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Translation

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Treatment of rail defects

Traitement des défauts de rail
Schienenfehlerbehandlung

UNION INTERNATIONALE DES CHEMINS DE FER
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Contents

Summary

The objective of this leaflet is to supplement the information in *UIC Leaflet 712* by giving recommendations regarding the maintenance of rails (monitoring and elimination of defects).

The document contains three chapters:

1: Key inspection factors

2: Defect classification and action to be taken

3: Detection methods.

and three Appendices

- Examples of research results on crack growth rates
- Defect management
- Qualification of operators and approval of inspection equipment.

This document takes account of recent experience acquired by railways on the how these problems develop and the measures to be applied to rail defects caused by contact rolling fatigue which is an increasingly common phenomenon.

This document is limited to describing the principles of monitoring and eliminating rail defects which may result in rail cracks and breakages.

1 - Key inspection factors

1.1 - Simple laws concerning crack growth

Defect crack growth can be expressed as an increase in defect size per accumulated gross ton traffic load (million gross tons - MGT). Defect size can be denominated in mm or percentage of cross section of rail head. Crack growth depends on many factors where the most important are:

- static axle loads,
- dynamic wheel loads,
- rolling stock running characteristic (traction, brakes, etc),
- rail section,
- rail steel,
- defect type,
- temperature differential (rail temperature - stress free temperature),
- residual rail stress,
- rail head wear,
- track geometry.
- track stiffness.

As a part of the "UIC/WEC Joint research project on Rail Defect Management", a sensitivity analysis was performed to demonstrate how different traffic and track conditions affect crack growth rate (see Fig. 2 - page 3). Fig. 1 shows the result of the analysis.

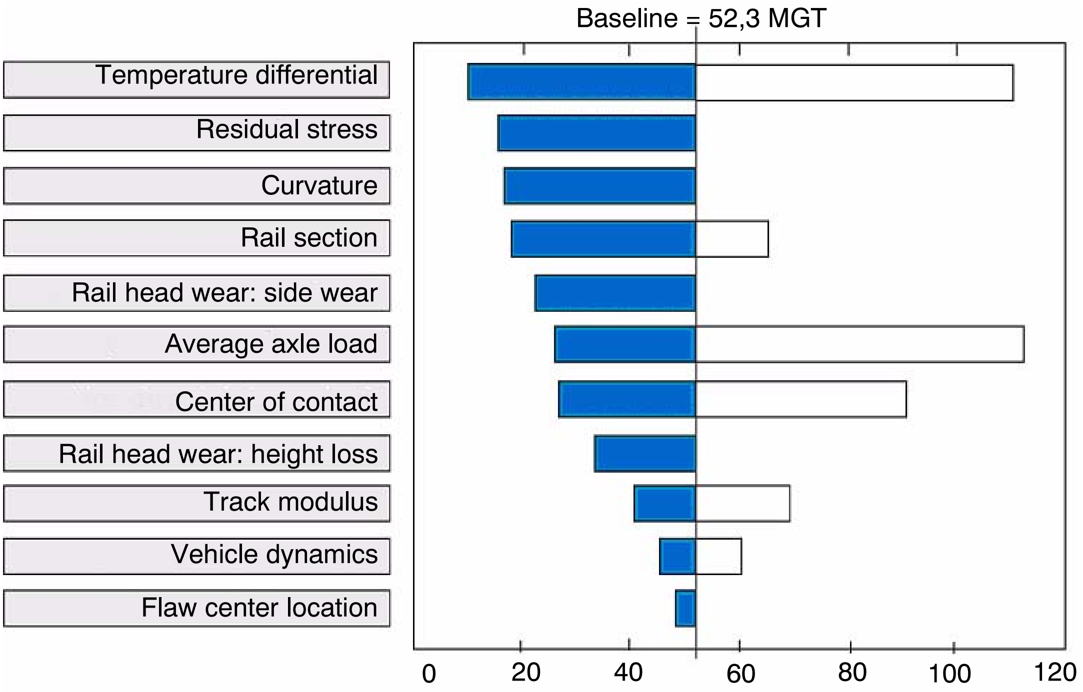


Fig. 1 - Influence of various factors on crack growth rate (variation of the P-F interval)

The various factors are ranked according to the impact the crack growth caused has on rail life span (million gross tons).

A crack will have a certain detectable size (P - potential). This depends on the detection technique used. From this size the propagation of the crack can be followed until it reaches the critical size where a rail break can be expected (F- failure). The time or traffic load between these sizes can be used to define the P-F interval.

