DEFECTOSCOPIC DEFECTS RAILS FOR RAILWAYS AND PURPOSE CRACK DETECTION

Eva BREZOVÁ[1*]

[1] *Ing. Eva Brezová, Alexander Dubček University of Trenčín, Faculty of Special Technology, Pri Parku 19, 91106 Trenčín, Slovakia*

**Corresponding author E-mail address: eva.brezova@tnuni.sk*

Abstract

Rail is the one of the most important materials to support and guide railway vehicles safely and smoothly. Since rail sufferes from various interacting forces and environmental atmosphere, wear and fatigue pose large problems with wheel and rail. Hence, wear and fatigue of wheel and rail have been studied so far to keep running safety and some level of riding comfort of vehicle taking into account track maintenance cost. In this review, rolling contact fatigue (RCF) of rail which is one of typical fatigue phenomenon for steel wheel - on-rail system is focused on and the history of RCF defects and the maintenance experience of their mitigation measures in railways are described. The concept of mitigation strategy is balance between wear and RCF. Controlling wear amount is a key word to mitigate RCF defects based on selecting rail material suitable for vehicle/track interaction together with grinding and lubrication. Furthermore, the purpose of Japanese bainitic steel rail is to obtain the suitable amount of wear to prevent the initiation of RCF crack.

Keywords: Defects, Rail, Wear, Rolling Contact Fatigue, Preventive Grinding

1 Introduction

Rail is the one of the most important materials for rail way infrastructure to support and guide railway vehicles safely and smoothly. Vertical force and lateral force based on typically vehicle weight and dynamic behaviour such as vehicle negotiating curves interact between wheel and rail. Also, traction force for driving and braking of vehicle interacts between wheel and rail longitudinally. In addition, thermal axial force acts on rail and longitudinal friction force interacts between rail and rail fastening system particularly under continuous welded rail (CWR).

Since rail is suffered from such various interacting forces and environmental atmosphere, wear and fatigue pose large problems with wheel and rail. Hence, wear and fatigue of wheel and rail have been studied so far to keep running safety and some level of riding comfort of vehicle taking into account the economical aspect of track maintenance cost. However, the phenomena of wear and fatigue have been understood to obtain better solutions from the practical point of view but not enough from the best practice.

In this review, rolling contact fatigue (RCF) of rail which is one of typical fatigue phenomenon for steel wheel-on-steel rail system is focused on and the history of RCF defects and the maintenance experience of their mitigation measures in Japanese railways are discussed.

Crack detection gauges and components switches on lines ZSR governed by the relevant provisions of ZSR:

- TS 3-4 „ non-destructive testing rails “
- S 3-3 „defects of rails “

Other documents:

- qualification under STN EN ISO 9712 a UIC 960
- methodology in accordance with the relevant STN EN ISO a UIC
- Those regulations, as well as other regulations and measures are ensured comprehensive crack detection inspection at ZSR.
- The main purpose of crack detection is the identification and localization errors rail switches and components, which could jeopardize rail safety.

What is Rolling Contact Fatigue:-

Rolling contact fatigue (RCF) is a family of damage phenomena that appear on and in rails due to overstressing of the rail material. This damage may appear first on the surface (e.g. head checks, shelling, squats) or the subsurface (deep seated shell). In either case, these phenomena are the result of repeated overstressing of the surface or subsurface material by millions of intense wheel-rail contact cycles. The problem of rolling contact fatigue in rails grew in size both domestically and internationally through the 1990s, and was brought to worldwide attention through the loss of life in theHatfield (UK) derailment in 2000. According to FRA statistics, in the eight years from 1995 to 2002, rolling contact fatigue was strongly implicated in 122 derailments, and may have contributed to 160 more.

Beyond the safety implications, there is a substantial economic cost associated with RCF. A European study suggests that the cost of RCF to the European railway network, including inspection, train delay, rail replacements and weld repair, rail grinding and derailments, is about 300 million per year. The cost of RCF to the North American rail industry is believed to be a significantly greater amount. Two key processes govern RCF - crack initiation and crack propagation. These processes are governed by a number of factors including environmental conditions, rail and wheel profiles, track curvatures, grades, lubrication practices, rail metallurgy, vehicle characteristics, track geometry errors, and rail grinding practices. They all play a role in the formation of RCF and – universally – can be used to control and minimize RCF.

