European railway review

n° 3/2004, pp. 77-83, cart., fig., phot. - *(REVUE) - S/C : 0610*

Technologie de la ligne à grande vitesse de Madrid à la frontière française.

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Technology of the high speed line from Madrid to the French border

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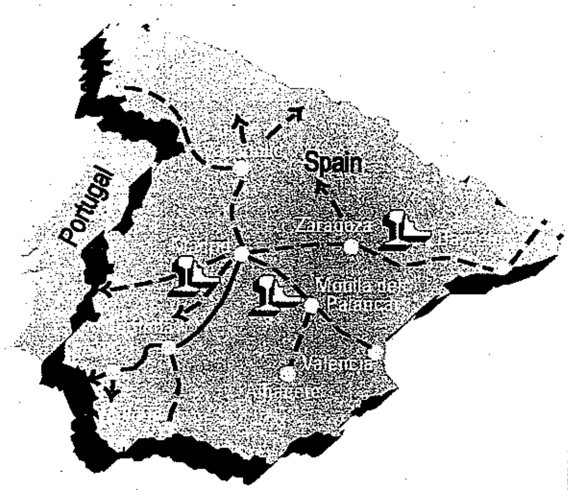
The Spanish infrastructure operator GIF is currently planning and constructing a high speed line from Madrid to the French border via Barcelona, thereby linking the Iberian Peninsula to the European high speed network. This line uses a variety of high speed turnouts and expansion joints, which this article looks at in detail.

In December 1996, the Spanish parliament decided to establish a railway infrastructure management with the task to build new high speed lines within the framework of the European railway infrastructure. GIF (Gestor de Infraestructuras Ferroviarias) was founded. One aim was given top priority: to connect the inner-Spanish high speed line Madrid-Seville to the European high speed network. This line has been in operation since 1992 and was already equipped with European standard gauge. The line went from Madrid via Guadalajara, Zaragoza, Lérida and Taragona to Barcelona. From here a connection was established via Gerona to the French border. An additional expansion on the French side resulted in the connection to the European high speed network.

Figure 1: High speed lines in Spain



Subsequently, new high speed lines have become part of the project. They lead from the north-south basic line to the centres of economy and tourism of the Mediterranean, such as Castellon, Valencia, Alicante, Cartagena and Malaga. The north west via Segovi-Valladolid and Medina del Campo was also included. Figure 1 shows the extent to which investment in new high speed lines was made.

Line Madrid-Barcelona-French border

The new high speed line from Madrid to the French border measures approximately 790 km. Plans are to complete the construction as far as Barcelona by 2004/2005. Constructions were made in three segments and have been completed to a great extent. This line uses a great variety of high speed turnouts and expansion joints:

- Madrid-Zaragoza-Lérida: 166 turnouts; 94 expansion joints
- Lérida-Martorell: 80 turnouts; 72 expansion joints
- Martorell-Barcelona-French border: 50 turnouts; 30 expansion joints

High speed trains such as ICE, TALGO or AVE will reach speeds of up to 350 km/h on this line. To connect these cities, further development of the Alstom Pendolino train as well as the use of trains with exchangeable gauges (type Brava, CAF), which reach a top speed of 350 km/h, will be required. Unlike the development of the Madrid-Seville line, these new lines are planned for mixed utilisation in order to transport goods to the European network.

At intervals of 25 to 30 km, single crossovers with a branch-off speed of 220 km/h were installed. The rail distance of the crossovers is 4.7 m. This high speed ensures an economically optimal utilisation of the Magistrale at little loss of journey time. The same high speeds are used when changing the tracks in railway stations. The sketch of a railway station along the line (Figure 2) shows an

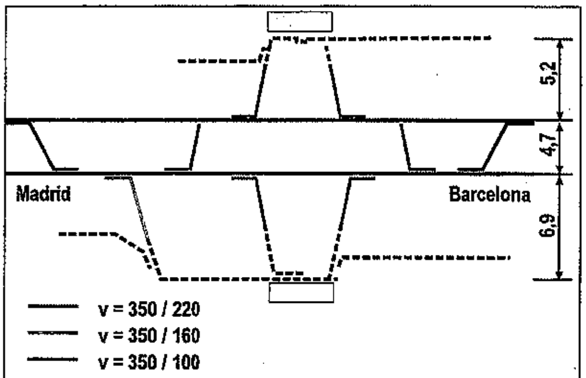


Figure 2: Typical railway station along the line

exemplary arrangement of the turnout with the planned speed in the enter and exit area and at the single crossovers.

