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Improvement of Range and Production Technique of Railway Rails

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Efficiency of using UIC60 type rails instead of P65 type on Ukrainian railways is shown. Steel saving is 8.8 tons per 1 km of track. Technological advancement of steel killing is investigated at JSC "Iron & Steel Works "Azovstal" which enabled to satisfy requirements of category B according to DSTU 4344:2004 regarding to the length of nonmetallic inclusion lines for М76ФБ steel grade. Developed and implemented industrial technology of hardening inner edges of M76T steel rail head of P65 type ensures reduction of inner wear by 40%.

Keywords: RAILS, STEEL, SECTION, TREAD SURFACE, KILLING, MICROALLOYING, NONMETALLIC INCLUSIONS, HARDENING, INNER EDGES, WEAR, OPERATIONAL TESTS, LOAD INTENSITY, WEAR RESISTANCE

Introduction

The durability and non-failure operation of rails is defined by resistance to contact-fatigue defects: shearing distortions, chips on the lateral sides of rail head, internal longitudinal and cross-section cracks and wear resistance in curved tracks under conditions of heavy traffic of freight and passenger trains. Reduction in traffic volume made service conditions of track bed structure of domestic railways more similar to service conditions characteristic for countries of Western Europe which predetermined the possibility of using European rails UIC60 instead of P65 rails.

UIC60 rails are used on the European railways with working capacity 50-70 million tons gross per 1 km of track per year and also on portions of line with increased motion speed.

Results and Discussion

UIC60 rail profile corresponds to P65 rails by weight category and certain sizes (**Figure 1**). At equal thickness of rail base the height of UIC60 rails is 172.0 mm (P65 rails - 180.0 mm). Nevertheless, in the total mass of profile the part of metal of UIC60 rail head is 40.1 %, and for P65 rails - 34.1 %. The profile of tread surface of rail head is formed by several curves of different radiuses. The smaller radius of tread surface for UIC60 rails reduces eccentricity of the rail loading but increases the contact stress. Nevertheless, the optimum contact of wheel with the rails reduces deterioration of lateral side of the rail head and wheel flanges as the contact point is located closer to the basis of wheel flange.

An advantage of UIC60 rails as compared to P65 ones is a higher head (by 6 mm) which enables more polishing operations of tread surface during service life of the rails. To decrease stress level the inclination of bottom side of the head is more than for P65 rails.Technical and economic indices considering the expenditures connected with current maintenance of tracks basically depend on the rail type [1]. Expenditures connected with trackworks at operation of UIC60 rails are lower as compared to P50 rails and a little more than for P65 rails (**Figure 2**).

Application of UIC60 rails instead of P65 ones provides metal saving up to 8.8 tons per 1 km of track. Now, UIC60 rail manufacture is mastered at JSC "Iron & Steel Integrated Works "Azovstal" according to Specifications of Ukraine 27.1-00190319-1283-2002 [2] from steel of standard chemical composition (M76T).