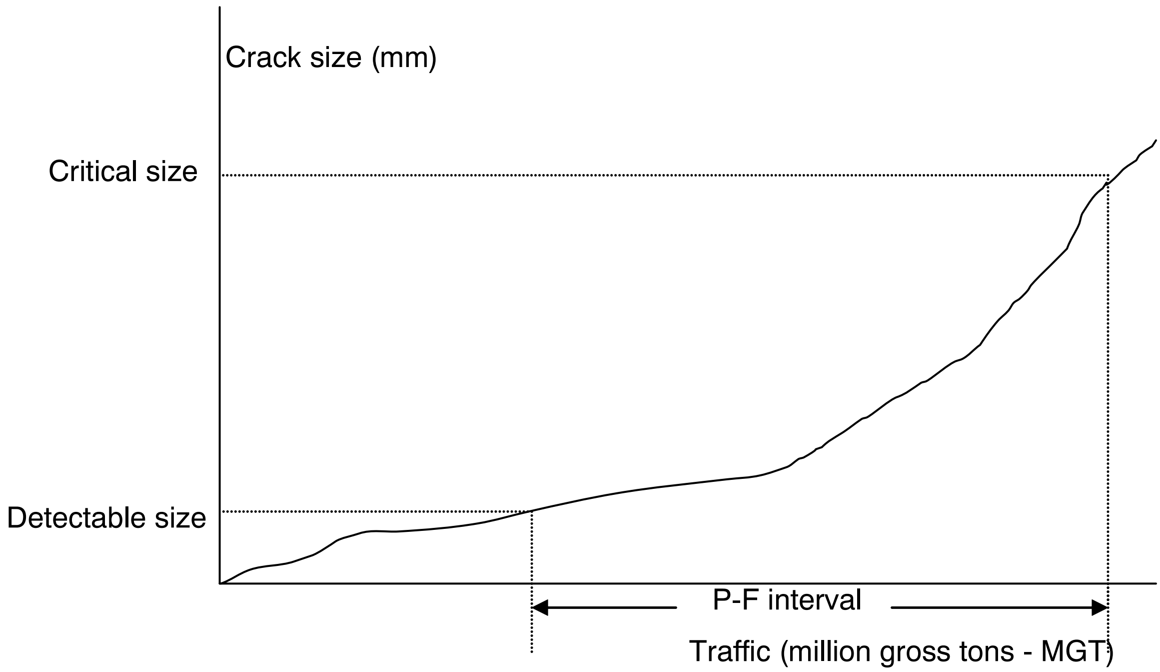


Fig. 2 - Definition of the P-F interval

For all type of defects, crack growth rates can vary considerably. However simple crack growth models can be produced for transversal defects in the rail head area (see Appendix A - page 21).

1.2 - Key parameters for planning of inspection cycles

Minimum requirements

- Track class:
  Derived from national rules, normally based on traffic load and/or speed.

- Traffic load:
  May be the real traffic load or an equivalent traffic load, for example based on the UIC groups.

Recommended requirements

In addition to the minimum requirements, the following conditions are to be taken into account:

- Line criticity
  Criticity is defined as the product of the frequency of incident and incident gravity, both in terms of safety and traffic punctuality, for example, accidents in tunnels, on bridges, etc. This factor can be calculated based on an analysis of rail breakage statistics.
  The criticity of a line may also be defined according to traffic flow. For example, the risk of traffic disruption on a single track line used by a high number of trains is higher than on a double track line where a change of track is possible.

- Special areas
  These are areas where experience has shown the risk of defects occurring is high and which must be subject to a shorter inspection cycle, with specialised methods to be applied in some cases for detecting specific defects:

  - Rails susceptible to production related defects or which have been manufactured using old production techniques (ingot casting, high levels of impurities, inappropriate NDT final production control);

  - Environmental consequences caused by the presence of salt and other chemicals which, in conjunction with electrical currents, can lead to rail corrosion. Such areas are to be monitored using appropriate methods and inspection cycles (e.g. tunnels, level crossings);

  - Tracks which are susceptible to rolling contact fatigue defects;

  - Machined rail components such as switches, crossings and rail ends on fish-plated tracks.

- Combined maintenance activities
  When various maintenance activities are to be carried out in the same area at the same time on a section of track closed to traffic for this purpose, a preliminary inspection campaign shall be carried out to detect as many rail defects as possible to be corrected during this combined maintenance period.

Use of state of the art technology

Monitoring the development of rail defects (risk based rail management).

The evaluation of the data gathered from previous inspections will indicate tendencies for the number and growth of rail defects. These tendencies can be used to define the optimum inspection cycle using a pre-defined risk analysis based on the characteristics of the track.

The inspection interval can be adjusted according to whether there is an increase or decrease in the defect rate.

1.3 - Rail inspection cycles

1.3.1 - Overview

Rail inspection is a vital component in rail maintenance. It is a way of ensuring an acceptable security level for traffic and a viable maintenance level for rail and the underlying track.

Every infrastructure manager has its own defect management policy, which makes it impossible to recommend specific inspection cycles. For this reason the present leaflet merely indicates factors to be taken into consideration when planning inspection cycles. It is the responsibility of the infrastructure manager to adapt these factors according to its own requirements.

The periodicity of the inspection cycles based on the key parameters defined in point 1.2 - page 3 may be adjusted according to local climatic conditions.

Ultrasonic inspections are problematic in very cold conditions. In addition, it is difficult to achieve a good welding quality at very low rail temperatures.

1.3.2 - Planning of inspection cycles

The planning of rail ultrasound inspections is a complex issue on account of the high number of variables and consequences.

Inspection cycles are traditionally organised at fixed intervals according to track class. While this is a simple planning method, it nevertheless results in unnecessary inspections being carried out in some cases and too few in others.

With the development of planning and IT tools it is now possible to use more sophisticated methods which make efficient use of inspection resources. This calls for consistent collection and management of track data (see Appendix B - page 23).

For some rail production methods, replacement of the rail may be more effective than monitoring until defects appear (for example defect 213 - *UIC Leaflet 712*).

