locomotive; axes wear; methods of research;
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METHODS OF RESEARCH OF LOCOMOTIVE AXES WEAR

Summary. Wheels of locomotive axes are subject to wear during operation, when the wheel is contacting the track in the railway curves both with its rolling surface and flange. The quality of both of the mentioned surfaces has a direct impact on railway traffic safety; therefore, their wear is under special control. Statistic methods of research of wear of locomotive axes can be efficiently divided into two types: regression and probability. The article discusses the examples of research completed in Lithuanian railways. Recommendations on which method is the most appropriate method to use in which situation is provided according to results of the research.

СТАТИСТИЧЕСКИЕ МЕТОДЫ ИЗУЧЕНИЯ ИЗНОСА КОЛЕСНЫХ ПАР

Аннотация. При прохождении локомотивом кривых, колеса колесных пар подвержены износу в момент соприкосновения поверхности качения и гребня с рельсами. Качество обеих упомянутых поверхностей оказывает непосредственное влияние на безопасность движения; по этой причине их износ требует особого контроля. Статистические методы изучения износа колесных пар можно разделить на два типа: регрессионные и вероятностные. В статье обсуждаются исследования, проведенные Литовскими железными дорогами. По результатам этих исследований даются рекомендации по выбору подходящего в той или иной ситуации метода.

1. GOAL AND OBJECT OF RESEARCH

Wheels of locomotive axes are subject to wear during operation. When idle, one locomotive axis is exposed to 11 tons of static load, whereas, when in traction mode, the static load can be up to 1.5 times more. Due to this reason, two points of wheel-track contract experience wear more or less. These are rolling surface and flange. The wear is especially intensive, when the wheel is contacting the track in the railway curves both with its rolling surface and flange [7]. When the wheel is spinning, both of these surfaces spin with the same angular velocity, yet, they are at a different distance from the wheel rolling center; therefore, their linear velocity differs leading to an inevitable slip of one of them and, certainly, a more intensive wear. The quality of both of the mentioned surfaces has a direct impact on railway traffic safety; therefore, their wear is under special control. The simplest mean of control is periodic measuring of the wheel profile and restoration of the same by turning, if necessary. Turning the wheel profile constitutes a component part of locomotive maintenance system; therefore, the scope of work can be estimated. To do that, one needs to estimate the wear of wheel profile during locomotive operation.

Statistic methods of research of wear of locomotive axes can be efficiently divided into two types: regression and probability.

In the research with the use of regression method, we periodically document the surface wear of the wheels under investigation. Usually, 3–5 locomotives of the same series operated on the same route are selected, while corresponding wear is measured each 10–20 thousand kilometres of run. Then, after 100–200 thousand kilometres of run (depending on operating conditions and intensiveness of wear), the results of measuring are generalized to make conclusions.

When investigating the wear using the probability method, it is not necessary to periodically monitor the entire process of wear. It is possible to use statistic data for a relatively short period of time (the period of time necessary to measure the required number of wheels can be, for example, 10, 20 or 50 locomotives). If there are locomotives of different run in the fleet (of course, of the same series and operated at the same sections), after measuring their wheel wear it is possible to form dependency of size of wear on the run.

Each of these methods has its advantages and shortfalls. The advantage of the regression method is that the research makes it possible to define critical moments of wheel operation precisely (with accuracy to 10 thousand kilometres of run): the switchover from trouble-free life to normal operation, then, to increased wear. However, a small number of wheels (3–5 locomotives, as mentioned) is examined using this method, although, research work content and period are large. The research with the use of probability method makes all measuring completed fast (it is necessary to measure the required number of wheels only once), therefore, the scope of work is not that large, whereas, the period of research is substantially shorter than that of the research using regression method. Aim of the research – to identify the cases when it is purposeful to consistently monitor certain diameter of locomotives' wheel flange and when it is possible to analyze the data recorded from the locomotives with different mileage.

