Facing challenges under Mixed Traffic Regime of Semi High Speed and Heavy Axle Load & their Impart on Track

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Synopsis

High speed rail (HSR) system is a complex system not only in terms of technical specifications, but also with respect to operations and maintenance over the track structure. In a developing & vast country like india, question of whether the line will be operated as mixed (passenger and freight) or dedicated only to passenger traffic required to be decided considering the local & traffic requirements by suitable modeling. Track structure is basically considered as the most important and costly railway asset. Its maintenance is vital to assure safety and operating practices are also of great importance to assure that a good level of service is provided. This will be different for the dedicated and mixed HSR traffic scenarios. The type of corridor creating influence the maintenance patterns: i.e. preventive maintenance planning, maintenances scheduling and assignment issues.

1. Introduction:

Nowadays high speed network is going to be grown with a fast rate over the world. Many countries in Asia, Europe, America and Africa including India are stimulated to start and develop their high speed network. Among all assets is the any network signal Track structure is basically considered as the most important and costly asset of railway. Track maintenance is generally accounted around 25-35 percent of operation costs.

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One important and critical feature concerns about the Track maintenance regime and restrictions of the line whether the it will be operated as mixed or dedicated traffic. This aspect will have influence on the maintenance strategic patterns mainly over the preventive maintenance planning, maintenances scheduling and assignment issues which can be different on the dedicated or mixed HSR traffic scenarios. These shared track and corridor operations pose a variety of technical challenges needing solutions in order to assure safe, reliable and efficient passenger and freight service. Track structure and maintenance, rail line capacity, rolling stock design, signaling systems, defect detection and highway grade crossings are just some of the areas needing attention.

2. Dedicated Vs. Mixed HSR Scenario

Basically high speed lines are more operated and used as passenger services to carry people as fast as possible and also most of the HSR lines and services over the world are dedicated to this purpose currently. But on the other hand there is another approach to operate a high speed line which can be called as mixed HSR traffic patterns. Thus the operation of HSR lines varies from a country to another one by following three main types.

I. Type 1: Exclusively high speed passenger traffic: dedicated HSR traffic

ii. Type 2: Exclusively passenger services, high speed services mixed only with conventional passenger trains with lower speeds

iii. Type 3: Mixed traffic types: high speed and conventional passenger services mixed with freight trains.

In mixed HSR scenario, strict track parameters are need to be maintain for high speed train for safety passenger on one hand and a suitable rail weight per length must allow for the heavy freight traffic, whose high axle loads cause deterioration of the track on other hand therefore it is very difficult and excessively costly to maintain track conditions which are adequate for running passenger trains safely and in comfort at high speeds.

As per some study, near 27% of track maintenance costs have been increased in heavy axle load traffic regime in comparison to the dedicated HSR conditions, mostly due to the increase of rail grinding and tamping needs.

Further, since in mixed HSR scenario, different types of freight and passenger vehicles have different braking regimes and are operated at various maximum speeds; therefore the operation of mixed HSR traffic is more complicated than the dedicated HSR scenario.

3. MAINTENANCE-OPERATION INTERACTIONS

Various technical-operational challenges between daily operation and maintenance planning can be classified mainly as the following titles:

a) Capacity and traffic block

b) Safety concerns

a) Capacity and traffic block Concerns

In advance rail system, most of the maintenance and inspection practices need to allocate some free hours between 1 hr to 6 hr or even 8 hours just for this purpose. This leads to reduction in line capacity. Doe to hearing traffic growth free state are declined on side and there is accumulation volume of maintenance observe due to declaration of tree slot for maintain leading to track degradation The impact of maintenance on capacity is especially critical in shared-use HSR systems (mixed traffic lines types 2 or 3) .

b) Safety Concerns

This concern can be classified to three levels such as safety provision by maintenance, safety concerns through maintenance and safety concerns after maintenance.

i) Safety provision by maintenance :- it is more essential in HSR network because the faster a vehicle is traveling, the more damage will be done in an accident as well as there is less time for operators to receive and act upon train control information. This can be either preventive maintenance (PM) by pre-scheduling & pre-dictating the maintenance activities or corrective maintenance (CM) which is depended to the failures and defects which are happened and should be treated immediately or in short term. PM being predictive, allocation & availability of resources in the form of man , material & traffic block may prescheduled but in CM , same are dynamic in nature according to the daily spot failures, incidents, train accidents and other technical problems.

ii) Safety through maintenance activities:- it is not only for maintenance workers and gangs but also for other trains and rolling stocks who pass through the same line or adjacent line with normal or even restricted speed. Because of this fact that during maintenance and renewal tasks, one or some failures have been occurred, the level of safety is decreased in comparison to the ordinary operation time,

iii) Safety provision after some maintenance:- If it has not been performed functionally in right direction or might have failed some critical or noncritical task may leads to serious safety concerns.

