Influence of Track Design and Health Conditions on the Vehicle-Track Interaction Loads

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The geometry and quality of typical Conventional Lines (CL) and High Speed Lines (HSL) have a fundamental impact on the dynamics performance of the running vehicles and on the loads exchanged between the vehicle and the track. For a given service, a careful analysis of the operation conditions is required in order to design a track friendly vehicle. To this end, Alstom has developed and validated reliable simulations methodologies and tools for the analysis of the complex vehicle-track multi-physic systems. The use of simulation tools for the analysis of the influence of the mission profile of the train and the maintenance condition of the track, with some hints for improvement of maintenance criteria, will be the objective of this paper.

How the mission profile of the train and the status of the track, varying from the nominal condition to the admissible maintenance limits, influence the vehicle/track interaction loads can be analysed via Multi-Body Systems (MBS) software simulations. The study is focused on track loads in different scenarios of track status, with particular view on (i) the effect of track quality, layout and construction characteristics on the vehicle/track interaction and track damage and; (ii) the impact of wear of rails on the dynamic behaviour of the train. The parameters and criteria required by the standards about running safety, ride quality and track fatigue are evaluated case by case. The interested reader can find more details in references [1-3].

This work focuses on the consequences of the track design characteristics and of the state of maintenance on the vehicle/track loads. The track parameters, like curvature, cant, rate of change of cant, gauge, rail profile, track stiffness and damping, are not the same for all the railway lines and deviate from the mean or designed values while time passes, thus affecting the loads on the track and on the vehicle components, and consequently their damage. In the following some examples of impact analysis are provided.

Given a constant cant deficiency, a significant variation of the distribution of the quasi-static track shift forces (SumY) among the wheelsets of the bogie and vehicle can be observed in function of the curve radius (Fig.1 left). On the other hand, higher cant deficiency, or Non Compensated Accelerations (NCA), on the same curves originates both the increase of the mean SumY forces and a different force distribution between wheelsets, as shown in Fig. 1 (centre). Figure 1 (right) shows the analysis of curve distribution on two typical lines: Line 1, a conventional line with high percentage of small radius curves; Line 2, an example of high speed line.

The effect of the track quality (track defects), consists in a further increase of the wheel/rail contact forces, depending on the speed, NCA and dynamic properties of the vehicle, as illustrated in Fig.1 (centre). Other parameters like the rate of change of cant, related to the length and gradients of the curve transitions, the track stiffness and damping values, the transitions between open track and tunnels, the bridges, can highly influence the forces exchanged between vehicle and track, determining the higher or lower margin to the running safety and to the loads on the vehicle and track components.

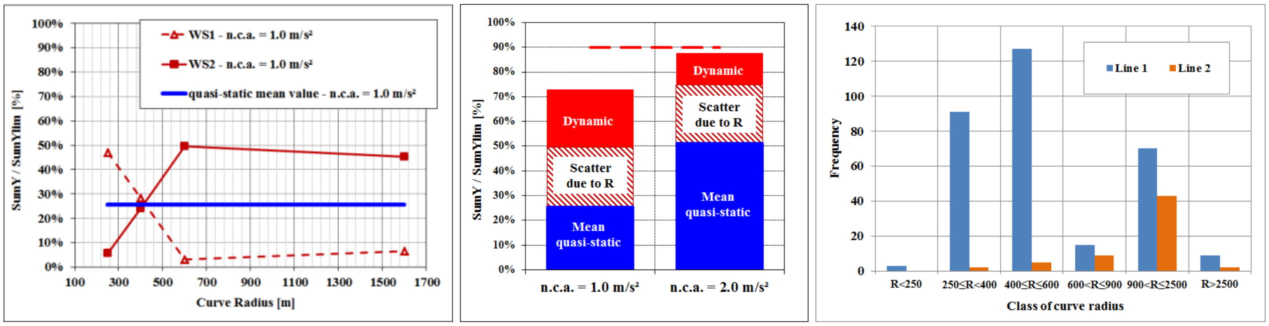

Fig. 1: (left) Variation of quasi-static SumY/SumYlim in function of curve radius; (centre) Components of track shift force SumY; (right) example of curve radii classification

Another important factor for the loads on vehicle and on track is the wheel/rail contact geometry, determined by the wheel profile, the rail profile, the rail cant and the wheelset and track gauge. A derived and synthetic parameter for the evaluation of the wheel/rail geometric conditions is the equivalent conicity γ_{eq}. Among the factors that can lead to a variation in the γ_{eq}, the wear of the rail, that can be observed during the revenue service, is considered here.

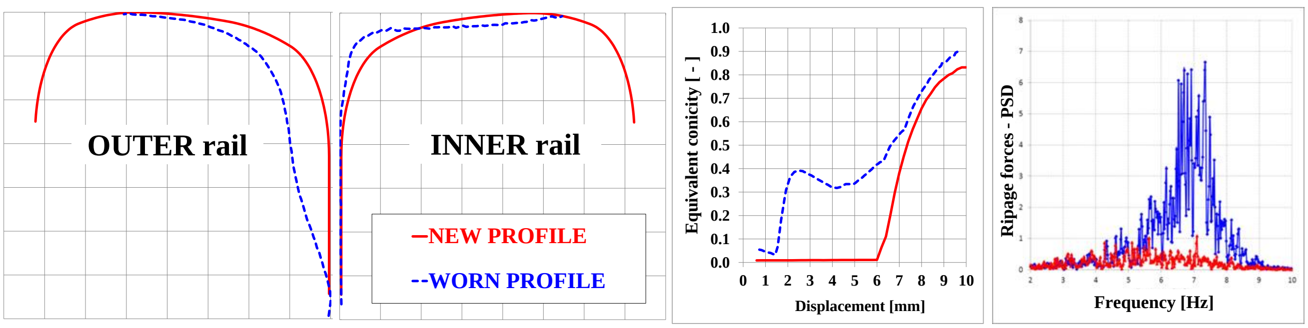

Fig. 2: (left) New and worn rail profiles; (centre) Equivalent conicity γ_{eq} function; (right) Track-shift forces analysis (PSD)

Figure 2 (from left to right) shows difference in shape of new (red) and worn (blue) rail profiles in curve, the equivalent conicity γ_{eq} calculated with new S1002 wheel profile and the effect of the two contact condition on the track-shift forces, correlating the track-shift forces level to the maintenance status of the rails. Further examples concerning the impact on the vehicle dynamic behaviour of other parameters like rail cant (1/20 or 1/40) can be found in works [2,3].

The track geometry (layout and irregularities), track design characteristics and wear of rail profiles affect the vehicle/track loads, becoming an important factor in the design and life cycle cost of the rolling stock.Hence, the simulations considering the track health conditions and service tolerances are important for a reliable assessment of the loads exchanged between vehicle and track.

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