2 - Defect types and minimum measures to be taken

2.1 - Defect types

Efficient rail defect management is dependent on the defects being classified into a small number of defect types.

Defect type is defined by the potential detection methods, growth rate and risk of breakage in relation to size.

Rail defects can therefore be divided into 6 categories.

2.1.1 - Transversal cracks

Related to the following UIC codes (*UIC Leaflet 712* - see Bibliography - page 27):

111	211	411
		421
		431
		471

In case of train passage, an oscillating stress will be exerted on the rail defect, which could lead to fatigue growth of the defect.

Low temperatures and their resulting thermal stresses will reduce the critical size for this defect - rail breakages therefore occur more frequently in the winter.

The crack grows exponentially causing a reduction of the rail cross-section and consequently reducing the rail strength considerably.

The size of the defect can be given in mm or as a percentage of the rail head surface.

2.1.2 - Longitudinal horizontal cracks

Related to the following UIC codes:

112	212	412
1321	2321	422
1322	2322	432
	239	472

Longitudinal horizontal cracks can occur in the rail head or web, or in the transition area between the rail head and web or rail web and base. These cracks are progressing longitudinally in the rail parallel to the longitudinal rail axis. The cracks may propagate upwards or downwards before breakage occurs.

Longitudinal horizontal cracks on the rail can have serious consequences in case of rail breakage since loss of wheel guidance may result. Longitudinal cracks can occur over long sections and thereby result in several breakages. In case of high residual stresses, these cracks can spread into the rail web area relatively quickly.

Longitudinal horizontal cracks can be caused by micro-cracks on rail ends. Thermal cuts without preheating increase the risk of crack formation.

This defect may be caused by internal segregation linked to the manufacture of materials. It may also be caused by defects in welded joints in the web area.

Longitudinal cracks in head - web area can start as fatigue cracks in the highly stressed area between the head and web. These cracks are common in jointed tracks.

Fig. 3 - Typical example of a horizontal crack on an aluminothermic weld

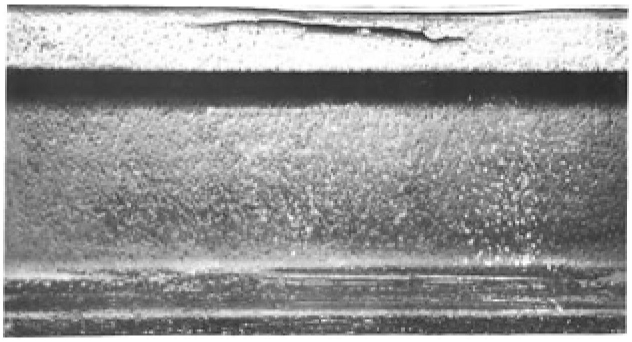


Fig. 4 - Typical example of a horizontal crack in the rail head

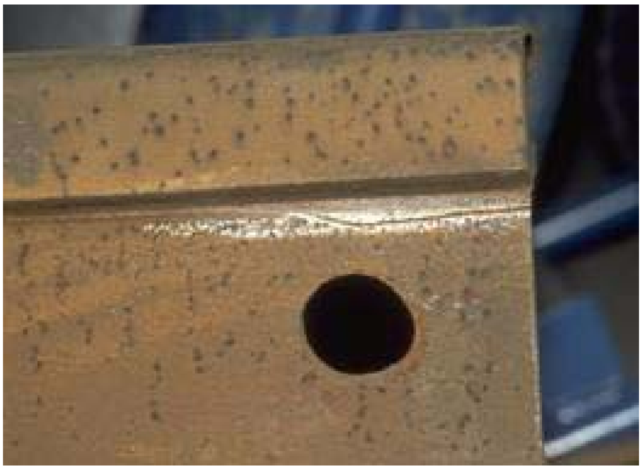


Fig. 5 - Typical example of a horizontal crack on a rail end

2.1.3 - Longitudinal vertical cracks

Related to the following UIC codes:

113	213
133	233
153	253

This defect type is mainly attributed to production problems in relation to metallurgy or rolling.

Old production methods such as the Thomas process and ingot casting, generate a higher concentration of phosphor, sulphur, nitrogen, manganese and hydrogen in the rail's vertical plane of symmetry. The presence of inclusions can lead to steel splitting. Modern rail production methods have virtually excluded this type of defect. Difficulty in detection and the possibility of rail head breakage over a long distance (meters) makes this type of defect one of the most dangerous with a high risk of derailment.

The development of this defect type can be divided into two stages:

- Stage 1
  The crack starts growing along the affected rail and can get very long (there have been reports of cracks up to 120 m in length).
  At this stage a specific detection procedure is necessary for NDT (see point 3 - page 16 for more detailed information).
  The crack grows in height as traffic loads increase and eventually reaches the rail web (in case of 113 and 213) and the running surface.

- Stage 2
  The crack reaches the surface, becomes visible and then starts to open (in case of 213 railhead widening), and the rail loses strength and integrity.
  At this stage the defect can be detected visually or using ultrasound inspections. Rail head widening can also be measured (monitoring of the variation of rail head width).

Fig. 6 - Typical example of a longitudinal vertical crack at stage 2.
At this stage, the crack can be detected easily by ultrasound.

The growth of this defect type is related to the compression stresses and wheel impact on the rail, in other words axle load, speed and traffic type combined with the wear of the upper surface of the rail and steel quality.