2. EXAMPLES OF RESEARCH

A research of regression wheel wear was completed in Lithuanian railways with 2M62 series locomotives produced in Russia with the run from the date of production amounting to million kilometres and more. The goal of the research was to investigate and compare the mechanism of locomotive wheel wear when flange lubrication systems are and are not used. Based on the research results, a conclusion was made that it is reasonable to use flange lubrication systems for the locomotives operated in Lithuania [1, 2]. After Siemens ER20CF locomotives were purchased, the need to design maintenance and repair system according to operating conditions has emerged. This way, we have the need to examine the mechanism of their wheel wear and compare them with mechanism of wheel run for corresponding 2M62 series locomotives produced in Russia. The mechanism of Siemens ER20CF locomotive wheel wear was preliminary investigated using both the regression and probability methods [6]. The principal difference between wheel wear of 2M62 and ER20CF locomotives is that in the wheels of 2M62 the abrasion of the flange determines the limit of reserve. However, in ER20CF locomotives it is determined by the abrasion of rolling surface. Therefore, when describing the process of the research, flange wear research results are presented first, when further information discusses the research of rolling surface wear patterns and their results.

3. RESEARCH USING THE REGRESS METHOD

The regression wheel wear research was completed with 2M62 series locomotives produced in Russia. These are two-section locomotives, where each section has six axes. The locomotive runs from the date of production amounts to one million kilometres and more. Wheel flange wear was investigated. Wheel flange wear was measured each 20–25 thousand kilometres of run. Variation of wear with increase of locomotive runs with and without the use of flange lubrication equipment is shown on Fig. 1 and 2, correspondingly.

After investigating the wear of locomotive wheel flange with and without the use of its lubrication system using the regression method (Fig. 1 and 2), it was determined that the use of flange lubrication system causes the service life of locomotive wheel until profile turning to increase up to 25% in this case, sometimes up to 30% [3]. Therefore, a conclusion was made that it is reasonable to use flange lubrication equipment. Moreover, it was established that the wear of the flanges of the first axis wheels is more intensive.

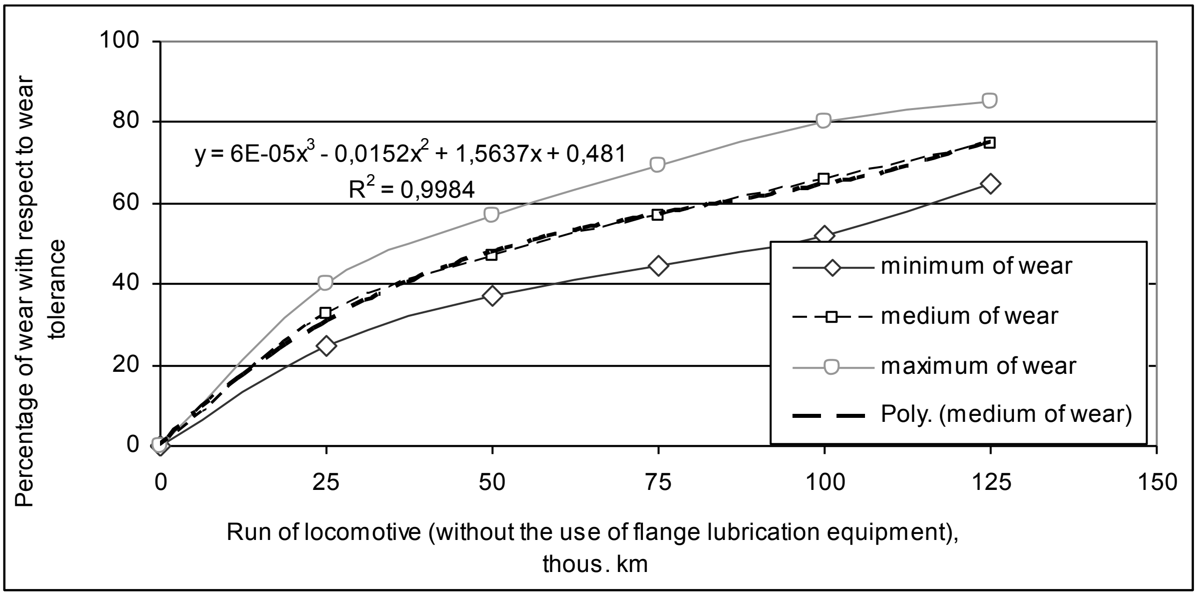

Fig. 1. Variations of flange wear with increase of locomotive run without the use of flange lubrication equipment
Рис. 1. Изменение износа с увеличением пробега без использования оборудования смазки гребня колеса

