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Influence of locomotive operating characteristics on wheels in contact with the rails

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Summary. The article describes the main factors that determine the realizable thrust. The results of the investigation of the parameters of the contact wheel and rail, depending on operational factors and add to the load of devices due to the body with a cart. The improved design adds to the load device, which improves traction and braking as the locomotives. The results of changes the coefficient use of coupling weight in the implementation of traction.
Key words: the coefficient use of coupling weight, slick wheels in contact with the rail, adds to the load device, operational factors.

INTRODUCTION

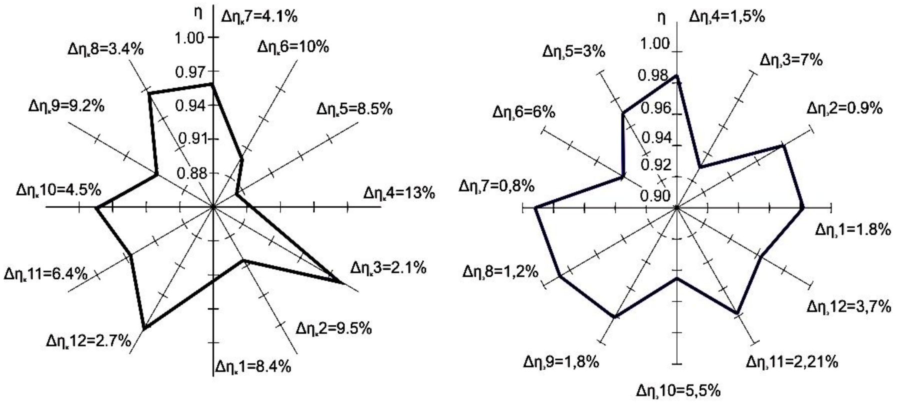
Achieving high traction qualities in the design and operation of a modern locomotive is an urgent task. Redistributing static loads of wheel sets on the rails in use is the main cause of the deterioration of the locomotive traction qualities, their accelerated wear, high impact on the way and, as a result, causes a decrease in freight and railway capacity and disorders of the track.

MAIN MATERIAL AND RESULTS OF INVESTIGATION

When designers of locomotives believe [Konyaev A.N., Spiryagin I.K., 1971], that the static load of wheelset to the rails are the same, they have deviations from the calculated values [Gorbunov N.I., Kravchenko K.A., Popov S.V., 2009, Gorbunov N.I., 2006]. Redistribution of loads from the wheel set on the rails is estimated the coefficient use of coupling weight η. Redistribution of loads from the wheel set on the rails is estimated utilization of adhesion weight η. Changing loads from of wheel sets on the rails depends on various design and operational factors [Belyaev A.I., Bunin B.B., Golubyatnikov S.M., 1984, Golubenko O.L., 1999, Ivanov V.N., Belyaev A.I., Oganiyan E.S., 1979]. Based on the analysis set and expressed as a percentage of them major influence on the efficiency of coupling weight in fig. 1 [Gorbunov N.I. Kashur A.L., Popov S.V., Kravchenko K.A., Fesenko A.I., 2008, Gorbunov N.I., Kostyukevich A.I., Kravchenko K.A., Fesenko A.I., 2010, Fufryanskiy N.A., Dolganov A.N., Nestrakhov A.S. 1988, Sapronova S., 2010, Cherneckaya N., Kolodyazhnaya L., 2010]. In the implementation of the traction the most unfavorable conditions for a skid are created for one wheelset, which has the least load on the track, all other things being equal. When reducing the actual load wheel pair, compared to the calculated (nominal), there is a proportional reduction of its maximum thrust and efficiency of the locomotive as a whole.

Redistribution of loads from the wheel set on the rails changes the contact area and the distribution of normal stresses on it. Of particular interest is the identification of the influence of operational factors and add to the load on the device parameters of the contact.

