Viktor KROTOV, Sergej KROTOV*
Rostov State Transport University
sq. Rostovskogo Strelkovogo Polka Narodnogo Opolcheniya, 2, Rostov-on-Don, 344038, Russia
**Corresponding author.* E-mail: svk-19587@yandex.ru

APPLICATION OF THE METHOD OF THE PRINCIPAL COMPONENTS FOR THE ANALYSIS OF BEARING ABILITY OF THE WHEEL PAIR OF THE CAR

Summary. Application of the method of the principal components at the analysis of bearing ability of the wheel pair of the car**.** In this article it is given proof of the method of the principal components to the analysis of calculation of the stress-deformed condition of the wheel pair of the freight car. The statistical result estimation method allows to get mathematical models for researching parameters of the reliability of the wheel pair at changing of loading parameters.

ИСПОЛЬЗОВАНИЕ МЕТОДА ГЛАВНЫХ КОМПОНЕНТОВ ДЛЯ АНАЛИЗА НЕСУЩЕЙ СПОСОБНОСТИ КОЛЕСНЫХ ПАР ВАГОНОВ

Аннотация. Используется метод главных компонентов для анализа несущей способности колесных пар вагонов. В данной статье приводится доказательство метода главных компонентов при анализе напряженно-деформированного состояния колесной пары грузового вагона. Статистический метод оценки результатов позволяет получать математические модели с тем, чтобы исследовать параметры надежности колесной пары при изменении параметров нагрузки.

The wheel pair of the car is a responsible element of the rolling stock and of its high carrying capacity depends the reliability and the safety of the system of the wheel-rail and the carriage. For the reason of a large set of parameters (characteristics), it becomes possible to characterize the reliability of such responsible junction. Such opportunity gives introduction of numerical methods [1, 2].

Under the examination of the bearing ability of the wheel pair and its stressed and deformed conditions (SDC) of its elements, durability and reliability of their connection by means of rated complexes on the basis of the finite elements method (FEM) [3, 4], the number of indications quantity influencing in a varying degree to a bearing ability of the wheel pair, can surpass fifty.

Thus, the researching of multivariate casual attributes on the basis of the correlation matrix considering narrowness of linear stochastic communication [5] becomes a difficult problem and the question of a necessity for compression of the information is arising: the description of the factors influencing at bearing ability of the wheel pair by small number of parameters. These parameters can serve as the principal components reflecting existing laws, which cannot be measured or calculated [5].

In particular, for measuring the size of zones of coupling and sliding in wheel-axle assembly but namely they finally define the degree of its reliability, it is impossible to set physical experiment without breaking the integrity of the connection. The component analysis allows to mark out the system of indications having the essential influence on the investigated phenomenon.

For the method of the principal components in case of researching SDC of wheel pair for an estimation of its reliability it becomes possible to mark out the following directions [6]:

discovering the latent laws defined by external influence - for example, axial loading, points of the appendix of loadings, etc., and also internal - for example, size of tangents of forces or equivalent stresses;

the description of the investigated phenomenon by means of the principal components, which quantity will be much less of the quantities of the preliminary attributes;

the research, and on its basis it becomes possible, the output of the scientifically-proved decisions allowing to use effectively the wheel pair from the point of view of its reliability;

under the construction of regression model by results of the component analysis it is possible to forecast the changes of bearing ability of the wheel pair during its operation.

The method of the principal components consists in a finding the sequence of the orthogonal axes of coordinates along which each time in the decreasing order is defined a maximum of the full dispersion, and calculations can be stopped in any place, having defined, for example, only three main components but which will reproduce 60-80 % of a full dispersion. In the component analysis it is possible to use either covariance or a correlation matrix, which diagonal elements matter, equal to unit [6]. The individual dispersion of all variables in the component analysis is considered in whole as the general dispersion. It leads to the definite decision; however, it is almost unreal in all practical situations [6]. In particular, at the analysis of calculation of SDC of the wheel pair, in spite of the general dispersion of the allocated components reaches 100 %, but it is possible to refuse of some components under their substantial interpretation.

Let's show substantive provisions of the multiple components analysis on the basis of [7].