Conventional ballasted tracks are used for the entire line. The decision as to whether ballasted or non-ballasted tracks were to be used was made in favour of ballasted track, seeing that the time of planning was short and also that there was little experience with construction on non-ballasted tracks.

Turnout technology of the new high speed lines

High speed turnouts are manufactured in accordance with European standards and based on 10 years of experience with the high speed line Madrid-Seville. Additionally, information was exchanged over many years.

Discussions about new technologies and developments were regular items on the agenda of the commission Técnico-Mixta, consisting of AVE, TIFSA and BWG, with Spanish turnout producers being periodically involved. Subjects were:

- Standard data of TSI (interoperability guidelines) of the European Union
- Standard data of CEN
- Positive experience with the high speed turnouts of BWG on the high speed line Madrid-Seville, particularly as far as easy maintenance was concerned

Additionally, GIF generated a performance specification for the design of the turnouts. The target is to further develop tried and tested constructional elements for high speed turnouts that come as close as possible to the track behaviour. The overall concept pays special attention to the following key points:

- Low-wear and economic geometry of the turnouts and turnout connections
- Wear-reducing kinematic optimisation in the transit areas of the wheel under consideration of the rail inclination
- Low-maintenance economically optimised vibration damping of the turnouts
- Low-lubrication moveable components
- Low-maintenance setting system with optimal availability

All relevant data of turnout development (Table 1) and constructional demands (Table 2) were deliberated and discussed in detail.

Constructive and productive implementation

The total line Madrid-French border measures almost 800 km of track and houses approximately 290 high speed turnouts and 176 expansion joints. Three turnout geometries for branching-off velocities of 100, 160 and 220 km/h were

Table 1: Geometrical demands with regard to the turnout

Maximum jerk at the beginning of the turnout	< 1.0 m/s²
Maximum jerk in the turnout	< 0.4 m/s²
Maximum lateral acceleration	< 0.5 m/s²
Combination of curves in the turnout	Clothoid segment – circular arc – clothoid segment
Curve in the single crossover	No straight line, only clothoids to the apex
Length of the arc segments	Each roughly 1/3 of the entire geometric length
Geometry of the tongue	Wear-resistant FAKOP
Inclination of rails	1:20

determined. Depending on the length of the viaducts, the arrangement of the expansion joints varies between an extension length of ± 150, ± 300 and ± 600 mm.

of turnout. The tongue device itself is 63 m, with the tongue measuring 61.7 m without welding. The crossing houses eight HRS locking devices with hollow sleepers and eight end-position testers. The