During stage 1 the defect has a very low growth rate, developing over decades, whereas stage 2 is faster and can become dangerous within a short period of time.

Fig. 7 -

Fig. 8 -

Examples of longitudinal vertical cracks giving a clear indication of their length

2.1.4 - Head-checking

Related to the following UIC code: 2223

Head checking is a rolling contact fatigue phenomenon and occurs mainly on the high rail in curves with high shear stresses and relatively low wear. It is a growing concern for infrastructure managers and difficult to detect in the early stages.

The defect starts directly under the surface (less than 1/10 mm), develops immediately and reaches the surface very quickly. Under traffic loads, these cracks may turn downwards with a risk of multiple breakages.

It is relatively difficult to predict the development of this kind of defect.

Preventive rail treatment (grinding, milling, planing) on sections with a tendency to develop rolling contact fatigue defects is usually recommended to preventively correct this type of defect.

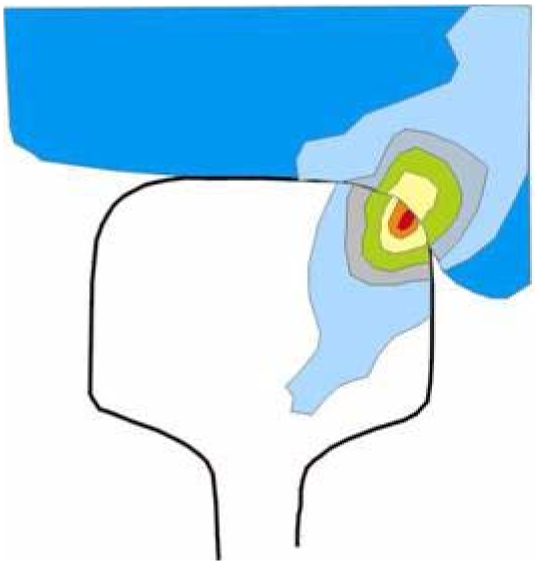


Fig. 9 - Head-checking emergence zone

Fig. 10 - Typical example of head-checking on the high rail of a curve

2.1.5 - Squats

Related to the following UIC code: 227

Squats are a rolling contact fatigue phenomenon which occur mainly on straight lines with high shear stresses, especially zones where accelerations and braking occurs. Rolling stock with ABS and anti-spin devices are believed to worsen the situation.

The origin and development of squats is the same as for head-checking, but the critical defect size for squats is higher.

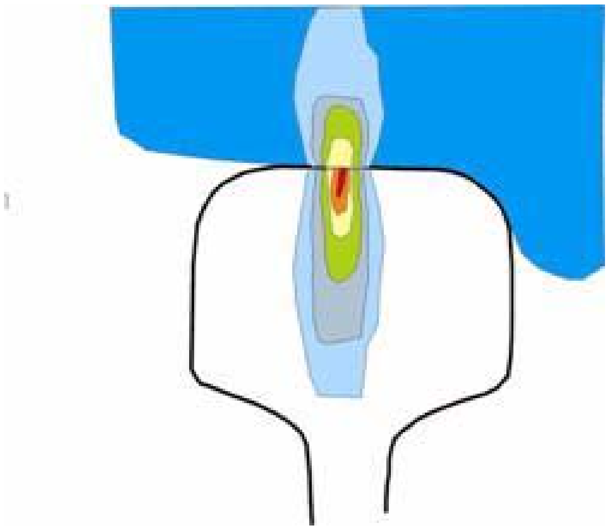


Fig. 11 - Squat emergence zone

Fig. 12 - Example of a breakage under a squat

Fig. 13 - Several squats often occur together

Fig. 14 - Typical V-shaped crack on the running surface

2.1.6 - Oblique cracks (mainly around bolt holes)

Related to the following UIC codes:

135	235
	236

Oblique cracks in fishplate chambers usually start at bolt holes due to lacking or inadequate chamfering. It is not possible to inspect this area visually without removing the fishplates.

Inspection of such joints using a measuring car poses some difficulties since contact (and back wall echo) in the case of low joints cannot always be guaranteed.

The defect growth rate varies with the dynamic loads exerted by wheels passing over the joint. Low joints generate high dynamic forces which lead to further track degeneration.

2.2 - Minimum measures to be applied according to defect category

This chapter sets out the minimum measures to be taken for each type of defect defined in point 2.1 - page 6 (transversal cracks, horizontal longitudinal cracks, vertical longitudinal cracks, head checking, squats and oblique cracks around bolt holes) and according to the size of the crack.

The minimum measures to be taken are subdivided into 4 categories characterised by the type of action to be taken and the deadline that should not be exceeded.

These 4 categories are based on the "Definitions and recommendations" in *UIC Leaflet 712* (see Bibliography - page 27) which are explained in more detail relating to the deadlines to be respected in particular.

Each defect type is allocated to a category of measures depending on the size of the defect in question.

Category 0: *Prohibition of traffic and immediate removal of the rail* Applies to defects which no longer permit, even with the application of exceptional and provisional measures, the normal operation of the track. This generally means a broken rail.

Category I: *Immediate removal of the rail* Applies to defects which could result in a rail breakage at any time. A maximum deadline of 2 weeks may be tolerated. Only in cases where safe conditions can be re-established (for example by reinforcing the rail with fishplates), can this deadline be extended to 6 weeks.

