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INFLUENCE OF OPERATONAL FACTORS ON REDISTRIBUTION OF WHEEL PAIRS VERTICAL LOADS UPON RAILS

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Summary. The article investigates the problem of load redistribution of wheel pairs upon rails in mode of traction forces realization. Dependences revealing influence of operational factors on engagement weight utilization factor have been obtained on the basis of experiment planning theory. The solution on regulation of additional loading device effort in operation taking into account obtained dependences has been proposed.

Key words: engagement weight utilization factor (EWUF), experiment planning theory, traction qualities, redistribution of vertical loads of wheel pairs upon rails, correlation.

INTRODUCTION

Achievement of high traction qualities at design and operation of modern locomotive is an actual task. Redistribution of wheel pairs static loads upon rails in operation is the main reason of locomotive traction qualities degradation, their accelerated wear, increased influence upon rail road and as a result leads to decrease of rail road transporting and carrying capacity and rail road derangement.

While designing a locomotive, static loads of wheel pairs static loads upon rails are supposed to be equal [Konyaev A.N., Spiryagin I.K., 1971]. In reality, they have certain deviations from calculated values [Gorbunov N.I., Kravchenko K.A., Popov S.V., 2009]. It is connected with different design and operational factors analysis of which is presented in scientific papers of Golubenko A.L. [Golubenko A.L.., 1986], Gorbunov N.I. [Gorbunov N.I., 1987], Konyaev A.N. [Konyaev A.N., 1972] and other authors [Gorobchenko O.M., 2007, Ivanov V.N., Belyaev, A.I., Oganyan E.S., 1979, Tasang E.N., Yakovenko V.V., Saffron E.N., 2000, Gorbunov N.I. Kashur A.L., Popov S.V., Kravchenko K.A., Fesenko A.I., 2008, Kravchenko K.A., 2010, Gorbunov N., Kostyukevich A., Kravchenko K.A., 2010].

The aim of the given scientific paper is estimation of operational factors influence on locomotive traction qualities. It is generally accepted that engagement weight utilization factor may be effectively used as an estimation criterion [Yevstratov

A.S. 1987, Lions N.V., 1979, Biryukov I.V., Savoskin A.N., Burchak G.P., 1992, Minov D.K., 1965]. Results of mathematical simulation and experiment planning theory have been used in providing such estimation.

MAIN MATERIAL AND RESULTS OF INVESTIGATION

Method of experiment planning theory allows to decrease a number of experiments substantially and to obtain mathematical model of process under investigation, to estimate mutual and independent influence of every factor on the process of traction force realization. Method of experiment planning provides for the choice of factors, their levels and intervals of variation, determination of system response, planning matrix compilation, and obtaining of regression equation [Evdokimov Y.A., Kolesnokov V.I., Teterin A.I., 1980, Adler Y.P., Makov E.V., Granovsky Y.V., 1971, Gorbunov N.I., Kravchenko K.A., Popov S.V., Krysanov M.A., Kovtanets M.V., 2009, Kadomskaya K.P., 2002].

As applied to defined problems for carrying out numerical experiment the following factors been varied: change of the first wheel pair diameter caused by wear; change of locomotive mass due to consumption of servicing materials stock and change of wheel pair weight caused by wheel tyres wear; influence of frictional damper in the first stage of the spring suspending; change of the first and the second stages of the spring suspending rigidity in the process of operation (tabl. 1).

Calculations have been done for six-axes main-line diesel locomotive 2TE116 type and four-axes yard diesel locomotive TEM103 type.

The second stage of TEM103 yard diesel locomotive spring suspending has an increased rigidity – 45 kH/mm. The results of static simulation proved that rigidity of such a quantity does not affect engagement weight utilization factor. That is why this factor has not been investigated for a yard diesel locomotive. Influence analysis of frictional dampers placed on the first stage of locomotive spring suspending 2TE116 type, at the expense of spring suspending blocking considerably reduces engagement weight utilization factor. At designing yard locomotive TEM103 rationalization proposal as to placing hydraulic dampers in the first stage of spring suspending has been made. That is why blocking of spring suspending by dampers has not been considered at the stage of numerical experiment planning. Thus a number of factors for the main-line diesel locomotive 2TE116 equaled six factors, and four factors for a yard locomotive.

For the 2TE116 locomotive design a number of pair interrelations equals 15, a number of triple ones – 20; for TEM103 locomotive design – pair – 6, triple – 4.

The solution of the problem i.e. establishment of dependence of maximum engagement weight utilization factor on factors under investigation has been obtained in the form of following equation:

$$y = f(x_1,...,x_k),$$

where: f – response function; x_1, x_2 – factors; $y = \eta$.