For this purpose, the program POISK and NZD which composed on Fortran 2008 have developed at the chair of railway transport of Volodymyr Dahl East Ukrainian National University.



a б

Fig. 1. The effect of parameters on the efficiency of the locomotive coupling weight:
a – structural ($\Delta\eta_{к}1$ - distance from the center to the outer bogie poles; $\Delta\eta_{к}2$ - elastic longitudinal bracing; $\Delta\eta_{к}3$ - optimum stiffness ratio of the first and second stage spring suspension; $\Delta\eta_{к}4$ - base bogie; $\Delta\eta_{к}5$ - angle to the horizontal leashes; $\Delta\eta_{к}6$ - the distance between the first and second wheel sets; $\Delta\eta_{к}7$ - body weight; $\Delta\eta_{к}8$ - weight of the bogie; $\Delta\eta_{к}9$ - location of the traction motors; $\Delta\eta_{к}10$ - kind of connection with the wheel bogie frame pair; $\Delta\eta_{к}11$ - the location of the pivot hinge above the rail head; $\Delta\eta_{к}12$ - distance from the center of bogie to the internal supports locomotive);
б – operating ($\Delta\eta_{э}1$ - weight change first wheelset; $\Delta\eta_{э}2$ - body weight change due to the expense outfit materials; $\Delta\eta_{э}3$ - force generated add to the load device; $\Delta\eta_{э}4$ - stiffness of the first stage spring suspension; $\Delta\eta_{э}5$ - stiffness of the second stage spring suspension; $\Delta\eta_{э}6$ - friction damper; $\Delta\eta_{э}7$ - rigidity parts, joins damper to axle boxes; $\Delta\eta_{э}8$ - stiffness of the end support the second stage spring suspension; $\Delta\eta_{э}9$ - stiffness of the supports of the second stage spring suspension; $\Delta\eta_{э}10$ - controlled spring suspension; $\Delta\eta_{э}11$ - frequency disturbances from the twitch of the fixed and variable component forces thrust; $\Delta\eta_{э}12$ - wear bandage rolling circle first wheelset)

With the program POISK determined coordinates of the initial contact with a rail wheel set track. These coordinates enter for the program NZD, intended to build a function of the initial gap and the iterative solution of normal contact problem [Golubenko A.L., Kostyukevich A.I., 1989, Kostyukevich A.I., 1991].

In the programs, the following symbols: *P* – vertical load on the wheel on the rail; *YR, YK* – coordinates of the initial contact; *TT* – angle, the value of which is determined by solving the problem of finding the initial point of contact; *YN, FI* – transverse displacement and rotation of the wheelset with respect to rail track; *N1, N2* – dimension of the surface grid; *DX, DY* – step of the surface grid $O_A i$ и $O_A j$ respectively; *E* – defined by the accuracy of the solution; *NR N*K – codes form contact surfaces; D4 – the accuracy with which the equation is solved initial points of contact; *ddy* – displacement of the origin of system $O_A ijk$ along $O_A j$; *A1* - coefficient a_{ll}; *ITER* – the number of cycles of iterations to achieve the desired accuracy of the solution; *FK* – contact area; *PSI* – average specific contact pressure.

All calculations were performed for not threadbare wheel profile shunting locomotive TEM103 according to GOST 52366-2005.

Table 1 and figure 2 shows the calculated normal tasks for the first shunting locomotive wheelset TEM103, adjusting the vertical load of the action add to the load devices [Kravchenko K.A., 2010]. The angle of rotation relative to the wheelset rail track - 0 º, lateral shift – 0 mm, the vertical load from the first to the direction of travel wheels on rails - 103 kN. From fig. 2, and shows the distribution of specific pressures on cells of contact, the maximum of which is for the contact is 650 MPa. The shape of the contact is shown in fig. 2b. The results which were calculated are shown in table 2.

Table 1. Input data and results of the solution of the problem of normal

Input							
P, кg	*YR*, mm	*YK*, mm		*TT*, rad	*YN*, mm		*FI*, gr
10292	.04	-797.63		.0000E+00	.00		.0
N1	*N2*	*DX*, mm	*DY*, mm	*E*	*NR*	*NK*	*D4*, mm
16	22	1.0	1.0	10.560	0	0	.1941E+00
The calculated results							
ddy	*A1*			*ITER*	*FK*, mm **2		*PSI*, N/mm **2
-	.1890E-03			22	239.0		43.1*9.81

The analysis of table 2 shows that with the increase of the vertical load from 88 kN to 132 kN contact area increases from 211 mm^2 to 281 mm^2, with an average surface pressure is increased from 426 MPa to 478 MPa, the maximum pressure - 620 MPa to 680 MPa.

