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Translation

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Recommendations for the use of rail steel grades

Recommandations pour l'emploi de différentes nuances d'aciers à rails

Empfehlungen für die Verwendung unterschiedlicher Schienenstahlsorten



UNION INTERNATIONALE DES CHEMINS DE FER
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Summary

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

The manufacture and acceptance of rails are the subject of *UIC Leaflet 860*.

A particular point to note is that the names of the steel grades have been altered in European Standard *EN 13674-1*: the reference value used is no longer the tensile strength but the minimum hardness of the running surface.

The aim of *UIC Leaflet 721* 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.

1 - Introduction

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The aim of *UIC Leaflet 721* 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 was first published in 1980 and was intended to give recommendations for the use of rails made from hard and extra-hard steel grades.

At the time, steel grades with a minimum tensile strength of 880 N/mm² were considered hard and those with a minimum tensile strength of 1 080 N/mm² were considered extra hard.

Increases in railway traffic, heavier 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 according to *UIC Leaflet 860*) as standard equipment for their track.

Rails of steel grade 260 and 260 Mn are not exempt from the problems that arise in curves with small and very small radii and/or heavy loadings.

Compared to rails made from inferior steel grades, these lateral and vertical wear problems arise later or in another form (corrugation, head-checking).

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 grades are offset by longer service life and/or lower maintenance outlay.

In small and very small radius curves and/or subject to high 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.

The decision as to which measures to select can only be taken on the basis of the prevailing specific operating conditions (speed, traffic type, track geometry and permanent-way design, lubrication, weather conditions, etc.).

Various railways are currently carrying out tests on particular steel grades, such as bainitic rail steel, and micro-alloy rails, in order to remedy or attenuate problems, notably those resulting from rolling contact fatigue (e.g. head-checking).

This leaflet does not deal specifically with these special steel grades.

2 - Criteria for determining steel grade selection

The various criteria used to select a steel grade are grouped under the three following headings:

- local parameters,
- maintenance methods,
- economic assessment.

2.1 - Local parameters

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

2.1.1 - Curve radius

Lateral wear is always inversely proportional to the curve radius. In some cases, the development of rolling contact fatigue defects, for example head-checking, is retarded by wear, especially lateral wear, caused by train running.

However, rail contact fatigue defects appear more frequently and cause serious problems on curve radii through which trains run at higher speeds.

Corrugation also occurs frequently on the low rail in curves.

2.1.2 - Tonnage carried

The tonnage carried is the actual daily or annual tonnage (mega gross tonnage - mgt) in the zone under consideration.

2.1.3 - The impact of falling and rising gradients

On steep rising and falling gradients, of around 20 ‰ and more, the following specificities must be borne in mind:

- on falling gradients with small curve radius, the lateral force exerted by train wheels and the effect of braking contribute to excessive lateral rail wear on the high rail; this wear is amplified if the rails are not lubricated;
- however, rising gradients of the same nature contribute to wheel-slip defects on rails and to propagation of rail-surface corrugation on the low rail;
- account must also be taken of the different effects of push-pull train working.

2.1.4 - Speed and cant on curves

These days lines often carry a wide range of traffic types in push-pull mode (freight trains, tilting trains, double-decker trainsets, shuttle trains with driving trailer). Given their different operating requirements, a compromise must be struck when setting the cant in curves. In practice the result of that compromise is that some trains run on a cant deficiency and others on excess cant.

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.

2.1.5 - Axleload

A higher axleload is conducive to crushing on the low rail.

2.1.6 - Type of rolling stock

Certain types of motive-power 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.

2.2 - Rail maintenance methods

Maintenance methods (lubrication and grinding) help combat the wear and rolling contact fatigue phenomena referred to in point [2.1 - page 4](#). By applying these methods appropriately, maintenance costs can be reduced.

2.2.1 - Lubrication on the gauge corner of the high rail

Irrespective of the method applied (manual lubrication in exceptional circumstances, fixed automatic lubricators, or lubrication by rolling stock), lubrication remains the most reliable means of retarding rapid lateral wear on high rail in curves.

Use of a harder steel grade does not resolve the problem of lateral rail wear if the rail is not lubricated. At best, the wear is delayed.

Furthermore, the fact that damaged metal is removed less rapidly may cause rolling contact fatigue to develop more quickly.

It is not so much the amount of lubrication, but rather the regularity and precision of application of a lubricant that are of paramount importance. Account must be taken of the influence of weather conditions (e.g. temperature, humidity) on the results of lubrication.

2.2.2 - Rail grinding

This track maintenance measure prolongs rail service life by preventing the emergence of defects or by delaying their development. There are in principle two types of rail grinding: preventive grinding and corrective grinding.