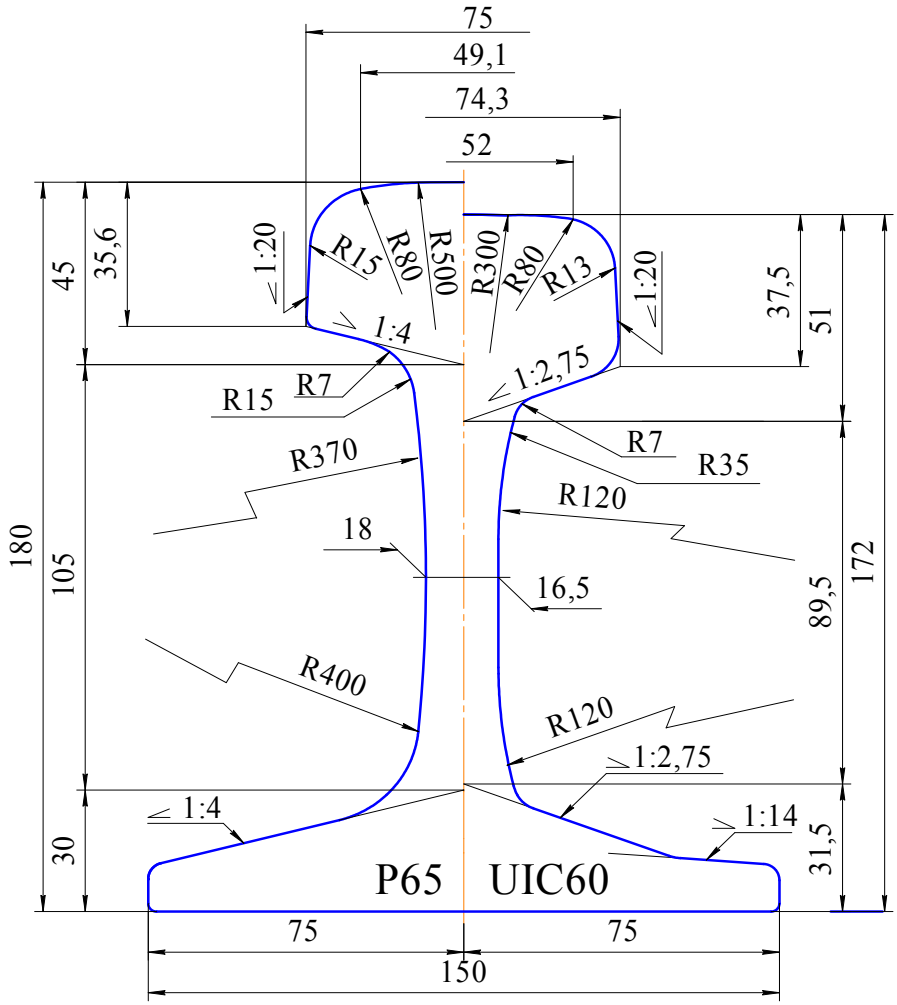

Figure 1. Cross-section and basic dimensions of P50, P65 and UIC60 rails

Table 1. Key dimensional characteristics of P65, UIC60 and P50 rails

Parameters, mm	Rail types		
	P65	UIC60	P50
Head width:			
- top	49.1	52.0	45.7
- bottom	75.0	74.3	72.0
Head height	45.0	51.0	42.0
Inclination of head bottom	1:4	1:2.75	1:4
Neck radius	370.0	120.0	325.0
Neck thickness	18.0	16.5	16.0
Neck height	105.0	89.5	83.0
Inclination of rail base	1:4	1:2.75 и 1:14	1:4
Thickness of rail base, B	150.0	150.0	132.0
Rail height, H	180.0	172.0	152.0
Ratio B/H	0.833	0.872	0.868

Positive results of operational test of UIC60 rails enabled to include this type of rails in the national standard of Ukraine DSTU 4344:2004 [3]. JSC "Iron & Steel Integrated Works "Azovstal" produced more than 16 thousand tons (~140 km of track) of this type hot-rolled rails used on the main routes of cargo transportation and traffic railways of Ukraine.

When improving rail production technique, the great attention is given to the main areas of rail quality improvement - to reduction of nonmetallic inclusions in the rail steel, maintenance of high level of hardness and strength properties of rails when their plastic properties and impact strength are constant.

Impurity of rail steel is defined by oxygen content in steel, reduction of which results in decrease of amount and length of lines of nonmetallic inclusions as well as size of individual nonmetallic inclusions. It is necessary to raise fatigue strength which is very actual for P65 rails.

Analysis of technical documentation showed that European standard EN 13674-1:2003 regulated the residual content of oxygen and length of nonmetallic inclusions in rails, thus, for example, in rails produced in France the maximum size of nonmetallic inclusions was 7-10 microns. In Russia, GOST P51685:2000 regulates oxygen content which should be not more than 0.002 % in rails of class B and not more than 0.004 % in rails of other classes as well as the length of lines of nonmetallic inclusions. The maximum size of nonmetallic inclusions does not exceed 35-50 microns. The national standard of Ukraine DSTU 4344:2004 regulates only the length of nonmetallic inclusions (**Table 2**).

Impurity analysis of P65 rails currently produced at JSC "Iron & Steel Integrated Works "Azovstal" from M76T steel showed that all rails satisfied the requirements of DSTU 4344:2004 regarding the length of lines of aluminum oxide inclusions, titanium nitrides and vanadium, and only 25 % of rails meet the requirements of DSTU 4344:2004 regarding the length of lines of brittle fractured oxides (aluminates, silicates, spinels).