Without the use of flange lubrication equipment when the locomotive run is 125 thousand kilometres, the average wear of its wheel flange (middle line in fig. 1) accounts for 70-80% of the allowed wear reserve. The biggest wear (the top line) is over 80% and the smallest (the bottom line) – 60% of the allowed wear reserve.

Fig. 2 illustrates that with the use of flange lubrication equipment, when the locomotive run is 125 thousand kilometres, the average wear of its wheel flange accounts for 40-50% of the allowed wear reserve. The biggest wear is over 60%.

The regression method was also used to investigate the Siemens ER20CF locomotive wheel roll surface wear. Defects of the rolling surface were detected in several locomotive wheels after 170 kilometres of run. To determine the reasons, several researches were completed [6]. Among other research, regression researches of rolling surface wear were completed at the run interval from 130 to 170 kilometres The results of regression research of rolling surface wear for Siemens ER20CF locomotive wheel are provided in Fig. 3.

While analyzing Fig. 3, we can see that at the section from 130 to 170 thousand kilometres of run (over 40 thousand km) the average rolling surface wear of a wheel increased from 1.35 to 1.66 mm, amounting to 0.129 mm for every 10 thousand kilometres on the average.

Fig. 3 demonstrates the average rolling surface wear of a wheel. Therefore, no specificities of wheel wear having one or another locomotive run is noticeable here. The wear of rolling surface of each axis wheel differs. Therefore, the regression research of rolling surface wear of a wheel according to axes took place.

Fig. 4 shows that the first and the fourth axis wheel experienced the most of wear, whereas, the second and the fifth axis wheels have worn the least. This is natural as the first axes of three axis bogies (i.e. the first and the fourth locomotive axes) are loaded in the braking mode or in the curves the most.