Let is available p casual variables $X_1, ..., X_P$ with multivariate distribution, a vector of averages $\mu^{p\times 1} = (\mu_1, ..., \mu_p)'$ and covariance a matrix $\Sigma^{p\times p} = (\sigma_{ij})$. It is required to define interrelation between variables $X_1, ..., X_P$. This interrelation can be measured by covariance or dispersions and correlations between variables $X_1, ..., X_P$. It is possible to find linear combinations $Y_1, ..., Y_P$ of variables $X_1, ..., X_P$ $(q < p)$ and it becomes possible to get structure of dependence $X_1, ..., X_P$. The essence of a method consists in the following: such linear combinations of variables are to be searched

$$Y_1 = \sum_{j=1}^{p} \alpha_{1j} X_j, ..., X_P = \sum_{J=1}^{p} \alpha_{pj} X_j ,$$

that

$$cov(Y_i Y_j) = 0 \; i, j = 1, ..., p, i \neq j ,$$

that is

$$V(Y_1) \geq V(Y_2) \geq ... \geq V(Y_p),$$

$$\sum_{i=1}^{p} V(Y_i) = \sum_{i=1}^{p} \sigma_{ij} .$$

Variables $Y_1, ..., Y_P$ are not correlated and ordered on the increment of the dispersion. The general dispersion $V = \sum_{i=1}^{p} \sigma_{ii}$ remains constant after the transformation. Then the subset of the first q variables Y_i will explain the most part of the dispersion and in result we'll get the compressed description of the structure of dependence of the initial variables, and the detection of the parameters which are not a subject measurement at numerical experiment on a method of final elements becomes also possible. The method of the principal components as a matter of fact also consists in definition of factors α_{ij} $i, j = 1, ..., p.$ If to assume, that the joint distribution of initial variables is normal, in that case the linear combinations of normally distributed sizes will have normal distribution, too and are completely defined by parameters μ and Σ. Then it is possible to put $\mu = (0, ..., 0)'$ and the structure of dependence set by a matrix Σ will describe completely distribution of variables $X_1, ..., X_p$.

Let the matrix Σ is known and we have $Y_1 = \alpha_{11}X_1 + ... + \alpha_{1p}X_p$. It is required to find $\alpha_{11}, ..., \alpha_{1p}$, that the size

$$V(Y_1) = \sum_{i=1}^{p}\sum_{j=1}^{p}\alpha_{1i}\alpha_{1j}\sigma_{ij}$$

was maximal at $\Sigma_{j=1}^{p}\alpha_{ij}^2 = 1$, that provides the uniqueness of the decision. Solution received further $\alpha_1 = (\alpha_{11}, ..., \alpha_{1p})'$ is to be called as own vector and it corresponds to maximal eigenvalue of the matrix Σ. This own value is equal to a dispersion $V(Y_1)$. Then a linear combination $Y_1 = \alpha_{11}X_1 + ... + \alpha_{1p}X_p$ refers to as the first main component of the variables $X_1, ..., X_p$. It explains $100V(Y_1)/V$ percent of the general disperse. The following q components are found thereby.

In the analysis of the principal components, it is found such turn of the coordinate system that the variable Y_1 corresponding to one of new coordinate axes, has the maximal dispersion and the variable Y_2 corresponding to another axis, has not been correlated with Y_1 and thus would have the maximal dispersion. The other positions of coordinate axis are similarly found.

For research was used the matrix of initial size 38×96 where enter six independent, varying at different levels of original variables (it is executed at full factorial numerical experiment - 96 calculations [8]). Consequently, the calculation of the wheel pair on FEM parameters of the stress and deformed condition of the object in various points of a roll surface, coupling the wheel and the rim, coupling the disk and the nave, and also the parameters of the stress and deformed condition of the wheel-axle assembly are received.

All parameters of loading, except the temperature field, varied on two levels. A temperature field on three: at absence of braking, at service long braking and at emergency braking. Levels of braking modes correspond: 0 - to absence of braking; 1- to emergency braking of the car up to a full stop; time of braking takes 48 seconds, and in this case the thermal stream brought to a surface of a wheel was accepted equal 151,5 kW; 2 - to long braking at movement with constant speed of 60 km/h and time of action 1200 seconds, that corresponds to a thermal stream of 39,44 kW [9].

In the following table the levels of a variation of load parameters of the wheel pair of the freight car are presented.