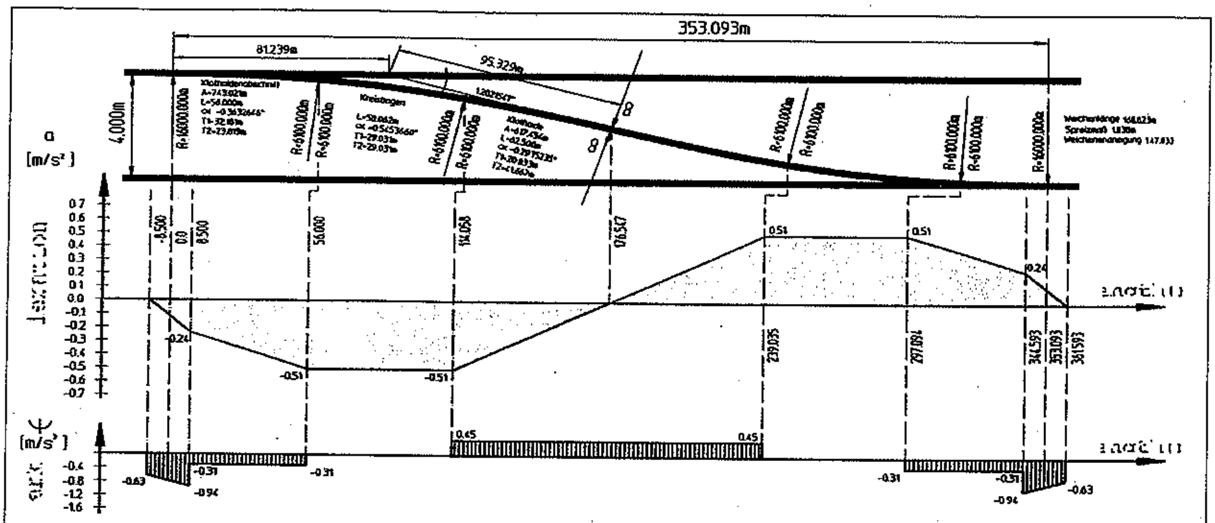


Figure 3: Sketch of the geometric configuration 7

Construction works started in autumn 1999. According to the schedule, the prototype was to be completed within one year. The installation of the first turnouts was planned for 2000 and two thirds of all turnouts are to be implemented by the end of 2004.

To generate and to ensure the required capacities and the experience and knowledge necessary when working with high speed turnouts and expansion joints, with the agreement of GIF, the group AJA UTE – consisting of the partners BWG and their affiliated plant JEZ, the turnout producers Alegría, Amurrio and Cogifer – was founded. The most important coordination between the parties involved was performed by the company Pasch with headquarters in Madrid. As specialists for high speed turnouts, BWG and Cogifer split the work, with BWG being responsible for the leadership in the technology to be used for the construction of the turnouts and expansion joints and Cogifer for the constructive processing of the moveable crossings.

Basis of and condition for the technological leadership of BWG is the experience in high speed technology gained in many years in the constructive, productive, logistic and service sectors.

Based on the technological demands, the following three types of turnouts were developed:

crossing has a constructional length of 28.8 m. A VCC locking device is fitted to the tip of the crossing. Additionally, three setting devices guarantee that the crossing block is in the correct position. Moreover, this position is guaranteed by four position testers. The longest non-welded intermediate rail measures 62.4 m and the shortest 20.4 m. Plans are for 138 turnouts of this type to be used as track connection or areas of transition, respectively.

Figure 4: FAKOP

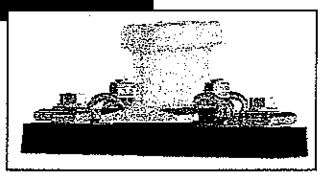


Figure 5: Highly-elastic standard ribbed plate with a base rigidity of 17.5 kN/mm

For v = 350/220 km/h

For a branch-off velocity of 220 km/h, the turnout EW 60-17000/7300-1:50 fb with a total length of 180 m is used. Figure 3 shows the geometric configuration of a track connection using this type

For v = 350/160 km/h

For a branch-off velocity of 160 km/h, the turnout EW 60-10.000/4000-1:33 fb with a total length of 130 m is used. This geometry is based on the high speed turnout already used on the line Madrid-

Seville. It is used both as branch-off and as connection turnout.

For v = 35/100 km/h

EW 60-3.000/1.500-1:22 fb, with a total length of 81 m, has a branch-off velocity of 100 km/h. This geometry was selected according to the model of a turnout developed for DB AG.

Constructive elements

In the following, examples of innovative components used in high speed turnouts are introduced:

FAKOP geometry in the tongue device

Kinematically optimised areas of transition (Figure 4) in the tongue device offer the following advantages:

- Continuity of sinusoidal run from the track through the tongue device
- Less lateral wear at the tongue, due to control of the wheel through the contact of wheel/rail on the branching-off turnout line
- Longer life cycle of the tongue device, due to thicker tips of the tongue and in the transition area
- Increased position stability in the tongue device, due to controlled sinusoidal run
- Increased travelling comfort, due to reduced transversal stress
- Total advantage: considerably reduced maintenance expenses