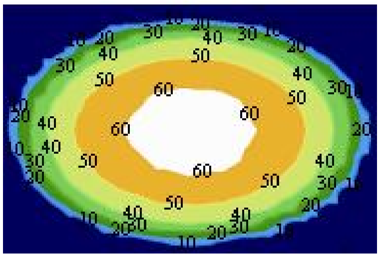
Noting the negative impact of operational factors on the parameters of the contact. For the first wheelset contact area decrease is 9%. In turn, the use of devices to add to the load first wheelset can increase the contact area by 7%.

To increase the vertical load for implementing improved traction finish loading device (fig. 3), which was introduced on shunting locomotive TEM103 PJSC "Luganskteplovoz" [Gorbunov N.I., Kashura A.L., Kravchenko K.A., Popov S.V., Dogadin V.A., Bogopolskii E.M.,Osenin J.J., 2009].

Add to the load device is mounted on the frame 1 trolley locomotive (fig. 3). When moving from the place of the locomotive using the "*Increase clutch*", located on one of the control panels, turned finish loading device. In the cavity of a cylinder 2 with the cover 14 at a pressure of 0.4 MPa, the air is supplied, the piston rod 15 with a 3 move up, release spring 16 is compressed. Lever 5, rotating about an axis 12 through 13 and thrust rollers 8, 9 based on Polozkov 10 welded to the frame 11 of the locomotive. With further movement of the piston rod 15 effort from 3 through the fork 4, lever 5, the axis 12 and the bracket 6 to 7 is transmitted to the suspension crossmember frame 1 trolley, increasing the load on the wheelset is toward the cross beam (fig. 4).

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	**6**	**17**	**20**	**17**	**4**	0	0	0	0	0	0
0	0	0	0	0	**21**	**31**	**33**	**34**	**33**	**30**	**17**	0	0	0	0	0
0	0	0	0	**22**	**33**	**38**	**41**	**43**	**42**	**39**	**34**	**20**	0	0	0	0
0	0	0	**16**	**35**	**42**	**46**	**48**	**49**	**48**	**45**	**41**	**34**	**13**	0	0	0
0	0	0	**32**	**41**	**47**	**50**	**53**	**54**	**53**	**51**	**46**	**40**	**30**	0	0	0
0	0	**17**	**38**	**45**	**51**	**55**	**57**	**58**	**57**	**55**	**51**	**45**	**37**	**14**	0	0
0	0	**28**	**42**	**49**	**54**	**57**	**59**	**60**	**59**	**57**	**54**	**48**	**40**	**25**	0	0
0	0	**34**	**44**	**51**	**57**	**59**	**61**	**62**	**61**	**59**	**56**	**51**	**44**	**33**	0	0
0	**8**	**37**	**47**	**54**	**59**	**61**	**63**	**64**	**63**	**62**	**58**	**53**	**46**	**37**	**4**	0
0	**12**	**38**	**48**	**54**	**59**	**62**	**64**	**65**	**64**	**62**	**59**	**54**	**47**	**38**	**9**	0
0	**13**	**39**	**48**	**55**	**60**	**62**	**64**	**65**	**65**	**63**	**59**	**54**	**47**	**39**	**10**	0
0	**12**	**38**	**48**	**54**	**59**	**62**	**64**	**65**	**64**	**62**	**59**	**54**	**47**	**38**	**8**	0
0	**8**	**38**	**47**	**54**	**59**	**62**	**63**	**64**	**63**	**62**	**58**	**53**	**46**	**37**	**4**	0
0	0	**34**	**44**	**52**	**57**	**60**	**61**	**62**	**61**	**60**	**56**	**51**	**44**	**33**	0	0
0	0	**28**	**42**	**49**	**54**	**57**	**59**	**60**	**59**	**58**	**54**	**48**	**41**	**25**	0	0
0	0	**17**	**38**	**45**	**51**	**55**	**57**	**58**	**57**	**55**	**51**	**45**	**37**	**14**	0	0
0	0	0	**32**	**41**	**47**	**51**	**53**	**54**	**53**	**51**	**46**	**40**	**30**	0	0	0
0	0	0	**16**	**35**	**42**	**46**	**48**	**49**	**48**	**46**	**41**	**34**	**13**	0	0	0
0	0	0	0	**23**	**34**	**39**	**42**	**43**	**42**	**39**	**34**	**21**	0	0	0	0
0	0	0	0	0	**20**	**31**	**34**	**35**	**34**	**31**	**18**	0	0	0	0	0
0	0	0	0	0	0	**5**	**16**	**19**	**16**	**4**	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a



