Mechanisation in the production process of the technical station - ensuring the safety of train traffic

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Abstract. The article is devoted to the replacement of brake pads at railway infrastructure car maintenance facilities. This article studies the problem of replacing friction pads in passenger cars, when the checks jam under the influence of external dynamic and temperature factors during operation. According to the standard technology the replacement of the defective pad is carried out with the use of manual devices, which does not meet modern requirements. A new screw puller for replacing the brake pads of wagons is proposed. The screw pair is calculated and its rational parameters are specified. Key words: friction pad, cheque, defective pad, brake pad replacement, screw puller, screw pair, thrust screw, rotary bearing, lever, train traffic safety.

1 Introduction

A brake pad is a friction element in the mechanical part of the braking system. When rubbing against the wheel surface, the brake pad heats up and deforms. Unequal adherence of the deformed pad to the wheel surface leads to high contact stresses, local heating and rapid wear of brake surfaces, which poses a threat to traffic safety. In order to reduce dangerous failures at technical stations, parts requiring replacement are identified. The applied technology of pad replacement is characterised by a high share of manual labour and labour-intensive work, especially when the pad is jammed in winter [1,2].

2 Problem statement

To clarify the problem of brake pad removal, let us briefly review the steps of the basic technology. Shoe replacement is performed after fencing, fixing the train with released brakes, by acting on the exhaust valve chain. The initial stage is the removal of the upper cotter pin using a homemade device (bent tube) and a hammer. If the cotter pin is jammed, it is pulled out with a crowbar. After removing the cotter pin, the cheque is knocked out with a hammer (Fig. 1a), and the end of the cheque is not seldom damaged. The final operation is removal of the cotter pin and brake shoe (Fig. 1b).
Time standard for brake pad replacement is not more than 2 minutes. Practice shows that in case of jamming of the cheque, under the influence of dynamic loads or temperature factor (formation of ice on the cheque) the time for dismantling the pad increases significantly. In addition, when dismantling the cheque with an impact tool there is deformation of the shank of the cheque, which reduces its life. From the above it follows that dismantling of brake shoes of passenger cars is performed with the use of primitive tools (hammer, crowbar) which do not always meet modern requirements for productivity and quality of work. At the same time, the safety of train traffic depends a lot on the serviceability of braking equipment elements. The basic technology of brake pad replacement has a significant reserve for increasing efficiency.

3 Research questions

In order to increase mechanisation of works at the technical station, we propose a screw puller for extraction of the brake shoe cheque. Advantages of screw-nut transmission are: possibility of slow translational motion; significant gain in force; simplicity of construction; small dimensions; possibility of self-braking [3]. The new design of the screw puller is explained in Fig. 2a and Fig. 2b.

Fig.2a - shows the screw puller, front view with a partial section of the moulded body with threaded hole.

Fig. 2b - shows the screw puller, side view with a section of the brake shoe.

Positions in the figures denote: 1 - cheque, 2 - brake shoe, 3 - brake shoe, 4 - pin, 5 - cast housing with threaded hole, 6 - power screw, 7 - tetrahedron, 8 - threaded hole for fixing the handle, 9 - screw, 10 - telescopic handle, 11 - thrust bearing, 12 - pusher, 13 - pusher whiskers, 14 - guide grooves.
The device works as follows. Removal of the cheque 1 of the brake shoe 3 using the proposed device is carried out in the following way. The moulded body with a threaded hole 5 is connected to the brake shoe 2 by means of a pin 4. Set the pusher 12 in the required position relative to the cheque 1 of the brake shoe 3 due to the mobility of the kinematic pair of the cast body 5 and the brake shoe 2. Having fixed the device in working position, start turning the telescopic handle 10. The telescopic handle 10 is made removable with fastening to the square 7 by means of screw 9 through the threaded hole 8. When turning the telescopic handle 10, the power screw 6 starts to move upwards from the lower position. At the same time, the thrust bearing 11 does not transmit the rotational torque to the pusher 12. As a result, the pusher 12 makes translational movement in the direction of the cheque 1 of the brake shoe 3 on the friction surfaces - pusher whiskers 13 and guide grooves 14. As the telescopic handle 10 continues to rotate, the pusher starts to squeeze out the cheque 1 of the brake shoe 3. The sign of shifting of the cheque 1 from the wedged position is free rotation of the telescopic handle 10.

