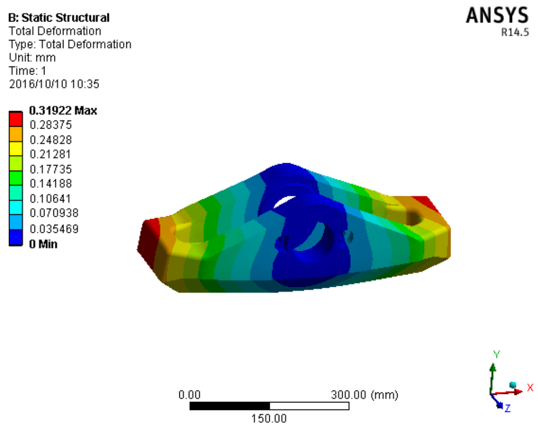


Figure 2. Deformation nephogram of flat slipper

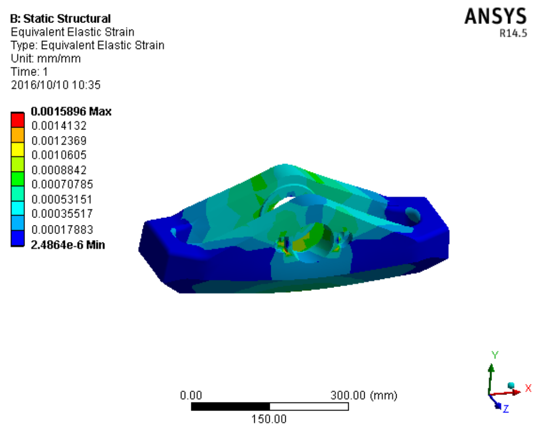


Figure 3. Strain nephogram of flat slipper

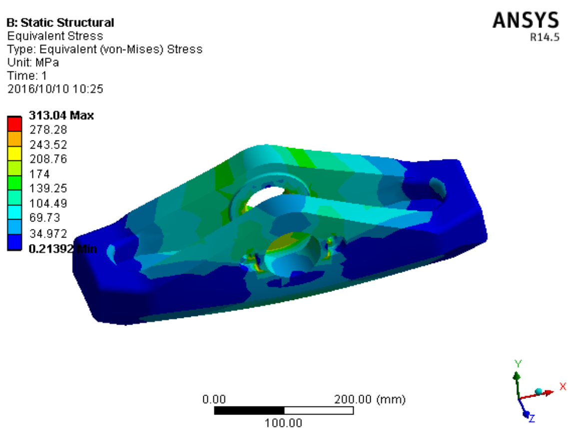


Figure 4. Stress nephogram of flat slipper

## IV. Wear Analysis and Experimental Study for Flat Slippers Considering Oblique Cutting

In the practical operation of the shearer, the sliding between the flat slipper and the pin rail is in the form of plane contact friction. The flat slipper works under heavy load with slow sliding speed. The working condition is so complex that the wear of flat slippers and pin rails are severe. In this chapter, in accordance of the load properties of flat slipper and pin rail, the wear characterization of their materials was complemented. The typical friction and wear test was designed considering the practical operation condition, the change laws of wear under different wear stages and loads with or without lubricant were obtained, and the wear failure mechanism between slippers and pin rails was investigated.

### *A. The Wear Test of Flat Slippers*

#### *1) Preparation of samples*

Cr28MnV was taken as the material of anti-wear board of the flat slipper and the upper samples and ZG35CrMnSi was taken as the material of pin rail and the lower samples. Picture of samples is shown in Fig. 5. The right part of Fig.3.1 is the upper sample and the left part with a groove is the lower samples for lubricating tests.

Figure 5. Picture of upper and lower samples

A Brinell Hardness Tester (HBS-3000) was used to detect the surface hardness of those samples. Parameters are listed here: head diameter -- 5mm, load -- 750kgf, holding time -- 10s. Resultant data are obtained as the average value of three test results and listed in Tab. I.

TABLE I. Surface Hardness Results of the Samples

| | Material | Heat treatment | Hardness/ *HB* |
|---|---|---|---|
| Upper samples | Cr28MnV | 860°C quenching+ 680°C annealing | 270.2±8.0 |
| Lower samples | ZG35CrMnSi | Tempering | 201.4±2.6 |

#### *2) Wear test design*

MMU-10G was used as the wear tester. Applied loads are varied as 300N, 650N, 1000N and 1350N for 60min under the sliding speed of 120r/min. Weight before and after wear test was determined by an optical electro-balance, so that the wear mass can be obtained, as seen in Tab. II. The wear rate was calculated according to (7):

$$K_M = M/(s \cdot A) \quad (7)$$

where $K_M$ represents wear rate of the material, M is the quality of wear mass after wear test, s is the sliding distance and A is the contact area between upper and lower samples.