4. INFRASTRUCTURE AND EQUIPMENT :-

(a) Slab track

Recent research would suggest that slab track offers lower life cycle costs in high speed rail systems. Slab tracks are not widely used on freight lines because the geometry is not adjustable, and the track superstructure is less resilient in the event a derailment. In addition, the initial cost of slab track systems is generally higher than ballasted track. However, in a shared corridor environment where capacity is constrained, slab track may offer a benefit of extra capacity due to lower track occupancy for maintenance purposes. The tradeoff point between ballasted and slab track could be investigated for different traffic scenario.

(b) Ballasted track

On a ballasted track system, the track superstructure must be optimized for the combination of freight and passenger traffic. Ties, fastening systems, and ballast must be selected taking into account the loading characteristics of both train types. On ballasted track with higher track classes, track surfacing activities may be more frequent to maintain track geometry. A ballasted track way performs well in mixed traffic conditions for HAL and HSR traffic.

(c) Special track work

Turnouts with higher diverging speeds may be utilized in order to minimize train delay when entering shared track or when passing from one main track to another. New innovations in turnout geometry and components must be designed to accommodate heavy axle as well as high speed wheel loads. In addition, optimizing the diverging route configuration of mainline turnouts may better accommodate certain traffic patterns. Rail crossings with asymmetrical traffic may also benefit from premium crossing designs with feature uninterrupted running rails for the predominant route.

(d) Curve super elevation

Curve super elevation is typically set for the predominant traffic speed on a rail line. On freight lines, curves are typically elevated for the balancing speed or slight unbalance for a freight train.

Conventional passenger trains may operate at a higher unbalance than freight traffic, but on especially sinuous lines like in ghat section this may lead to numerous speed restrictions that negatively impact the average speed of a passenger train. With heavy-axle freight operation, changing curve elevation to accommodate passenger trains could potentially impact rail life and increase risk of low rail rollover on curves.

(e) Track stiffness transition zones

Highway grade crossings, bridges, tunnels, and areas featuring special trackwork are locations where the vertical stiffness of the track structure typically increases when compared conventional ballasted track. These stiffness transition zones may be problematic when considering track vehicle interaction and track component lifespan.

(f) Rail wear and defect rate

By increasing superelevation on curves, a railway line can accommodate higher speed traffic for the same degree of curve. Freight traffic traveling at speeds below the balancing speed of the curve will impart higher loads on low curve rails. Increased rail stress can lead to the increased rate of rail defect formation. Rail corrugation and other short wave irregularities can increase dynamic loads on the track structure. In particular weld geometry can have an impact on higher speed dynamic loads. At higher speeds, these types of defects may have a detrimental effect on passenger ride quality. The impact of weld geometry could be investigated as it relates to ride quality and dynamic track loads.

(g) Highway grade crossings

Implementing higher speed passenger service on existing corridors may increase risk to the automotive as well as to rail traffic at highway grade crossings. The elimination of level crossing gate in vision item for Indian railway & there are same location where grade separation is not feasible, suitable barriers for safety of train.

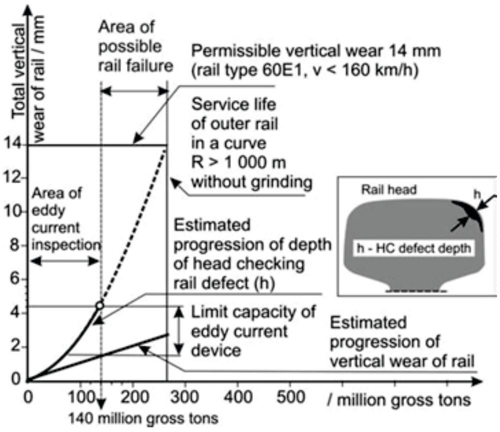
(h) Wayside defect detection

For many years, the use of wayside automated defect detection equipment has helped reduce the frequency of mechanical component caused derailments. To further mitigate the risk of these types of derailments in a mixed use environment, an intensified deployment of this type of equipment could be investigated.

5. Management of PWay assets

(a) Management of Rail :- Rails are the track components which account for a large proportion of the cost of new railway infrastructure, P-way about more than 30 % for ballasted track and 20 % for slab track. Further, service life of sleepers are much more than the rail, rail management plays a key role in the optimization of track costs including the costs of track maintenance. Rail management includes optimal choice of rail (the rail profile, and the grade and structure of the steel used), in-situ rail inspection, lubrication, grinding, rail repair, rail renewal and/or rail reconditioning. Rail cost considerations are not new, but the consideration of life cycle costs was, however, rare. With the help of the life-cycle cost analysis it is possible to make an accurate and transparent decision on material selection, preventive and corrective maintenance strategy and renewal schedule.

