

Rail Wheel interaction in the context of heavy axle load

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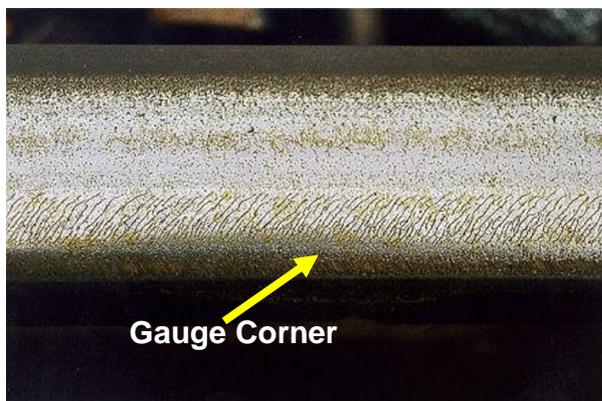
S E/P.way/USFD/MAS

Introduction:

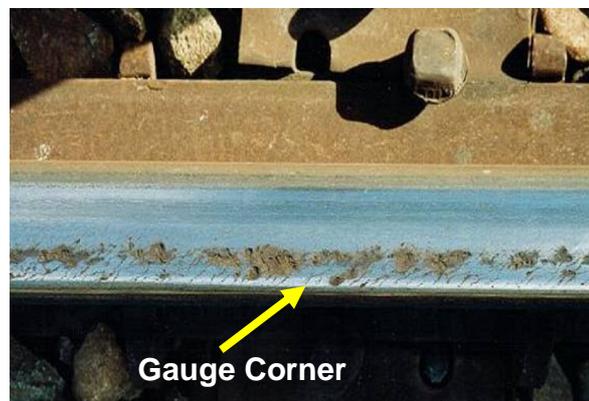
Indian railways the largest rail industry in Asia, Fourth largest in the world with more than 60,000kms of track running across the length and breadth of the country carrying freight traffic for about 700 million tonnes per annum. To meet out the future requirements it is necessary to increase the carrying capacity and speed of freight traffic. Indian railways has planned to introduce 25tonnes axle load goods traffic in the first phase and with a plan to introduce 32 tonnes axle load goods traffic in the Dedicated Freight Corridor. Rail tracks are subjected to intense bending and shear stresses, plastic deformation and wear. The dynamic axle load sustained by rails are massive, under normal conditions the contact stresses between rail/wheel can reach 1500mpa. However it can exceed 4000mpa.due to poorly matching rail and wheel profiles. Despite showing improvements in metallurgy of rail steel, better maintenance practices rail failures still occur. As the axle load, speed and traffic volume increases the number of failures also increases dramatically. This paper discusses about some of the rolling contact fatigue rail failures which the permanent way engineers are facing after introduction of heavy axle load freight traffic with increased speed.

Gauge corner cracks/Head checking:

Gauge corner cracks/head checks are groups of fine surface cracks at the gauge corner at regular intervals along the rail (1–6 mm), mainly on outer rail of curves, can grow to 2-5 mm in depth, at a downward angle of about 10° to 30° to the rail surface, gradually spreading across the rail head. Generally contact stresses are low in the crown area and high contact stresses are generated on the gauge corner of the outer rail and they break out as spalls.