Investigations related to improvement of rail steel deoxidation method by replacement of complex reduction alloy KMKT and ferrotitanium by silicocalcium with inoculation by vanadium and niobium are carried out in order to decrease impurity of rail steel at JSC "Iron & Steel Integrated Works "Azovstal". Thus, steel M76ФБ microalloyed with vanadium (0.01-0.03 %) and niobium (0.003-0.015 %) and not containing titanium is suggested instead of steel grade M76T. Such change of deoxidation and microalloying method showed the possibility to satisfy requirements of DSTU 4344:2004 regarding the length of lines of nonmetallic inclusions (**Table 3**).

It is necessary to note that M76ФБ steel rails of P65 type both as hot-rolled and after hardening from high-frequency current heating have higher strength properties and hardness than M76T steel rails. Application of such steel grade in UIC60 rail production also will provide high level of strength properties and hardness.

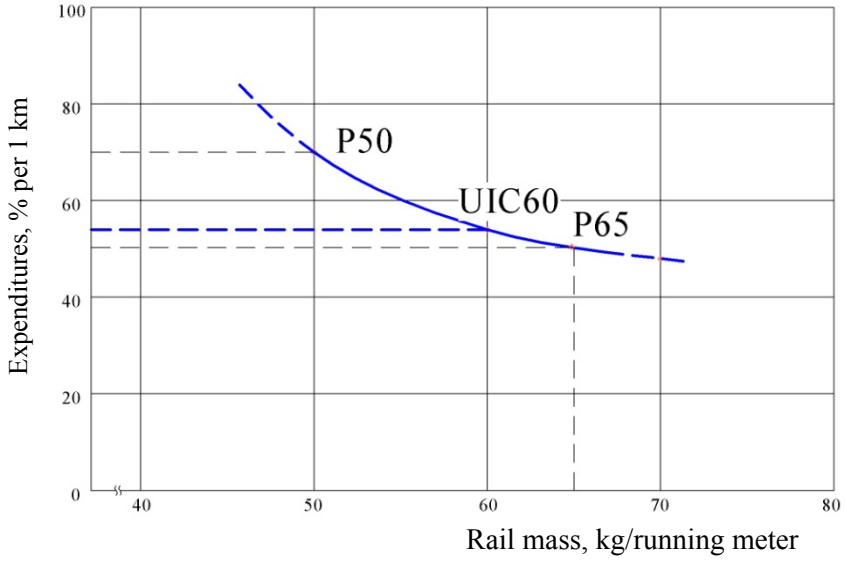

Figure 2. Expenditures connected with trackwork and current maintenance of the track using P50, UIC60 and P65 rails

Industrial method of hardening lateral faces of P65 rail head made of steel M76T was developed and introduced at JSC "Iron & Steel Integrated Works "Azovstal" to decrease intensity of lateral deterioration of the rail head. This hardening method ensures hardness of quenched lateral faces and tread surface of rail head within 302-388 HB which meets the requirements of Specifications of Ukraine 2 7.1-00190319-1288-2002 (**Figure 3**).

Actual tests of experimental batch of P65 rails with the quenched lateral faces, tracked in 2003 on the Lviv railway curved track with radius of 295-320 meters, showed that intensity of lateral deterioration of currently produced rails (without additional cooling of lateral faces) was 1.42-1.77 times higher than intensity of lateral deterioration of rails with quenched lateral faces.

Further improvement of UIC60 rail quality by means of adoption of hardening method, including lateral faces, use of new techniques of rail steel

Table 2. Requirements to length of nonmetallic inclusion lines

Class	Length of nonmetallic inclusion lines, mm, not more			
	Aluminum oxide, titanium nitride		Brittle fractured oxides	
	DSTU 4344	GOST P 51685	DSTU 4344	GOST P 51685
B	1.0	Not allowed	1.0	0.5
I (T1)	2.0	0.5	4.0	4.0
II (T2)	2.0	0.5	8.0	8.0
III (H)	2.0	0.5	4.0	8.0