Category II: *Removal of the rail* Applies to defects that do not represent an immediate hazard for operation but could develop into a potential hazard after the date of removal. These defects are to be repaired within a time limit not exceeding 12 months. Only in cases where safe conditions can be re-established (for example by reinforcing the rail with fishplates), can defects of this type remain in the track until an inspection carried out as part of a regular inspection cycle places the defect in a higher category.

Category III: *Keep rail under inspection* Applicable in case of defects that do not, at this stage, represent a hazard for operation. These defects do not require repair but should be recorded and examined during the normal inspection cycles with the objective of monitoring their change.

These periods are to be considered as deadlines which may be adapted on consideration of the key parameters (see point 1.2 - page 3).

If any deadlines are exceeded, appropriate supervision is necessary (i.e. additional monitoring).

Some defects that can develop in a transversal rail breaks, may be secured by fishplates and can therefore remain in the track for longer. The types of defects that can be secured by fishplates are as follows: 211, 411, 421, 431, 471, 227, 2223, 2251.

In case of all other defects, the fitting of fishplates is not appropriate

Table 1 - page 14 defines the categorisation of defects based upon size. This is to be considered as guidelines which may be adapted on consideration of the key parameters (see point 1.2).

Table 1 : Category of measures depending on defect size

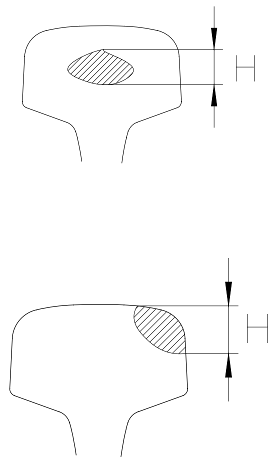
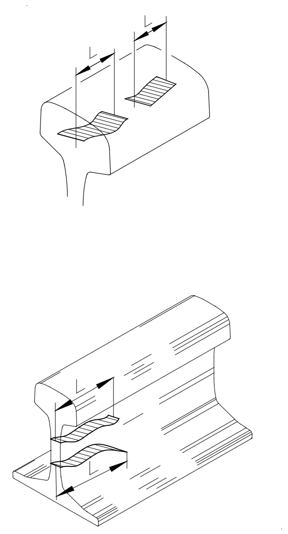
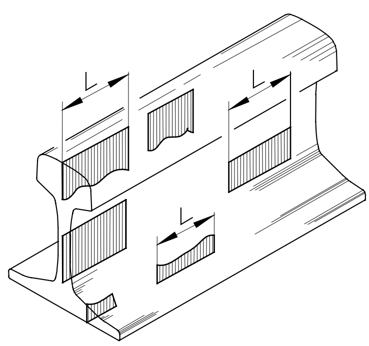
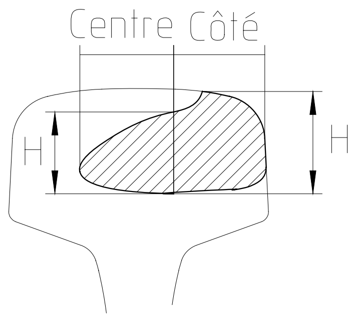
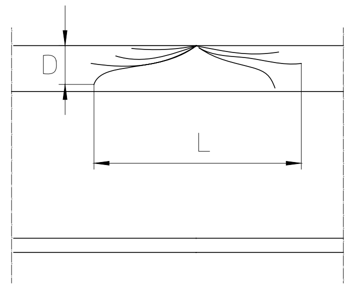
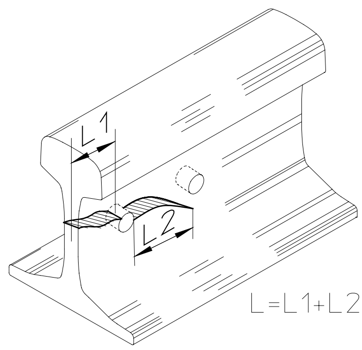
Defect types	Category I	Category II	Category III	
Transversal crack in rail head	H > 25 mm	10 mm < H ≤ 25 mm	H ≤ 10 mm	
Longitudinal horizontal crack	L > 200 mm	50 mm < L ≤ 200 mm	L ≤ 50 mm	
Longitudinal vertical crack	Visible	L > 50 mm not visible	L ≤ 50 mm	

Table 1 : Category of measures depending on defect size

Head-checking	Rail head center H > 5 mm, or Rail head side H > 20 mm	Rail head side 5 mm < H≤ 20 mm	Rail head side H ≤ 5 mm	
Squat	D > 25 mm or L > 200 mm	10 mm < D < 25 mm or 50 mm < L ≤ 200 mm	D < 10 mm or L ≤ 50 mm	
Bolthole cracks	L > 100 mm	40 mm < L ≤ 100 mm	L < 40 mm	

L = Defect length H = Defect height D = Defect depth

Important note:

Defect categorisation and correction deadlines are generally defined with reference to an individual defect on a fixed rail. In the following cases a more strict categorisation is necessary:

- Several defects within a small distance of each other can lead to multiple breaks; a combination of different defect types can result in a quicker growth rate and/or a greater risk of complex/long breakage;

- Rail defects which occur on rail ends or on non-fixed rail sections are more dangerous in case of a potential breakage.