Tab. 1

Levels of adjustable parameters

<table>
<tr><td>Vertical loading on an axis (VERT)</td><td colspan="2">216 кN</td><td colspan="2">245 кN</td></tr>
<tr><td>Horizontal loading on a wheel (POPER)</td><td colspan="2">60 кN</td><td colspan="2">120 кN</td></tr>
<tr><td>The twisting moment (MOKR)</td><td colspan="2">0</td><td colspan="2">1710 кN·sm</td></tr>
<tr><td>Mode of braking (TORM)</td><td>0</td><td colspan="2">1</td><td>2</td></tr>
<tr><td>Eccentricity of a touched point to a rail (EXCENT)</td><td colspan="2">2,8 sm</td><td colspan="2">7,5 sm</td></tr>
<tr><td>Thickness of a wheel rim (TOLOBOD)</td><td colspan="2">7 sm</td><td colspan="2">2,2 sm</td></tr>
</table>

The parameters presented in tab. 2 as a result of multiple component analysis are standardized, as productive ($V_7 - V_{38}$) and initial ($V_1 - V_6$) attributes have various dimensions. In this case are included both the maximal and minimal values of researched parameters as the minimal values of the same pressure are bearing the additional information, concerning the bearing ability of wheel pair. For the multiple component analysis the package of the statistical analysis, for example «Statistica 6.0» can be used.

In wheel-axle assembly: SUMFORSE-size of total force in contact; MAXPRESS-maximal contact pressure; MINPRESS-minimal contact pressure; MAXROUND-maximal district contact pressure; MAXAXIS-maximal axial component in contact; NORMCONT-normal component in contact; TANGCONT-tangential component in contact. The designation «ZSKOL» represents the size of the area of sliding and coupling zones in wheel-axle assembly of the wheel pair.

Here conditionally marked symbols "*S*" and "*T*", accordingly normal stresses σ and tangents stresses τ of stress tensor, the second and third letters - direction of stress. Stresses or pressure with an abbreviation «max» and «min» concern to a wheel (in various points) and without them - to connection of a wheel and an axle: EQUMAX - the maximal equivalent stress in a wheel (σ_{equ}), EQU_STR - an equivalent stress in a zone of junction of a wheel and an axis, SX_MAX - the maximal value of a normal pressure in a wheel (σ_x), TXZ - the maximal value of a tangent stress in a wheel-axle assembly (τ_{xz}). Last three variables - movements in wheel-axle assembly, *Y* - on a vertical, *X* - on a horizontal, *Z* - along axes of the wheel pair.

Further presented tab. 3 follows, that for the further analysis it is enough to leave 8-10 components, explaining 90 % of a dispersion, the others possess considerably smaller values of own numbers.

In the first column there are own values of components, in the second - percent of the general dispersion explained by component, in the third - the sum of own numbers, as it was predicted, equal to quantity of the variables participated in the analysis - 38; in the fourth column - summation of percent % of the dispersion explained by taken components, is obvious, that 38 components are settled with 100 % of a dispersion.

In this case 10 components are explained with 89,6% of a dispersion, from them 8 components have own numbers more than 1.

Further the schedule (Fig.1), showing the distribution of own numbers for ten components is presented.

From the given distribution follows that first four components explain more than 70 % of the general dispersion and at fast evaluation it is possible to stop on interpretation of these components as one of the primary goals of the multiple component analysis is the reduction of quantity parameters for the description of the investigated object: in particular - bearing ability of the wheel pair.

It is necessary to note, that after interpretation allocated components and (or) calculation of their values, this productive material can be used and in monitoring systems of real time for the information on bearing ability of the wheel pair, for example, every possible combinations of loading factors can be compared with regression model of sizes of the area of the sliding and coupling zones in force-fit connection.

Let us express one of the major parameters of bearing ability of the wheel pair through the allocated components, for example, size of the area of sliding zone, using data from the tab. 1:

$$ZSKOL = -0{,}474 f_1 - 0{,}633 f_2 + 0{,}009 f_3 + 0{,}077 f_4 + 0{,}27 f_5 + 0{,}049 f_6 - \\ - 0{,}013 f_7 + 0{,}095 f_8 + 0{,}138 f_9 - 0{,}203 f_{10}.$$