The amplitude and position of the crack initiating stresses varies depending on the contact geometry, load, and friction conditions. Under high friction conditions shear stresses are large but very shallow. Under low friction conditions, the peak shear stress decreases but extends deeper into the railhead. The result is that some RCF defects are initiated at the surface and others below the surface.

2 Defects of rails

Important aspect of the distribution of errors is their shape and size.
Effectively manage issues mistakes rails assumed error distribution rails into several categories.
Defects type is determined by non-destructive methods, its growth rate and the risk of fracture according to the size. This is a various cracks, voids, inclusions, defects structure of materials and incorrect physical or chemical properties of materials.
Rolling contact fatigue will lead to surface and subsurface cracks as stated earlier. Based on the nature and location of the failures, they are classified as follows.

2.1 Transverse cracks

Passage trainsets exposes errors rail vibrations that can cause enlargement (growth) errors due to contact fatigue.
At low temperatures and their respective thermal stress critical defect size increases the rail such that the rails fractures are more common in winter. The crack increases exponentially, and so reduces the cross-section of the rail at that location, which significantly reduces its strength.

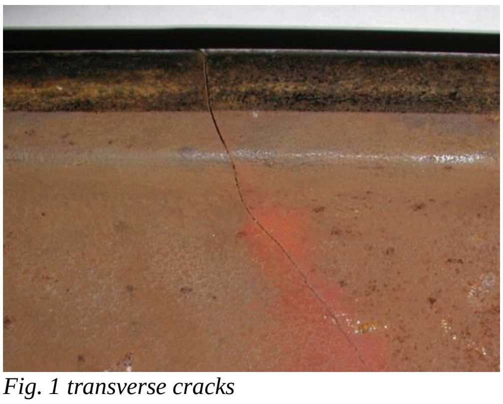

Fig. 1 transverse cracks

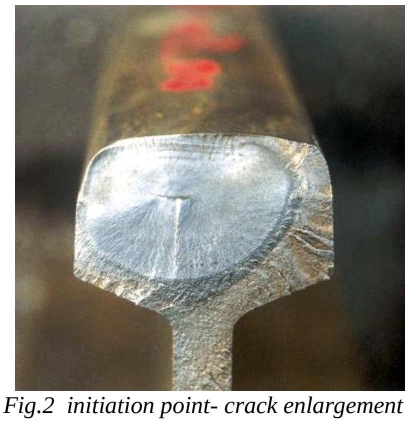

Fig.2 initiation point- crack enlargement

2.2 Longitudinal vertical cracks

- Related to the production process rails (rolling in the production process)
- A frequent occurrence in older types of rails
- Development defects in two phases

Cracking spreads in the direction of the length of the rail

Cracking reaches surface

Surface Initiated Defects:-

2.3 Head checking

Head checks are fine surface cracks resulting from cold working of the metal under contact stress. The slip which occurs between wheel and rail in curves of over 1000m radius leads to high tangential forces around the Gauge corner of the rail head with high coefficient of friction (>0.3). This further leads to high surface stresses and where the rail wear is small to surface cracks.

The Head checks appear at a spacing of 1 to 5mm along the rail in the Gauge corner of the outer rail in curves. Pieces of metals may break out from between the checks. The transverse cracks on the surface also appear. Beneath the surface cracks, subsurface defects may develop which are potentially dangerous. Rapidly evolved very quickly and will appear on the surface.

Uniquely identified errors Head Type Checking occur in different-sized groups and each oblique cracks have different lengths and shapes. The most commonly takes the form similar to the letter "C", "V" and "S" with rotation angle from 35 ° to 60 ° to the longitudinal axis of the rail in the main direction of movement of rolling stock.

