ANALYSIS OF RELIABILITY OF AXLE BOX BEARING UNITS OF FREIGHT CARS

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ABSTRACT

The authors present an analysis of reliability of axle boxes. Provided data characterize its level in relation to the total freight car fleet. The estimation of parameters of failure flow due to damage to roller axle boxes in cars of total fleet compared with universal covered car fleet is given. The question arises on causes of failures and possibility of having a mathematical model that could help in determining the reliability degree of axle boxes.

Keywords: railway, car, axle box, roller axle bearing, reliability, failure, analysis of causes, statistical dependence.

Background. *Being in complex operational and weather conditions, axle box should continue to operate regardless of external factors. Axle bearings perceive and transmit to wheel sets strain of a laden body and dynamic stresses resulting from car's movement on curved sections, track switches, track irregularities and rail joints. Each, sometimes insignificant, malfunction could result in a technical failure and threatens transportation safety of passengers or goods.*

Objective. *The objective of the authors is to investigate axle box bearings of freight cars during their operation.*

Methods. *The authors use general scientific and engineering methods, calculation, evaluation approach, comparative method.*

Results. *These risks are confirmed by the analysis of distribution of accidents'causes classified by car economy for the period 1995-2012. It is obvious that failures of axle boxes led mostly to critical work situations.*

According to the Ukrainian Railways (hereinafter-UR), the number of cars' uncoupling due to excessive heating of roller axle bearings, which was discovered by remote control devices, varies widely: from 352 cases in 1995 to 33 – in 2012. However, it is necessary to add to this amount cases of high heating of roller bearing assemblies detected by car inspectors with the help of external signs. In 2011, such defects were registered on 1122 cars, a year later – on 1437 cars.

Table 1 shows main causes of heating of axle box and car's uncoupling of a train.

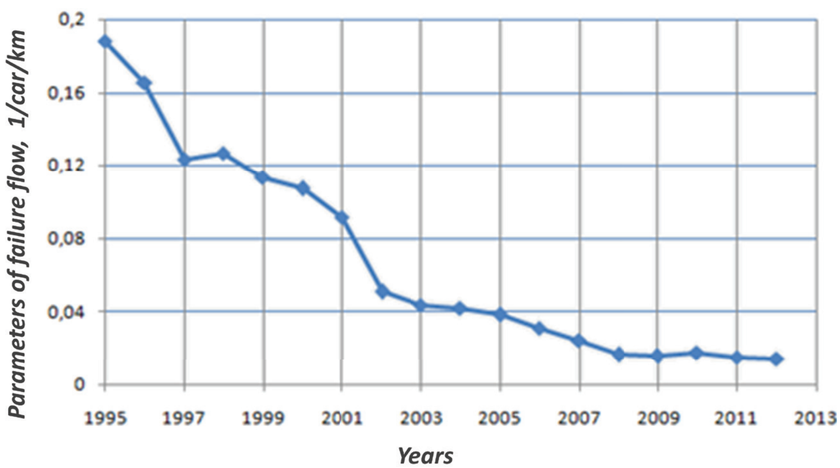
Evidence suggests that the most dangerous in terms of traffic safety is damage to the frontal fastening (almost 25% of the total number of uncoupling).

The causes of frontal fastening's failure are adequately described in the scientific literature [1-3]. Let's analyze the load circuit of axle cylindrical bearings.

Radial and axial forces Q affect axle bearings while moving. Nature of axial forces action is much more diverse. Thus, when passing curved sections of the track, axial forces will be permanent. At the same time, lateral oscillations of the car cause transient axial loads. And when passing lateral horizontal irregularities, axial forces acquire the character of a shock.

The axial force is able to reach high values, particularly in freight cars [4]. It can act towards a fillet, as well as towards a butt end of an axle neck. The reason is the presence of only central spring suspension in the structure of cargo bogies. As a result, a side bogie frame, which has a large mass and acceleration resulting from the passage of track irregularities, rests on the axle bearing body.

Transferring axial force is performed through rollers of only one of bearings depending on the direction of action. Direct pressure on the frontal fastening causes it to weaken and sometimes under the influence of large dynamic forces and accumulation of defects in the metal – to destruction.



Pic. 1. The dependence of change in the parameter of freight cars' failure flow due to the heating of axle boxes.

Table 1

The main causes of excessive heating of axle boxes

Causes of uncoupling	Percent of the number of uncouplings
	2009-2012
Faults of separator	2,44
Faults of frontal fastening	24,39
Actuation of «herringbone» type	13,41
Turn of inner ring	4,88
Complete destruction of bearing	4,88
Pollution or flooding of lubrication	15,85
Cracks and chips of rings	6,10
Blow holes on the rolling surface of rings	4,88
Other causes (human factor)	23,17
Total:	100,0

Table 2

Causes of failures of roller axle bearings, detected by external features

Causes of uncouplings	Percent of the number of uncouplings
	2009-2012
Faults of frontal fastening	12,53
Faults of separator	18,65
Scores «herringbone» type	8,91
Destruction of bearing	0,42
Turn of inner ring	3,69
Cracks of rings	3,69
Blow holes on the surface of roller's rings	2,78
Electric burn	0,21
Availability of water	15,31
Faults of labyrinth ring	1,04
Human factor	15,87
Causes not determined	9,05
Other	7,86
Total:	100,0

The action of axial forces leads to a skewing of rollers, thereby creating antisymmetric loads in the separator. When combined with high dynamic efforts (especially in winter), this leads to the appearance of fatigue cracks in the corners of separators' windows with their subsequent destruction.