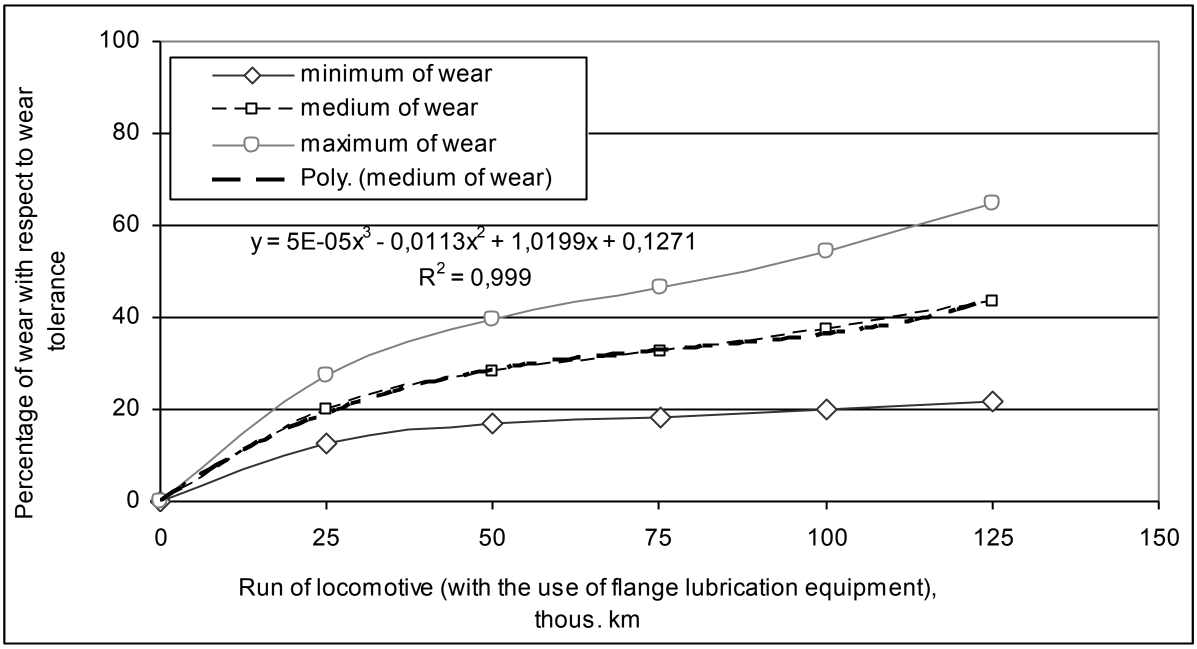

Fig. 2. Variations of flange wear with increase of locomotive run with the use of flange lubrication equipment
Рис. 2. Изменение износа с увеличением пробега с использованием оборудования смазки гребня колеса

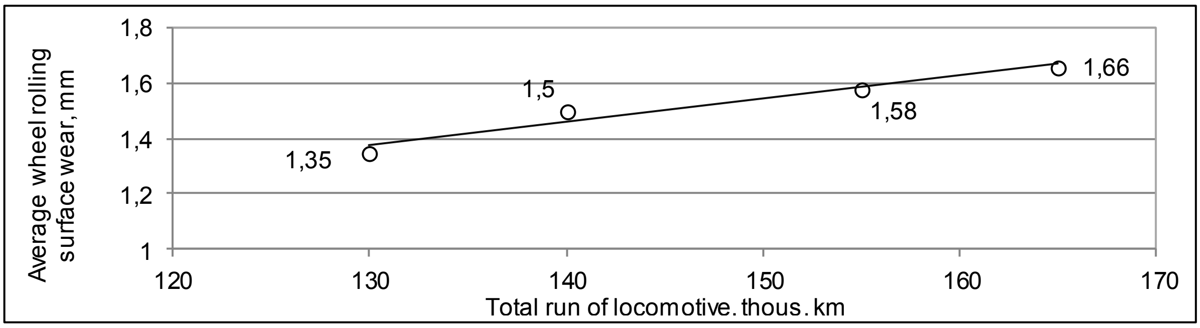

Fig. 3. The results of the regression research of rolling surface wear for Siemens ER20CF locomotive wheel
Рис. 3. Результаты исследования износа поверхности катания колеса локомотива Siemens ER20CF регрессионным методом

To examine a large number of locomotive wheels at once in a short period of time, probability research of rolling surface wear of wheels was performed, as well. The research was performed with M62 series locomotives. These are six axis locomotives with the run from the date of production amounting from 1.5 to 3 million kilometres.

The profile of wheel roll is periodically restored by its turning. Therefore, it is difficult to compare wear in locomotives with different run (as it is periodically turned) that is why the thickness of wheel rim is compared. The dependence of wheel rim on locomotive run indirectly characterises wheel run surface wear intensity.

The results of probability research of rolling surface wear for M62 locomotive wheel rim thickness according to total run from the date of production is provided on Fig. 5.

