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RAIL INSPECTION OF RCF DEFECTS

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Rail defects due to rolling contact fatigue (RCF) threaten the traffic safety around the world. That hazard is more distinct on railways without adequate maintenance strategy. Realization of interoperability of European railway network demands from every infrastructure manager to have a maintenance plan for the infrastructure subsystem. Besides that, this plan includes rail inspection and strategy against RCF defects. This paper emphasizes the importance of rail inspection and early detection of RCF because the most of RCF crack should be removed in rail grinding campaigns (preventive, cyclical and corrective activities) during the whole rail service life.

Key words: rail, rail defects, rolling contact fatigue, inspection

INTRODUCTION

Total track length in the European Union is about 370 000 kilometers. For about 150 years, the steel rail has been a part of European railway infrastructure. In the ”infrastructure” subsystem [1], the rails operate in a harsh environment and have a little redundancy.

Rail wear, rolling contact fatigue and plastic flow are major contributors of rail deterioration depending on the operational conditions (traffic type, speed, axle load, traffic density, rail/wheel profile and material, characteristics of bogie, track design, maintenance policy, weather and environment, etc.) and lead to the surface or subsurface initiated cracks on the rail.

Managing the flows of process is an important part of logistics, dating back to the 600 BC, i.e. to the ancient times [2].

Rail break is the last phase of crack development process and might lead to catastrophic derailment. The consequences can include death, injury, costs and loss of public confidence. In addition, these events may have devastating and long-lasting effects on the industry. Mostly known traffic accident happened in Hatfield on October the 17 th 2001. Rail breakages appeared on 35 m of rail length with 300 critical rail breaks. After this disaster, EU began with intense safety inspections.

Furthermore, the rail inspection costs are estimated at about € 70 million per year in EU (assuming annual vehicle ultrasonic inspections followed by manual verification of detected defects) [3].

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The objectives of this research are phenomenon, experiences and rail inspection of defects due to rolling contact fatigue (RCF) [4-12]. Around the globe there are two main RCF types of rail defects: squats (defect type 227 [5]) and head checkings (HC - defect type 2223 [5]). The considerations in this paper are limited to these two main types of RCF defects.

The research of squats was conducted by visual inspection on the railway section Vrbnica – Bar (Montenegrin railways), during May and June 2012 [10].

The visual inspection of HC defects was conducted on the following sections: Belgrade Centre – New Belgrade (from km 0 + 700 to km 2 + 854) and Belgrade – Šid – state border (from km 4 + 446 to km 13 + 400), on Serbian railways [13].

The goal of this study was to define the optimal rail inspection strategy that should provide extension of rail service life, reduce overall rail maintenance costs and improve safety of railway traffic.

RAIL INSPECTION

The effectiveness of rail inspection depends on the efficiency and accuracy of the inspection method and the necessary equipments. It also depends on the knowledge, skill, ability and experience of inspectors. Furthermore, it depends on the real conditions for implementation (temperature, visibility, contamination etc.) and on traffic management during rail inspection.

False detections and undetected rail defects in inspection are an important issue and their reduction is a big challenge.

An optimal detection method for squats and head checkings should provide early detection of rail damage and reliable data about measured length, depth and spatial position of fissures in rail head. This kind of method for non-destructive testing of rail in track does not exist so far. In praxis, several detection methods are combined in order to increase possibility of early detection of the defect.

Professional literature [6] recommends the visual inspection, optical system by camera, ultrasonic testing by using vehicle, and manual check by ultrasonic testing.

Visual inspection

Rail network should be subject to a visual inspection twice a year (every six months), with the help of photographs and video images. This method takes a huge number of man-hours and includes the subjectivity. It is recommended for sections with 50 m length, which are classified with respect to the maximum crack length (Figure 1). Information about RCF defects, which were observed during the visual inspection, is entered in the form in accordance with [5] and saved in a database. The other necessary details and photos of RCF defect are attached to the form (Figure 2).

By inspection of HC defects, special attention should be drawn to the outer rail in curves: usual in curves with radius R ≤ 3 000 m, and most often in curves with R ≤ 1 500 m. The HC defect shows as fine, short, raked, surface fissures at more or less regular distance (usually 1-7 mm but up to a few centimeters, depending on the rail steel quality). Surface fissures point out the fissures already exist below the surface, extending to certain depth and in certain direction inside the rail head. With increasing rail hardness, the spacing between the cracks is reduced [14]. Orientation of HC cracks is shown in Figure 1 [13]. It is especially dangerous when cracks spread at shallow angles of approximately 15 ° into the rail head and the cracks distance is reduced to 0,5 mm. In this case multiple rail fractures may occur, which always leads to train derailment. Besides that, rail switches, rail weld zones, expansion joints and sections with irregular track geometry should also be carefully visually investigated.