In much the same way, we shall express, for example, the general component through attributes (variables):

$$F_1 = -0{,}028V_1 - 0{,}265V_2 - 0{,}059V_3 - 0{,}074V_4 + 0{,}077V_5 + 0{,}356V_6 + \\ + 0{,}896V_7 - 0{,}666V_8 + 0{,}837V_9 - 0{,}617V_{10} - 0{,}439V_{11} - 0{,}474V_{12} - \\ - 0{,}309V_{13} - 0{,}032V_{14} - 0{,}876V_{15} + 0{,}608V_{16} - 0{,}921V_{17} + 0{,}577V_{18} - \\ - 0{,}921V_{19} + 0{,}577V_{20} - 0{,}913V_{21} - 0{,}21V_{22} - 0{,}804V_{23} + 0{,}811V_{24} - \\ - 0{,}912V_{25} + 0{,}785V_{26} - 0{,}747V_{27} + 0{,}744V_{28} - 0{,}788V_{29} + 0{,}67V_{30} -$$

$$-0{,}575V_{31}+0{,}194V_{32}-0{,}095V_{33}+0{,}309V_{34}+$$
$$+0{,}384V_{35}+0{,}824V_{36}+0{,}227V_{37}-0{,}833V_{38}.$$

Thus, each of allocated components represents a linear combination of variables participating in the multiple component analysis.

Tab. 2

The values of factors received on a correlation matrix

Variable	Factor coordinates of the variables, based on correlations (planFac H							
	Fact 1	Fact 2	Fact 3	Fact 4	Fact 5	Fact 6	Fact 7	Fact 8
VERT	-0.028	-0.047	-0.059	0.030	-0.046	0.066	0.082	0.938
POPER	-0.265	-0.673	-0.144	0.122	-0.382	-0.322	0.185	-0.085
MOKR	-0.059	-0.011	-0.602	-0.761	-0.038	0.039	0.002	-0.057
TORM	-0.074	0.127	0.645	-0.522	-0.289	-0.393	-0.024	0.097
EXCENT	0.077	0.497	-0.297	0.256	-0.362	-0.495	-0.012	-0.075
TOLOBOD	0.356	0.011	0.069	-0.092	-0.205	0.255	0.662	-0.080
SUMFORSE	0.896	-0.291	0.043	-0.137	-0.197	-0.143	-0.059	0.038
MAXPRESS	-0.666	-0.706	0.101	0.052	-0.068	0.004	0.097	-0.022
MINPRESS	0.837	0.108	0.266	-0.049	-0.099	-0.012	0.047	-0.026
MAXROUND	-0.617	0.063	-0.326	0.057	-0.015	0.158	0.263	-0.017
MAXAXIS	-0.439	-0.818	0.145	-0.020	0.067	-0.098	0.055	-0.006
ZSKOL	-0.474	-0.633	0.009	0.077	0.270	0.049	-0.013	0.095
NORMCONT	-0.309	-0.339	-0.515	-0.693	-0.044	0.020	0.009	-0.057
TANGCONT	-0.032	-0.182	-0.418	-0.171	-0.263	-0.117	0.158	0.251
EQUMAX	-0.876	0.229	0.285	-0.156	-0.002	-0.220	-0.072	0.054
EQUMIN	-0.513	-0.336	0.355	-0.195	-0.281	0.040	0.057	-0.023
SX_MAX	-0.876	0.304	0.174	-0.129	0.041	-0.080	0.058	-0.027
SX_MIN	0.608	0.127	0.534	-0.457	-0.195	0.064	0.168	0.004
SY_MAX	-0.921	0.287	0.191	-0.100	0.056	-0.050	0.039	0.002
SY_MIN	0.577	-0.028	0.384	-0.219	-0.183	-0.040	-0.005	-0.066
SZ_MAX	-0.913	0.278	0.217	-0.121	0.036	-0.065	0.034	0.004
SZ_MIN	-0.210	0.352	0.646	-0.361	0.083	0.344	0.182	-0.058
TXY_MAX	-0.804	0.285	0.332	-0.242	-0.009	-0.209	-0.065	0.055
TXY_MIN	0.811	-0.282	-0.295	0.287	0.042	0.199	0.045	-0.057
TXZ_MAX	-0.912	0.159	-0.147	-0.042	-0.025	0.188	-0.007	-0.025
TXZ_MIN	0.785	-0.089	0.151	0.338	-0.075	-0.086	-0.029	0.048
TYZ_MAX	-0.747	0.128	-0.007	-0.059	0.077	0.250	-0.072	0.147
TYZ_MIN	0.744	-0.081	0.354	-0.228	-0.044	0.327	0.146	0.031
EQU__STR	-0.788	-0.208	0.008	0.312	-0.353	0.142	0.133	-0.045
SX	0.670	0.635	-0.102	-0.186	0.178	0.029	-0.017	0.014
SY	-0.575	0.261	-0.099	0.440	-0.531	0.144	0.070	-0.041
SZ	0.194	0.623	-0.446	-0.005	-0.425	0.067	0.022	0.034
TXY	-0.095	0.225	0.152	0.580	0.316	-0.294	0.517	0.018
TXZ	0.309	0.123	-0.296	-0.292	0.544	-0.404	0.423	-0.000
TYZ	0.384	0.751	-0.273	0.044	-0.095	0.042	0.021	0.068
X	0.824	-0.280	0.215	-0.038	0.091	-0.038	-0.104	0.056
Y	0.227	0.087	0.516	0.757	-0.016	-0.000	-0.056	0.045
Z	-0.833	0.291	-0.029	0.255	0.213	0.126	-0.039	-0.046