3 - Detection methods

3.1 - Overview

There is no single, universally applicable inspection method - all have advantages and disadvantages. It is therefore recommended that inspection systems be combined or alternated in order to ensure that certain defect types do not remain undetected.

Examples of detection methods include:

- specific visual inspection of rails (may be the only way of detecting certain defects);
- track machine detection;
- manual inspection ("Walking Stick");
- manual inspection with semi-automatic equipment (e.g. for rail height measurement).

While automated measuring cars are well suited to detecting rail defects, this process must be followed by a manual inspection for a more precise identification of the defect type.

The following requirements are to be fulfilled:

- Localisation of the defect: using spray paints, by indicating the distance in kilometres from fixed points on the track (components and/or milestones) or by GPS.
  In order to ensure traceability and future defect monitoring, the location of the defect must be identified to within 1 meter following manual inspection.
- Detection errors: defects registered by the automatic detection system which however do not exist in reality or are smaller than the minimum size defined by the infrastructure manager.
  Detection error rates must remain below 30 % to ensure efficient use of resources and satisfactory quality levels.
- Undetected defects:
  the measuring system may fail to detect defects for numerous reasons:
  - loss of back wall echo,
  - poor calibration,
  - the position of the defect in relation to the transducers.

  This problem can be minimised by the following procedures:
  - suitable calibration methods (see Appendix C - page 24);
  - inspection of some track sections to check the consistency of the data produced by the measuring cars;
  - alternate use of different measuring systems (use of other measuring cars or manual measuring-SPG, "Walking Stick", etc.).

3.2 - Recommendations on detection methods

The detection of defects consists of discovering the defects likely to affect the rails using suitable methods. The methods implemented depend on the possibilities available to and the particular difficulties of each railway.

In the context of the development of rail monitoring techniques, the following inspection methods are now used in particular:

- **Visual inspection:** this inspection can be improved by dye penetration crack detection methods.
- **Ultrasonic inspection:** either using an inspection vehicle or manual examination
- **Other inspections:** these methods can largely be applied as part of regular inspections such as:
  - eddy current inspection,
  - track geometry inspection,
  - video camera inspection and measurement of rail profile, etc.

The efficiency of these inspection methods for detecting a given defect can be graded at one of the four levels: :

- **A : The majority of defects are detected:** indicates that a defect as defined in *UIC Leaflet 712* can be identified in most cases with the appropriate detection method.

- **B : Detection of these defects possible:** indicates that the defect may potentially be detected with the appropriate detection method.

- **C : Detection of these defects rare:** indicates that these defects are only detected occasionally.

- **D : Unsuitable detection method:** this method is unsuitable or does not enable detection of the defect type in question.

UIC Leaflet 712 defect code	Detection method			
	Visual	Ultrasonic inspection		
		Vehicle/ machine	manual	Others
111	C	B	A	Visual check depending on the size of the defects
112	B	AB	A	No other methods
113	B	BC[a]	AB	Measurement of the variation of the width of the rail head
121	A	C	BC	Optical system by camera
122	A	C	BC	Optical system by camera
123	A	D	D	Measurement of the rail profile
124	A	D	D	Measurement of the rail profile
125	A	D	C	Optical system by camera
127	A	C	B	No other methods
1321	C	B	A	Visual inspection after removal of fishplates; test with hammer
1322	C	B	A	Visual inspection after removal of fishplates; test with hammer
133	C	C	B	Visual inspection after removal of fishplates
134	A	D	D	After visual detection, evaluation by ultrasonic testing
135	C	B	A	Visual inspection without fishplates; test with hammer
139	B	C	C	No other methods
153	D	C	BC[b]	No other methods
154	A	C	C	After visual detection, evaluation by ultrasonic testing
211	C	A	A	Visual check depending on the size of the defects
212	C	A	A	Track geometry check
213	C	BC[a]	AB	Measurement of the variation of the width of the rail head
2201	A	D	D	Track geometry check, optical system by camera
2202	A	D	D	Track geometry check, optical system by camera

UIC Leaflet 712 defect code	Detection method			
	Visual	Ultrasonic inspection		
		Vehicle/ machine	manual	Others
2203	**A**	**D**	**D**	Track geometry and rail profile check
2204	**A**	**D**	**D**	Measurement of rail profile
221	**A**	**C**	**BC**	Track geometry check, optical system by camera
2221	**A**	**C**	**BC**	Track geometry check, optical system by camera
2222	**A**	**C**	**BC**	Manual check in specific situations
2223	**A**	**BC**	**BC**	Manual, optical system or eddy current
223	**A**	**D**	**D**	Measurement of rail profile, track geometry check
224	**A**	**D**	**D**	Measurement of rail profile
2251	**A**	**D**	**C**	Track geometry check, optical system by camera
2252	**A**	**D**	**C**	Track geometry check, optical system by camera
227	**A**	**A**	**A**	Manual check by ultrasonic testing, optical system by camera
2321	**C**	**A**	**A**	No other methods
2322	**C**	**A**	**A**	No other methods
233	**C**	**C**	**B**	No other methods
234	**A**	**D**	**D**	After visual detection, evaluation by ultrasonic testing
235	**B**	**A**	**A**	No other methods
236	**B**	**A**	**A**	No other methods
239	**B**	**C**	**C**	No other methods
253	**D**	**C**	**BC**[b]	No other methods
254	**A**	**C**	**C**	After visual detection, evaluation by ultrasonic testing
301	**A**	**D**	**D**	Track geometry check, optical system by camera
302	**A**	**D**	**D**	Optical system by camera
303	**A**	**D**	**D**	Track geometry check
411	**C**	**A**	**A**	No other methods