b

Fig. 2. The distribution of the contact pressure, 10*N/ mm^2:
a - in a numerical form (based on the results of calculation in the program NZD);
b - in outline form (processing of the results of calculations in the software environment MathCad)

Table 2. Modeling of the contact wheel pair shunting locomotive TEM103

№ of wheelset	The load of the wheels on the rails, kN			Contact area, mm^2			Contact pressure, MPa			Maximum contact pressure, MPa		
	without add to the load device	***given the operational factors***	***with add to the load device***	***without add to the load device***	***given the operational factors***	***with add to the load device***	***without add to the load device***	***given the operational factors***	***with add to the load device***	***without add to the load device***	***given the operational factors***	***with add to the load device***
1	96	88	103	231	211	239	423	426	440	630	620	650
2	110	112	103	249	253	243	449	451	436	660	650	650
3	111	110	116	253	251	262	449	447	450	660	650	670
4	125	132	119	271	281	265	469	478	457	700	680	680

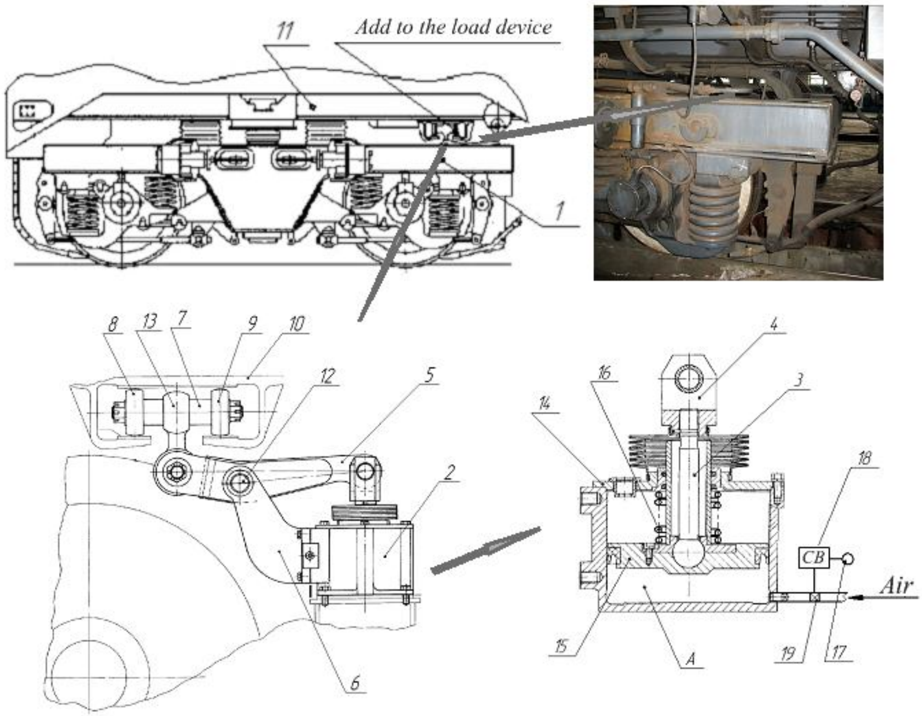


Fig. 3. Installation of the device to add to the load bogie shunting locomotive TEM103