Table 3. Nonmetallic inclusions in rails

Steel grade (smelting)	Length of nonmetallic inclusion lines, mm, not more			
	Titanium nitrides		Brittle fractured oxides	
	Head rail	Bottom rail	Head rail	Bottom rail
M76ФБ (1)	-	-	0.85-0.65-0.47	0.45-0.35-0.70
M76ФБ (2)	-	-	0.36-0.37-0.23	0.25-0.60-0.35
M76T (3)	0.62-0.82-0.74	0.83-0.81-0.68	1.09-0.83-0.94	1.65-0.35-0.80

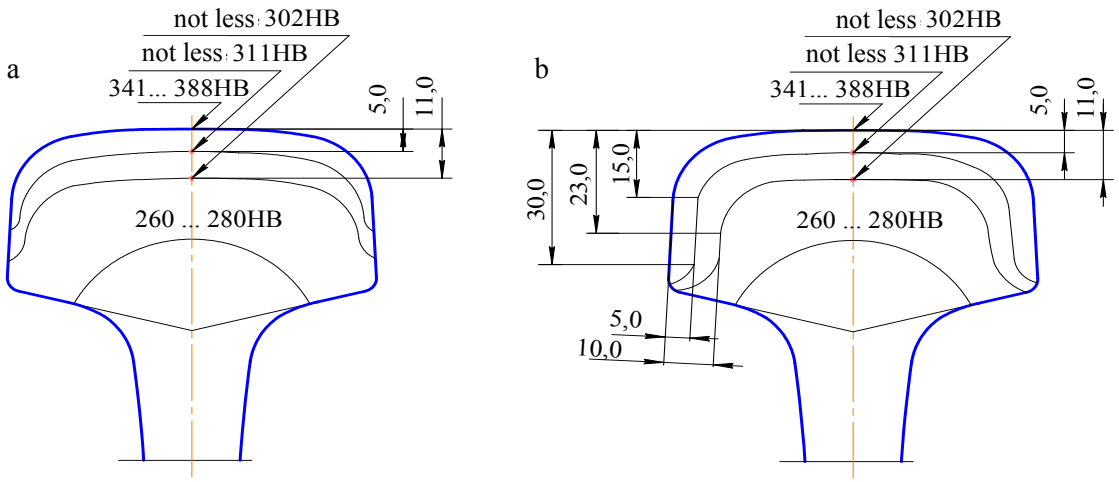

Figure 3. Hardness change in depth of quenched rail heads at JSC "Iron & Steel Integrated Works "Azovstal"**:** *a* - currently produced; *b* - rails with quenched lateral faces

deoxidation with microalloying and inoculation for raise of contact-fatigue strength and wear resistance is in the long term.

Conclusions

The comparative analysis of geometrical and constructional parameters of UIC60 and P65 rails as well as results of actual tests of experimental batches of rails showed that it was reasonable to apply UIC60 rails instead of P65 rails on railways for the purpose of metal economy at volume of cargo and passenger trains traffic existing in Ukraine, axial loads of rolling stock and traffic speeds. Increased height of UIC60 rail head as compared to P65 rail enables more profile polishing operations throughout the term of their service.

Advanced rail steel deoxidation method providing replacement of complex reduction alloy КМКТ by silicocalcium and inoculation by vanadium and niobium is developed to enhance contact-fatigue strength of P65 type rails. This method meets the requirements of DSTU 4344:2004 regarding content of nonmetallic inclusions in steel. It is possible to use this method for UIC60 rails manufacture.

Worked out and adopted industrial hardening of lateral faces of currently produced M76T steel rails of P65 type provides hardness of lateral faces at the distance up to 5 mm from a lateral surface not less than 311 HB. As a result, the lateral deterioration of rails dropped by ~40 %.

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Совершенствование сортамента и технологии производства железнодорожных рельсов

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В условиях ОАО «МК «Азовсталь» проведены исследования по совершенствованию технологии раскисления рельсовой стали, что позволило обеспечить требования категории В по ДСТУ 4344:2004 в части длины строчек неметаллических включений на стали марки М76ФБ. Разработана и внедрена промышленная технология закалки боковых граней головки рельсов типа Р65 из стали марки М76Т, обеспечивающая снижение бокового износа на ~40 %.