When a car moves, axial forces are transmitted to butt ends of rollers in a sliding mode «steel on steel» to directional clamps of rings. Through this friction mode between clamp and butt ends of rollers intense heat evolution and disruption of oil film between surfaces occur. Due to the dry friction output strength of clamps' metal reduces significantly. This leads to microseizure of metal in the contact zone and causes damage of «herringbone» type to rollers and clamps of bearing rings. In the future, the presence of this actuation contributes to the appearance of cracks, chips or even completes destruction of clamps.

In addition, there is an increased resistance of bearings to rotation, which is accompanied by local heating in the contact zone. This speeds up the aging process of oil and causes its contamination with wear product.

Skewing of rollers creates additional stress concentration in the contact area of rollers with raceways of rings and thereby leads to intensive formation of blow holes.

There is a reason to assume that a significant proportion of faults that are detected during a scheduled inspection, as well as most emergency failures result from insufficiently substantiated constructive scheme of axle box, where the axial load is transmitted through butt ends of rollers in the sliding friction mode.

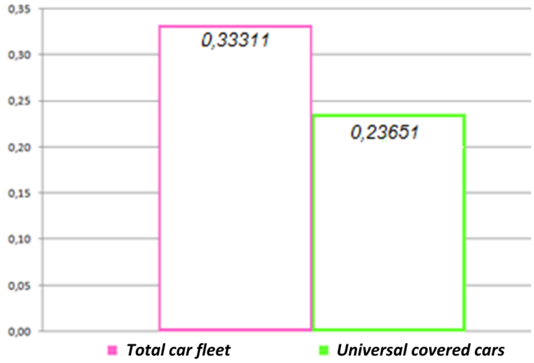
At the same time a considerable number of uncouplings is caused by the fact of appearance of heating of axle bearings at characteristic actuation of butt ends of rollers «herringbone» type.

Table 2 shows causes of failures of roller axle bearing that have been detected by car inspectors on external signs.

It is confirmed that at the first places there are failures of frontal fastening and separator. But they are followed by failures caused by the action of so-called «human factor», because mistakes of maintenance staff led to defects.

As a result of the processing of statistical data on uncoupling of cars en route, provided by the General Directorate of car economy of UR, the dependence that characterizes the change in the number of uncoupling on determined cause during 1995-2012 period, was obtained.

If we start counting from 1995, the corresponding dependence will have this form



Pic. 2. The value of freight cars' failure flow of total fleet by damage to axle boxes in comparison with universal covered car fleet (2012).

$$\Delta(t) = 0,005t^4 - 45,41t^3 - 13646t^2 + 2\cdot10^8 t + 9\cdot10^{10} \quad ,(1)$$

where t is years, counted from 1995.

The consistency degree of obtained theoretical dependence on experimental data was tested by means of correlation coefficient R, which is defined as:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left[y_i - f_i(t)\right]^2}{\sum_{i=1}^{n} y_i^2 - \frac{1}{n}\cdot\left(\sum_{i=1}^{n} y_i\right)^2}, \quad (2)$$

where y_i is empirical data;

$f_i(t)$ is data obtained by calculation;

n is a number of data pairs.

Pic. 1 shows the change in the parameter of freight cars' failure flow due to failure of axle bearings (per 1 million car / km) because this measure enables us to generalize the changes that have occurred over fixed time on railway transport: reduction of working fleet of cars, fluctuations in freight turnover, exclusion of cars from the inventory, etc.

The corresponding dependence of parameter of freight cars' failure flow through the heating of axle box has a form:

$$\omega(t) = 0,000003t^3 - 0,019t^2 + 37,88t - 24338, \quad (3)$$

where ω is failure flow parameter, t is years.

These data indicate the reliability level of axle boxes for the total fleet of freight cars. Although here it should be borne in mind that in recent years there was a restructuring of the fleet, which resulted in the fact that vast majority of cars were distributed among certain operators, which became not only their owners, but also persons responsible for the maintenance of cars in good technical condition. There are different owners and, of course, different responsibilities. And it is more difficult now to differentiate causes of failures against this background.

Pic. 2 shows the parameters of failure flow due to damage of roller axle bearings for the total car fleet in comparison with universal covered car fleet in 2012.

Conclusions. *Here the situation is very clear: in universal covered cars failure flow parameter is 1,4 times less, that is, their axle bearings have a greater level of reliability. But to find reasons for this, it is necessary to analyze the technical condition of elements of wheel sets' axle boxes of these cars, to develop a mathematical model that will determine reliability indicators.*

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