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THE ANALYSIS OF WEAR INTENSITY OF THE LOCOMOTIVE WHEEL – SETS

The wear dynamics of wheel – set tyres of Diesel locomotives was investigated. Based on the results obtained, it is possible to forecast the safe operation period of wheel – set tyres between overhauls, to improve their maintenance and planning of overhauls and to achieve more efficient allocation of resources to the repairs of traction rolling stocks.

Keywords: *wheel-set, locomotive, intensity of wear, lubrication*

1. Introduction

The locomotive wheel-sets are major components of the running gear. They are most heavily wearing units often requiring expensive repairs. Rolling stock safety and uniform motion largely depend on their performance. Therefore, it is extremely important to determine wear intensity of the wheel-sets at various stages of their service life.

The analysis of the above characteristic will enable us to determine more accurately the safety margin of the wheel tyres and the supply of spare wheel sets needed by a locomotive park, as well as to establish the optimal servicing and repair intervals, allowing for more efficient allocation of resources to traction rolling stock repair.

2. Research object

The intensity of wear of two wheel set surfaces (running surfaces) and the flanges is considered.

2.1. The intensity of wheel – set tyre wear

As wheel tyres are wearing out the running surface profile of the wheel is gradually losing a conical shape. Wearing action causes the formation of a groove (a cut) on the surface of the wheel flange.

The wear of the wheel tyres is caused by two factors. The first is plastic deformation when the metal is forced out from the running surface towards the flange. The second is thermal effect taking place at the time of wheel spinning or when stopping the locomotive. This causes the formation of a hard martensite structure on the running surface.

Heavy deformations of the wheel tyres and railhead occur due to long – term wheel and rail interaction. In this case, cyclic effect of contact stresses can cause a residual deformation. Though it can not completely destroy the wheel tyre, normal operation may be disturbed by vibration and dynamic loads.

The change of the wheel tyre dimensions depends on the wear of the running surface which is determined by a cut size (i) (Fig 1) as well as by the reduction of the flange thickness (a) (known as natural wearing). These transformations also depend on the removal of a metal layer while recovering the thickness and height of the flange by turning the wheel tyre and its running surface (known as technological wear), being, therefore, determined by the general wear intensity.

The formation of a cut (i) in the wheel tyre is caused by plastic deformation of metal under the action of normal forces. The second factor is the separation of the wheel's metal particles at the contact point with the rail due to friction. The value of the normal force depends on the load applied to the wheels, while friction intensity is determined by normal pressure and the values of the coupling coefficient.

2.2. The analysis of wear intensity of the wheel – set flanges

A major factor affecting the flange (a) wear is its sliding relative to the rail during the movement of the locomotive when it is either approaching the profile plane of the rail head or departing from it [1, 2].

Due to the (10 mm) gap between the flange and the rail head the wheel-sets are swaying. Regular wheel tyre flange movement towards and away from the rail is a major cause of their intensive wear.

The wearing of the locomotive wheel-sets is also caused by a number of minor factors, i.e. chemical composition of the wheel tyres, physical properties and uniformity of the metal used, quality of manufacture, strength factors, climatic conditions, loading conditions, operation under maximum load, air temperature, humidity and dust content, the contamination of wheel-tyre surfaces with abrasive materials (e.g.

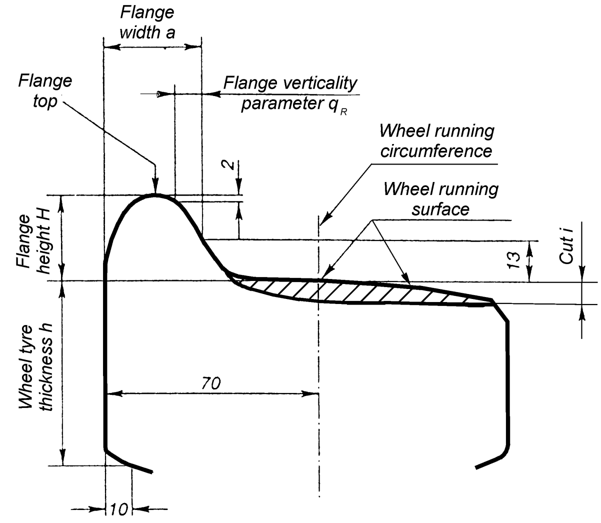

Fig.1. Running surface profile and control parameters of the wheel

putting sand between the wheels and rails), track condition determining the dynamic load intensity, speed of the locomotive, lubrication of the wheel at the contact points with the rail, etc.

It is hardly possible to distinguish a single most important factor among listed above. Special research would be needed for this purpose. However, it is possible to define the overall effect of various factors on the wear of the wheel – sets under service conditions. Such investigations could be rather complicated as well as requiring special equipment and research conditions.

