The reduced wear of wheel pair flanges of freight cars

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Abstract. Reduced wear of rails and wheels of rolling stock is a very important task of railway transport. Solving this problem not only increases the lifespan of wheels and rails, but often leads to a positive reduction of fuel consumption for train traction, reduces noise when the train moves in curves. The intensity of wear of rails and wheels of rolling stock depends on many factors. The experience of Ulan Bator railways shows that since 1992, the flange of the wheels has started to wear out intensively, thereby increasing operating costs to repair and reducing service life of the railcar wheel pairs. In order to determine comprehensive measures for the rotation of wheel pairs as well as to determine the intensity of wear of the flange thickness of railcar wheel pairs, experiments have been conducted on the wear and turning of wheel pairs of freight cars. To substantiate comprehensive measures for the rotation of wheel pairs and determine the intensity of wear of the flange thickness of the railcar wheel pairs, experimental tests on a freight car after the overhaul with the 33-mm flange thickness have been carried out throughout the year.

1. Introduction

The track length of the Ulan Bator railway is 2430 km, of which 1814.13 km are the main track, 379.39 km are station tracks, 211.61 km are approach lines. The main route from the border of the Russian Federation to the border of the People’s Republic of China is 1113 km. In the main trunk line, 350 km are occupied by P65 type rails and 1,435.74 km are occupied by P50 type rails. The reduced wear of rails is up to 3 mm. The length of the curve sections of the track with a radius of less than 600 m is 551 km, i.e. 30% of the main track run. 272 km of track are operated on reinforced concrete sleepers, and 842 km of track on wooden sleepers. There are 1528 pieces of construction equipment in the railway in total, including 141 pieces with R65 rails and 1124 pieces with P50 rails. All point switchings are operated using wooden blocks. Over 900 km of the main route, the ballast is crushed quarry, and it is the sand and gravel mixture in the remaining sections. About 30% of the track with a crushed quarry ballast have a layer thickness under the sleeper of less than 15 cm with a contamination of more than 20%.

Reducing the wear of rails and wheels of rolling stock is a crucial task in railway transport. Solving this problem not only increases the lifespan of wheels and rails, but often results in to a positive reduction of fuel consumption for train traction and reduces noise when the train moves in curves.

The intensity of wear of rails and wheels of rolling stock depends on many factors. For the last 10 years, there have been significant changes in the construction of the track and the rolling stock caused by technical advancements in the railway transport [1-4]. The experience of the Ulan Bator Railways...
shows that since 1992 the wheel flange has been wearing out intensively, as a result of which, the running costs for repair are increasing, and the service life of the railcar wheel pairs is decreasing.

To reduce the wear of wheel pairs, as well as to increase the service life of wheels on the Ulan Bator railway, there has been a thorough experimental research related to ensuring guaranteed safety. According to the analysis of the research, the following proposals were made: 1) to reduce the permissible size of the flange thickness; 2) to grind thin-rimmed wheel pairs with a different profile of the taping line and run them into operation; 3) to insert the template DSH-4 on the working surfaces of the wheel pairs in order to determine the sharp flanges; 4) to set the minimum size of the wheel pair flange thickness to 24 mm during operation; 5) to introduce the lubrication of rails [5-11].

2. Experimental studies Experiment No. 1

To carry out complex measures to rotate wheel pairs and determine the wear intensity of the thickness of the flange of wheel pairs of railcars, there was an experimental study to determine the wear of freight railcars with 33-mm thickness of the flange over a year. As a result of these studies, the data obtained are listed in Table 1.

The results of experimental studies of the flange thickness are listed in Table 2.

When carrying out the experiment, we took into account the calculated wear of the thickness of the flange of wheel pairs of railcars according to the formula:

\[ H = L \times H \]  

where \( L \) is the railcar run (km), \( H = 0.00008 \) is the wear of the flange for 1 km of the railcar run (mm).