The technical result is an increase in operational efficiency of extraction of brake shoe cheques. The technical result is achieved by the fact that in the device for extraction of wedged checks of brake pads containing a power screw, thrust bearing, rotary handle, additionally introduced a cast body with a threaded hole connected to the brake shoe with the help of a finger, the pusher has a guide whiskers associated with the grooves, and the end part of the power screw is made in the form of a tetrahedron, on which a telescopic handle is installed.

The body with a threaded hole ensures its reliable connection with the brake shoe. In addition, this connection ensures mobility of the kinematic pair of the housing relative to the brake shoe to give the required position of the pusher in space. The load on the pusher is directly transferred via the bearing to the power screw, which reduces friction losses in the
mating elements. This makes it possible to apply the required force on the brake pad cheque to be removed with less labour and reduces the distortion of the power screw.

The pusher increases the area of contact with the brake shoe cotter pin at different positions and connection dimensions depending on the design and technical condition of the friction unit. The pusher whiskers in contact with the guide grooves prevent misalignment of the bearing surface during the power screw stroke in the direction of the brake shoe cotter and during its reverse movement. The contact plane of the tappet can have a grooved surface, which will provide a more reliable contact in the interaction zone.

A thrust bearing between the tappet and the power screw reduces friction in the sliding pair of the tappet whisker guide and tappet grooves, which reduces the force of brake cheque extrusion.

The telescopic handle ensures that the power screw is rotated with the required smoothness of movement to ensure that the brake cheque is removed without visible deformation. The telescopic handle allows the force on the power screw to be adjusted.

4 Materials and methods

To clarify the operating parameters of the screw puller, let's perform the calculation of the screw-nut transmission. Initial data for calculation of self-locking thrust thread are taken according to the reference literature [4,5,6].

The torsional torque of the thrust screw in the dangerous section is determined by the formula:

\[ M_r = F \times \frac{d_2}{2} \times \tan \alpha \tan \varphi \]  

where  
\( M_r \) - torque torsion of the screw in the dangerous section, Nm;  
\( F \) - axial load on the screw, N;  
\( d_2 \) - nominal diameter of the thread, mm;  
\( \alpha \) - angle formed by the tangent to the screw line, deg;  
\( \varphi \) - reduced friction angle, deg.

Angle formed by the tangent to the screw line

\[ a = \arctan \left( \frac{P_h}{p \times d_2} \right) = \arctan \left( \frac{3}{3.14 \times 21.75} \right) = 0.00439 = 2.5^0 \]

Induced friction angle

\[ \varphi = \arctan \left( \frac{f}{\cos (\varphi)} \right) = \arctan \left( \frac{0.18}{\cos (2^0)} \right) = 0.18 = 10.2^0 \]

Considering that the value of \( \varphi \) exceeds \( \alpha \), the self-locking condition is fulfilled. Consequently, the moulded body with the threaded hole of the screw-remover will not move spontaneously along the axis of the thrust screw without applying the load from the lever [7]. Then the torsional torque of the screw in the dangerous section of the threaded hole of the housing and the thrust screw will be:

\[ M_r = 800 \times \frac{21.75}{2} \times \tan (2.5^0 + 10.2^0) = 2 \text{Nm} \]

As a material of the lever is chosen carbon steel grade St 2 according to GOST 380-2005, with an elastic limit of 190 MPa [8]. The load, which will be applied to the lever, is taken in the range from 90 to 320 N. To determine the length of the lever \( R_p \), the value of
force $F$ equal to 150 N is taken. The torque of the force on the lever is 2 Nm. The length of the lever is determined by formula (2) [3,4]:

$$R_p \geq \frac{M_r}{F} = \frac{2 \times 10^3}{150} = 13\text{mm}$$  \hspace{1cm} (2)$$

To improve ergonomics and reduce the applied force, the lever length can be set at 150 mm. We can use formula (3) to determine the lever diameter required for bending strength:

$$d_1 \geq \sqrt{\frac{2 \times F \times R_p}{0.1 \times \sigma_b}}$$ \hspace{1cm} (3)$$

where $d_1$ - nominal diameter of the lever, mm;
$F$ - operator load on the lever, N;
$\sigma_b$ - stress on the lever at the moment of bending, N/mm
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$F$ - operator load on the lever, N;
$\sigma_b$ - stress on the lever at the moment of bending, N/mm2.

$$\sigma_b = \frac{1.2 \times \sigma_t}{S} = 76\text{MPa}$$

where $\sigma_b$ - stress on the lever at the moment of lever deflection, N/mm2;
$\sigma_t$ - elastic limit of steel St.2 for the lever, N/mm2;
$S$ - distance between thread turns, mm.