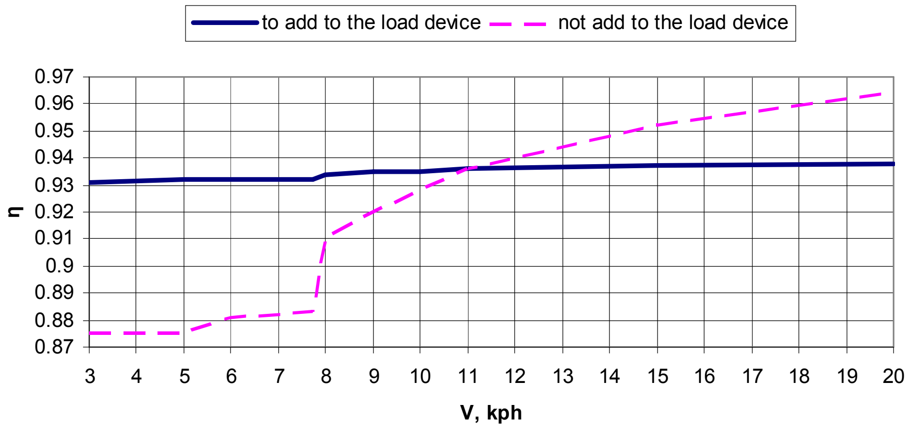


Fig. 4. Change of use of the coupling weights of the first wheel set on the speed

Application add to the load device can increase the coefficient use of coupling weight (η), but when you reach 11 kph its effectiveness decreases (fig. 4). Therefore, at a speed of 11 kph begins operate the control unit 18 connected with a speed indicator 17. From the cavity A of the cylinder 2 through the electromagnetic valve 19 air coming out, and, under the action of letting go spring 16, the piston 15 is returned to its original position.

The difference in the vertical loads on the axles bogie is substantial. To address the phenomenon proposed a complex control system (CCS) redistribution of vertical loads from the wheel pairs on rails [Gorbunov M.I., Kashura O.L., Kravchenki K.O., Popov S.V., Kovtanets M.V., Golembievsky K.V., 2008], which is a system add to the load device on bogie frame and control system. Depending on the driving mode and the operating conditions, the control system changes the functionality of the devices add to the load. In the traction mode in the work included add to the load device two and four axle bogie, herewith loading the first and third axes. To improve braking performance under braking triggered add to the load device first and third axle bogie, herewith loading minimally loaded two and four wheel pairs. On freewheel CCS operates as a shock absorber [Gorbunov N.I., Kravchenko K.O., Popov S.V., Fesenko A.I., Grishchenko S.G., Nesterenko

V.I., Lewandowski V.O., 2009], and redistributes the load curves on the sides of bogie, thus improving traction, braking, dynamic quality shunting locomotive and efficiency blending in a curve track sections.

CONCLUSIONS

The studies found a negative impact of operational factors on the parameters of the contact. For the first wheelset contact area decrease is 9%. In turn, the use of devices to add to the load first wheelset can increase the contact area by 7%. To improve traction and braking qualities proposed design improvement and the location add to the load of devices on bogie of the locomotive, by extending their functionality.

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ВЛИЯНИЕ ЭКСПЛУАТАЦИОННЫХ ХАРАКТЕРИСТИК ЛОКОМОТИВА НА ПАРАМЕТРЫ КОНТАКТА КОЛЕСА С РЕЛЬСОМ

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Аннотация. В статье рассмотрены основные факторы, от которых зависит реализуемая сила тяги. Представлены результаты исследования параметров пятна контакта колеса с рельсом в зависимости от эксплуатационных факторов и применения догружающих устройств в связи кузова с тележками. Предложено усовершенствование конструкции догружающего устройства, которое позволяет повысить тягово-тормозные качества локомотивов. Представлены результаты изменения коэффициента использования сцепного веса при реализации тягового усилия.

Ключевые слова: сила тяги, коэффициент использования сцепного веса, пятно контакта колеса с рельсом, догружающее устройство, эксплуатационные факторы..