Preventive grinding is designed to improve the quality of the running surface of newly-laid rails. When applied systematically as a maintenance measure, it pre-empts the emergence of certain rail-surface defects.

Corrective grinding is designed to remove rail defects that have already developed (corrugation, head-checking, ballast marks, etc.) by reprofiling the rail to optimise wheel/rail contact.

2.3 - Economic assessment

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

Point 3 - page 7 deals with the various aspects of the economic assessment.

3 - 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.

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

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

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

3.1 - Technical criteria

The diagram in Appendix A - page 9 indicates in which circumstances it is recommended to use normal and hard steel grades.

Steel grades 200 and 220 do not figure in the diagram as they are hardly used anymore for new rails, although they are still widely found in track.

The ranges for use of the various steel grades indicated in the diagram are based solely on two parameters: **curve radius** and **actual tonnage carried**. There is also an overlap zone in the diagram, where the choice of steel grade will depend on the other local criteria listed in point 2 - page 4.

The recommendations made in Appendix A are in line with the current practices of railways running mixed passenger and freight traffic with a maximum axleload of 22,5 tonnes on conventional lines.

The lower limit in the diagram (i.e. the limit hard rails/normal or hard rails) can be shifted to the right in the case of **heavy trains with 25-tonne or heavier axleloads**, rendering the use of hard steel more frequent.

Priority is given to normal steel grade for **high-speed traffic**.

Given the substantial loads and small radii encountered, hard steel is frequently used for **suburban traffic**, in line with the general rules set out in the diagram in Appendix A.

In the case of **steep rising and falling gradients, cant deficiency, excess cant** and **aggressive rolling stock**, the lower limit in the diagram (i.e. the limit hard rails/normal or hard rails) can be shifted to the right, rendering the use of hard steel more frequent.

3.2 - Economic criteria

The most appropriate steel grade must be based on economic study.

As an example, one possible method is illustrated here below.

$$P = \frac{C}{n} + M$$

P = mean 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 mean annual maintenance cost is $M + \Delta M$:

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

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 granted that the difference is minor compared to the investment and maintenance cost, the formula can be simplified by considering the maintenance cost equivalent.

The formula can therefore be simplified as follows:

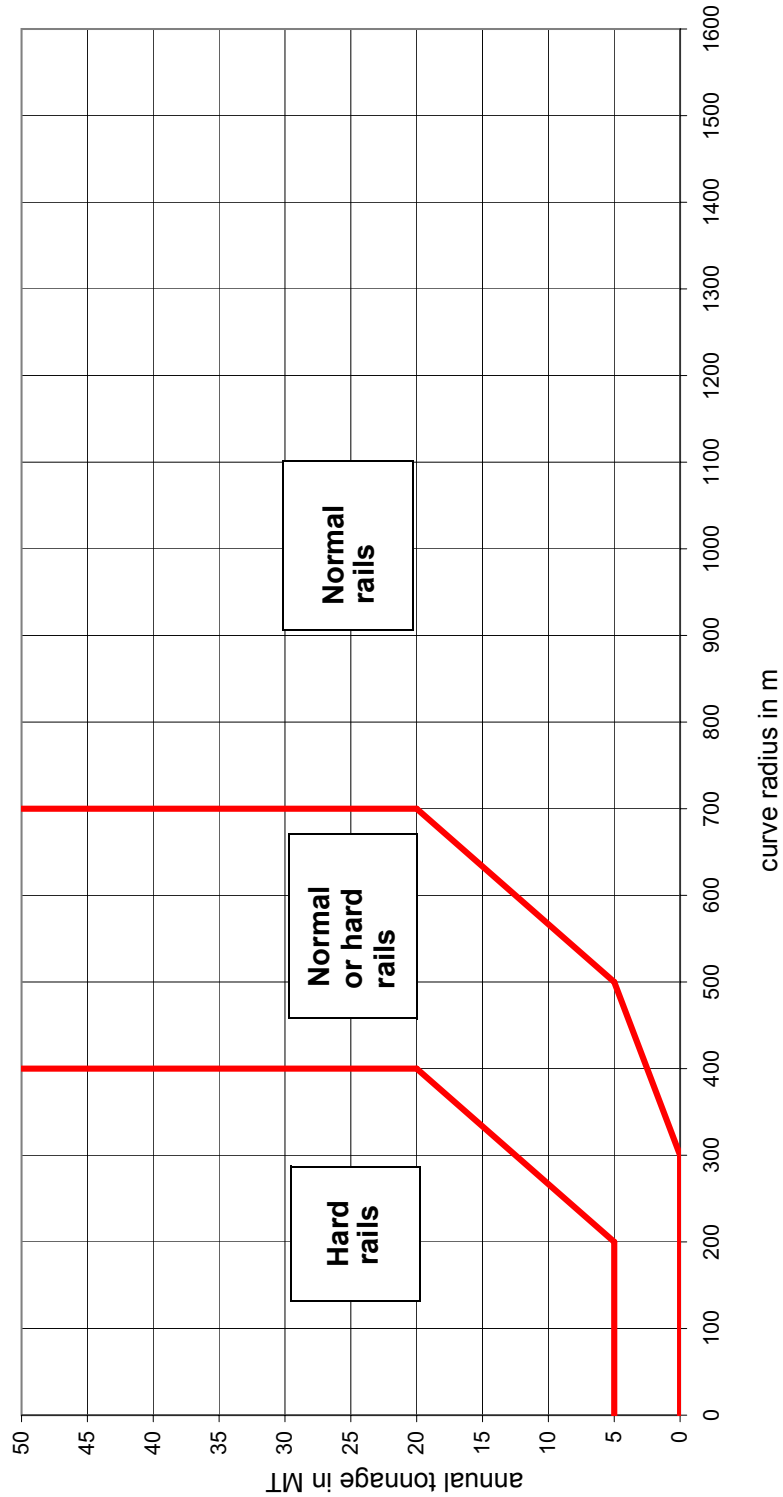
$$\begin{aligned}
 & P' < P \\
 \Rightarrow & \frac{C + \Delta C}{n + \Delta n} < \frac{C}{n} \\
 \Rightarrow & \Delta n > n \frac{\Delta C}{C}
 \end{aligned}$$

