Statistical study of the wear of wheel pair flanges of freight cars

V E Gozbenko1,2, B Tuvshintur1, S K Kargapoltsev

1 Irkutsk State Transport University, 15 Chernyshevsky Street, Irkutsk, 664074, Russia
2 Angarsk State Technical University, 60 Chaykovskogo Street, Angarsk, 665835, Russia

E-mail: irgups-journal@yandex.ru

Abstract. Reduced wear of rails and wheels of rolling stock is a very important task of railway transport. The flange profile studies were conducted to determine the machining sizes for the flange of railcar wheel pairs. The studies made it possible to determine that the rejection criterion characterizing dangerous form of the flange wear is a horizontal projection forming the worn-out surface of the flange between the points located at about 2 mm below its top and 13 mm above the average taping line. There are calculations made on the wear of the wheel pairs of gondola cars of the EC70 model manufactured in China after three years of operation.

1. Introduction
According to the reports of the VU-53 form of the freight car depot VChD-1 of the Dzunkhara station of the Ulan Bator Railway, 3,740 wheels with different faults were machined in 2014, but most of the wheels turned out to be with worn flanges [1-5].

Analysis of the wheel pairs of railcars and their faults showed that the main ones are: 1) No. 14 (thin flange) - 41%; 2) No. 22 (shelled treads) - 36%; 3) No. 20 (slid flats) - 21%. There were no other faults, for example, No. 73 (the difference between the diameters of the wheels) detected in the car depot, but the depot data say that it reaches 19% [6-11].

Earlier, with a 1524 mm gauge, the high flange in the taping line increased first, and then the wear of the flange began to increase more slowly [12-19]. After the gauging was done, the situation changed - the flange began to wear out faster. Within 5 months, June - October 1995, in the wheel pairs of freight cars (Ulan Bator Railway), the thickness of the wheel pair flanges reached the limit, i.e., less than 23 mm. High flanges began to increase slowly, so the corresponding machining was minimized. Therefore, the service life of the wheel pairs has significantly decreased. As a result of these measures, the service life of the wheel pairs began to decrease. To increase the time of service of wheel pairs of railcars on the Ulan Bator railway, a series of measures were undertaken in 1995-1998 [20-24]. Upon reaching the flange thickness 25-26 mm, railcar wheel pairs were rotated. Since January 1998, the technology of building-up the flanges has been introduced. The wheel pairs were rotated alternately when the desired flange thickness was reached. The first wheel pair was replaced by the third, the second wheel pair was replaced by the fourth pair, etc. To carry out comprehensive measures for the rotation of wheel pairs and to determine the intensity of wear of the flange thickness of railcar wheel pairs, experiments have been conducted on determining the wear and machining of wheel pairs of freight railcars.
2. Research Methods
The wear of the flanges of wheel pairs of gondola cars of model EC70 made in China after 3-year operation has been calculated. With that, the railcar mileage ranges from 60-70 thousand km, the main cargos are iron ores at the sections between the Eroo – Dzamyn-Ude stations of the Ulan-Bator Railway.

The statistical data for the calculation were obtained from 248 railcars after the repair in the freight car depot of the Dzunkhara of the Ulan Bator Railway. As is known, the release thickness of the flange of wheel pairs is 33 mm. When operating these railcars for 3 years after the release, a change in the thickness of the flange of wheel pairs of railcars ranges within 0-7 mm. Sample size \( n = 496 \div 1984 \), depending on the wheel pair of the railcar. The level of significance is accepted \( \alpha = 0.005 \) reliability \( \gamma = 0.95 \).

We will carry out a statistical study for wheel pairs in 248 railcars. The calculation is based on the results of the data obtained on the first wheel pair, the second wheel pair, the third wheel pair, the fourth wheel pair, the first bogie, the second bogie, the left wheels, the right wheels and the data on all wheel pairs.

Let us make a series of the distribution of the sample \([13, 29-31]\), dividing by 7 parts and finding the length of the partial interval \( h = \frac{7-0}{7} = 1 \).

3. Research Summary
A number of distributions of the frequencies of the sample and the distribution of the relative frequencies are given in Tables 1 and 2.

### Table 1. A number of distributions of the frequencies of the sample

| Numeric interval | 0-1 | 1.5-2 | 2.5-3 | 3.5-4 | 4.5-5 | 5.5-6 | 6.5-7 |
|------------------|-----|-------|-------|-------|-------|-------|-------|
| \( n_i \)       | 1   | 11    | 113   | 192   | 135   | 42    | 2     |
| \( n_i/n \)     | 0.002 | 0.022 | 0.228 | 0.387 | 0.272 | 0.085 | 0.004 |

### Table 2. A number of the distribution of the relative frequencies

| \( x_i \)   | 0.5 | 1.75 | 2.75 | 3.75 | 4.75 | 5.75 | 6.75 |
|-------------|-----|------|------|------|------|------|------|
| \( n_i/nh \) | 0.002 | 0.022 | 0.228 | 0.387 | 0.272 | 0.085 | 0.004 |

We find selected numeric characteristics according to the formulas:

\[
\bar{x}_b = \frac{\sum x_i n_i}{n}, D_b = \frac{\sum x_i^2 n_i}{n} - (\bar{x}_b)^2, \sigma = \sqrt{D_b}
\]  

(1)

where \( k \) is the number of intervals;