Wheel-sets are not manufactured in Lithuania, being imported from other countries. Therefore, we can not make any technological solutions aimed at increasing wheel tyre strength. But we can determine the changes in major wheel-set dimensions under various service conditions (i.e. road section, loading, speed, flange operational conditions, etc.).

In order to reduce the wearing of the wheel tyre flanges the proper lubrication system should be provided in a locomotive. It supplies oil to the tyre flange when the locomotive is running along the curved track sections, with the most heavy friction between the flange and the rail. Taking into account the direction of the locomotive movement the flanges of the front wheel-sets of every locomotive section are lubricated. Oil quantity as well as the time and duration of lubrication are controlled by a gyroscopic curve sensor fixing the curve radius.

The tests [3,4,5] performed in the laboratories of various countries have shown positive results of using the above technology in practice [3,4,5], but did not yield any relationships concerning the wear intensity of the wheel tyre flanges and the running surfaces during their service life, because all the factors encountered in service conditions can not be reproduced in the laboratory.

3. The experiment

Three groups of factors referring to the locomotive, track and the lubricant used determine the conditions of testing. It was assigned that oiled and not oiled wheel – set tyres would run under the same conditions, i.e. along the same tracks, perform the same work (t km brutto) and both sections of the locomotive would always draw the trains simultaneously.

For experimental purposes two locomotives 2M62 (each of them having 12 wheel-sets in two sections), not provided with wheel tyre lubrication system, and one locomotive 2M62 having a lubrication system were chosen. Technical characteristics of these locomotives are given in Table 1.

Tab. 1. Technical characteristics of the locomotive 2M62

Characteristic	Value
Mass, thous. kg	238
Axle load, kN	198,3
Axles, units	12
Maximum driving force (at the speed of 20 km/h), kN	195
Speed, km/h Average (in testing) Maximum allowable Minimum	 44 100 20
Average mass of rolling stock (in testing), thous. kg	2400

At the beginning of the experiment all the wheel-sets were new, with their tyre dimensions conforming to the rated parameters given in Table 2.

Tab. 2. Main control dimensions of wheel tyre profile

Control dimensions	The largest wheel tyre cut, mm	Flange thickness	Wheel tyre thickness
Initial (rated)	0	33,0	77,0
Limiting	7,0	25,0	36,0*

* this wheel tyre thickness is obtained by turning its running surface when restoring tyre profile in case of excessive wear of the flange (a < 25.0 mm).

The measurements of the wearing wheel tyre profile were made every month when the locomotive returned to the depot for maintenance or repair. The average distance run between the measurements of the locomotives not provided with a wheel tyre lubrication system was 10,8 thous. km, while for those having such systems it reached 10,5 thous. km.

The locomotive wheel-sets were measured in the locomotive depot in Vilnius. It was assigned that oiled and not oiled wheel tyres would operate under the same conditions, i.e. running along the same track sections. Their performed work (tkm brutto) should also be the same, while both sections of each locomotive would always operate simultaneously.

The intensity of wearing of the locomotive wheel tyres, and their flanges in particular, largely depends on the track length. Therefore, the locomotives being investigated ran along the same tracks. Major characteristics of the tracks are given in Table 3.

In Table 3 we can see that curved tracks make about 30 % of the total railroad length. The distribution of the curve lengths according to their average radius is shown in Fig.2.

Tab. 3. Distribution of railway length according to the radius of track curves.

Nr	Length	track		Average curve radius	Wooden sleepers	Number of switches, on the track, km units,	Downgrades, %
		Straight tracks	Curve				
1.	374	64	36	1964	45	168	0,1
2.	160	61	39	2160	20	72	-1
3.	205	78	22	2202	10	95	-0,5
4.	178	52	48	2081	19	80	0,7
5.	186	70	30	4198	34	90	0,1
6.	366	64	36	2018	43	164	-0,1
7.	98	25	75	2248	14	36	-1,5
8.	48	66	34	943	6	22	-0,1

In Fig.2, we can see that the greatest track length (11.1 %) corresponds to the curves with the average radius from 620 m to 1200 m. Curves with the average radii lower than 650 m make 4.8 %, while those with the average radii above 1200 m constitute 9.1 % from all the curves considered.

The data on the lubricant used for oiling the wheel –sets are given in Table 4.