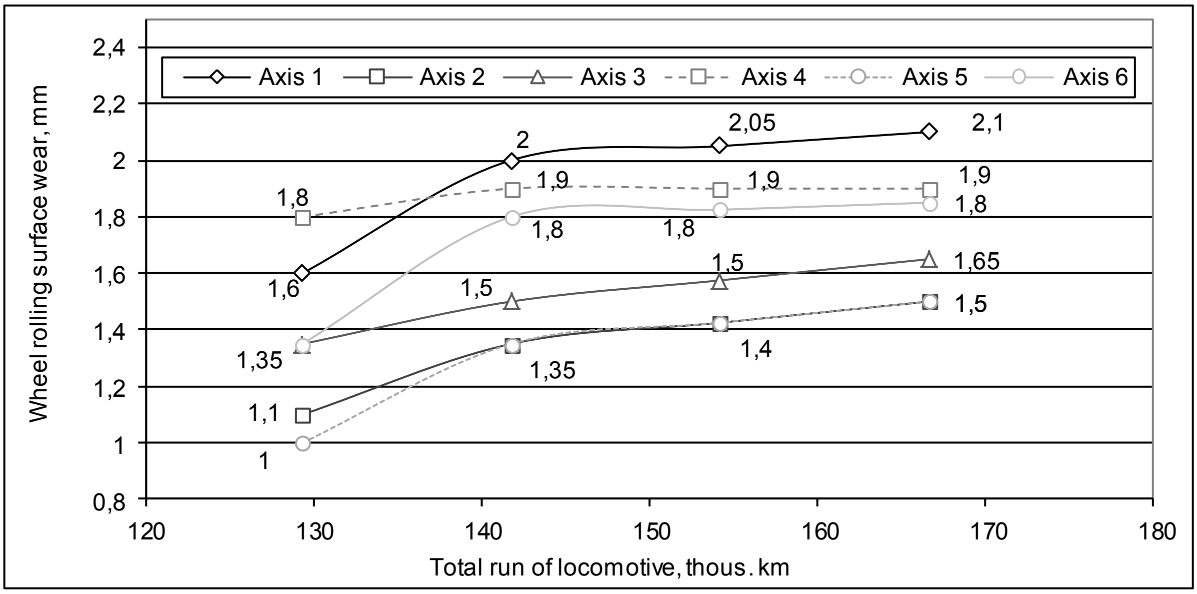

Fig. 4. The results of the regression research of rolling surface wear for Siemens ER20CF locomotive wheel according to axes

Рис. 4. Результаты исследования износа поверхности катания всех колес локомотива Siemens ER20CF регрессионным методом

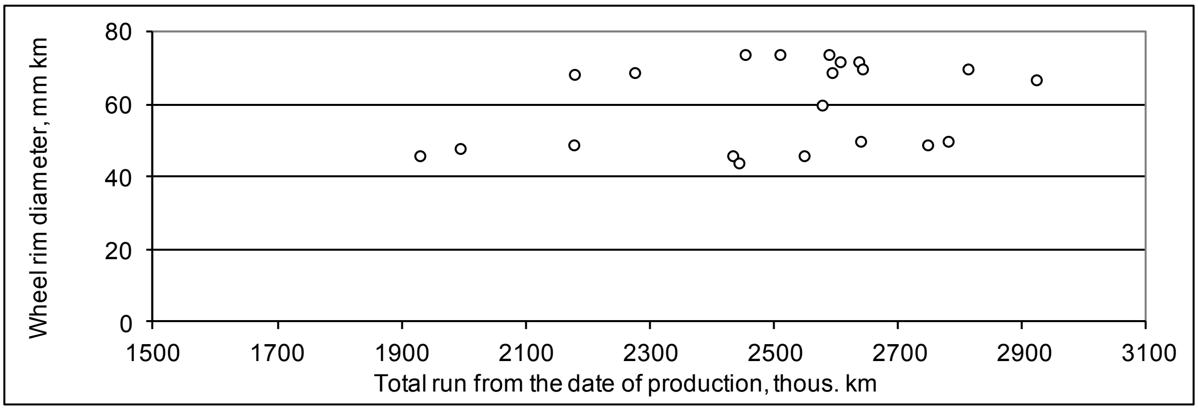

Fig. 5. The results of the probability research of M62 locomotive wheel rim diameter according to total run from the date of production

Рис. 5. Результаты исследования износа поверхности катания колеса локомотива М62 вероятностным методом

As wheels of different locomotives are turned with different periodicity (on demand), pic. 5. does not provide any drill pattern. However, when examining the run after the overhaul work (when a wheel is turned) we can expect to witness such a pattern.

The results of the probability research of rolling surface wear for M62 locomotive wheels diameters according to total run from the overhaul repair are provided on Fig. 6.

Fig. 6. The results of the probability research of rolling surface wear for M62 locomotive wheel thickness according to total run from the overhaul repair

Рис. 6. Результаты исследования износа поверхности катания колеса локомотива M62, учитывая общий пробег после капитального ремонта, вероятностным методом

Fig. 6 illustrates wheel rim thickness dependency on the run after the overhaul of the locomotive pattern, but it is very weak (R^2~0,4). After the run of 1000 km the wheel rim thickness decreased by 0.0435 mm (curve direction coefficient). ER20CF wheels are solid, therefore, it is impossible to examine their wheel rim thickness. In this case the wheel diameter is measured.

