

UIC-RECOMMENDATIONS FOR THE USE OF RAIL STEEL GRADES

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The paper elaborates overlook criteria to determine the choice and recommendations for the use of rail steel grades according to draft UIC-recommendations leaflet 721R from 2003. which was prepared by Infrastructure Commission from International Union of Railways based on European standard EN 13674-1.

Key words: UIC-recommendations, criteria for choice, rail steel grades, use

UIC-preporuke za uporabu čelika za željezničke tračnice. U članku su pregledno obrađeni kriteriji za izbor i preporuke za uporabu čelika za željezničke tračnice prema nacrtu UIC-preporuka 721R iz 2003. koji je izradila Komisija za Infrastrukturu Međunarodne željezničke unije (UIC) na temelju Europske norme EN 13674-1.

Ključne riječi: UIC-preporuke, kriteriji izbora, čelici za željezničke tračnice, uporaba

INTRODUCTION

The manufacture and acceptance of railway rails is the subject of UIC Leaflet 860 O-Technical specification for the suppl of rails - 8th edition, 1.7.1986. and Codex UIC 860 V from International Union Railways as well from 1986.

The present edition of UIC Leaflet 721 R only refers to steel grades specified in European standard EN 13674-1.

The aim of Leaflet 721 R is to provide assistance in the selection of rail steel grades so that the most suitable rail is chosen for the specific railway operating conditions in each case.

UIC Leaflet 721 R was first published in 1980 and was intended to give recommendations for the use of rails made from hard and extra-hard grades of steel. At the time, steel grades with a minimum tensile strength of 880 MPa were considered hard and those with a minimum tensile strength of 1080 MPa were considered extra hard. Increases in railway traffic, greater axleloads, higher speeds and the introduction of new generations of rolling stock have increased the loadings on rails (in curves especially). Today, in light of developments in rail manufacture and changing prices for rail steels, most railways now opt for steel grades 260 and, to a very limited degree, 260 Mn (steel grades 900 A and 900 B) as standard equipment for their track. Rails of steel grade 260 and 260 Mn is not exempt from the problems that arise in curves with small and very small radii and/or heavy loadings. Compared to rails made from infe-

rior steel grades, these lateral and vertical wear problems arise later or in another form (corrugation, head-checking).

The Requirements of the Codex UIC 860 V

Technical conditions of manufacture and delivery of railway rails was standardized in Codex UIC 860V of the International Railroad Union, which has been harmonized with the world trends. Table 1. gives a survey of the prescribed values regarding chemical composition and tensile properties for four types of normally hard rail steels [1 - 8].

Table 1. shows that increase of tensile strength of railroad steels is obtained by the increase of carbon, manganese, silicium and chromium content, while the required purity of steel is obtained by reduction of the allowed content of phosphorus and sulfur.

The Requirements of the Draft new European Norm

The draft of new European Norm pr EN 13674-1: June 1999.-Part 1 covered flat bottom symmetrical rails having a linear mass 46 kg/m and above. This draft EN has prepared under the direction of the European Committee for Standardisation (CEN¹) from national standards bodies of 19 states² and it is distributed for review and comments.

¹ Comite Europeen de Normalisation (CEN) = European Committee for Standardization;

² Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland und United Kingdom;

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Table 1. Prescribed chemical composition and tensile properties of rail steels according to UIC 860V 8

Tablica 1. Propisani kemijski sastav i vlačna svojstva čelika za tračnice prema UIC 860 V 8

Grade of steel	Chemical composition, elements in % of mass						Tensile strength, R_m N/mm ²	Elongation A_5 , min, %
	C	Mn	Si	Cr	P _{max}	S _{max}		
R0700	0,40-0,60	0,80-1,25	0,05-0,35	-	0,05	0,05	680 - 830	14
R0900A	0,60-0,80	0,80-1,30	0,10-0,50	-	0,04	0,04	880 - 1030	10
R0900B	0,55-0,75	1,30-1,70	0,10-0,50	-	0,04	0,04	880 - 1030	10
R1100*	0,60-0,82	0,80-1,30	0,30-0,90	0,8-1,3	(0,025)	0,03	≥ 1080	9

* Other alloy elements such as V or Mo, Nb can be applied according to agreement between manufacturer and the buyer.

Modern rail production technology and the requirements of high-speed railways within the Community have demanded a completely new look at the philosophy and content of this part draft pr EN XXXX. Whenever possible this part of draft pr EN is performance based, adopts the European Quality System standard EN ISO 9002 and requires manufacturers to offer the latest proven technology.

Two major divisions of the draft proposal EN are:

- qualifying tests and
- acceptance tests.

The qualifying tests introduce a number of performance requirements not previously seen in national or international standards (such as fracture toughness K_{Ic}). They also include typical results from relevant acceptance tests.