Highly elastic standard ribbed plate

The construction involves mounting on an elastic base using standard ribbed plates with a base rigidity of 17.5 kN/mm (Figures 5 and 6) and is characterised by the following qualities:

- A buckled flat spring characteristic generated by upper and lower elastomer springs with defined depression of the entire base
- Identical depression over the entire turnout length, allowing for different rigidities of single rail, several rails on a base and a crossing that is considerably more rigid that a single rail

Table 2: Constructional demands with regard to the turnout

Rail profile	UIC 60 900 A quality HSH
Tongue profile	UIC 60 900 B quality HSH
Sleeper division	600 ± 20 mm
Tongue type	Non-welded flexible tongue with drop forging inclined 1:20
Ribbed base plates	Elastomer springs galvanised to ribbed plates with a rail depression of approximately 2 mm. This results in a base rigidity from 10 to 17.5 kN/MM, depending on the track rigidity, so that the sinking in the areas of rigid elements, such as the crossing, is identical to that in the area of simple rail bases
Elastic ramp turnout/track	Length of the elastic ramp between rigid track and more elastic turnout = 0.5 s journey time
Stock rail bracing	Divided inner stock rail bracing with intermediate layer under stock rail type 'Brandenburg'
Type of crossing	Moveable crossing for v = 160 to 350 km/h
Type of sleeper	Reinforced concrete sleepers for turnouts with fit-through bolting, dimension w/h 0 300/220 longest sleeper approximately 3.3 mm, longer sleepers divided with elastic vibration absorbers
Turnout setting system	Optimised setting system with single drives and testing of the final position with setting reserve for high availability
Locking device	HRS locking device with adjustable pressing-down force in the tongue device and VCC (French construction) in the moveable crossings
Hollow sleeper	Hollow sleeper of steel in tongue devices and moveable crossing with integrated drive housing

- Vertical depression of the components without dynamic tilting of the track units
- When mounted onto the sleepers, the plates are defined through a spacer bushing and braced to an elastic spring. Measuring is not required
- Due to a special elastic intermediate layer inserted between rail and plate, the system reduces sound and dampens vibration
- The plate system can easily be aligned vertically or horizontally on the sleeper
- For many years, the system of highly elastic ribbed plates has been successful both in light rail, due to the sound-reducing effect, and in high speed traffic, due to its vibration-damping effect and the more favourable distribution of the wheel load
- It is particularly the load-distributing effect that lowers maintenance expenses

Separated highly-elastic inner stock rail fastening

The construction of the separated highly-elastic inner stock rail fastening (IBaV) is characterised by the following qualities:

- The slide chair is separated from the base plate and is connected with it by a retainer and two tension springs
- The tip of the glide chair presses onto the foot of the stock rail. The wheel load takes effect on the tongue via slide chair on the stock rail.

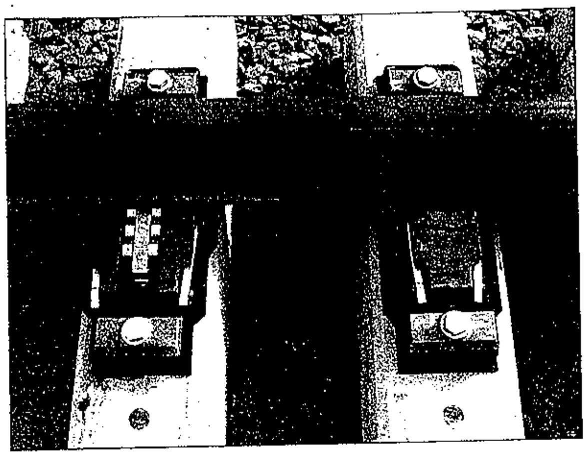


Figure 6: Separated inner stock rail fastening

Through to the transition area, tongue/stock rail, there is vertical force on the stock rail, rendering a tilting of the stock rail impossible. The system does not require overload protection

- Unlike other systems, the stock rail need not be tilted for assembly but can be placed onto the base plate vertically. Subsequently, the stock rail is fastened with two springs. This simplifies assembly work particularly with long tongues similar to those applied in high speed traffic