Initial stage



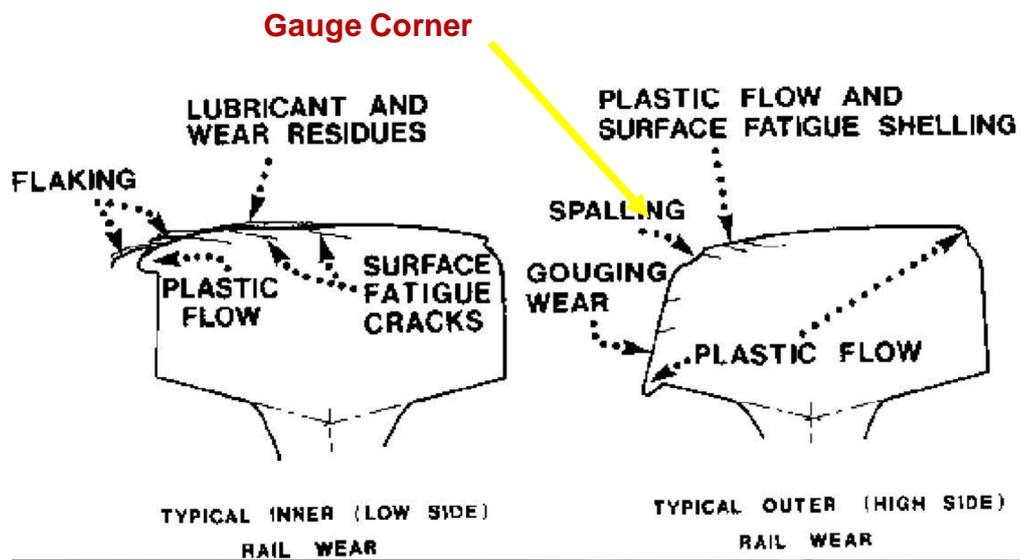
Severe stage

Gauge corner cracks/head checks may also be found near the welds as welded profiles may vary slightly in comparison with actual rail profiles. A slight variation in weld profile has a major effect on contact stresses. If head checks are not controlled, they can cause rail break. Grinding is the most common practice employed to remove gauge corner cracks/head checks and severe gauge corner cracks /head checks require immediate replacement.

Running Surface Cracks/Checking:

A surface condition that occurs on the running surface of the inner and/or outer rails. Initially the defects appear as a snakeskin like pattern on the rail head. In the latter stages the cracks produce "spalls" that can be up to about 10-15 mm wide, up to 3 mm deep, and can be continuous along the rail length.





Gauge corner, running surface cracks/checking and shelling defects are initiated by the high shear stresses that can develop at the wheel/rail contact region when such stresses exceed the allowable limits for the rail material. The factors that influence the shear stresses are

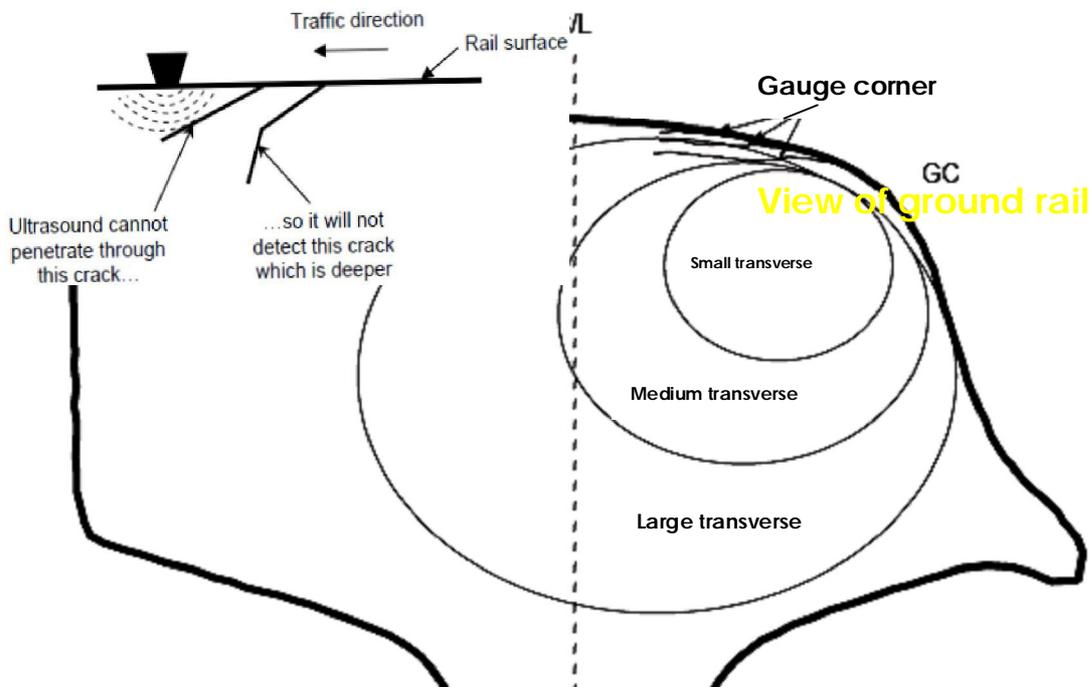
- The normal, dynamic and impact wheel loadings and the range of factors that influence such loadings, including track geometry, bogie characteristics, wheel and rail vertical irregularities, track super elevation, etc.
- The respective radii of the wheels and rails at their contact region and consequently the wheel and rail profile characteristics.
- The diameter of the wheels (smaller diameters result in higher stresses).