The acceptance tests have been designed to control those characteristics of the rail steel and rail that are of relevance to the production of high quality rails and the demands of the railway operator. The principle of the acceptance criteria is based on measured hardness values and not on measured tensile tests, which form part of the

Table 2. Steel grades hardness range, fracture toughness and other [11]

Table 2. Raspon vrijednosti tvrdoća čelika za tračnice, lomna žilavost i drugo [11]

Steel grade	Hardness range HBW	Fracture toughness K_{Ic} / MPa m ^{1/2}		Description	Branding lines
		Minimum value			
		single	mean		
200	200-240	30	35	C-Mn	
220	220-260	30	35	C-Mn	—
260	260-300	26	29	C-Mn	==
260 Mn	260-300	26	29	C-Mn	===
320 Cr	320-360	24	26	1 % Cr	====
350 HT	350-390	30	32	C-Mn HT	=====
350 LHT	350-390	26	29	Low alloyed HT	=====

qualifying tests. On this hardness values are given new markings steel grades for railway rails [9 - 11].

Table 2. gives seven steel grades for rails, hardness range, minimum fracture toughness values, description and branding lines on web. These steel grades reflect trends in railway usage (either non heat treated - HT = on heat treated steels).

Internal quality of rails shall be ultrasonically tested by a continuous process ensuring that entire rail length and cross-sectional area are inspected

(at least 70 % of the head and at least 60 % of the web). Surface quality included control: all protrusions, hot marks and seams from rolling, wear patterns, hot scratches, slivers etc.; cold marks, surface microstructural damage (martensite or white phase), automatic foot inspection on surface defects (cracks).

Rail profiles, dimensions, properties and linear masses shall be in accordance with is prescribed in draft pr EN. This draft pr EN contains 21 different profiles railways rails with linear masses from 46 till 60 kg/m. The profiles given at the Figure 1. have following designations: 49 = 49 E1 (previous DIN S 49), and UIC 60 = 60 E1 [11].

CRITERIA TO DETERMINE THE CHOICE OF STEEL GRADE

The various criteria used to choose a steel grade are grouped under the three following headings: local parameters, maintenance methods, economic assessment [12].

Local parameters

These parameters influence the development of wear and rolling contact fatigue defects:

- curve radius (lateral wear, corrugation on the low rail in curves, head-checking, rail contact fatigue defects cause serious problems on curve radii on which trains run at higher speeds),
- tonnage carried (the actual daily or annual mega gross tonnage – mgt in the zone under consideration),
- the impact of falling and rising gradients (of around 20 % and more),
- speed and cant on curves (a wide range of traffic types which are either pulled or pushed, cant deficiency contributes to lateral wear on the high rail and to propagation of rolling contact fatigue defects whereas excess cant causes crushing on the low rail),
- axleload (a higher axleload is conducive to crushing on the low rail),
- the type of rolling stock (which are harsh on the track

may exert substantial forces in curves or high adhesion forces which are conducive to rail damage, smaller wheel radii may also contribute to rail damage).

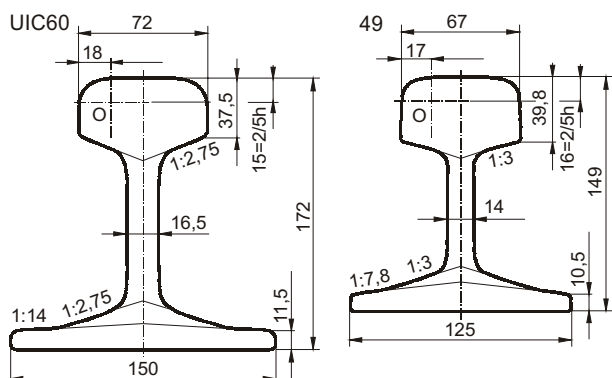


Figure 1. Shape and basic dimensions of rails, type 49 and UIC 60, O = center of sample for testing of tensile strength from the head of Z-rails

Slika 1. Izgled i osnovne razmjere tračnica tipova 49 i UIC 60, O = centar uzorka za ispitivanje vlačne čvrstoće iz glave Z-tračnica

Rail maintenance methods

Maintenance methods (lubrication and grinding) help combat the wear and rolling contact fatigue phenomena referred to in local parameters. By applying these methods appropriately, maintenance costs can be reduced [12]:

- lubrication on the gauge corner of the high rail (remains the most reliable means of retarding rapid lateral wear of the high rail in curves, the regularity and precision of application of a lubricant that are of paramount importance),
- rail grinding (prolongs rail service life by preventing the emergence of defects or by delaying their development, preventive grinding to improve the quality of the running surface of newly-laid rails and corrective grinding to remove rail defects that have already developed by reprofiling the rail to optimize wheel/rail contact).

Economic assessment

Account must be taken not only of the technical considerations but also of the economic ones when choosing a steel grade for rails.