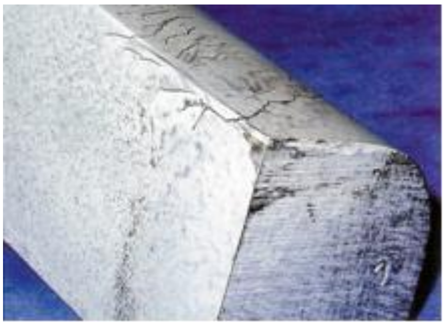

Fig.5 Longitudinal section through the cracks Head Check

According to their linear dimensions of their divided:

- short (fine cracks, sometimes together with gray patches, cracks of up to 10 mm)
- medium (slightly enlarged number of gray spots and cracks length 10-19 mm)
- long (large number of gray spots and cracks length 20-29 mm)
- critical (extremely large number of gray spots and cracks with a length of 30 mm)

Fig.6 this shows the development of a crack

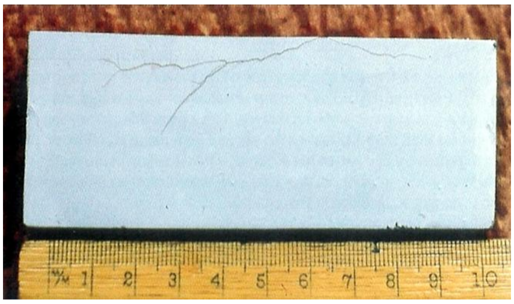

Fig.7 section through defect

2.4 Squats

This defect is common in tracks catering to high speed passenger trains with low axle loads. It is found both in straight and moderately curved track. The first superficial indication of the failure is appearance of fine surface cracks located at the Gauge side of the running band and lying at an angle of 45 degree to the forward direction of traffic in plan view. This is followed by the appearance of dark spot on the running band. The depression will be up to 1.6mm and cause higher dynamic wheel/rail forces.
Such cracks may initiate from a white itching martenisitic layer(WEL) on the surface of the rail due to plastic flow resulted from longitudinal traction of locomotive wheels causing a surface layer of rail material ratchets until crack develops on the center of the railhead on the field side.
Information on the origin and evolution Head checking are also valid for Squats, but Squats critical defect size is important.

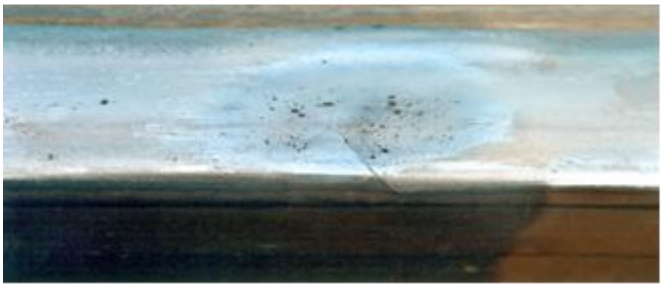

Fig.8 Squats - A typical crack formation in the shape V of a tread in the railhead

3 Sub-Surface initiated cracks

3.1 Shattering Defects:

These defects which develop around 10 to 15 mm below the rail head from longitudinal cavities caused by the presence of Hydrogen. These cavities develop under the influence of thermal and residual stresses from roller straightening and cooling processes in the normal rail section during the manufacturing process or at the welds.
Hence improving the rail quality by reduction of Hydrogen content in the rail steel and measures for reducing the residual stresses at the manufacturing stage and control of welding procedure to prevent water entrapment at weld joints can reduces this type of failures in rail and welds respectively

3.2 Gauge Corner Defects:

These effects are formed on the high rails in curves of sharper radius generally and on routes of heavy axle loads with moderate speeds. An elliptical shell-like crack with characteristic crack growth rings propagating transverse to rail section under the influence of contact stresses and shear stress develops at first.
Later due to bulk stresses and residual stresses in the rails, cracks initiate from the shell either upward or downward. The upward cracks lead to shelling on the Gauge face, where as downward propagation will lead to fracture/formation of kidney.

The preventive practices could be by way of using Head hardened rails manufactured by clean steel making process and suitable steps for shifting and spreading the contact area away from the Gauge face by conformal grinding.

3.3 Initiation and development of RCF Defects:-

The three stages of initiation and growth of fatigue cracks in rails are observed.

Stage 1. Cracks are initiated by severe plastic flow at and just below the surface of the head of the rail. The plastic flow hardens the surface material and makes it brittle. This leads to ratcheting of particles, which may eventually get separated. In the process voids will be left in between particles making the real contact area (RCA) much less than the elliptical contact area as given by Hertz. This will further accentuate the contact stresses leading to further detachment of particles. At a later stage the left over particles, which are very hard to wear act as nuclei for initiation of cracks. The initially high growth rate is rapidly attenuated as crack deepens into the rail.
These cracks are inclined at a very shallow angle, about 15 degrees, to the head of the rail and in the same direction as the direction of the passage of wheels. The severe plastic strains in this region locally modify the metallurgical structure of the rail.