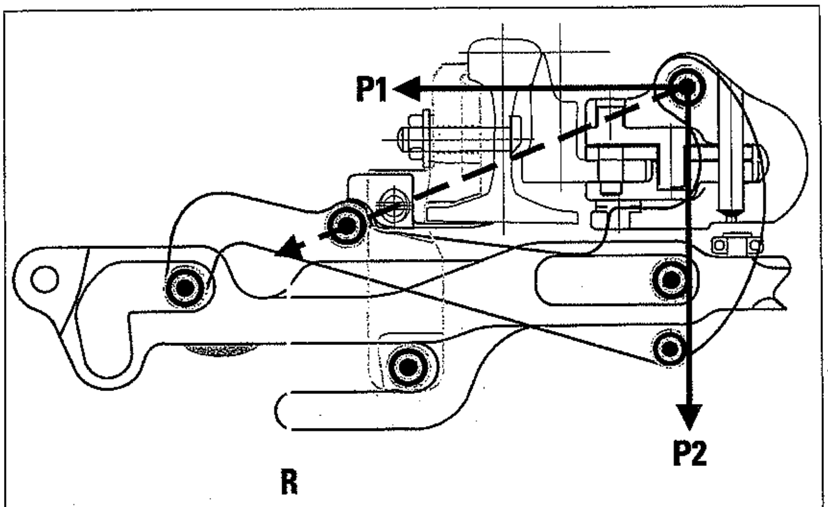


Figure 7: HRS locking device with retainer function in the tongue device

Vibration dampers for the connection of divided sleepers

The use of vibration dampers for the connection of divided sleepers (Figure 7) is characterised by the following qualities:

- Long sleepers in the areas between the rails and the crossing are separated (shortened) to reduce the vibration amplitudes. The component vibration damper serves a coupling between the two sleeper ends and transmits transversal forces, which are minimised at the area of coupling, to retain the gauge. This ensures a quieter and more stable position of the sleeper. The 'whip effect' at the end of the sleeper is significantly reduced

Figure 8: HRS locking device fitted into the turnout

- As a side effect, it is possible to transport large turnout segments, pre-assembled with sleepers, on standard wagons. The maintenance of special wagons, accompanied by significant additional expenses and logistics, is no longer required
- The improved position stability reduces maintenance expenses
- Transport expenses for completely assembled turnouts are reduced
- The logistic requirements connected with transport and mounting of pre-assembled turnouts are simplified and less expensive, seeing that certain equipment is no longer needed

Low-lubrication HRS locking devices

The use of low-lubrication HRS locking devices (Figures 8 and 9) is characterised by the following qualities:

- All movements inside the locking systems, including the locking process, are performed by rolls. The roller friction is considerably lower than the usual gliding friction. The setting forces are reduced. Availability is increased
- Due to the high contact of the tongue in locked condition, it is not only braced horizontally with the stock rail, but also a depressing force takes effect on the slide chair. For this reason, tongue, stock rail and slide chair act as one unity. The locking device is pre-tensioned when being set
- During the opening movement of the locking device, the tongue is raised by a connecting link to minimise friction between tongue foot and slide chair. To support this process, tongue rollers are arranged in the area of the locking device
- An eccentric bolt that can be moved and fixed with a standard wrench is used to set the locking device and to regulate the device tongue/stock rail
- All rollers in the locking device are elastically supported. This leads to a damping of the entire system

The production of the turnout components was split between the partners of the executing group according to the technical capabilities of the partners. BWG delivered the following components:

- All forged tongues UIC 60 B / UIC 60 A with a forged length of 600 mm, the forged part being inclined to 1:20, and tongues of HSH quality

- All highly elastic ribbed plates, including the elastic transitions in front of and behind the turnouts
- All vibration dampers to connect the separated sleepers
- All HRS locking devices for the tongue devices
- Part of the tongue devices in pre-assembled mode with ribbed plates mounted
- All basic components of the expansion joints

For final assembly, all components were joined at the location of our Spanish partners. Supported by BWG, the Spanish partners also took over the logistics regarding transport to the site. They were in charge of the accompanying supervision during the installation of the turnouts performed by Spanish companies. Additionally, assembly sites were set up at the location of the construction. The pre-assembly was performed there. This means that the fully assembled turnout segments could be transported directly to the site of construction.