The service life of rail depends on several factors. It depends particularly on the cumulative operating load, axle load and vehicle conditions, the level and structure of vehicle speeds, rail quality and rail profile, the track quality, the position on the railway line (curve, straight track, inclination), rail maintenance and the treatment during the transportation and installation. An inadequate rail maintenance strategy decreases the rail service life due to shortened renewal cycle. On the modern railway lines for mixed traffic, radii of curves are defined based on the speed of the fastest passenger train. In such circumstances (Rmin 1 000 m), rail wear, rolling contact fatigue and plastic flow are major contributors of rail deterioration depending on the operational conditions. Due to this Rail management necessarily needs to involve preventive rail grinding. It must be a standard activity of the rail maintenance plan. Aim of preventive grinding is to provide optimal conditions in wheel-rail contact at the beginning of exploitation, to remove usual irregularities that appeared during rail installation and track laying, to reduce rail noise and future development of rail surface defects.Figure 1 shows the theoretical service life of the outer rail without rail grinding in a curve with a radius R > 1000 m. Consideration was based on the estimated linear progression of vertical wear 1 mm/100 mill. gross tons, side wear 0 mm and



permissible max. vertical wear 14 mm and speed v < 160 km/h. By the presumed exponential growth of HC defect without grinding, the real service lifespan was multiple shorter due to possible rail failure. Exponential growth of HC rail crack was expressed as an increase in defect size per accumulated gross ton traffic load (gross million tons – GMT).

The preventive rail grinding is maintenance activity that must be carried out without exception. In practice, the rail service life of the outer rail in curves (300 m ≤ R ≤ 3 000 m) is limited by head checking (HC) rail defect and the rail service life of the inner rail in curves is limited by long-pitch corrugation. HC crack should have a certain detectable size which depends on the detection technique used. The timely inspection of rails provides early detection of the initial fissures and detection of fissures below the rail head surface. Also, cyclical grinding of outer rail in a curve enhance the service life of rail & might provide simultaneous replacement of both rails and concrete sleepers.

Long-pitch corrugation generally occurs on the inside stretches of curves and affects the service life of inner rails. However, the long pitch corrugations can sometimes occur on the high rails of curves and sometimes on both. This is mainly a function of the inappropriate superelevation of the rail, which may lead to the higher load on one rail comparing to other.

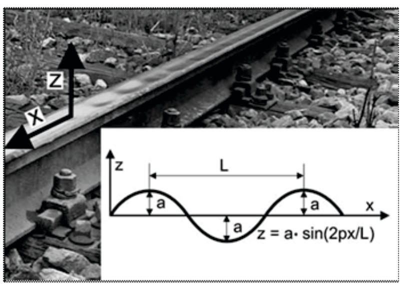


Fig 2

Figure 2 shows an irregular surface of rail head with defect and the sinusoidal model of longitudinal shape of this rail defect. Long-pitch corrugation significantly shortens the life span of inner rails.

Vertical acceleration of unsprung mass per wheel produce additional dynamic stress and contributes to deterioration of track geometry. The increase of ballast pressure results in decrease of maintenance cycle. This phenomenon is more prominent in the lines for heavy and mixed traffic.

In view of above , it is concluded that Rail wear, rolling contact fatigue and plastic flow are major contributors of rail deterioration depending on the operational conditions on modern railway lines for mixed traffic and high speed trains . Not all cracks impose derailment risk, but they are the major contributors to rail and track degradation. Fortunately, some of the rail defects are removed by wear and by rail grinding process during initial stages of crack development. The uncontrolled development of rail defects threatens traffic safety and increases the cost of rails maintenance: it may lead to premature removal of rails and complete rail failure.

(b) **Management of Special track structure:-** The nature of the structure of railroad tracks creates a unique challenge at the point where two tracks intersect. Special trackwork, such as turnouts and crossing diamonds and their constituent components, plays a vital role in railway infrastructure by providing route flexibility to trains as they travel across a network. Discontinuities in wheel/rail contact at the running surface and increased the vertical and lateral stiffness levels of special track work result in high impact loads and dynamic interactions between rail wheels and the specialty components that constitute turnouts and crossing diamonds leading to damage to the track ensues in the form of plastic deformation, component wear and rolling contact fatigue

Both high speed rail (HSR) passenger traffic & Heavy axle load (HAL) freight traffic require special track work components that minimize impact loads. However, notable differences between passenger traffic & freight traffic is the that High speed rail lines require turnouts and crossings that minimize or eliminate the need to slow the train while maintaining passenger safety and comfort.