The results of the probability research of Siemens ER20CF locomotive wheel diameter according to total run from the date of production are provided on Fig. 7.

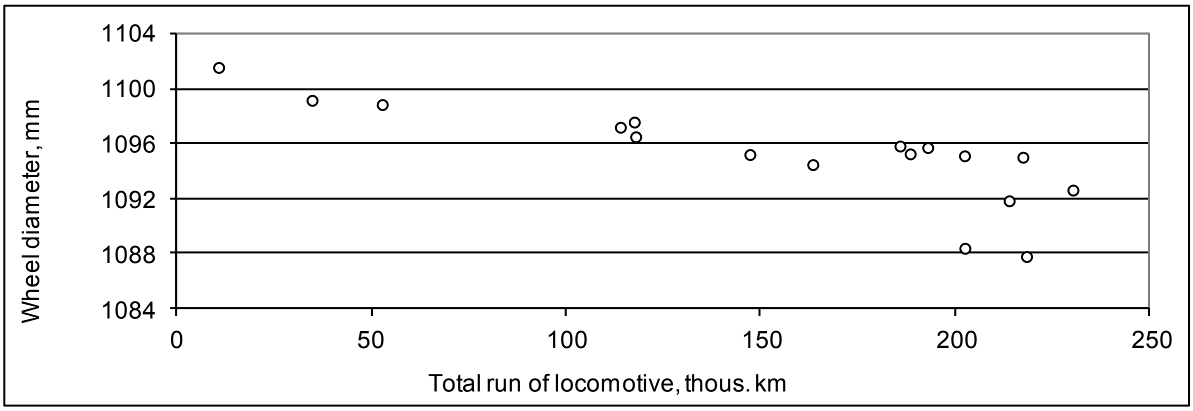

Fig. 7. The results of the probability research of Siemens ER20CF locomotive wheel diameter according to total run from the date of production

Рис. 7. Результаты исследования износа поверхности катания колеса локомотива Siemens ER20CF со дня его производства вероятностным методом

While analyzing the Fig. 7, we can see that the flange width during the first 150 thousand kilometres of run reduced by 4-5 mm on the average. After the second hundred thousand kilometres of operation, the spread of the flange width values is greater than their variation over the same period of run. It is obvious that the research results are more reliable after the first 150 thousand kilometres of run.

Having approximated the line dependency (throughout all interval of the research) it is evident that the wheel diameter reduction intensity is similar to the intensity of wheel rim reduction illustrated in pic. 6. (direction coefficient here – 0,0418, in pic. 6. – 0,0435). In this case correlation is better and equals to R^2~0,65. It is obvious that correlation from obtained dependencies is better in pic. 1. and pic. 2. (R^2~0,99) than in pic. 6. and pic. 7. (R^2~0,4-0,65). Despite different values have been analyzed, the strength of correlation was determined by the different way of research. When examining the change of indicators according to the change of locomotives run, correlation is stronger than comparing them at the same time in the locomotives with different runs.

It is not enough to analyze the average rolling surface wear for locomotive wheel alone. The rolling surface of wheels even of the same axis can experience wear and reduction of diameter when turned with different intensiveness. The difference in wheel diameter for Siemens ER20CF locomotives between the wheels of the same axis, depending on the total run, is provided on Fig. 8.

