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MAJOR TECHNICAL FEATURES OF TGV TRAIN SYSTEMS

Із збільшенням швидкостей руху поїздів TGV, виникає багато проблем, пов'язаних з дизайном використовуваними матеріалами та безпекою. Вирішення цих проблем потребує великих інвестицій від залізниць Франції в науково-дослідні проекти. Інвестиції повинні отримати вигоду в далекій перспективі. Нові лінії TGV повинні бути відкриті у місцях, де є достатня потреба у поїздках на великі відстані, що спричиняють отримання розумної вигоди системними операторами TGV.

С увеличением скоростей движения поездов TGV, возникает множество проблем, связанных с дизайном, используемыми материалами и безопасностью. Решение этих проблем требует крупных инвестиций от железных дорог Франции в научно-исследовательские проекты. Инвестиции должны принести выгоду в отдаленной перспективе. Новые линии TGV должны быть открыты в местах, где есть достаточная потребность в поездках на большие расстояния, способствующих получению разумной прибыли системными операторами TGV.

With increase of the speed limits of the TGV train systems, there are many problems arising as regards the design, used materials and safety. Solutions to these problems demand heavy investments from the SNCF company into research and development projects. As such investments must be profitable in a longer term, new TGV lines have to be established between places where there is a sufficient need for long distance travel able to bring reasonable profit to the TGV train system operator.

Introduction

The TGV (**Train à Grande Vitesse**) stands for the high speed train in French. It refers to more than just the trains. Indeed, the TGV is a system which comprises train, track and signalling technologies that when combined make high speeds (typically 300 km/h) possible. The TGV system is owned and operated by SNCF, the French national railways, and is an integral part of French rail travel. Today there are approximately 350 train sets of this system in service.

Historical overview

The TGV program was launched in the late 1960s. In its early stages, the program was considered a technological dead end. Conventional wisdom at that time held that steel wheel on steel rail technology had been explored to its fullest, and it was time to move on to more innovative technologies like magnetic levitation and jet-powered hover trains. As a result, the project did not receive any government funding.

Nevertheless, SNCF followed its idea to develop a high speed rail system that would have remained compatible with the existing railway infrastructure. Especially in the heart of the cities it was extremely important to use existing facilities because building any new tracks in that areas would be prohibitively expensive.

Present situation

Even if it did not seem so at the beginning, the TGV project was incredibly successful. After intensive prototype testing started in the early 70's there was a first part of the Paris-Lyon line put into operation on 27 September 1981.

It became one of the few parts of SNCF that turned a significant profit, and completely paid for itself (including construction costs) in only a decade. The French government, faced with this success, hailed the new system and offered its backing for further development of the nascent high speed rail network. The TGV had become a technological symbol associated with France. Since then, new TGV lines and trains have been built, and improvements made with each generation. In 1989, the TGV Atlantique made its debut, serving points west of Paris. The trains incorporated many improvements over the earlier Sud-Est generation, a sign of the continuing research and development being conducted by SNCF and its contractors. Most notably, the 1981 speed record (380 km/h) was pushed to 515.3 km/h on 18 May 1990, using the newer generation equipment.

Today, there are three major trunk lines radiating out of Paris, the most recent one being the Nord-Europe line, opened in 1993 and connects Paris to Lille, Belgium, the Netherlands, Germany, and Britain through the Channel tunnel. Extensions continue to be built, although budgetary constraints have slowed the momentum of the TGV expansion.

Technical features

Concerning the train itself, its most striking aspect is the aerodynamic styling of the nose. But that is not the most innovative feature of the TGV train system. There are many others which are not so evident but are worth to be described.

1. Articulation

As regards the articulation, cars are not merely coupled together; they are instead semi-permanently attached to each other, with the ends of the two adjacent cars resting on a common two-axle truck. That is why it is more appropriate to speak of «trailers» than of «cars».

There are several good reasons for this design. The TGV was designed from the beginning to be a very lightweight train; so it made sense to reduce the number of axles. Placing the wheels between the trailers also reduces interior noise levels, provides more space and a higher plane for the suspension (secondary suspensions are in red on the picture), and improves aerodynamics (due to the lower height and small inter-trailer gaps). Articulation of the train also allows adjacent trailers to be dynamically coupled by dampers, and makes possible a clean, quiet passage from one trailer to the next.

2. Brakes

Current TGV train sets use three brake systems: disks, dynamic brakes on powered axles and in some cases tread brakes for emergencies. For speeds of 350 km/h and more, these conventional brakes lose their ability to stop the train in a reasonable distance and cannot perform a safe emergency stop. The problem is simple: kinetic energy, which must be dissipated as heat in the braking system, grows as the square of speed.

For the TGV Nouvelle Génération, an entirely new brake system is needed. Adhesion at high speeds is insufficient to perform quick stops using wheels alone. The wheels tend to skid, and the brakes can overheat and wear quickly, increasing maintenance costs. Therefore, it is necessary to use a system that bypasses the wheel/rail interface. This system, the magnetic induction brake, is based on existing magnetic brake technology which was originally explored using the Zébulon test vehicle. Magnetic induction brakes dissipate kinetic energy of the train as heat in the rail, by way of induced eddy currents. They are only effective above about 220 km/h (137 mph), because they put so much power to the rail that thermal damage to the railhead would result at lower speeds. There are several technical concerns with magnetic induction brakes. