



Facing Challenges Under Mixed Traffic Regime Of Semi High Speed And Heavy Axle Load-design Aspects

Nitin Garg*

1. Introduction:

At present in Indian railways we are moving towards the regime of semi high speed by operating the trains at 160 kmph in PWL-AGC section and simultaneously there is increase in axle load from 20.3t to 22.82 by CC+8+2 loading. In this context it becomes imperative to design the track in such a manner that requirements of both types of train operations are fulfilled. The primary difference is the priority given to considerations for passenger comfort and diverging speed. Semi High Speed Route lines require that turnouts and crossings minimize or eliminate the need to slow the train while maintaining passenger safety and comfort. In addition to design considerations, both operations impose different loading conditions on special trackwork. Impact loads vary significantly with train speed, and are the primary cause of track degradation. Both traffic impose impact loads due to irregularities in the track and in the wheels, but the combination of axle load and train speed makes the differences in load magnitude and track damage extremely complex. By definition, the loads from High Axle Load freight trains are higher in magnitude and longer in duration than loads from High Speed Trains. In order to design the track catering to both requirements, few challenges are elaborated below which we face while doing so:

*XEN/TP/ALD/NCR



1 INNOVATION IN TURNOUT GEOMETRY

Increases in diverging speed and rider comfort can be achieved through optimal turnout geometries and the use of movable point crossings. Another alternative is to orient turnouts such that the direction of high-speed traffic corresponds with the straight movement through the turnout. On the other hand, special trackwork on High axle freight lines is designed to withstand the high tonnage on a specific route while minimizing maintenance. Since the diverging speed is typically less important on freight lines, the goal of innovative crossing designs for High axle load is to eliminate the gap in the running rails on the mainline. This may be achieved through:

a) Flange bearing crossings

The traditional approach to the design of crossing diamonds is to create small gaps in the intersecting rails to allow a train to pass through another track without having to separate the grade of the two lines. High impact loads from wheels are often imparted on the edges of the crossing where these gaps occur, which greatly increase wear and reduce the life cycle of these components. Not only do these high impact forces cause damage to the rail, but the supporting earthwork below a crossing diamond is also negatively affected. In an attempt to mitigate these impacts under increasing axle loads, and increase the life cycle of crossing diamond components, the use of flange bearing technologies is recommended. With flange bearing technology, the gap in the running surface of the rail is eliminated because the flange of a wheel is used to support the train as it is essentially lifted over the intersecting track. One type of flange bearing technology is a full flange bearing crossing diamond as shown in Figure 1 below. In this type, wheels on trains traveling on both tracks at a crossing are ramped up and supported by the flanges so that intersection occurs at the same level surface for both routes. The elimination of



flangeway gaps for both routes mitigates the issue of high impact forces on the components of the crossing diamond. In a field trial, within the first 22 months of service, practically no maintenance related to this diamond was required despite it having supported approximately 60 MGT per year since its installation. Although the speed on both routes had to be reduced to 40 miles/h, an advantage of this technology is that the relative speed of each route can be the same. Further evaluation on the potential longer life cycle of this crossing is still being performed. This type of diamond may be beneficial at a crossing where the freight and passenger traffic volumes on each line are similar. Because of the lower speeds required on these diamonds, this technology would not be ideal



Fig 1: Partial Flange bearing Diamond



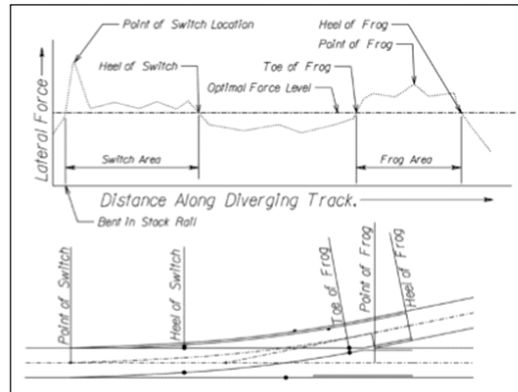
Full flange bearing diamonds.

b) Turnout geometry

At present TWS are being used in Indian railways for high speed routes. These TWS allow at present a speed of 50 kmph on loopline side. But turnouts designed for high-speed operation are generally longer in length in order to reduce lateral accelerations and provide a more gradual change of direction. Too rapid a change in lateral acceleration can cause a phenomenon known as entry "jerk," which causes passenger discomfort. Figure 2 illustrates various components of a turnout where lateral forces can exceed this optimum force level, and thus should be targets for analysis and potential redesign.