4. Measurement technique

Measurements of the cut in the wheel tyre and the thickness of its flange were made by a specially programmed gauge (Fig.3). A wheel – set tyre is located so that it could rotate. A measuring device can move along the axles of the wheel, therefore, putting it in

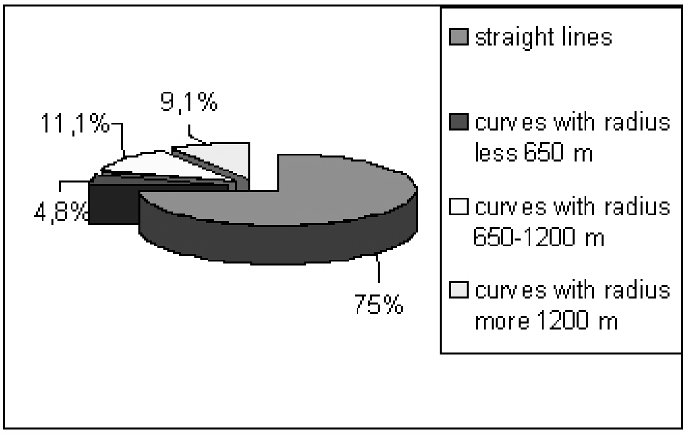

Fig.2. Curve lengths depending on their average radius

Tab. 4. Characteristics of the lubricant for wheel set oiling

Characteristic	Value
Dynamic viscosity	900-100 MPa
Density at 20^0C	1050 kg /m^3
Operating temperature	From -40 to +90^0C
Allowable t^0 of area surface	From -100 to 500^0C
Solvability in water at 25^0C	0,2 kg /m^3
Friction coefficient	0,1
Boiling t	250^0C
Ignition t^0	300^0C
t^0 of thermal decay	3500^0C
Biological disintegration	90 %
Period of keeping quality	two years

the required position allows us to measure both the tyre cut and the flange wear.

All measurements are made according to special programs available in the device. First, the thickness gauge is supported against the internal surface of the wheel (the initial gauge position, see Fig.3). In this way, the gauge length for measurements in the horizontal plane is obtained. When the gauge moves to the outside surface of the wheel, its coordinate on the top of the flange is fixed. This is the gauge length in the vertical plane. When the wheel is revolving, the gauge is supported against it at the point where measurements should be made. The program compares the current coordinates of the gauge with the basic coordinates. Based on this, the values of the parameter to be obtained are calculated.

The thickness of the flange (a) – horizontal distance, 20 mm below the flange top (Fig.2).

The height of the flange (H) – vertical distance between the flange top and the running wheel surface. The difference between measured flange height and that of the new or turned flange determines the size of the cut (i), caused by wearing, with respect to the running wheel circumference. The cut is measured in the plane of the running wheel circumference, being 70 mm away from the inside wheel tyre surface [4].

The values of the largest tyre cuts of every wheel (along its perimeter) and the flange wear are registered in the database.

During the experiment the mileage of a locomotive between the beginning of the experiment and each measurement was also logged.

The measurement error of the cut and flange thickness was ± 0.05 mm.

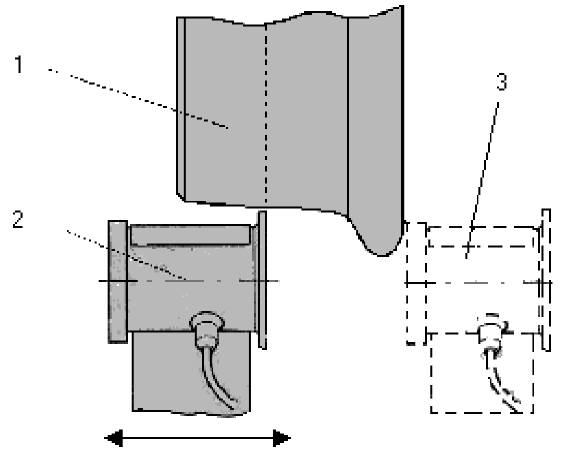

Fig.3. A schematic view of flange thickness measurement: 1 – wheel tyre, 2 – wear gauge; 3 – initial position of the gauge

5. The results obtained

In the experimental period, the highest mileage for the wheel-sets not provided with a lubrication system was 135.5 thous. km, while for those having a lubrication system it reached 141.6 thous. km.

The values obtained for the control parameters, with the fixed mileage values, are random variables. Therefore, the dependence of these parameters on mileage may be determined by means of a regressive analysis. The course line reveals the trend and the character of the change of this sequence of data. With the help of Excel 97 software package the polynomials – mathematical expressions of curves – were calculated. In this way, the data were processed and the following regression equations were obtained:

The extent of the wheel tyre wear with respect to its tolerance zone:

$$i = 4 \cdot 10^{-7} \cdot L \tag{1}$$

Graphical representation of this expression is given in Fig.3.

The extent of the flange wear with respect to the its tolerance zone:

not oiled:

$$A = 2 \cdot 10^{-14} \cdot L^3 - 7 \cdot 10^{-9} \cdot L^2 + 0{,}0012 \cdot L \tag{2}$$

oiled:

$$A = 3 \cdot 10^{-14} \cdot L^3 - 8\ 10^{-9} \cdot L^2 + 0{,}0009 \cdot L \tag{3}$$

here, i – the extent of wheel tyre wear with respect to its tolerance zone; L – mileage, km; A – the extent of flange wear with respect to its tolerance zone.