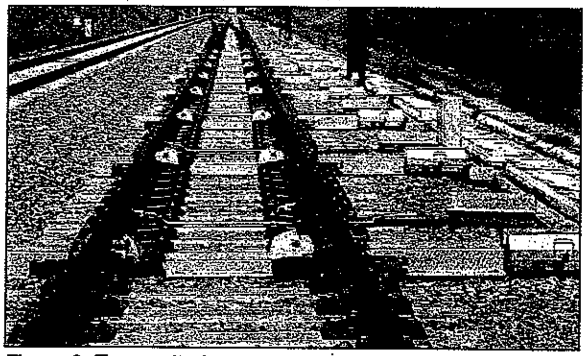


Figure 9: Turnout in the new track

The system of expansion joints

As far as speed, gauge behaviour and dynamics in the area of viaducts are concerned, an exemplary technological concept and first class manufacturing is required.

Figure 10 shows the system of the BWG expansion joints which takes into consideration special requirement such as:

- No changes of the gauge due to longitudinal motion of the bridges
- Continuous rigidity with load-distributing effect in track and turnouts
- Universal track configuration for longitudinal motion of bridges of ± 150 to ± 600 mm
- Construction of auxiliary bridges with extension lengths (from ± 300 mm) in the area of the bridge joint with the same depression, respectively, sagging behaviour as in the track

Additional tests of the described construction performed at the Madrid-Seville line fully confirm the quality of the concept generated and implemented by the engineers.

Summary

In addition to the new Madrid-Zaragoza-Lérida-Barcelona-French border line, a number of new high speed projects are in the planning stage or currently under construction in Spain. The equipment on the sections Segovia-Valladolid, the

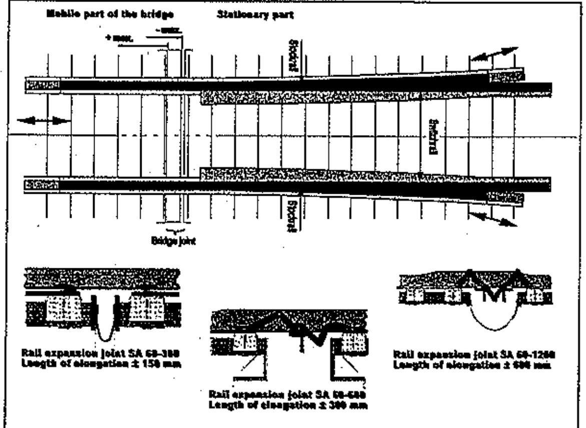


Figure 10: The system of the BWG expansion joints

connection of Toledo to Madrid and Almodavar-Bobadilla has begun to be implemented. This line section also used the above described turnout technology. The decision was based on admission and test related runs on the Madrid-Zaragoza line. The turnout technology was shown to have excellent behaviour and top qualities.

Concentrating BWG know-how and manufacturing capacities, the expectations of GIF with regard to deadlines, quality and available total budget can be met.

The modulation, up until now all-encompassing, is an excellent and positive example for a successful, concentrated and target acheiving cooperation between planners, technology and turnout producers. This motto shall remain valid for the future construction of the Spanish high speed network.■

Hubertus Höhne began his career in the Permanent Way Construction division of Deutsche Bahn AG. From 1987 – 1991, Mr Höhne's secondary employment was as an expert with Deutsche Eisenbahn Consult (DEC) for the Metro Sao Paulo project in Brazil and the Great Belt project in Denmark. Until 1991, he remained at Deutsche Bahn AG and his last position there was engineer and section leader for technical innovations, based in the head office of the DB Turnout Technology division. In 1991, Hubertus Höhne was appointed head of the design, development and sales departments of Butzbacher Weichenbau GmbH, today known as BWG GmbH & Co. KG. Since 2000, he has been a member of the executive board of BWG and is responsible for technology-related matters.