Fig 2: Concept of optimum lateral force in turnout design



The ultimate goals of increasing diverging speed through a turnout within the same footprint with reduced lateral forces and accelerations are to improve ride quality and decrease component wear. It is likely that upgrading a single turnout will have no major effect on increasing the capacity of a line. Rather, a greater amount of improvement can be achieved by performing low-cost modifications to several turnouts over a given section of rail line, which would increase the average speed of the trains over that section. Following locations in a standard turnout cause speed restrictions: the toe of the switch which causes both a kink in the alignment and a change in curvature; the heel of the switch which causes a change in curvature, the toe and heel of the crossing which both cause a change in curvature; the gap at the "V" of the crossing where high vertical impacts can occur, and the lack of cant/superelevation in the lead curve on which high lateral forces act. These constraints are the lead distance between the SRJ and ANC, the interlocking footprint of the turnout, the crossing angle, and the location of the SRJ and ANC. The optimized turnout comprised of back-to-back spirals with larger radii entering and leaving the turnout, and a smaller radius in the body of the turnout. Use of a larger radius for switch entry for the diverging rail through means of a spiral allows a smaller entry angle of a turnout, which lowers lateral forces and acceleration, and allows a higher



diverging speed. The result of this optimized design was that while maintaining the same lead length and turnout angle as the optimized turnout saw lateral forces reduced by approximately 40%. Operating speeds for this test were 40 miles/h which is more representative of freight train operation. One of the tested turnouts consisted of larger entry and exit radii, meaning it had been created with spiral transitions into and out of the turnout. From these results it can be seen that this design for the geometry of a turnout can significantly reduce lateral loads from freight train operations.

c) Gauge widening at switch entry:

Another method that can be used to reduce the thrust due to high axle load can gauge widening at the switch entry. It causes the wheels to ride outwards on the taper of the tread, thus steering a train away from a closed switch point. This also allows for the switch rail to be thickened, reducing wear on this component and increasing its life cycle. This gauge-widening concept is demonstrated

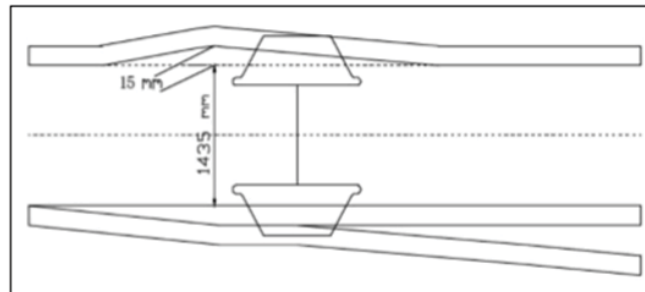


Fig 3: Gauge widening switch structure

Immediately behind the wheels, an exaggeration of the widened gauge is depicted. It can be seen that the lines of contact between the rail and the wheel tapers have been moved outward relative to the track centerline. This can be compared with the case where this contact would occur under a normal design where the gauge remains constant through the turnout. This has showed a 40% decrease in maximum forces for the turnout with KGO, which increases the life of the turnout components.



d) Multiple point machines with swing nose crossing

A design factor in many turnouts is the presence of a switch machine to align the points for movement of rail traffic on the desired route. For smaller-sized turnouts, a single switch machine is often adequate to provide the power needed to move the switch points. With the implementation of the larger turnouts necessary for high-speed operation, more power is needed to move the longer rail components. To provide a smoother ride for passengers and for safety reasons, it is necessary that the whole point is moved uniformly. Currently, more support locations along the moving point are necessary to successfully "throw" the switch in some larger turnouts,. High-speed turnouts not only require an adequate number of these supporting locations for proper alignment, but in some cases multiple switch machines are necessary to provide adequate power to do so. As a solution to this problem, a type of turnout where multiple slave drive units are connected by hydraulic lines to a primary active unit has been successfully used in Europe. Such a design arrangement can be done in the



1) IMPROVING SPECIFICATION IN BALLAST AND SUB BALLAST:

Recently there has issue of correction slips in IRPWM where it is suggested to reduce the frequency of deep screening from 10 yrs to 500 GMT. It implies that due to increasing axle load, there has been deterioration in the ballast very rapidly. In order to overcome this, it is suggested that bituminous sub ballast can be used in the



construction of traffic with high axle load and high speed tracks. This ballast becomes all the more important in light of the data of Rail-weld fractures analysed over a period of 3 years at NCR HQs which reveal that 50% of the fractures occurred in A route only because the deep screening was due for more than 5 years. Thus this period needs to be further increased by choosing some better quality of ballast which can withstand such high axle loads.