The difference in the initiation characteristics of the surface cracks and shelling defects namely surface or sub-surface is primarily due to the influence of the

ratio of tangential to normal forces, T/N on the resultant shear stresses. It is evident that at the lower T/N values up to 0.2 the maximum shear stresses are obtained at some depth from the rail contact surface, which corresponds to the region in which shelling generally develops. Higher axle loads increase the normal forces and hence may reduce the T/N values, which in turn would enhance sub-surface crack initiation. On the other hand, the higher T/N values which are obtained in relatively sharp curves due to adverse vehicle dynamics, such as hunting lead to both considerable increases in the resultant maximum shear stress and also a shift in the location of the maximum shear stress closer to the rail surface, where the checking cracks initiate.

The main reason for the growth of the checking and shelling cracks is the work hardening of the rail steel which occurs due to the plastic deformation of the rail material, particularly at the higher axle loads. The work hardened layer can be up to 8-10 mm in depth. The plastically deformed material in the work hardened layer exhibits high compressive residual stresses. Such stresses inhibit fatigue crack growth, and therefore generally prevent the growth of the much shallower checking cracks into the rail head. On the other hand, the deeper shelling cracks may be able to penetrate through the

compressive work hardened layer and continue growing on a transverse plane, thus developing into transverse defects, under the action of other stress environments, including rail bending, thermal stresses, and residual stresses due to rail manufacture. Contamination of the rail surface predominantly by water, also lubricating grease, which is often found in the vicinity of lubricators, can accelerate the propagation of checking cracks into longer and deeper cracks. They can mask the ultrasonic signal during routine inspection and hence prevent the detection of larger and deeper defects that may be present within the rail head, including any such defects that may have developed from the shallower initial cracks.