UIC Leaflet 712 defect code	Detection method			
	Visual	Ultrasonic inspection		
		Vehicle/ machine	manual	Others
412	B	A	A	No other methods
421	C	B	A	Manual inspection by ultrasonic testing
422	B	A	A	No other methods
431	C	A	A	No other methods
432	B	A	A	No other methods
471	C	A	A	No other methods
472	B	C	B	Track geometry check
481	A	B	B	No other methods

a. This defect requires specific ultrasonic inspection. The inspection is carried out either at points on the side of the rail head with a 0° probe, or continuously with transverse ultrasonic inspection at 55°, bearing in mind that the latter method can prove problematic if there is a high level of rail wear.

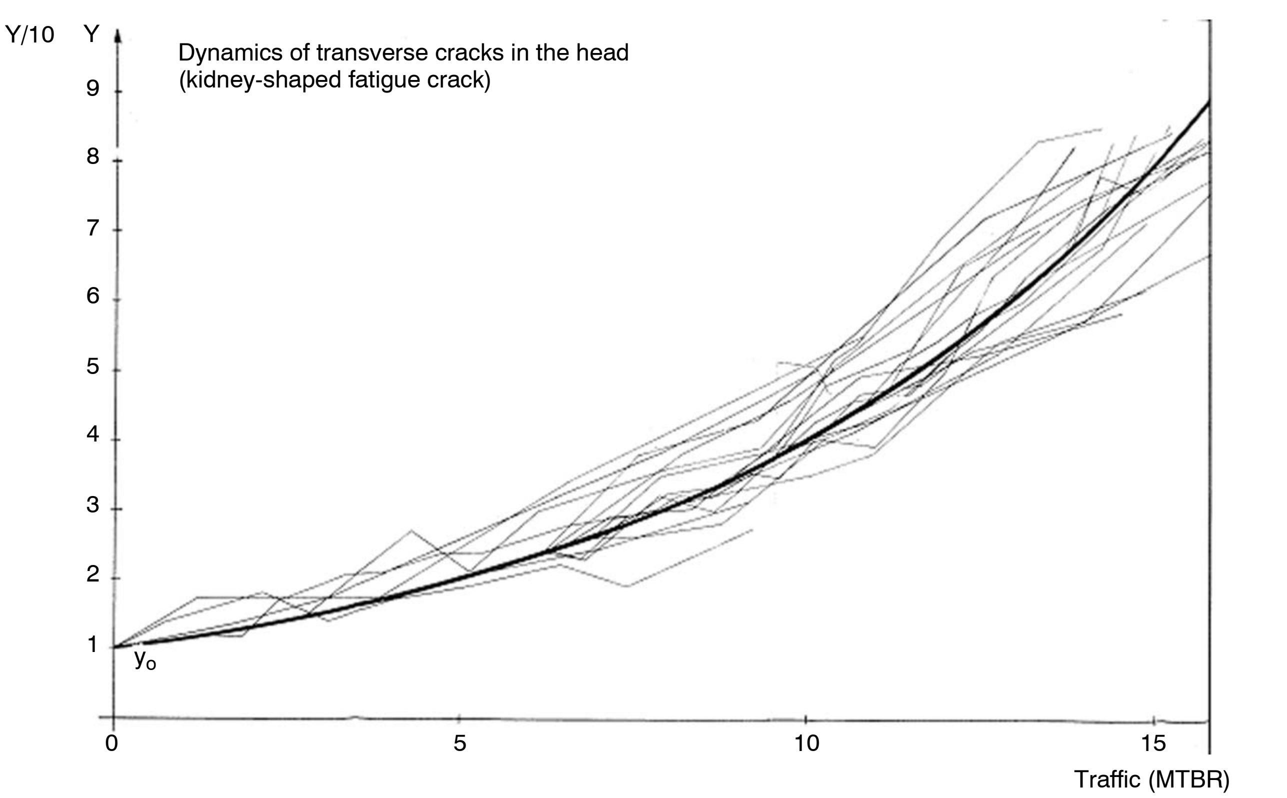
b. It is possible to check for these defects manually with a handset from the upper side of the foot.