Table 1. **Critical values of variables**

Parameter	**Locomotive type**	
	TEM103	**2TE116**
Wheel pair weight, kH		
$x_{1\max}$	20,51	17,7
$\bar{x}_1$	19,01	16,23
$x_{1\min}$.	17,5	14,76
Servicing materials weight, *kH*		
$x_{2\max}$	553,87	863,3
$\bar{x}_2$	529,25	813,03
$x_{2\min}$.	504,62	762,75
Rigidity of the first stage of spring suspending, κHm		
$x_{3\max}$	2,0	2,0
$\bar{x}_3$	1,9	1,9
$x_{3\min}$.	1,8	1,8
Rigidity of the second stage of spring suspending, κHm		
$x_{4\max}$	-	11,0
$\bar{x}_4$	-	10,4
$x_{4\min}$.	-	9,8
Locomotive wheel radius, m		
$x_{5\max}$	0,525	0,525
$\bar{x}_5$	0,5215	0,5215
$x_{5\min}$.	0,518	0,518
Friction damper rubbing power, κH		
$x_{6\max}$	-	8,0
$\bar{x}_6$	-	4,0
$x_{6\min}$.	-	0

Datum point (basic or zero level), around which experimental points symmetric to zero level are determined, is chosen to make s plan of numerical experiment. Results of the experiment based on the chosen set of factors allow to make a model used to determine values in other points of factor space.

The search of a mathematical model starts with the consideration of possible states of the system under investigation.

Regress equations have been obtained in the result of mathematical simulation all calculations being done using the computer program “Planning experiment for rail-road transport” (certificate № 31722 от 21.01.2010) developed by the authors of the article [Gorbunov N.I., Kravchenko K.O., Krisanov M.A., 2010].

Value EWUF in the centre of the plan for 2TE116 equals 0,79875, estimation of regress equation absolute term – 0,79875. Values of EWUF in the centre of the plan for TEM103 – 0,86075 , estimation of an absolute term – 0,86075 .

Regress equation of engagement weight utilization factor 2TE116 locomotive depending on operation factors in a encode form may be presented as:

$$\begin{aligned}\eta &= 0,79875x_0 + 0,005937x_1 + 0,009125x_2 - 0,00281x_3 + 0,002437x_4 - \\ &+ 0,0115x_5 + 0,008187x_6 - 0,0001875x_1x_2 + 0,0001875x_2x_3 + \\ &- 0,0005x_2x_5 + 0,000125x_1x_5x_6.\end{aligned} \tag{1}$$

Final regress equation in natural coordinate system is:

$$\begin{aligned}\eta &= -2,514 + 0,0188m_{wp} + 0,00164m_{sm} - 0,00585GI + 0,0041GII + \\ &+ 5,99R + 0,0533F_{fr} - 0.00000254m_{wp}m_{sm} - 0,0243m_{wp}R + \\ &+ 0,00136m_{wp}F_{fr} + 0,000037m_{sm}GI + \\ &- 0,00285m_{sm}R - 0,0985RF_{fr} + 0,006m_{sm}RF_{fr},\end{aligned} \tag{2}$$

where: m_{wp} – the first wheel pair weight; m_{sm} – servicing materials weight; GI – rigidity of the first stage of spring suspending; GII – rigidity of the second stage of spring suspending; R – locomotive wheel radius, F_{fr} – friction damper rubbing power.

Regress equation of engagement weight utilization factor TEM103 locomotive dependence on operation factors in an encode form may be presented as:

$$\begin{aligned}\eta &= 0,86075x_0 + 0,0055x_1 + 0,004x_2 + 0,00025x_3 - 0,0005x_4 - 0,00025x_1x_2 + \\ &+ 0,00025x_1x_2x_3.\end{aligned} \tag{3}$$

Final equation for TEM103 locomotive is:

$$\begin{aligned}\eta &= -0,582 + 0,075m_{wp} + 0,0027m_{sm} + 0,681GI - 0,143R - 0.000135m_{wp}m_{sm} + \\ &+ 0.0357m_{wp}GI - 0.00128m_{sm}GI + 0.0000675m_{wp}m_{sm}GI.\end{aligned} \tag{4}$$

Obtained regress equations (2) and (4) allow to estimate influence of locomotive variable in operation factors on EWUF.

Total negative effect resulting from functioning of all factors for the main-line diesel locomotive 2TE116 equaled to 8,5 %, for the yard diesel locomotive TEM103 - 2,4 %. Influence degree for each of the factors on final parameter (EWUF) has been determined using pair correlations (τ_{xy}) [Pozhidaev V.F., 2006]. Calculations results are presented in the diagram (fig. 1), the calculations show that the most negative influence on the locomotive TEM103 produces pair action of wheel pair weight change and body weight change resulting from servicing materials, for 2TE116 locomotive – bending diameter change along the rolling circle taking into account wheel pair wear.