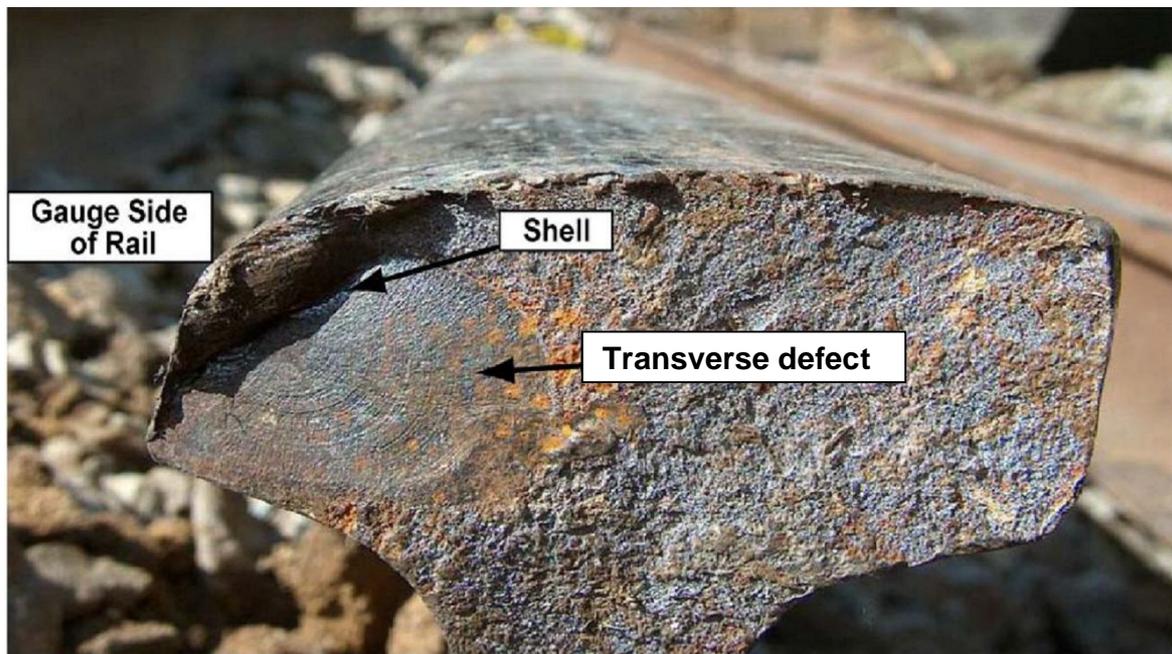


Gauge corner cracks/checking and various transverse defects

Shelling:

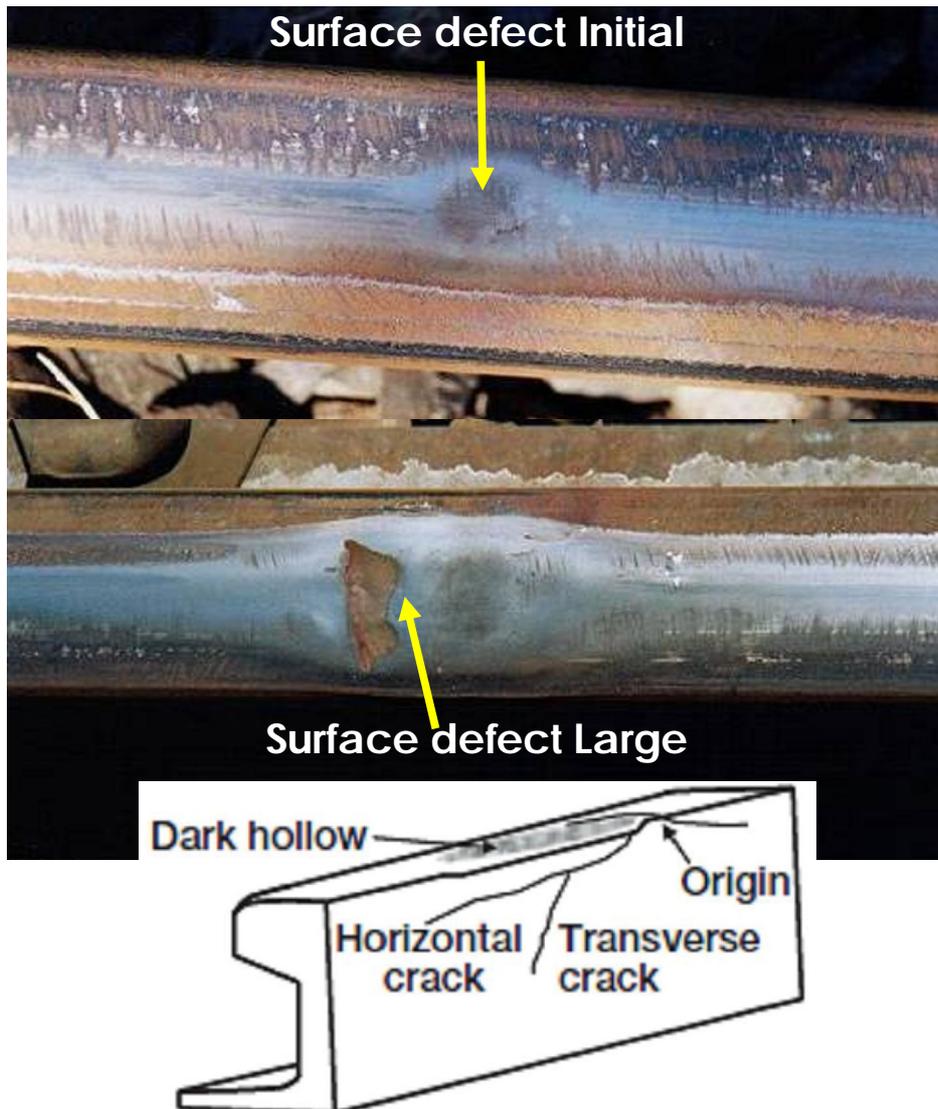
This is an internal defect that initiates at a depth of 2-8mm below the gauge corner of the outer rails of curved track on higher axle load routes. In the initial stages of development, shelling defects become

