Experimental Investigation of Wear Behaviour of 40MnB

Xuejiao Ma\textsuperscript{1, 2,*}, Bo Chen\textsuperscript{1, 2}, Kun Feng\textsuperscript{1, 2} and Pengxiao Zhu\textsuperscript{1, 2}

\textsuperscript{1}State Key Laboratory of Intelligent Manufacturing of Advanced Construction Machinery, Xuzhou Construction Machinery Group, Xuzhou 221004, China
\textsuperscript{2}Jiangsu Xuzhou Construction Machinery Research Institute Co., Ltd, Xuzhou 221004, China

*Corresponding author e-mail: mxj_xcmg@126.com

Abstract. Dry sliding wear (pin-on-disc) tests were carried out under different loads and sliding speeds at room temperature for 40MnB. The present work attempts to explore wear mechanism of 40MnB. Compared with friction speed, it was found that the effect of load is more obvious. At a certain friction speed, the wear loss increase obviously with the increase of load, and the friction coefficient increases at first and then decreases slightly. Increased load leads to higher shear stress and higher interface temperature, thus cause the contact point to adhere and peeled. On the other hand, under a certain load, the friction speed has little effect on the wear rate. Surface temperature increases with the increase of friction speed, making easier plastic flow of the steel. The wear mechanism of 40MnB is adhere wear and abrasive wear.

1. Introduction
Driving wheel, guide wheel, supporting wheel, sprocket and track plate, as important units of walking and supporting of tracked construction machinery, are subjected to transverse resistance, lateral extrusion and wear during operation. Low alloy cast steel can obtain an excellent strength, toughness and wear-resistant properties through proper heat treatment. It can be used as wear resistant parts under impact load. Low alloy steel castings are widely used in crawler excavators. An adequate wear resistance is also necessary for steels used in the mining, earth moving and railroad industries [1]. Some researchers have done some research about wear mechanisms under different conditions. The wear mechanism of steel involves adhesion, oxidation, plastic flow of material, strain hardening, generation of surface and sub-surface cracks and associated structural changes. [2] They also found that ploughing [3, 4], flake formation [5], micropolishing [3, 4], cohesive failure or fragmentation [3, 4, 6], spalling [3, 4, 7], removal of hard particle phases [8], and binder extrusion [8] is the wear mechanisms under different conditions. In the present study, attention focuses on wear mechanism of 40MnB at different loads and speeds.

2. Material and Experimental Procedures
The chemical composition of 40MnB is analyzed by Thermo Fisher ARL3460 Optical Emission Spectrometer. The result is shown in table1. The hardness of 40MnB is 29.2HRC. In order to evaluate the wear-resistance performance of 40MnB, the dry sliding wear tests were carried out on a MMW-1 pin-on-disc apparatus. The pin is made of 40MnB with the size of 10mm×10 mm. The experimental surface of the pin has a maximum 0.30μm surface roughness. The disc is made of Q235. The pin rotate
against a fixed disc at a radius of 20mm under three normal loads of 50N, 100N, 150N and three sliding speeds of 0.2m/s, 0.3m/s, 0.4m/s. The friction coefficients are continuously collected at a frequency of 1Hz. After each test, the pin is washed with acetone then dried and weighed. The weights are using a Sartorius BSA224S digital balance with an accuracy of 10⁻⁴g. Then the weight loss is calculated by the difference in mass before and after the test. Each group is repeated three times and the mean value is calculated. Wear morphology of the tested sample is analyzed by FEI InspectS50 scanning electron microscope.

Table 1. The composition of 40MnB (wt %)

|   | C   | Mn  | Si  | P   | S   | Ni  | Cr  |
|---|-----|-----|-----|-----|-----|-----|-----|
|   | 0.39| 1.24| 0.21| 0.20| 0.015| 0.15| 0.09|

3. Results and Discussion

3.1. Effect of load on the wear behavior

All tests are performed with the sliding speed of 0.1m/s and loads of 50N, 100N, 150N for 1 hour. It is shown in fig1 the effect of load on the wear resistance of 40MnB. It can be observed that the wear loss is 0.37g at the load of 50N. With the load increases to 100N, the wear loss increases to 0.42g. When the load increases to 150N, the wear loss sharply increases to 0.62g. With the load increase from 50N to 100N, the wear loss increased slightly. However, the increase of load from 100N to 150N leads to an almost 50% increase in wear loss. Fig2 shows the trend of friction coefficient with the increased load. When the applied load is 50N, the friction coefficient is 0.842. As the load increase from 50N to 100N, the friction coefficient increase to 1.037. The friction coefficient slightly decreases to 1.033 as the load increase to 150N.