Tab. 3

All eigenvalues of a correlation matrix

Value number	Eigenvalues of correlation matrix, and related statist Active variables only			
	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	14.2594	37.5247	14.2594	37.525
2	5.0118	13.1889	19.2712	50.714
3	3.8010	10.0026	23.0721	60.716
4	3.6752	9.6716	26.7473	70.388
5	1.8634	4.9036	28.6107	75.291
6	1.4428	3.7969	30.0535	79.088
7	1.1872	3.1242	31.2407	82.212
8	1.0517	2.7677	32.2925	84.980
9	0.9332	2.4557	33.2256	87.436
10	0.8261	2.1740	34.0517	89.610
11	0.6470	1.7026	34.6987	91.312
12	0.5190	1.3659	35.2178	92.678
13	0.4397	1.1570	35.6574	93.835
14	0.3733	0.9824	36.0307	94.818
15	0.3188	0.8388	36.3495	95.657
16	0.2988	0.7864	36.6483	96.443
17	0.2608	0.6863	36.9091	97.129
18	0.2181	0.5739	37.1272	97.703
19	0.1787	0.4703	37.3059	98.174
20	0.1523	0.4007	37.4582	98.574
21	0.1198	0.3152	37.5780	98.889
22	0.0967	0.2546	37.6747	99.144
23	0.0763	0.2007	37.7510	99.345
24	0.0559	0.1471	37.8069	99.492
25	0.0526	0.1385	37.8595	99.630
26	0.0316	0.0832	37.8911	99.714
27	0.0284	0.0748	37.9196	99.788
28	0.0215	0.0566	37.9411	99.845
29	0.0149	0.0393	37.9560	99.884
30	0.0125	0.0328	37.9685	99.917
31	0.0106	0.0278	37.9791	99.945
32	0.0062	0.0163	37.9853	99.961
33	0.0049	0.0130	37.9902	99.974
34	0.0044	0.0115	37.9946	99.986
35	0.0037	0.0096	37.9982	99.995
36	0.0012	0.0032	37.9994	99.999
37	0.0004	0.0011	37.9999	100.000
38	0.0001	0.0003	38.0000	100.000