Stage 2. Continued propagation in the same inclined direction occurs under the influence of the stress field produced by the wheel rail contact. The reversedshear stresses which cause the growth, first increase with depth causing an acceleration, but then decease with distance from the contact causing a slow down.
Typically the effect of the contact stress field extends upto 10 to 15mm below the surface. The sub surface plastic flow that takes place under the influence of contact stresses, locked up stresses due to plastic deformation, cracking at surface level and the shear stress in the rail head leads to metallurgical changes in the presence of inclusions. Annular rings with inclination towards the Gauge face will be formed. This will facilitate faster propagation of cracks initiated in this region either upwards or downwards.

Stage 3. The bulk stresses and the residual stresses in the rail causes a branching, either up or down. Upward branching leads to a flake of material becoming detached. Downward branching, at an angle of about 70 degrees Inclination can cause continued propagation until a fracture of the rail occurs the sequence of growth rates of cracks is therefore initially high, followed by a dip before "handshaking" with the increasing rates of stage2, which then decrease to a further handshake with stage 3. It is important to realize that the handshake between each stage is not automatic and crack arrest is possible. Not all initiated cracks inevitably lead to failure.
The interaction of fatigue and wear is important because at its simplest level, if the wear rate at the head of the rail is high, then cracks will be worn away faster than they can form. More subtly, the three stages of growth of crack previously discussed, need to "handshake" as stage 1 changes to 2 and 2 becomes 3.
This changeover occurs at a minimum growth rate, which might be higher or lower than the wear rate at the head of the rail. Crack arrest is therefore possible if the handshake growth rate is lower than the wear rate. The details of these interactions are currently being studied in the AEA Technology Whole Life Model supported bytheoretical work from Dr. A Kapoor of the University of Sheffield.

4 Wheel burns

Wheel burns are the result of frictional heating produced by a spinning wheel set. Wheel burn the drive axle gives rise spontaneously turbid spots. The incidence especially in stretches of track where there are repeated starting off and braking railway vehicles. There is a gradual grinding material. This stain may disappear over time or may develop horizontally or diagonally in the railhead.

Fig. 9 example defect wheelburns

5 Shelling

Defect shelling is initiated from the internal defects of manufacture. In the early stage development of dark spots longitudinal, particular external rail strips in curves. Advanced development phase error is a separation of the tread and considerable local recess tread. The final development phase defects represents the formation of transverse cracks (often with their rapid development), leading to fracture rails. Removal can only exchange the rails.

Fig. 10 example Shelling in the final stage


Fig.11 shelling on the rail

6 Conclusions

Current number of types of defects rails is much larger, but the aim of the article was to become familiar with the methods and options selected correctly identify defects rails. On the basis of proper identification can be clearly classified the defects and take adequate measures for their early elimination. The purpose is thus safer to ride a train on rails.

References

[1] The Art and Science of Rail Grinding by Allan M. Zarembski, 2005.
[2] Mechanics and Fatigue on Wheel/Rail Contact by S. L. Grassie, 1990.
[3] Head of Project Development, Stahlberg Roensch, Germany COPYRIGHT 2005 Simmons-Boardman Publishing Corporation.
[4] Project on "Development of RCF in Rails and remedial measures in course no 525 at IRICEN, Pune.
[5] Paper presented in Glasgow Section on 14 Jan 2004 by Mark Demboskey in UK
[6] Vinod Bhangale, Sr. DEN/N/Nagpur, C. Railway
[7] Ashok Kumar, DEN/Track, Delhi, N. RailwayShiv Om Dwivedi, XEN/Const., N.Railway
[8] Prochádzka, M. : Visual inspection in pre and indirect operating examination. In Almanach Defektoscophic, Praha, 20-22.11.2001.s.239.
[9] doc.Ing. Harold Mäsiar, CSc. A kol.FŠT, Research cracking of the welding of high strength armor plates type ARMOX. 4/2014