| Date          | Relative size | Flange thickness | Wear | Wear after 100 km | Flange thickness | Wear | Wear after 100 km | Flange thickness | Wear | Wear after 100 km | Flange thickness | Wear | Wear after 100 km | Flange thickness |
|---------------|---------------|------------------|------|------------------|------------------|------|------------------|------------------|------|------------------|------------------|------|------------------|------------------|
|               |               | side A           | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B | side A | side B |
| 1/V           | 811935        | 31.7             | 32.1  | 32.1   | 32.2   | 32.7   | 32    | 32.6  | 31.7  |            |                  |                  |                  |                  |                  |
|               |               | Flange thickness | After the 4947-km run |            |                  |                  |                  |                  |                  |                  |                  |                  |                  |
| 1/VI          |               | 30.2             | 31.4  | 31.4   | 31.5   | 31.1   | 31.4  | 31.6  | 30.9  |            |                  |                  |                  |                  |                  |
|               |               | Flange thickness | Wear | 1.5    | 0.7    | 0.7    | 1.6   | 0.6   | 1     | 0.8     |                  |                  |                  |                  |                  |
|               |               |               | Wear after 100 km | 0.011  | 0.005  | 0.005  | 0.012 | 0.004 | 0.007 | 0.006 |                  |                  |                  |                  |                  |
| 1/VIII        |               | 29.1             | 30.3  | 30.6   | 30.1   | 29.1   | 30.9  | 30.9  | 30    |            |                  |                  |                  |                  |                  |
|               |               | Flange thickness | Wear | 1.1    | 1.1    | 0.8    | 1.4   | 2     | 0.5    | 0.7    | 0.9     |                  |                  |                  |                  |
|               |               |               | Wear after 100 km | 0.008  | 0.008  | 0.006  | 0.011 | 0.016 | 0.004 | 0.005 | 0.007 |                  |                  |                  |                  |
| 1/X           |               | 28.4             | 29.4  | 30     | 29.7   | 28.4   | 30.4  | 30.6  | 29.6  |            |                  |                  |                  |                  |                  |
|               |               | Flange thickness | Wear | 0.7    | 0.9    | 0.6    | 0.4   | 0.7   | 0.5    | 0.3    | 0.4     |                  |                  |                  |                  |
|               |               |               | Wear after 100 km | 0.014  | 0.018  | 0.012  | 0.008 | 0.014 | 0.010 | 0.006 | 0.008 |                  |                  |                  |                  |
|               |               | Wear after 100 km |            | 3.3    | 2.7    | 2.1    | 2.5   | 4.3   | 1.6    | 2     | 2.1     |                  |                  |                  |                  |
|               |               | Wear after 100 km |            | 0.010  | 0.008  | 0.006  | 0.008 | 0.014 | 0.005 | 0.006 | 0.006 |                  |                  |                  |                  |
|               |               | Wear intensity  |            | 2.0 times | 1.6 times | 1.2 times | 1.6 times | 1.75 times | minimal | 1.2 times | 1.2 times |                  |                  |                  |                  |

Table 1. Experimental studies Experiment No.1
Table 2. The results of experimental studies of the flange thickness

| Operation time       | Flange thickness, mm | Notes (measures taken) |
|----------------------|-----------------------|------------------------|
|                      | The thickness of      |                        |
|                      | the A-side flange     |                        |
|                      | The thickness of      |                        |
|                      | the B-side flange     |                        |
| 0                    | 33                    | 33                     |
| After 6 months       | 28                    | 32                     | Rotation of wheel pairs |
| After 12 months      | 32                    | 28                     | Repeated rotation of wheel pairs |
| After 16 months      | 27                    | 26                     |
|                      | 25                    | 25                     | Wheel pair machining     |
|                      |                       | 22 months in total      |

When calculating the thickness of the flange of wheel pairs of railcars, it is necessary to take into account the location of the wheel pair (see Fig. 1) under the railcars ($K_1$), temperature of the environment ($K_2$) and the flange ovality ($K_3$). These coefficients are given in Table 3-5 [12-15].

Figure 1. Location of wheel pairs.

Table 3. The location of the wheel pair under the railcars.

| Location of a wheel pair | wheel pair 1 A B | wheel pair 2 A B | wheel pair 3 A B | wheel pair 4 A B |
|--------------------------|------------------|------------------|------------------|------------------|
| $K_1$                    | 1.16             | 0.96             | 1.0              | 1.12             | 1.45             | 1.09             | 1.0              | 1.2              |

Table 4. The values of the coefficient $K_2$ (medium temperature).

| Month | 2: 3: 4: 9: 10 | 5: 6: 7: 8 | 11: 12: 1 |
|-------|---------------|------------|-----------|
| $K_2$ | 1.0           | 1.3        | 0.95      |

The diagram of the wear of the thickness of the flange at a coefficient of $K_2$ equal to 1 is shown in Fig. 2.

When carrying out the experiment, the wear of the thickness of the flange of wheel pairs of railcars was calculated according to the refined formula:

$$H_i = L_i \times 0.00008 \times K_1 \times K_2 \times K_3$$  \hspace{1cm} (2)

where 0.00008 is the wear of the flange for 1 km of the railcar run (km); $L_i$ is the run of the railcar (km); $K_1$ is the coefficient of location of wheel pairs; $K_2$ is the temperature coefficient of the environment; $K_3$ is the coefficient of ovality of the flange.
Figure 2. The diagram of the flange thickness wear.