The wear behavior just described above can be attributed to several factors. The first factor is that low friction coefficient and wear loss at 50N can be attributed to the low level of load. At this point, low level of load leads to low shear stress, resulting in slightly adhesive wear. Thus, the amount of wear debris is less, so the abrasive wear is also not obvious. Shear stress at the interface increase as the load increases to 100N. Meanwhile, the temperature of the interface increase with the increased load, softening parts of metal, which will cause the touch-point to adhere. Thus, adhesive wear becomes obvious at this time, leading to the removal of material from wear surface. These debris, peeled off by adhesion wear, penetrate into the surface of the sample and take away more materials, which increase the effect of the abrasive wear. The temperature of interface is even higher as the load increase to 150N. So the adhesive wear becomes more obvious. At the same time, more debris makes abrasive wear increase.

From Fig 2, we can see that the friction coefficient increases sharply with the increase of load from 50N to 100N, and then keeps almost stable. This is due to the interfaces of pin and disc is in good contact with each other under the load of 100N, leading to higher friction coefficient.

The surface morphology of the worn surface in fig3 (a) shows that the wear marks are very light under the action of 50N load, and there are little pits left by adhesive wear. It is shown in fig3 (b) that there are some marks of broken adhesion joint left by adhesive wear. The increased shear stress is responsible to the plastic flow of the material, causing the “ploughing” becomes deeper and wider as shown in fig3 (b). As the load increase to 150N, the “ploughing” becomes even deeper and wider as shown in fig3(c), but the number of marks of broken adhesion joint decrease. This is because that the increase of abrasive particles causes those traces to wear away quickly.
3.2. Effect of sliding speed on the wear behavior

Fig 4 shows the effect of sliding speed on the wear resistance of 40MnB. The tests were carried out with increased sliding speeds from 0.2m/s to 0.4m/s under the load of 30N for 1000 meters. It can be observed that the wear loss is 0.22g at the sliding speed of 0.2m/s, which increase to 0.30g at the sliding speed of 0.3m/s and 0.28g at the sliding speed of 0.4m/s. The effect of sliding speed on friction coefficient can be observed on fig 5. The friction coefficient is 0.950 when the sliding speed is 0.2m/s. The friction coefficient decrease to 0.820 and 0.815 as the sliding speed increase from 0.2 m/s to 0.3 m/s and 0.4 m/s.

Some researchers have strongly suggested that the surface temperature increase with increased sliding speed. [9-11] The friction energy is proportional to the square of the velocity, the increases of friction velocity leads to the increase of friction energy consumption, and resulting in the increase of friction heat. [12] Thus, the surface temperature is relatively low at the sliding speed of 0.2m/s, resulting in relatively low level of wear loss. As the sliding speed increase from 0.2m/s to 0.3m/s and 0.4m/s, easier occurrence of plastic flow cause by the high flash temperature reached, the wear loss increases. This is because at low sliding speed the debris generated is not ejected from the wear track, which continues to contribute to the abrasive wear in the wear process. Therefore, at sliding speed of 0.2m/s and 0.3m/s, this factor may be playing the important role. However, when the sliding speed increase to 0.4m/s, the wear debris generated is ejected out of the wear track and the abrasive wear is minimized.
And it was found in fig 5 that the coefficient friction gradually decrease when the sliding speed increase. At higher speed, the contact area can attain higher temperature which in turn can reduce the shear strength of interface leading to lower values of coefficient of friction. [13] Therefore, the friction coefficient decreases in every case.

The worn surface morphologies are shown in fig6. We can see that there are ploughs left by abrasive wear and small pits caused by adhesion wear on the worn surface. When the velocity increases to 0.3m/s or even 0.4m/s, the metal fluidity increases with the increased temperature on the worn surface, and the worn surface covers with a plough groove by abrasive wear. The wear surface morphology of the metal coincides with the wear data above.

**Figure 4.** Effect of sliding speed on the wear loss of 40MnB

**Figure 5.** Effect of sliding speed on the friction coefficient of 40MnB

**Figure 6.** SEM micrographs showing the worn surface morphologies of 40MnB at:
(a) 0.2m/s (b) 0.3m/s (c) 0.4m/s

4. Conclusion
In this paper, a serious sliding wear tests have been carried out for 40MnB at different sliding speed and load. The following conclusions can be drawn:

1) The effect of load on wear loss is quite obvious. At the load of 50N, adhesive wear is responsible to the slightly wear loss. Increased load leads to higher shear stress, making the removal of materials from interface. These debris become new wear particles. Thus abrasive wear is predominant at higher load conditions. Higher load make good contact between interfaces of pin and disc, leading to higher friction coefficient.
2) Increased sliding speed has little effect on wear loss. As the sliding speed increase from 0.2m/s to 0.4m/s, high flash temperature happens, making easier plastic flow of the steel. Higher temperature reduce shear stress, making coefficient friction gradually decrease when the sliding speed increase.
3) The main wear forms of 40MnB are abrasive wear and adhesive wear.

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