Then the diameter of the lever is:

$$d_p \geq \frac{3 \sqrt{2 \times 150 \times 150}}{0.1 \times 76} = \frac{3 \times 5921}{18} = 18\text{mm}$$

For steel rolled round section according to GOST 2590-2006 we choose diameter $d_p = 18$ mm [9]. Geo-metric parameters of the thrust screw lever are presented in Figure 3.

![Fig. 3 - Lever of the screw puller with refined parameters](image-url)
5 Results

The results of calculation of the screw pair of the puller designed to remove the cheque of the friction pad are presented in the table 1.

**Table 1. Technical characteristics of the device**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial force on the operating screw, N</td>
<td>800</td>
</tr>
<tr>
<td>Maximum pusher stroke, mm</td>
<td>60</td>
</tr>
<tr>
<td>Handle length, mm</td>
<td>150</td>
</tr>
<tr>
<td>Handle diameter, mm</td>
<td>18</td>
</tr>
<tr>
<td>Screw and nut material</td>
<td>Steel 35</td>
</tr>
<tr>
<td>Handle material</td>
<td>Steel St3.</td>
</tr>
<tr>
<td>Thread type of operating screw (pusher)</td>
<td>Stubborn</td>
</tr>
<tr>
<td>Bearing type</td>
<td>Single ball thrust bearing 8102H</td>
</tr>
<tr>
<td>Cheque retrieval time, sec</td>
<td>30</td>
</tr>
<tr>
<td>Overall dimensions, mm</td>
<td></td>
</tr>
<tr>
<td>height</td>
<td>180</td>
</tr>
<tr>
<td>width</td>
<td>50</td>
</tr>
<tr>
<td>length</td>
<td>45</td>
</tr>
<tr>
<td>Weight, not more, kg</td>
<td>5</td>
</tr>
</tbody>
</table>

6 Discussion

A graph of the force of the power screw as a function of tappet travel is shown in Figure 4. It is expected that in 90 per cent of cases the brake cheque will be removed up to maximum force values in the range of 500 N to 700 N. The maximum value on the screw will be in the case of stuck brake cheques and icing of the brake pads. The power screw can be treated with a lubricant for rubbing surfaces to ensure smooth running.

![Fig. 4 - Lever of the screw puller with refined parameters](image_url)
The efficiency of screw-nut transmission can vary within 0.6...0.8. In case of self-braking transmission $\eta < 0.5$. To increase the efficiency of the screw transmission of the proposed device can be used: antifriction metals (bronze, brass, etc.); metals for the nut and screw with different coefficient of friction; treatment and lubrication of the rubbing surfaces; use of threads with a small angle of inclination.

The proposed device for extraction of brake shoe chicks of passenger cars allows to increase the level of mechanisation of works of technology on replacement of brake pads during technical maintenance of cars at technical stations. The merits of the device for extraction of passenger wagons brake shoe chocks are:
- sufficient force on the pusher to squeeze out the brake shoe cheque;
- simple and small-sized design;
- smooth and quiet operation.
- quick setting of the device in working position;
- easy operation and maintenance;
- possibility of using a mechanised drive.

7 Conclusion

1. There is a new device for extracting passenger cars brake shoe cheques, which allows to increase considerably the productivity of shoe dismantling in case of jamming of the cheques. The device provides reduction of labour intensity of brake pad cheque extraction in conditions of technical stations more than three times due to reduction of friction losses in conjugated elements.

2. Two variants of the tappet with direct interaction of the support surface of the tappet with the cheque and through the thrust bearing are offered. The second variant is more preferable, because the friction between the pusher and the cotter pin is reduced and the possibility of its bending during dismantling is excluded.

3. The parameters of the screw pair of the proposed device are specified. The length and diameter of the handle were calculated, which amounted to 150 mm and 18 mm, respectively. With such parameters of the screw pair and the handle it is guaranteed to provide the extraction of the brake pad cheque under the most difficult conditions. Analytical dependences of the working screw force on the pusher stroke are plotted, and the average range at which the brake pad cheque is guaranteed to be extracted is determined.

The new screw puller can be effectively used at the passenger wagon maintenance facilities (without significant structural changes and freight wagons) as the basic objects of the railway infrastructure, the efficiency of the transportation process depends on the good condition of which. Timely and prompt replacement of wagon pads with the use of mechanisation means is a guarantee of train traffic safety. Besides, the device without significant design changes can be used for dismantling brake shoes of multi-axle freight wagons, which expands its functionality.

References