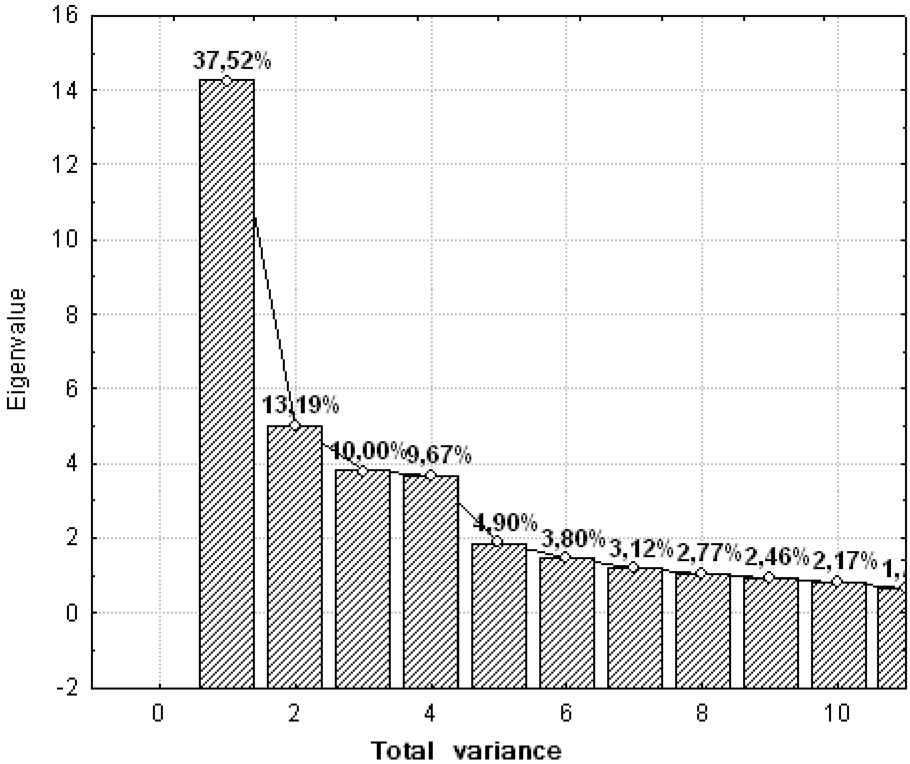

Fig. 1. Total variance of eigenvalues for first ten components
Рис. 1. Дисперсия собственных значений для первых десяти компонент

On the basis of resulted data, first of all it is a matrix of own numbers (tab. 1), it is necessary to take eight principal components having own numbers more than 1.

Let's assume that the first principal component is interpreted by us as «the stressed condition of the wheel pair».

From tab. 1, received "new" main component, in general, is not new from the point of view of characteristics of condition of bearing ability of the wheel pair. According to numbers of variable SDC of the wheel it is connected with variables (the highest loadings of factors) $V_{15} = -0{,}876$, $V_{17} = -0{,}876$, $V_{19} = -0{,}921$, $V_{21} = -0{,}913$, $V_{23} = -0{,}804$, $V_{25} = -0{,}912$, $V_{27} = -0{,}747$. Here high loadings have on components the maximal values of component stressed tensor: σ_x, σ_y, σ_z, and also τ_{xy}, τ_{xz}, τ_{yz}, σ_{equ} . Here it becomes possible to note also high factorial loadings of the «minimal» values of the tangential stress that is quite explainable by reciprocity law for shearing stresses.

The similar picture is observed with components of strain tensor in a zone of the wheel-axle assembly; high loadings have variables: there are components of a strain tensor σ_{equ} - $V_{29} = -0{,}788$, σ_x -$V_{30} = 0{,}670$, σ_y - $V_{31} = -0{,}575$, and also parameters of the deformed condition in one of the points of the wheel-axle assembly: moving along the horizontal axis X - $V_{36} = 0{,}824$, moving along the axis of the wheel pair Z - $V_{38} = -0{,}833$.

Therefore the first principal component is interpreted as «the characteristic of the stress-deformed condition of the wheel pair» as a whole. Its weight makes 37,5%. It is possible to suppose that the bearing ability of the wheel pair depends on 37,5% on the stress-deformed condition of the wheel pair. As this component has high loadings on a significant amount of variables, it is considered general.

The second component can be interpreted, as « the characteristic of bearing ability of the pressed fit connection ». This component is closely connected with the stressed state of the wheel and axle assembly: the maximal contact pressure in connection $V_8 = -0{,}706$, maximal tangent effort (along an axis) $V_{11} = -0{,}818$, horizontal reaction of the rail $V_2 = -0{,}673$, size of the area of sliding zones $V_{11} = -0{,}633$, normal stresses σ_x - $V_{30} = 0{,}63$, σ_z - $V_{32} = 0{,}62$, a tangent component τ_{yz} - $V_{35} = 0{,}75$.

Factors 30, 32, 35, describing stress-deformed state of the wheel-axle assembly, influence aside, opposite to attributes 8 and 11, and also to attributes 2 and 12. It means that the growth of ones can lead to increase in bearing ability, and growth of others, having opposite signs - to its reduction.

The weight of this component makes 13,2 %, that is it is possible to approve, that the bearing ability of the wheel pair depends on 13,2 % on reliability of wheel-axle assembly.

The weight of the third component makes 10 %. Given the component is connected with loading factors « the twisting moment » $V_3 = 0{,}622$ and « temperature influence » $V_4 = -0{,}645$ owing to various modes of braking. It is natural that this component also has turned closely connected with components of strain tensor in a disk (rim) of the wheel: σ_x - $V_{18} = 0{,}53$, σ_y - $V_{20} \approx 0{,}4$, σ_z - $V_{22} = 0{,}646$. These are the minimal values of stresses. It is clear that the temperature influence owing to braking creates additional intensity in a disk and a rim of the wheel.