Table 5. The values of the coefficient $K_3$

| Run $L_1$ (km) | Flange wear (mm) | The wear of the flange with a run of 1 km (mm) | coefficient $K_3$ |
|----------------|------------------|-----------------------------------------------|------------------|
| Up to 10000    | 33 – 29          | 0.0004                                        | 5.0              |
| 10.000 – 20.000| 29 – 28          | 0.0001                                        | 1.25             |
| 20.000 – 60.000| 28 – 26          | 0.00005                                       | 0.63             |
| 60.000 – 100.000| 26 – 25         | 0.000025                                       | 0.31             |

The wear of the flange thickness can be calculated by the formula:

$$
\sum H = H_1 + H_2 + \ldots + H_n
$$

(3)

Since January 2014, 4 test gondola cars were selected after the repair in the depot, formed into one train and used to transport coal along the Ulan-Bator-Baganur route. There were certain methods developed for the study and the following railcars were tested: two railcars, according to the current instructions for machining wheel pairs of freight cars, were used with the flange thickness of 33 mm. With the next two railcars, the machining was performed with the flange thickness of about 30 mm. On a trip in April and July 2014, the thicknesses of the flanges of wheel pairs for all four railcars under study were measured, with the measurements compared [16-23].

3. Experiment No. 2
To study the profile of the flange in order to determine the thickness with which it is necessary to machine the flanges of railcar wheel pairs.

It is accepted that the working surface of the flanges in the place of contact with the rail top should be released at an angle of 60°.
During operation, the flanges often change shape; therefore, the working surfaces are inclined at an angle of approximately 71°. This type of railway fault is called a sharp flange, and the wheelset with such a defect is prohibited from being brought under the wagon. On the basis of changes in the thickness of the crests and the study of geometrical data of the wheel, you can approximately determine how the thickness and other parameters of the bandage after turning the wheel are changed (see Table 6).

Table 6 makes it possible to determine in advance what kind of repair it is and for which railcars we need to bring the wheel pairs after machining (see Table 7).

Using the above data in Tables 6 and 7, we will determine the economic indicators after the wheel machining, with parameters with 24-mm thickness and 40-mm thickness.

If you machine the wheels with the flange thickness of 33 mm, then the bandage becomes 24.4 mm in size and such a wheel pair can already be brought under the railcar, but only with a current repair. If machining is carried out with the flange thickness of approximately 30 mm, then the thickness of the bandage becomes 29.6 mm and this wheel pair can already be brought under the railcar not only with a repair at the depot, but also with a current repair.

| Flange thickness, mm | Reducing the thickness of the bandage (mm), with the working surface being at an angle of |
|----------------------|---------------------------------------------------------------|
|                      | 60°                                                            |
|                      | 70°                                                            |
| 33                   | 15.6                                                           | 24.7       |
| 32                   | 13.8                                                           | 22.0       |
| 31                   | 12.0                                                           | 19.2       |
| 30                   | 10.4                                                           | 16.5       |
| 29                   | 8.7                                                            | 13.7       |
| 28                   | 7.0                                                            | 11.0       |
| 27                   | 5.2                                                            | 8.3        |

| Type of repair       | Wheel pair size                     |
|----------------------|-------------------------------------|
|                      | Flange thickness (mm) | Bandage thickness (mm) |
| Complete overhauling | 30-33                  | not less than 35       |
| At the depot         | 28-33                  | not less than 27       |
| Current              | 26-33                  | not less than 24       |

If you machine the wheels with the flange thickness of 33 mm, then the bandage becomes 24.4 mm in size and such a wheel pair can already be brought under the railcar, but only with a current repair. If machining is carried out with the flange thickness of approximately 30 mm, then the thickness of the
bandage becomes 29.6 mm and this wheel pair can already be brought under the railcar not only with a repair at the depot, but also with a current repair.

4. Experiment No. 3
When investigating the wear of the flange, we were able to determine that if the flange thickness can wear out to 29-26 mm at the working edge of the flange, the galling of metal into the top of the head of the flange should necessarily appear. Because of such faults in Ulan-Bator Railway, more than 500 railcars had to be uncoupled and repaired, which led to large economical costs.

Figure 4 shows the studied position of the pointed edge of the flange in the upper part of the flange (about 2 mm lower than the top of the flange) before rolling the wheel onto the switch point, which butts against the frame rail with a gap of 3 mm.

![Figure 4. The sharp flange during the wheel rolling onto the switch point.](image)

The rejection criterion, which characterizes the critical shape of the wear of the flange, can be represented as a horizontal projection forming the worn surface of the flange from a point located 2 mm below its top and of a point that is 13 mm higher than the average taping line.

According to the accepted terminology, the sharp flange is the galling of metal to the top of the flange on the edge of the transition of the worn-out part to the unworn one. This galling most often occurs under the action of friction forces during two-point contact of the wheel with the rail. This, as a rule, occurs in the curves at the moment when the contact moving along the flange, in contrast to the normal contact, does not open, and the flange sliding along the lateral surface of the rail is directed towards the top [24-28].

![Figure 5. The main faults of the flange of wheel sets of railcars – a) a method for eliminating a fault; b) a fault on the working surface of the flange; c) on a non-working surface.](image)
5. Conclusion

Based on a wide range of studies, the DSh-4 template was put into operation. As a result of these actions, the number of uncoupled railcars for the considered wheel pair faults with a sharp flange decreased by 80% and, accordingly, the cost savings were reduced.

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Figure 6. The diagram of the template DSh-4.
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