TABLE II. WEAR MASS RESULTS OF UPPER AND LOWER SAMPLES

| Applied load | Wear mass (mg) | |
|---|---|---|
| | Upper sample | Lower sample |
| 300N | 1.73 | 117.99 |
| 650N | 2.58 | 317.44 |
| 1000N | 5.64 | 660.67 |
| 1350N | 12.43 | 1347.90 |

The wear rate formulas, taking load per unit area (*p*) as a variation, were obtained by regression analysis. Equation (8) and (9) represent the wear rate formulas of the upper and lower samples, respectively:

$$K_{M1} = 1.89 \times 10^{-9} p^{1.25} \quad (8)$$

$$K_{M2} = 1.25 \times 10^{-7} p^{1.35} \quad (9)$$

The site picture of wear test is shown in Fig. 6. The groove of the lower sample is filled with coal powders to simulate the practical working environment.

Figure 6. Wear site picture

## B. Wear Analysis of the Flat Slipper Considering Oblique Cutting

The wear situation of flat slippers of MG500/1180-WD shearer was analyzed, considering the oblique cutting operation. Tab. III presents the working parameters of front and back flat slippers. Load data were obtained by practical testing for 5s.

TABLE III. WORKING PARAMETERS OF THE MG500/1180-WD SHEARER

| Parts | Contact area ($C_A$) | Load (F) | |
|---|---|---|---|
| | | Oblique cutting | Idle operation |
| Front flat slipper | $4.2 \times 10^4 mm^2$ | 30 $kN$ | 180 $kN$ |
| Back flat slipper | $4.2 \times 10^4 mm^2$ | 125 $kN$ | 180 $kN$ |

The needed variation p in wear rate calculation of (8) and (9) can be calculated by $F/C_A$.

In one mining cycle, the distance of oblique cutting, straight cutting and idle operation are 15m, 65m and 80m, respectively. Thus, in one mining cycle, friction sliding distance of each flat slipper is 160m, and that of each pin rail is equivalent to the length of 4 flat slippers -- 2.4m. Those values are used for the s parameter of (10). Thus, we can get the wear depth (ΔH) data through (7):

$$\Delta H = K_M \cdot s \quad (10)$$

The calculated results according to (10) are shown in Fig. 7 and can be used for qualitative comparison for the practical wear of the flat slipper.

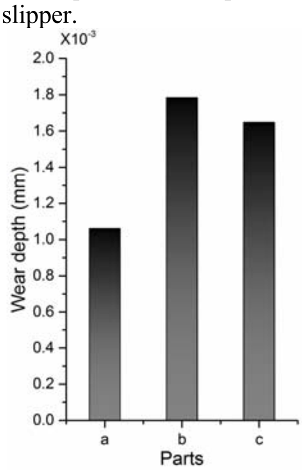


Figure 7. Wear depth of different parts after one cycle working: a--front flat slipper; b--back flat slipper; c--pin rail supporting flat slippers

From Fig. 7, the wear depth is not equivalent for pin rail, front and back flat slippers because the load situation of those three parts is different. The load for back flat slipper is the largest so that its wear depth is the largest. Therefore, in order to balance the wear lifetime of front and back flat slippers, front and back rollers should be interchanged: cutting process goes along the forward direction for one cycle and along the backward direction the next cycle. Then interchange of front and back parts can guarantee that the wear situation of both flat slippers is balanced after two cycles.

## V. CONCLUSION

A static model was built for the whole shearer machine. The maximum values of stress and strain of flat slippers for the walk mechanism of the shearer were obtained by static simulation of ANSYS. Then the wear experimental analysis of front and back flat slippers and their supporting pin rail considering oblique cutting. Results showed that wear depth results are not equivalent for pin rail, front and back flat slippers because the loads of those three parts are different. The wear situation of back flat slipper is the worst. In order to balance the wear lifetime of two slippers, an improvement approach was suggested: front and back rollers should be interchanged -- cutting process goes along the forward direction for one cycle and along the backward direction the next cycle. That interchange process can guarantee that the wear volumes of two slippers are balanced after each two cycles.

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