On the other hand, special track work on Heavy axle load (HAL) freight lines is designed to withstand the high tonnage on a specific route while minimizing maintenance.

By definition, the loads from HAL freight trains are higher in magnitude and longer in duration than loads from HSR trains. When irregularities incite dynamic interaction between rails and HAL wheels, a dynamic amplification of the load magnitude can occur at higher frequencies. HSR loads have a lower magnitude, but the faster speeds result in a greater amplification of the forces. In an attempt to mitigate these impacts under increasing axle loads, and increase the life cycle of crossing, diamond components crossing with flange bearing technologies are being used

i) Flange bearing crossings

In the 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 railcar as it is essentially lifted over the intersecting track. One type of flange bearing technology is a full flange bearing frog (FBF) diamond as shown in fig 3

Fig 3

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.

(a) Turnout geometry

Figure 4 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. It is desirable to make low-cost modifications to several turnouts over a given section of rail line instead of single turnout for visible improvement in the average speed of the trains over that section. The critical components and locations in a standard turnout that cause speed restrictions are the toe of the switch which causes both a kink in the alignment and a change in curvatureTurnouts 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. Passenger comfort is a critical factor that has resulted in the requirement to rigidly adhere to high maintenance standards for HSR necessary for safety. Any redesign of the turnout would focus that the lateral forces generated as a result of centripetal action on the car body while negotiating the turnout are remain within the tolerable region.

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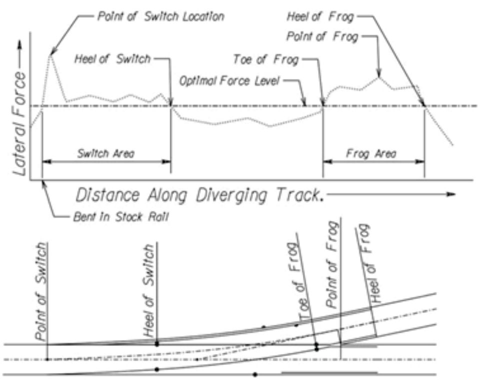

Fig 4

infrastructure. 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 by reducing the lateral forces by approximately 40%.

(iii) Gauge widening at switch entry:

Another method that can be used to reduce the thrust due to high axle load by the withed of kinematic gauge optimization (KGO). KGO is an innovative turnout design where the track gauge is widened at the switch entry area, reducing lateral impact loads. It does so by causing the wheels to ride outwards on the taper of the tread, thus steering a train car 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 depicted in Figure 5. As an exaggeration of the widened gauge at immediately behind the wheels.

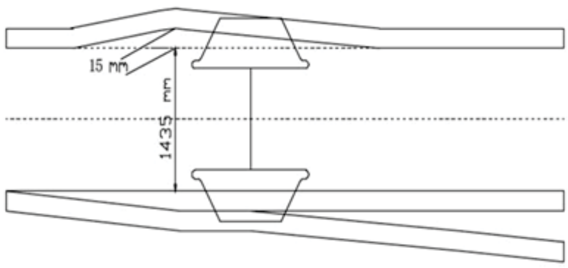

Fig 5

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. As per one study thus about 40% is decrier showed a 40% decrease in maximum forces for the turnout with KGO, which increases the life of the turnout components.

Operating speeds for this turnout were 190 miles/h for the mainline and 140 miles/h for the diverging route. Designing turnouts with transition curves in components such as the switch rail, lead rail, closure rails, or at points between the SRJ and ANC can mitigate unbalanced forces on the wheel set of a passing train. Making use of KGO technology and creating back-to-back spirals within an optimized turnout design can reduce wheel/ flange contact on the gauge side which in turn can minimize wear on the switch components.

6. Conclusions

It is an attempt to identify the challenges in mixed traffic system such as impact in the maintenance pattern due growth in traffic over the years for which proper balancing is required by optimum utilization of all the resources including traffic block. In safety category, assessing the risk of assets failure & adjacent track derailments during & after the maintenance activities , building of infrastructure such as grade crossing enhances the safety. In infrastructure, special track work, ballasted track, and track transition optimization were identified as top challenges. It is identify that Rail wear, rolling contact fatigue and plastic flow are major contributors of rail deterioration depending on the operational conditions on modern railway lines for mixed traffic and high speed trains . Not all cracks impose derailment risk, but they are the major contributors to rail and track degradation. Fortunately, some of the rail defects are removed by wear and by rail grinding process during initial stages of crack development. The uncontrolled development of rail defects threatens traffic safety and increases the cost of rails maintenance and it may lead to premature removal of rails and complete rail failure. Rail break is the last phase of crack development process and might lead to catastrophic derailment