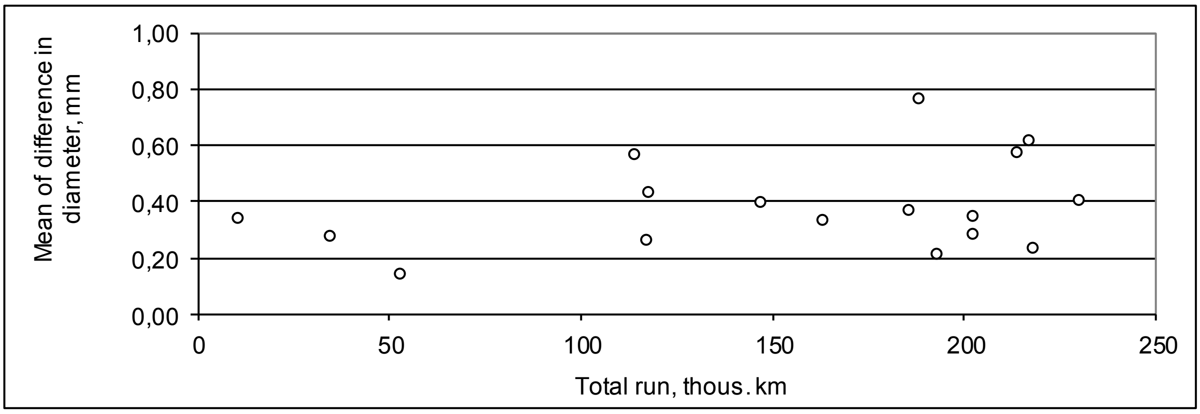

Fig. 8. The difference in wheel diameter between the wheels of the same axis depending on the total run
Рис. 8. Разница износа колес одной и той же колесной пары в зависимости от пробега

Fig. 8 shows that up to 50 thousand kilometres of run, the difference in wheel diameter between the wheels of the same axis amounts from 0.15 to 0.35 millimetre (approx. 0.2 mm on the average). With increase of locomotive run, this difference increases, as well. The variation of difference in wheel diameter between the wheels of the same axis according to total run of locomotive is provided on Fig. 9.

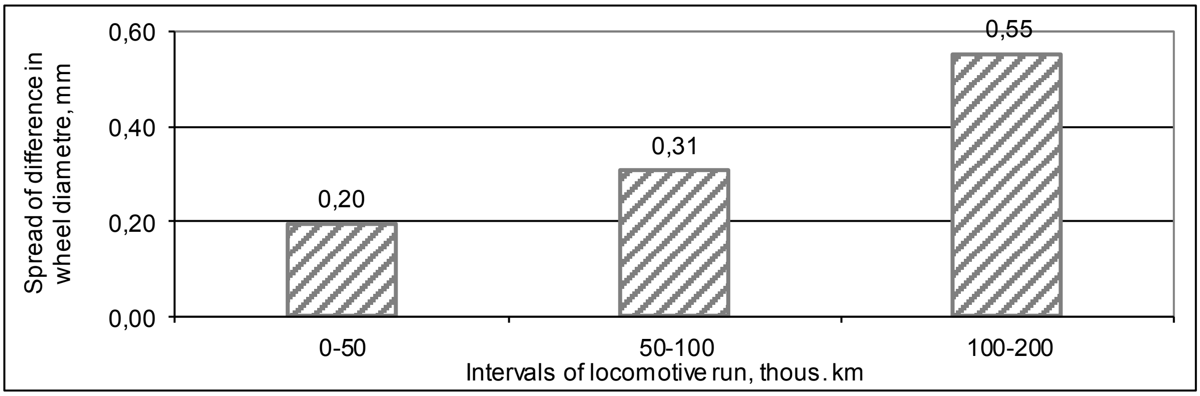

Fig. 9. The variation of difference in wheel diameter between the wheels of the same axis according to total run of locomotive
Рис. 9. Изменение износа колес одной и той же колесной пары в зависимости от пробега

Fig. 9 shows that up to 50 thousand kilometres of run, the difference in wheel diameter between the wheels of the same axis amounts to 0.2 millimetre, from 50 to 100 kilometres of run the difference amounts to 0.55 millimetre. It is obvious that, at the run interval from 50 to 200 thousand kilometres, the difference in wheel diameter between the wheels of the same axis every 50 thousand kilometres of run increased by approx. 0.2 millimetre.

Another specificity of the reduction of locomotive wheel diameter is the wheel diameter between different axes of the same locomotive. Fig. 10 demonstrates the reduction of wheel diameter of different axes of the same locomotive with increase of total run of locomotive.