noticeable as dark spots in the gauge corner region of the rails. Shelling defects do not form as regularly along the rail as gauge corner checking defects. The cracks can continue to grow in a longitudinal direction on that plane for some distance at an angle of about 10°-30° to the rail surface, and then either spall out into a shell or turn down and form transverse defects which can continue to grow on a transverse plane and, if not detected in time, eventually lead to rail failure.



Surface defect/Squat:

Unlike shelling, surface defects/squats appear in the crown area of straight rail sections. They are surface initiated defects formed by rolling contact fatigue and they are initiated from the gauge corner checking cracks. However, more recent work has shown that the more common squats that form on the crown of the rail head, are actually initiated from a hard and brittle layer with fine cracks present in the hard surface layer. A surface defect/squat is formed by two cracks, a leading crack and a trailing crack. Both these cracks propagate in opposite directions. The leading crack proceeds in the traffic direction, The leading crack is usually several times longer than the trailing crack and contains one main crack with a number of secondary or minor cracks branching off that crack. If preventive measures are not taken quickly, the crack will branch out and probably grow downward towards the rail web. In their initial stage, they look like depressions in the crown area. These defects can be prevented by grinding. Research has shown that rail grinding has an important role in reducing rail degradation, which can reduce rail brakes.

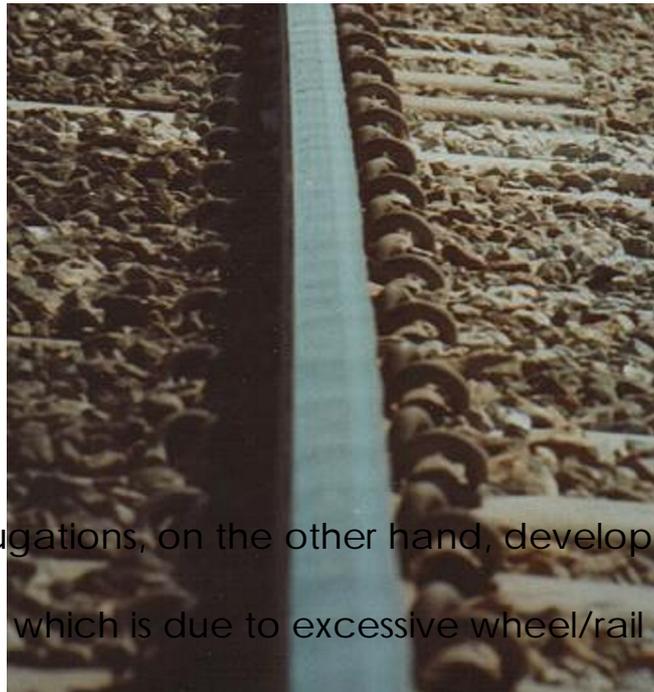
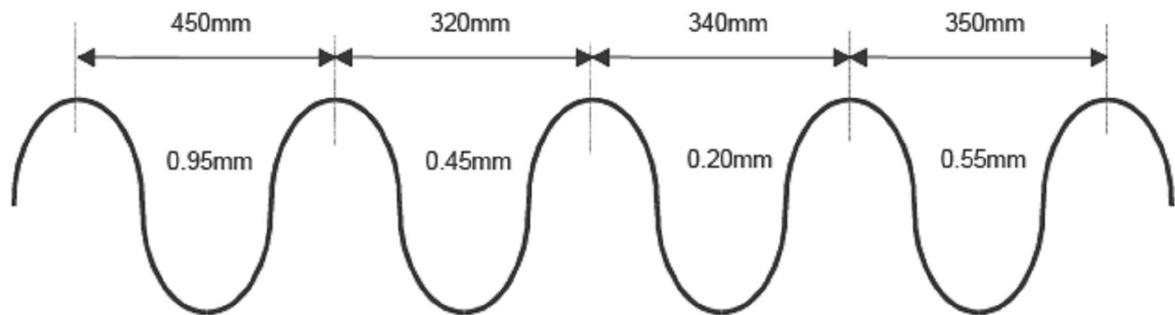