The curves referring to the flange wear are shown in Fig. 4.

The regression equations obtained show that the cut is monotonously increasing throughout the total service life until the mileage reaches 30 – 40 thous. km, with the worn – out layer reaching 1.5 – 2.5 mm. This proves a well - known fact that more intense flange wear takes place until the wheel tyre profile acquires the shape of the rail head [1]. Then, the intensity of wear decreases, increasing only when the mileage comes up to 150 thous. km.

The relationships obtained allow us to predict that turning of the wheel-sets because of worn-out flanges should be performed when the mileage of 160 thous. km is reached since the beginning of service of the wheel tyres, not provided with a lubrication system. When wheel tyre flanges are lubricated, the limit is 210 thous. km. Thus, it may be stated that the use of lubrication can increase wheel tyre service life by at least 1.3 times.

6. Conclusions

1. The investigation has shown that the flange is wearing out more intensely at the beginning of service till the mileage of 30 – 40 thous. km is reached, with the worn-out layer reaching 1.5 – 2.5 mm. Then, the flange wear intensity does not increase any more. The wheel tyre wear intensity stays the same throughout the whole period.

2. The intensity of the flange wear of the locomotive wheel tyres is about two times heavier than the increase of the cut, therefore the time between wheel-sets overhauls is determined by the extent of flange wear.

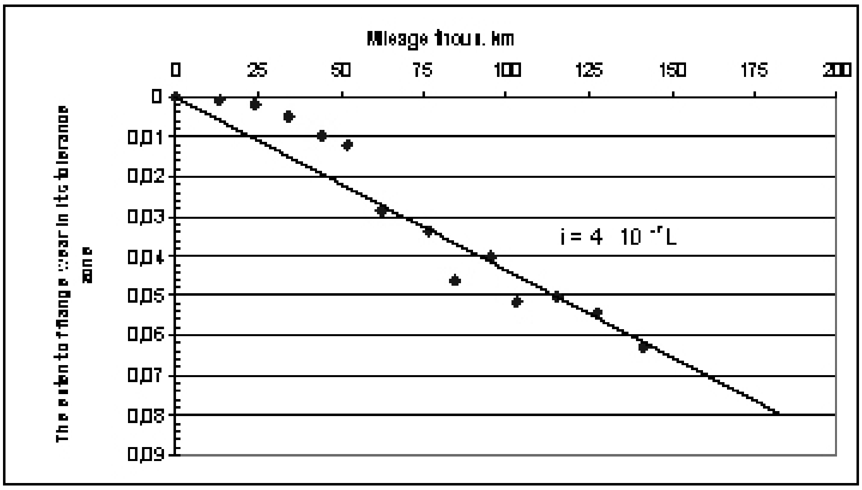

Fig. 4. The dependence of the wheel's cut on mileage

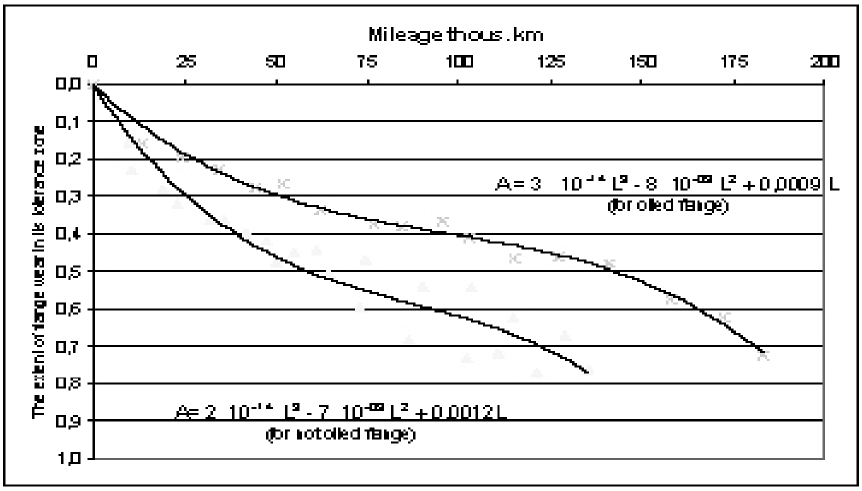

Fig.5. Intensity of wheel flange wear

3. It is possible to predict that the flange will be worn out to the limiting thickness after running 160 ± 3 thous. km without lubrication and after 210 ± 4 thous. km of mileage if it is lubricated.

4. The comparative analysis has shown that the provision of a lubrication system for the wheel – set flanges increases the mileage of the wheel – sets until turning is needed by about 30 %.

5. The data obtained in the research allow for more efficient planning and allocation of financial resources to purchase new wheel – sets as well as for their maintenance and repair.

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