In practical terms, the percentage increase in the service life must be greater than the additional investment cost.

An example of application of this principle is given in Appendix B - page 10.

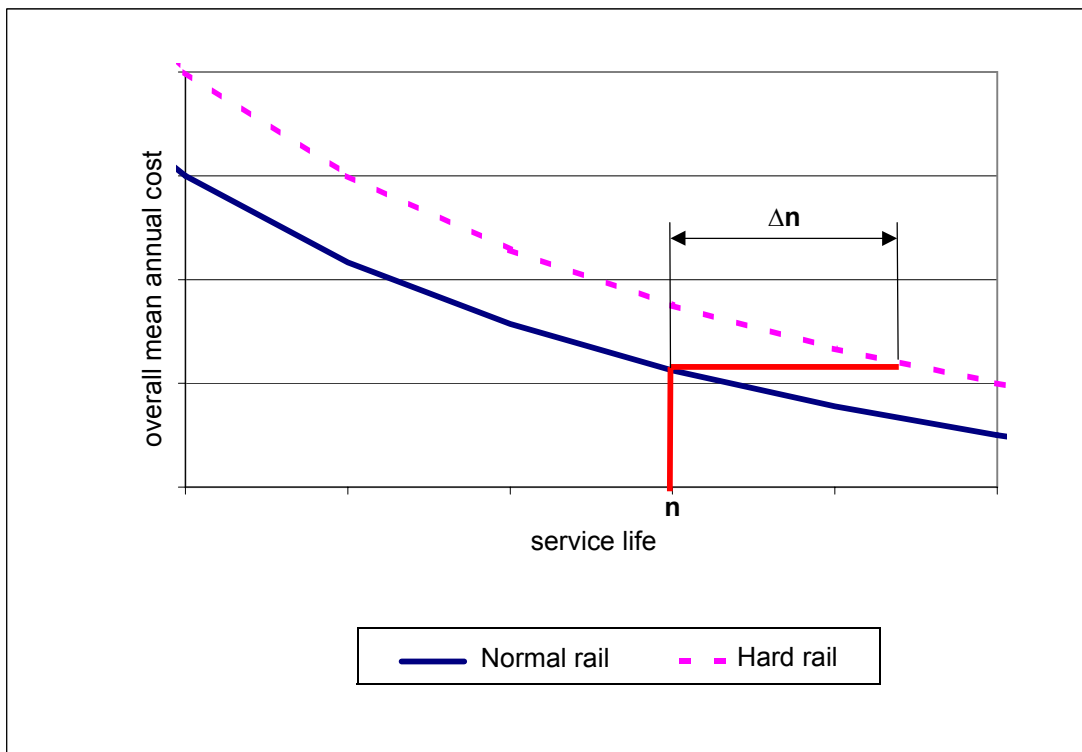
Application of these economic criteria is only valid if traffic conditions remain the same throughout the period in question.

Appendix A - Recommendations for use of normal and hard steel grade rails



Normal rails: 260, 260 Mn
 Hard rails: 350 HT, 350 LHT, 320 Cr

Appendix B - Example of an economic calculation



Example:

Normal rails reach a working life of n years at their renewal time.

Replacement of these normal rails with hard rails is only justified if the gain in service life for hard rails compared to normal rails is superior to Δn years ($\Delta n = n \Delta C/C$).

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