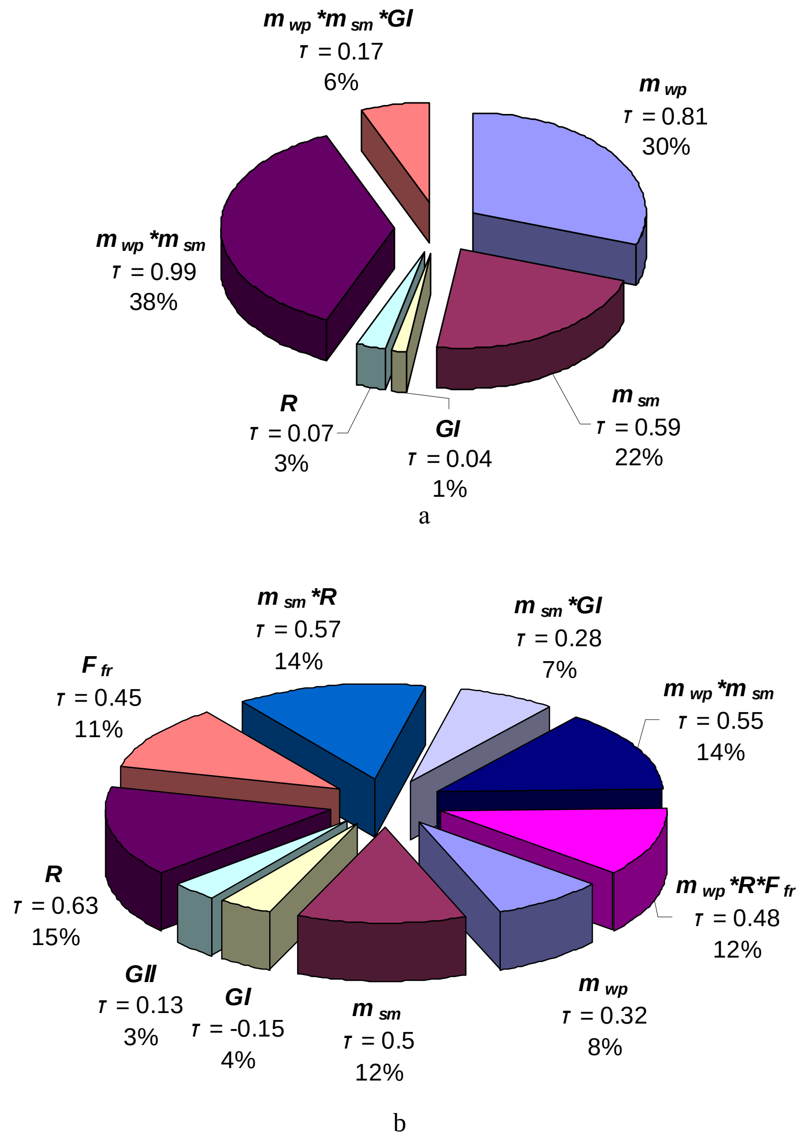

Fig. 1. Influence of operational factors on locomotive traction qualities:
a – TEM103; b – 2TE116

CONCLUSIONS

Redistribution of vertical loads of wheel pairs upon rails produces negative effect on locomotive traction qualities. Supposition that static loads of wheel pairs upon rails are the same is not true. Calculated values have deviations from calculated ones which is connected with different construction and operation factors. Conducted investigations resulted in compiling analytical EWUF dependences on operation factors. It was stated that total effect of operation factors, locomotive EWUF 2TE116 type has been reduced by 8,5%, locomotive TEM103 type – by 2,4%.

Incompatibility of engagement weight utilization factor to normative demands may be compensated by setting additional loading device between body and bogie, their description and operation have been presented in authors' patents [Gorbunov M.I., Kashura O.L., Kravchenko K.O., Popov S.V., Kovtanets M.V. Golembievsky K.V., 2008, Gorbunov N.I., Kravchenko K.O., Popov S.V., Fesenko A.I., Grishchenko S.G., Nesterenko V.I., Lewandowski V.O., 2009, Gorbunov N.I., Kashura A.L., Kravchenko K.A., Popov S.V., Dogadin V.A., Bogopolskii E.M.,Osenin J.J., 2009]. Effectiveness of the given solution is confirmed by engagement weight utilization factor by 6,8%. As vertical loads of wheel pairs upon rails are changed in operation, additional loading device effort should change within the 2% limit for locomotives TEM103 type and within the 6% – limit for locomotives 2TE116 type.

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ВЛИЯНИЕ ЕКСПЛУАТАЦИОННЫХ ФАКТОРОВ НА ПЕРЕРАСПРЕДЕЛЕНИЕ ВЕРТИКАЛЬНЫХ НАГРУЗОК ОТ КОЛЕСНЫХ ПАР НА РЕЛЬСЫ

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Екатерина Кравченко, Максим Ковтанец

Аннотация. В статье рассмотрен вопрос перераспределения нагрузок от колесных пар на рельсы в режиме реализации тяговых усилий. На основе использования теория планирования эксперимента получены зависимости, показывающие влияние эксплуатационных факторов на коэффициент использования сцепного веса. Предложено решение по регулированию усилия догружающего устройства в процессе эксплуатации с учетом полученных зависимостей.

Ключевые слова: коэффициент использования сцепного веса, теория планирования эксперимента, тяговые качества, перераспределение вертикальных нагрузок от колесных пар на рельсы, корреляция.