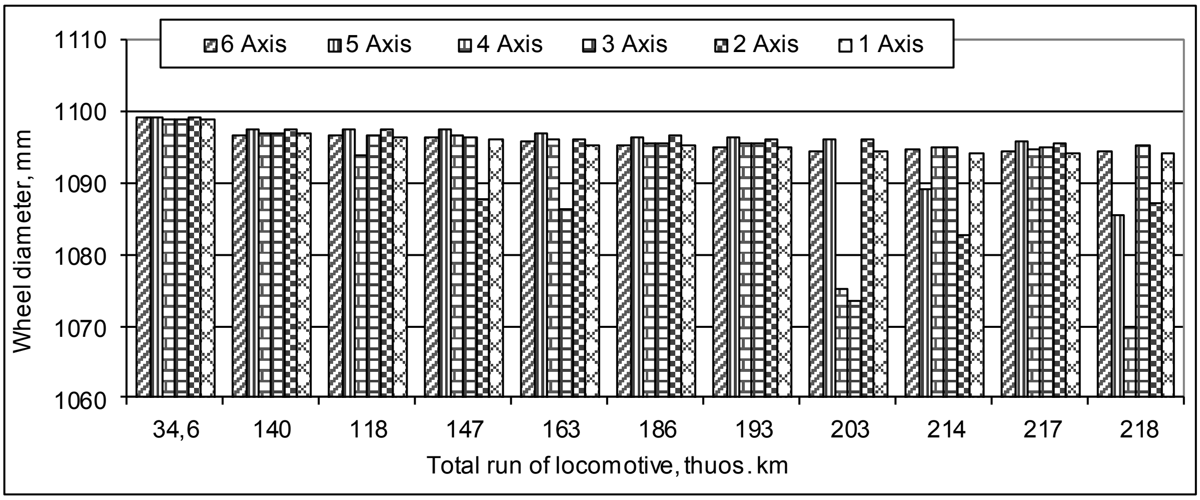

Fig. 10. The difference in wheel diameter between different axes of the same locomotive according to total run of locomotive

Рис. 10. Износа колес колесных пар одного и того же локомотива в зависимости от пробега

Fig. 10 shows that, in locomotives with total run substantially less than 150 thousand kilometres, the wheel diameter in different axes experiences reduction with no specific differences. Around 150 thousand kilometres of run (in this case, starting from 147.2 thousand kilometres) the axes with wheel diameter decreased more than that of others begin to differ, whereas starting from 200 thousand kilometres of run such cases appear with an increasing frequency (in this case, it is characteristic of 3 out of 4 locomotives). The largest deviation was noticed in the locomotive with 202.5 thousand kilometres of run, where signs of reduction of wheel diameter of the third and the fourth axis wheels were most noticeable. In the case mentioned, the wheel diameter is even 20 millimetres less than wheel diameter of other axes of the same locomotive, when, usually, such difference amounts to several millimetres. The shortcoming of this research is that it fails to provide clear evidence whether the difference in wheel rolling diameters originated suddenly or formed gradually.

CONCLUSIONS

1. The advantage of the regression method is that it is consistent, therefore, it is possible to define critical moments of wheel operation precisely: the switchover from trouble-free life to normal operation, then, to increased wear. The advantage of the probability method is that it makes all measuring completed fast (it is necessary to measure the required number of wheels only once), therefore, the scope of work is not that large, whereas, the period of research is substantially shorter than that of the research using the regression method.
2. The shortcoming of the regression method is that a small number of wheels is examined using this method, although, research work content and period are large. The shortcoming of the probability method is that it fails to reveal consistency of each wheel wear.
3. Both of the methods investigated are equally suitable to estimate average wear of wheel profile during locomotive operation, however, better correlation between run and wheel wear is obtained using regression method.

4. To estimate the average scope of wheel repair, it is enough to use the method of probability research as it is sufficiently precise and less time-consuming. To estimate the average scope of repair, it is not necessary to analyze the course of each wheel wear consistently.
5. It is necessary to use the regression method for investigation of efficiency of means for reduction of wheel read as well as difference in intensiveness of wheel wear according to axes or this difference between the wheels of the same axis, because in these cases it is necessary to consistently analyze the course of each wheel wear.

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