RECOMMENDATIONS FOR THE USE OF NORMAL AND HARD STEEL GRADE RAILS

These definitions apply in the following text:

- normal steel grade rails: rails in 260 or 260 Mn grade steel,
- hard steel grade rails: rails in 320 Cr, 350 HT or 350 LHT grade steel [12].

Rails made of 260 or 350 HT steel grade are by far and away the most commonplace today.

The maintenance policy (rail lubrication and grinding) has a substantial impact on the service life of rails, be they of normal or hard steel. As service life is a key factor in any economic analysis, the maintenance policy must be taken into account when choosing the steel grade for rails.

A key parameter in the selection of rail steel grades is the procurement and maintenance cost of the rails. It is important to consider whether the higher capital costs of 350 HT, 350 LHT and 320 Cr are offset by the longer service life and/or lower maintenance outlay.

In small and very small radius curves and/or subject to heavy loadings, many railways achieve a longer (and therefore more cost-effective) service life by laying rails made from steel grades 350 HT, 350 LHT or 320 Cr. The corresponding hardness of these rails is obtained either through heat treatment or by the addition of alloys like chromium, with or without structural change. Timely execution of maintenance measures (grinding and above all lubrication of the rails) has a decisive impact on the service life of rails in curves.

Often, a combination of these two measures (choice of rail steel grade and maintenance) is necessary in order to achieve a cost-effective service life for rails.

Both technical and economic criteria must therefore be considered when making that choice.

Technical criteria

Steel grades 200 and 220 are still widely found in track, they are hardly used anymore for new rails.

The ranges for use of the various steel grades indicated in the diagram are based on the curve radius and actual tonnage carried parameters alone. There is also an overlap zone in the diagram, where the choice of steel grade will depend on the other local criteria listed above.

These recommendations are in line with the current practices of railways running mixed passenger and freight traffic with a maximum axleload of 22,5 tones on conventional lines.

Economic criteria

The most appropriate steel grade should yield the lowest average annual overall cost. The average annual overall cost consists of the investment cost and the maintenance cost and may be defined using the following general formula:

$$P = \frac{C}{n} + M \quad (1)$$

where:

- P - average annual overall cost,
 C - investment cost,
 M - annual maintenance cost,
 n - service life of rails (in years).

The general formula for a rail made of harder steel is as follows. The service life is $n + \Delta n$ years, the investment cost is $C + \Delta C$ and the average annual maintenance cost is $M + \Delta M$:

$$P' = \frac{C + \Delta C}{n + \Delta n} + (M + \Delta M) \quad (2)$$

Hard rail is only justified if the cost P' involved is less than P .

Given that little is often known about the difference between the maintenance cost of normal grade rails and hard grade rails and that the difference is minor compared to the investment and maintenance cost, the formula can be simplified by considering the maintenance costs equivalent. The formula can therefore be simplified as follows:

$$P' < P \Rightarrow \frac{C + \Delta C}{n + \Delta n} < \frac{C}{n} \Rightarrow \Delta n > n \frac{\Delta C}{C} \quad (3)$$

In practical terms, the percentage increase in the service life must be greater than the additional investment cost. Application of these economic criteria is only valid if the traffic conditions remain the same throughout the period in question [12].

CONCLUSIONS

According to Codex UIC 860 V/1986, four pearlitic steel grades for railway rails were prescribed with tensile strength 700 till 1100 MPa (see Table 1.), but in draft pr EN/1999, seven pearlitic steel grades are specified giving a hardness rang between 200 to 390 HBW (see Table 2.).

Draft pr EN 13674-1 has two mayor divisions: qualifying tests and acceptance tests. The qualifying tests introduce a number of performance requirements not previously seen in earlier norm and they also include typical results from relevant acceptance tests. The acceptance tests

have to control the prescribed properties of the high quality rail steel according norm EN ISO 9002 and requires manufacturers to offer the latest proven technology. The principal of the acceptance criteria is based on measured hardness values and the tensile test values are only form part of the qualifying tests. The new properties of steels for railway rails on qualifying tests are: fracture toughness, fatigue crack growth rate, fatigue test, residual stress in rail foot etc.

UIC Recommendation Leaflet 721 R from 2003 for the use of rail steel grades only refers to steel grades specified in European standard EN 13674-1. A particular point to note is that the names of the steel grades have been altered (see Table 2.) and the reference value used is no longer the tensile strength but the minimum hardness of the running surface.

Criteria to determine the choice of steel grade are grouped under following 3 headings: local parameters, maintenance methods and economic assessment. Recommendations for the use of rail steel grades when we making choice say that both technical and economical criteria must be considered.

More stringent operating requirements and higher speeds call for significant quality improvements. This resulted in elaboration of the new European standard which mainly introduces new testing methods to be implemented in order to achieve greater safety in railway traffic.

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