New concepts for turnouts in urban rail transit infrastructure (TURNOUTS)

Final Report Summary - TURNOUTS (New concepts for turnouts in urban rail transit infrastructure)

The objective of the TURNOUTS project was to improve the vehicle-track interaction in the turnout systems for urban rail transit, and therefore improve their efficiency, enhance their safety levels, reduce the required maintenance, and restrain the emitted noise. These objectives were to be reached by reducing the loads and stresses in the frog and in the switch point / stock rail sections in comparison with a conventional turnout. The modern conventional turnout is of tangential geometry design and equipped with clothoidal transition curves. These eliminate the steady state flange contact-based form of curving condition in the diversion curve.

The following turnout systems were to be considered:
- turnouts with cast manganese and welded frogs;
- turnouts on concrete slab and on sleepers in ballast;
- turnouts with grooved rail and with vignole (T) rail;
- embedded turnouts (tram);
- free surface turnouts.

The objective was to obtain models capable of predicting the input forces within a margin of 3 dB considering known input data such as new or used wheel treads, track geometry, fixation characteristics, etc.

Two different simulation approaches were to be compared:
1. The first approach is based on a multi body dynamics model, which includes rails, fixation systems, foundation and vehicle. Some bodies are described using 3D finite elements and other bodies using lumped parameters. A numerical procedure was to be used to reproduce vehicle-track interaction whereby the equations of motion of track and vehicle are integrated simultaneously evidencing wheel-rail contact forces. This numerical simulation includes all non-linear effects and transient phenomena, which are relevant to
turnout negotiation.

2. The second approach is based on a non-linear 3D finite element analysis of the turnout system where the performance of the turnout (without vehicle) is calculated through a non-linear transient dynamic analysis. The input forces and finite element model parameters are derived from lumped parameter models, which are updated using experimental measurement results (static and dynamic).

Seven test sites had to be selected for evaluating the newly designed turnout systems. These sites had all to have different site specific characteristics such as concrete or ballast foundation, geometrical constraints, embedded or free running, tram or metro, requirement for manganese frog or welded frog, type of rolling stock, grooved rail and vignole rail.

In function of these actual site specific conditions, some of the above selected design measures had to be evaluated for each selected test site in terms of impact force reduction performance, using the validated models. For each test site, a different specific design had to be selected iteratively in function of its overall technical performance, cost, end-user preference and manufacturer preference.

The selected systems were to be constructed and tested in laboratory before installing and testing them on site. If possible, the systems were to be installed in a double turnout system with one turnout of the conventional design and the other one adopting the new design. The newly designed turnouts had to show a reduction of the impact force by at least 6 dB (factor of two) in comparison with the conventional ones. A conventional turnout exhibits a 10 dB increase in the vibration level (and hence impact force) in comparison with normal running on a tangent track. The newly designed turnouts were then to exhibit an increase in vibration level, which is no more than 4 dB in comparison with running on tangent track.

In other words, by reducing the impact force to 6 dB, this project targeted to increase the life time of the turnouts at least by a factor two and to reduce maintenance costs by 50 %.

The project was structured into six work packages (WPs), as follows:
WP 1: Modelling procedures for determining impact forces of turnout systems and sensitivity of these forces to changes in track and vehicle parameters
WP 2: Conceptual design of measures to reduce impact forces
WP 3: Modelling and optimisation of new turnout systems for use in selected field conditions
WP 4: Manufacturing of new turnout systems
WP 5: Lab testing and on-site installation and testing of the new turnout systems
WP 6: Final assessment.

In general, initially planned activities have well been accomplished and the results are fully compliant with the project's objectives. POLIMI and NTUA have developed innovative numerical modelling techniques capable to simulate the passage of a vehicle along the turnout, taking into account the variable geometry and stiffness of the turnout. These models have been validated on three different reference turnouts. Comparison with measured data has shown that the targeted accuracy of 3 dB has been reached.

The available seven designs, including drawings with geometry and material characteristics are:
1. new BFM frog with railpads with a stiffness of 50 kN/mm;
2. embedded FDP turnout with discrete rail fixations;
3. JEZ turnout with movable point frog;
4. D2S solution: turnout with under sleeper pads and ballast mat;
5. COGI embedded low profile turnout with wheel flange bearing;
6. COGI embedded low profile turnout, running on wheel tread;
7. industrial turnout with casted manganese steel crossing.

There were finally seven new turnouts manufactured and tested, corresponding with the seven designs listed above. There were finally seven new turnouts and one modified, corresponding with the seven designs listed above plus one longitudinally reprofiled turnout. The performance is considered as valuable, i.e. it shows a reduction of the impact forces with 50 %, for most of them. In cases where the performance is not reached, an explanation could be found, based on numerical modelling or technical installation contingences.

The project has realised a major technical breakthrough in turnout designs for urban rail. Following validated findings are of utmost importance:
- low rail can be used in turnout systems without jeopardising the system;
- completely embedded turnout systems (without discrete rail fixations) can be used without jeopardising the system;
- noise and vibration impact during turnout passage can be reduced to minimal (less than 4 dB or 4 dB(A) increase versus tangent track) when using: embedded turnout systems (COGIFER); hybrid turnout system (FDP); turnouts with movable point frog (JEZ);
- elastically supported frog (D2S);
- all validated turnout systems can be integrated in the street pavement (road traffic).

The major European industrial players for turnout systems (COGIFER, JEZ (VA) and BFM) have worked together in this project to come up with these solutions which are immediately applicable and available on the market.