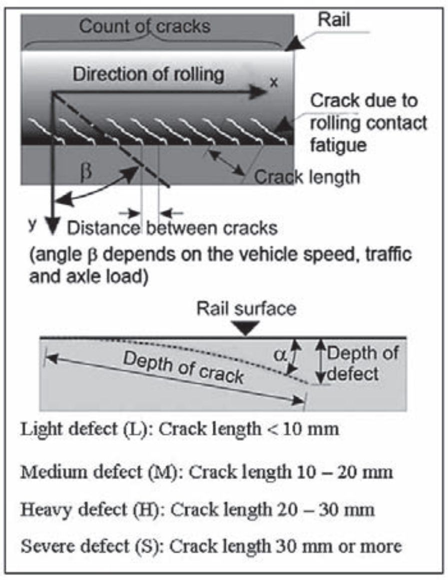

Figure 1 Classification of HC defects (visual inspection of HC defects on Serbian railways) [13]

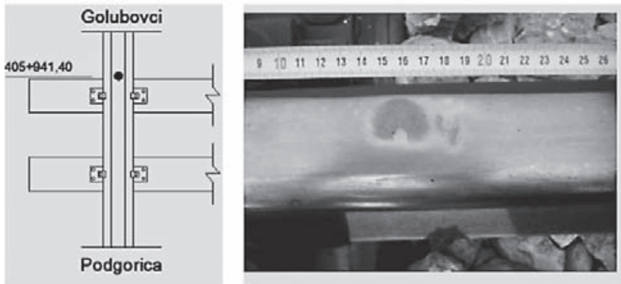

Figure 2 Defect squat (railway section Vrbnica - Bar, km 405 + 941,40)

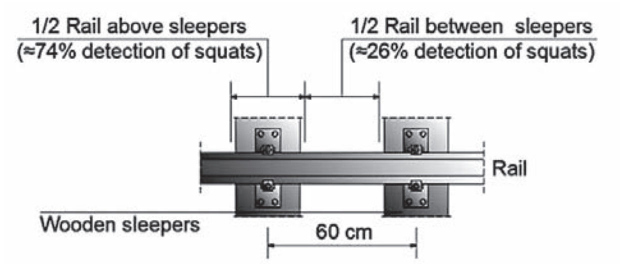

Figure 3 Squat locations on track by visual inspection on the railway section Vrbnica – Bar

Experiences of railway infrastructure managers show that squats can occur in straight track and large curves (radius 800 ÷ 1 600 m, mostly on the high rail). Also, they can occur in the transitions of sharp curves. There is the correlation of squat locations with the stiffness and damping characteristics of the track. Figure 3 shows the results of visual inspection on the railway section Vrbnica – Bar. During the visual inspection of this railway section [10], squats were often observed in corrugated zones on rail head and in the weld zones (about 10 ÷ 15 %).

Water appears to be essential to growth of squats. There is a notable lack of squats in tunnels (except where water is found).

By visual inspection it should be taken into account that moderate to severe squats can often be mistaken for wheelburn defects. Special attention should be drawn to the rails in main station tracks, in high-gradient tracks (about 10 ‰ and more), outer rail in curves, rails in switches, crossings, expansion joints and weld zones. Besides that, sections with irregular track geometry should also be carefully investigated.

Visual inspection is governed by weather conditions and by traffic management during rail inspection. Also, this method should be improved using the detection with fluorescent penetrates, especially under poor seeing conditions in tunnels, but the rail surface needs to be clean. Unfortunately, lubrication of the outer rail in curves and soiled rails can negatively influence a visual inspection. Also, it could cause misleading results of ultrasound (US) inspection, video inspection and eddy current (EC) inspection.