The same is about parameters of bearing ability of pressed fit connection. Given component is connected with a component of stress σ_z - $V_{32} = -0{,}446$, a component of moving along an axis Y - $V_{37} = 0{,}516$ and with pressure: normal $V_{13} = -0{,}515$, tangential $V_{14} = -0{,}42$.

Here it is obvious, for example, that at heating the disk at long service braking can decrease pressure in wheel-axle assembly; it says also about the moving of an investigated point on border of connection on an axis Y in a positive direction.

Based on the previously mentioned it is possible to characterize third component as « influence of factors of braking » on bearing ability of the wheel pair.

The fourth component on its character reminds third one. Its weight makes 9,7% and it is connected with following attributes: « the twisting moment » $V_3 = -0{,}76$, « temperature influence » $V_4 = -0{,}52$ and settlement values of variables for a wheel: normal pressure $V_{13} = -0{,}69$, components of a normal pressure σ_x - $V_{18} = -0{,}46$ and σ_z - $V_{22} \approx -0{,}4$. It is quite possible the integration of this components with the third one.

We interpreted other components similarly.

As a result of the lead multiple component analysis, considering a problem of compression of the information, the allocated components can be interpreted as follows:

1: the stress-deformed state of the wheel pair;
2: the bearing ability of the wheel-axle assembly;
3: a condition of the wheel pair at braking;
4: influence of horizontal loading on wheel pair;
5: deterioration of a wheel of the wheel pair;
6: influences of vertical loading on an axis of the wheel pair.

It is necessary to note that the received components can be the criterion validity for the combination of the parameters describing bearing ability of wheel pair chosen by us. We pay attention that the component «bearing ability of the wheel-axle assembly» is on the second place; therefore it is necessary to pay more attention of reliability of connection of a wheel and an axis in growth conditions of speeds of movement and loadings. In the countries using cars with high axial loadings they pay much more attention to wheel-axle assembly and press fit connection up to placing a tracker for integrity of connection on a wheel pair.

At account of more possible quantity of loading parameters and movements of a wheel pair, a chemical and physical condition of a wheel, a rail, etc., and considering the development of calculative sets it becomes possible to reveal other parameters of bearing ability of the wheel pair according to given methodology.

References

1. Yessaulov V., Taran Y., Sladkovsky A., Kozlovsky A., Shmurygin N.: *Design of Wagon Wheels Using the Finite Element Method.* Computers in Railways V.-Southampton, Boston: Computational Mechanics Publications, V.2, 1996, p. 69-77.
2. Sladkovsky A., Yessaulov V., Shmurygin N., Taran Y., Gubenko S.: *An Analysis of Stress and Strain in Freigth Car Wheels.* Computational Method and Experimental Measurements VIII.-Southampton, Boston: Computational Mechanics Publications, 1997, p. 15-24.
3. Sakalo V.I., Olshevskij A.A., Shevchenko K.B.: *RSFEM Program Package for Contact Units Investigation.* Consideration of Railway Transport Probms, Proceedings of Conference «Railway Bogies and Runnig Gears». Budapest, 2001, p. 162-164.
4. Krotov V.P., Krotov S.V.: *A condition of wheel pair the car at increase of loading modes.* Bulletin RGUPS, .№2, 2002, p. 36-39.
5. Dubrov A.M.: *Processing of the statistical main things given by a method a component*, Статистика, Москва, 1978.
6. Eberla K.: *Factor Analysis*. Статистика, Москва, 1980.
7. Afifi A.A., Azen S.P.: *Statystical Analysis. A Computer Oriented Approach*. Мир, Москва, 1982.
8. Evdokimov J.A., Kolesnikov V.I.: *Planning and the analysis of experiments at the decision of problems of friction and deterioration.* Наука, Москва, 1980.
9. Kiselev S.N., Ynozemtsev V.G., Petrov S.J., Kiselev A.S.: *Temperature of a field, deformations and pressure in seamless-rolled wheels at various modes of braking*. Bulletin of VNIIZhT, 1994, 7, p. 13-17.
10. Safety striker wheel assembly for gas lighters. United States Patent 5547370/ http://www.freepatentsonline.com/5547370.html

Received 14.04.2009; accepted in revised form 17.12.2009