Bituminous ballast consists of mixture of aggregate and bitumen. The mineral aggregate varies from very fine dust (filler) to a maximum particle size, which is usually around 40 mm. By varying the composition of the mixture, the ratio of the various constituents and the particle size distribution of the aggregate, the properties of the eventual mixture can be adapted to suit the specific requirements of the construction. Depending on the mix composition and the quality of the constituent bitumen and aggregates, the bituminous ballast mixture may be either stiff and of high stability and almost impermeable

A bituminous ballast construction may consist of one or more separate layers of possibly different composition. Depending on the design the various layers each perform a specific role in the construction

Advantages:

- a) **Bearing –Capacity:** Application of a monolithic layer (0.1 – 0.2 m) of bituminous ballast, as a sub-ballast layer will increase the stiffness of the total structure.
- b) **Geotechnical Stability:** The relatively high stiffness of the bituminous ballast sub-ballast layer will make a positive contribution to the compaction of the layers on top of the bituminous ballast layer. This improves the total stability. So the bituminous ballast mix as sub-ballast contributes to keeping the railroad geometry unaltered
- c) **Resistance to Vertical Deformation:** The relatively high stiffness of



the bituminous ballast layer compared to granular material will lead to less permanent vertical deformation by trainloads. The vertical loading conditions and the relatively short loading time are relatively small, so there will be no permanent deformation in the bituminous ballast layer

- d) **Noise and Vibrations:** Mechanical properties of the bituminous ballast layer will lead to a reduction in the vibrations and noise produced by passing trains. The use of modified bitumen (polymer modified bitumen, rubber crumb) can further improve the vibration dampening effect of the sub-ballast
- e) **Durability:** Ballast by the bituminous ballast layer, the ballast layer is strengthened and deterioration of the ballast is reduced. The bituminous ballast as sub-ballast layer increases the foundation modulus, providing a more rigid foundation, with the effect that there is a reduction of tension and shearing stress inside the ballast material, with consequently less fatigue and less degradation and wear of the individual aggregate particles. Because of the low air voids in the mix (1 – 3%) and because the bituminous ballast layer is buried, weather effects (temperature changes, Ultra Violet radiation, oxygen) will not affect the hot mix, so no deterioration (aging) of the bitumen will take place. Even if limited deformation of the sub-soil does take place, this will not affect the bituminous ballast layer because it is capable of withstanding the deformation without losing its integrity because of the visco-elastic properties of bitumen

2) GLUED JOINT

In high axle loaded LWR track, glued joints can be considered to be weaker than the surrounding track. They have a stipulated life of 200 GMT which means in an average HDN section of 80 GMT every 3 years there is a possibility of changing the Glued joint. In our increasingly heavy axle loads and high speed, there is always a possibility of it getting ruptured early. So there is a need to review



the existing design of glued joint. These joints are typically weaker, creating local track alignment issues in heavy haul service. This type of joint was originally designed to allow longitudinal movement of the two rails, relative to each other (i.e., it was designed for jointed rail track). This feature is detrimental in continuously welded rail track, as it can lower rail neutral temperature.



Fig 4: Advanced Rail Joints in Use in Heavy Haul Lines (l) Wrap Around Bar Insulated Joints, (m) Keyed Joint, and (r) Low Angle Taper Cut Insulated Joint

Recent developments have produced changes in joint bars, joint configurations, and foundations that have greatly improved the performance of rail joints in heavy haul service. Improvements in performance attributable to joint bars have come from longer bars of the same shape and bars that are integral to the joint foundation. Figure 4 shows three examples of heavy haul joints that use these concepts:

- a) The first is an insulated joint with “wrap-around” joint bars. This bar wraps around the base of the rail and is the bearing surface for the rail. This joint is as stiff as the parent rail and reduces relative movement of each rail with respect to the other rail and the joint bars.
- b) The second is a keyed joint (shown disassembled to reveal the mechanical keys). This joint uses mechanical keys between the rail and the joint bar to carry longitudinal and vertical load across the joint. This has advantages over conventional designs, which rely on fastener tension to create a compression joint. The keys are stronger and more durable under the impact and vibrations of



railway service.

The third is a taper cut insulated joint. This joint is configured as a lapped joint, rather than the conventional butt joint. It is inherently much stronger in vertical bending. The additional third glued surface, between the two rail ends, also makes this joint much stronger in the longitudinal direction. The overlapping rails allow “point slopes” on the rail ends to affect an impact free transition from one rail to the other.