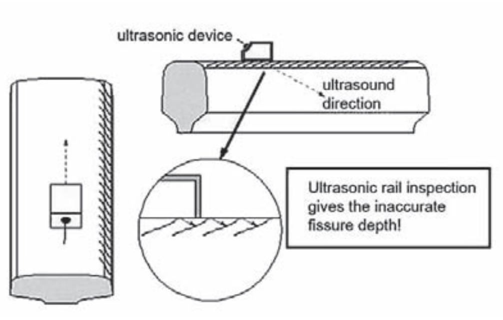

Figure 4 Unreliable measurement of HC depth using the US inspection [15]

Figure 6 Rail testing using EC device Phasec 2200 (NDT Laboratory JAT in Belgrade, 2012)

Ultrasound inspection

This method is not applicable for inspection of surface fissures at small distance and at small angle towards the upper rail head surface. Also, the method does not provide precise measures in the narrow zone of rail gauge corner. Combination of US and EC inspection improves probability of early detection of RCF defect. This is the way to discover the most, but not all RCF defects.

Figure 4 shows the condition when some of the deeper HC cracks are left undetected due to the limitation of the ultrasonic inspection method.

Eddy current inspection

The procedure of EC testing is based on the electromagnetic interaction between the magne- tic field of a test sensor and the currents induced in the metallic material. The EC field variations are caused by inhomogeneity of the rail steel surface and subsurface. These variations are used for sizing the crack depths (Figure 1).

The advantages of EC rail inspection are: early detection of the initial fissures, (depth 0,2 mm), detection of fissures below the rail head surface, portability of testing device, no use of consumable materials, instant reading of measuring results, possible integration of device in the recording cars and rail grinding trains. The vehicles are equipped with eight-channel devices for rail testing using the eddy current: four sensors on the left and four sensors on the right rail (Figure 5).

Depth of defect can be calculated indirectly by measuring the depth of crack and angle α of crack progression (Figure 1), or by installing the EC device in the rail grinding train. It is not possible to measure the angle α by using the EC method. Based on a long period of investigation, for calculation of HC defect depth, large range of angle values, from 15 ° ÷ 30 °, should be used. This is a serious disadvantage of EC inspection method, because depth of defect can only be measured indirectly [15]. The eddy current device, Phasec 2200, for manual testing (NDT Laboratory JAT in Belgrade, 2012) is shown in Figure 6. Standard sonde was used at operating frequency of 500 kHz.

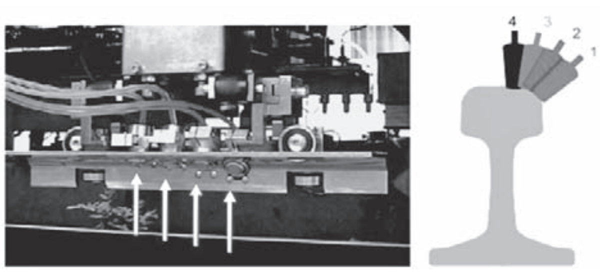

Figure 5 Inspection vehicle with eight-channel EC devices

DISCUSSIONS AND CONCLUSIONS

It is very difficult to predict the RCF crack development. It depends on several factors. Fortunately, some of the cracks are removed by wear process during initial stages of crack development. Not all cracks impose derailment risk, but they are the major contributors to rail degradation. However, the most of RCF cracks should be removed in grinding campaigns. Research and experience have shown that rail grinding has an important role in the reduce of rail degradation. Modern strategy of rail grinding includes preventive, corrective and cyclical activities. Besides that, in recent years, specially modified rail profiles in curves are widely used. Rail grinding can reduce rail brakes and early rail replacements. This can prevent derailments. Therefore early detection of RCF rail defects is extremely important.

Eddy current testing can detect any visible irregularities on the rail surface caused by steel changes. It is possible to prove the majority of the surface defects which have the influence on traffic safety. However, it is difficult to filter clearly the EC signal due to the effect of signal overlaps. It makes sense to combine the potential of a surface rail testing such as EC testing with a rail volume testing such as US testing. By combination of visual detection, US and EC methods, the quality and reliability of the information increase significantly.

In addition, the authors recommend visual inspection improvement by using video recordings. It is possible to create the software that will be able to recognize defect on rail head analyzing the video. The software should actually create a series of images from video, and then analyze each image for possible defect. In order to achieve this, software must include algorithm that can recognize defect pattern. When the pattern is recognized, station is calculated and linked with the image. Therefore, final software results are stations and images of possible rail defects. Afterwards, user can check the results and remove wrongly analyzed images. The proposed improvement of visual inspection is a part of an ongoing research project: "Research of technical-technological, staff and organisational capacity of Serbian Railways, from the viewpoint of current and future European Union requirements".

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Note: The responsible translator for English language is Marija Bratić, Pančevo, Serbia