Rail Corrugations:

Corrugation is a rail flaw in the form of wave like at rail head and manifests

itself as peaks and valleys, a periodic irregularity of the rail surface. Long pitch corrugations are about 300mm in wavelength and they generally develop under higher axle load (> 20 tonnes) mixed freight and passenger train operations. The depth of these corrugations can range from 0.1mm to above 2.0mm, and can vary.

Vertical profile of long pitch corrugations



Long pitch corrugations, on the other hand, develop because of the plastic flow of the rail material which is due to excessive wheel/rail contact stresses and due to

- Higher axle loads.
- Higher speeds, which increase the dynamic loads.
- Cupped welds and vertical dips at fish plated joints, which increase the impact loads.
- Higher track stiffnesses (concrete sleepers are much stiffer than timber sleepers), which increase the dynamic/impact loads.
- Higher rubber pad stiffnesses, which increase the dynamic/impact loads.

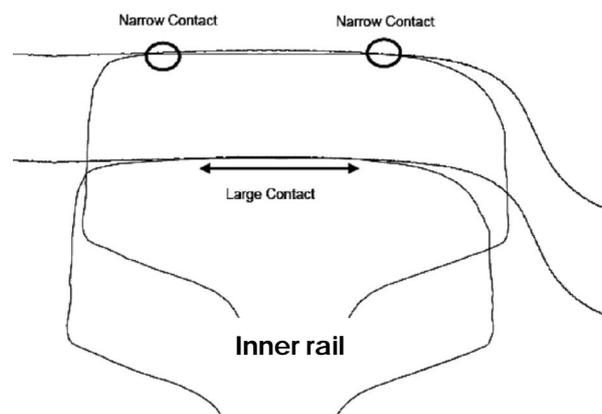
- Higher bogie suspension stiffnesses, which increase the dynamic/impact loads.
- Higher friction at the wheel/rail contact
- Poor matching of wheel and rail profiles, which leads to narrow wheel/rail contact and hence higher contact stresses.

Rail corrugations are of great concern because they increase the dynamic wheel loads and therefore the rate of deterioration and failure of various track components such as

- Rails, Welds and Bolt holes at insulated rail joints.
- Sleepers, particularly in the rail seat region.
- Ballast, which tends to powder and become rounded.
- Pandrol clips which become loose.
- Track geometry mainly because of the vibration and Corrugations can lead to the skewing of sleepers.
- Corrugations increases the wheel/rail noise
- Bridges and abutments, particularly when the track is not ballasted

The main procedures commonly used for reducing or eliminating rail corrugations are, Use of higher strength (mainly heat treated) rail steels and Application of improved wheel and rail profiles by rail grinding.

Some Wheel/rail contact conditions



Conclusion:

It is evident from the rail failure pattern on heavy axle load routes in advanced countries and also in our railways rail -wheel contact plays a major role in rolling contact fatigue defects. This can be controlled by continuous monitoring of rail profile for symptoms of rolling contact fatigue crack by periodical visual inspections, by advanced NDT inspections and by improving the rail -wheel contact area at identified stretches using rail grinding machines.