The results of the calculations are listed in Table 3.
Table 3. The results of the calculations

| $i$ | $x_i$ | $n_i$ | $u_i$ | $u_i n_i$ | $u_i^2 n_i$ | $(u_i + 1)^2$ |
|-----|-------|-------|-------|-----------|-------------|--------------|
| 1   | 0.5   | 1     | 0.5   | 0.5       | 0.25        | 2.25         |
| 2   | 1.75  | 11    | 1.75  | 19.25     | 33.69       | 83.19        |
| 3   | 2.75  | 113   | 2.75  | 310.75    | 854.56      | 1589.06      |
| 4   | 3.75  | 192   | 3.75  | 720       | 2700.00     | 4332.00      |
| 5   | 4.75  | 135   | 4.75  | 641.25    | 3045.94     | 4463.44      |
| 6   | 5.75  | 42    | 5.75  | 241.5     | 1388.63     | 1913.63      |
| 7   | 6.75  | 2     | 6.75  | 13.5      | 91.13       | 120.13       |
|     |       |       |       | 1946.75   | 8114.19     | 12503.69     |
|     |       |       |       | 3.925     | 0.95        |              |

Let us construct a histogram of the density of relative frequencies (see Fig. 1).

![Histogram](image)

**Figure 1.** The histogram of the density of relative frequencies for the first wheel pair.

Table 4. The results of the calculations

| The first wheel pair | 1   | 11  | 113 | 192 | 135 | 42  | 2   |
|----------------------|-----|-----|-----|-----|-----|-----|-----|
| $x_i$                | 0.002 | 0.022 | 0.228 | 0.387 | 0.272 | 0.085 | 0.004 |

The density function of normal distribution law:

$$f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-a)^2}{2\sigma^2}},$$

(2)

where $a = \bar{x}_b, \sigma = S = \sqrt{\frac{n-1}{n}}$.

Next, we find the confidence interval for the mathematical expectation $M(x)$ and the mean square deviation $\sigma(x)$ with reliability $\gamma = 0.95$

$$\bar{x}_b - t_{\gamma} \frac{S_x}{\sqrt{n}} < M(x) < \bar{x}_b + t_{\gamma} \frac{S_x}{\sqrt{n}}.$$
\[ S(1-q) < \sigma < S(1+q), \text{ at } q < 1, \]
\[ 0 < \sigma < S(1+q), \text{ at } q < 1. \]

Find \( q \) using [15]

To verify the validity of the hypothesis put forward, we use Pearson’s criterion at a significance level of \( \alpha = 0.05 \). The observed criterion value is calculated according to the formula:

\[ x^2_{\text{obs}} = \sum_{i=1}^{k} \frac{(n_i - \bar{n}_i)^2}{\bar{n}_i}, \quad (3) \]

where \( n_i \) – are statistical frequencies, \( \bar{n}_i \) – are theoretical frequencies, defined in the case of the normal law of distribution according to the formulas:

\[ n_i = \frac{nh}{S} \times \varphi(z_i); \quad z_i = \frac{x_i - \bar{x}_b}{\sqrt{\frac{S}{nh}}}; \quad \varphi(z_i) = \frac{1}{\sqrt{2\pi}} \times e^{-\frac{z^2}{2}} \quad (4) \]

Find the values of \( \varphi(z_i) \) with [4]

After calculating the value of the criterion, we conclude that the hypothesis proposed is true.

**Figure 2.** The intensive wear of the flange after the machining and to increase the life service of the wheel pair
Figure 3. The flange for wheel pairs without the flange building-up

Figure 4. The working part of the flange is the surface located within 2 mm from the top - 13 mm from the wheel thread

4. Conclusion

1. When comparing the thickness of the 30-mm and 33-mm flange, it was revealed that wheel pairs with the 30-mm thickness have the ability to avoid intense wear of the flange during a run of 120-130 thousand km i.e., approximately when worn down to 27 mm. Therefore, it is proposed to release wheel pairs with an initial thickness of 30 mm for the utilization with a depot and complete overhaul repairs. In this case, it becomes possible to increase the service life of the wheel pair for 44 months.

2. We recommend that the DSh-4 template be put into operation on the railway.

3. With a bandage thickness of up to 33-36 mm, machining is not recommended. For maximum use of the wheel pair resource, it is necessary to machine the flanges to 27 mm and then use them under the railcars that have undergone the current overhaul repair. It is necessary to introduce changes in the instructions for inspection and examination of wheel pairs of railcars.

4. It is necessary to set the schedule for the rotation of the wheel pair under the railcars, coming from the data on the railcar runs. This will result in savings in the measurement of the wheel pairs of the railcars during inspection.

5. To set the maximum thickness of the wheel flange when machining. This makes it possible to avoid the intensive wear of the flange after the machining and to increase the life service of the wheel pair (see Fig. 2).

6. According to the instructions for inspection and examination of wheel pairs of railcars, when machining the wheels, it is necessary to leave pittings on the flange with a depth of not more than 2 mm, located not more than 10 to 18 mm from the top of the flange for wheel pairs without the flange building-up, so that the rim will be ground 3-4 mm less (see Fig. 3).

7. Observance of technical requirements according to the “Reminder for railcar inspectors No. 724-2009 PKB TsV” according to clause 4.2.1 “Sharp edge on the upper parts of the flange, without cutting, is not subject to rejection. The working part of the flange is the surface located within 2 mm from the top - 13 mm from the wheel thread (see Fig. 4).

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