Appendix A - Examples of research results on crack growth rates

An *ORE Report D88* (see Bibliography - page 27 and List of abbreviations - page 26) based on a French/German survey suggests the following empirical formula for determining the growth of transversal rail defects:

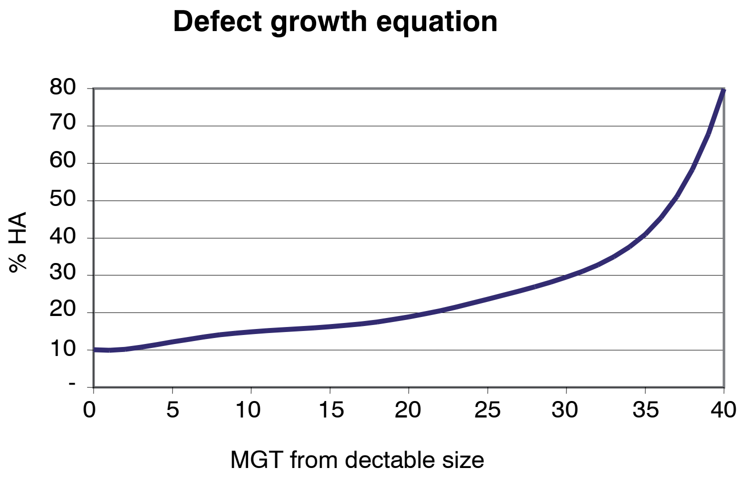
$Y = (2^{x/5}) \cdot 10$ where

Y = crack size as a percentage of rail head area
X = accumulated traffic load [million gross tons]



This survey is based on rails made using the Thomas/Martin process. For modern rails made from vacuum treated oxygen steel, a slower growth rate can be expected.

American studies carried out over the last 20 years suggest that transversal rail cracks will grow from a detectable size to a critical size of 80 % of head area within a range of between 10 to 50 MGT accumulated traffic loads. The figure below shows a model based on an accumulated traffic load of 40 MGT between the detectable (P threshold) and critical (F threshold) defect size.



Appendix B - Defect management

The handling of rail defects is often referred to as rail defect management. A key element in defect management is the definition of a rail test schedule. Traditionally, rail testing has been performed at fixed time intervals. However, this method does not always result in the optimum system in respect of cost and safety.

Different models can be used to find the optimum test interval based on the local track and traffic conditions. Some models are based on a defined risk level. The risk level is here often defined as the number of permitted rail breaks/track length unit over a given period of time. Other models use cost/benefit analyses which aim to find the test schedule which gives the most economically viable solution taking account of rail defects and including testing, repair and derailments.

Defect management models require certain input parameters:

- historical rail breaks per time unit (e.g. breaks per year),
- historical in service rail defects per time unit,
- profile, steel and age of rail,
- maximum allowed defect size,
- safe time between detectable and critical defect size,
- detection reliability,
- traffic data.

In case of a model based on a risk level, the infrastructure manager must define the acceptable risk level in terms of number of rail breaks per track length unit over a given period.

In case of a cost/benefit model, the infrastructure manager must define the following parameters:

- rail testing costs,
- costs for repairing rail breaks,
- costs for traffic interruptions caused by rail breaks,
- costs for repairing in service rail defects,
- costs related to a derailment caused by a rail break,
- probability of having a derailment caused by a rail break.

Appendix C - Qualification of operators and approval of inspection equipment

C.1 - Qualification of non-destructive testing (NDT) personnel

C.1.1 - Qualification of personnel carrying out manual ultrasonic inspections and inspections with ultrasonic test vehicles

Qualification according to *EN 473* or *ASNT SNT-TC-1A* (see Bibliography - page 27 and List of abbreviations - page 26), minimum level 1.

Additional training/examination for particular needs if required by infrastructure managers (IM).

C.1.2 - Qualification of personnel responsible for the classification and detection of defects using ultrasonic testing vehicles

Qualification according to *EN 473* or *ASNT SNT-TC-1A*, minimum level 1.

Additional training/examination for particular needs if required by IM.

C.1.3 - Qualification of personnel carrying out eddy current inspections (manual testing, testing with cars and vehicles)

Qualification according to *EN 473* or *ASNT SNT-TC-1A*, minimum level 1.

Additional training/examination if required by IM.

C.1.4 - Qualification of personnel responsible for magnetic particle inspection, visual inspection and dye penetration procedures

Qualification according to *EN 473* or *ASNT SNT-TC-1A*, minimum level 1.

Training/examination according to requirements specified by IM.

C.2 - Periodical approval of ultrasonic vehicles

Inspection vehicles fitted with calibrated equipment are tested on a test track with known natural or artificial rail defects. The tests are carried out at the normal inspection speed. A sufficient number of repetitions are to be performed at the instruction of the infrastructure manager.

An ultrasonic vehicle may be approved for a limited time or for a measurement campaign if:

- the equipment meets the requirements set by the infrastructure manager,
- the calibration procedure/the daily calibration monitoring process is approved by the infrastructure manager,
- a defined percentage of the natural or artificial rail defects are detected during the track tests.

In addition, the calibration is to be checked on a regular basis by the test vehicle operator.

List of abbreviations

ASNT: the American Society for Non-destructive Testing Inc.
(Association américaine pour les essais non destructifs)

ORE: Office for Research and Experiments, became ERRI, then in July 2004 was attached to UIC

Bibliography

1. UIC leaflets

International Union of Railways (UIC)
UIC Leaflet 712: Rail defects, 4th edition, January 2002

2. ERRI reports

International Union of Railways (UIC)
ORE D 88: Study of rail faults in the track, RP1, RP2 and RP3, published in 1965

3. European standards

European Committee for Standardization (CEN)
EN 473: Non-destructive testing - Qualification and certification of NDT personnel - General principles, December 2006

4. Miscellaneous

The American Society for Nondestructive Testing (ASNT)
Recommended Practice No SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing - This document provides guidelines for employers to establish in-house certification programs for the qualification and certification of nondestructive testing personnel, current version February 2007

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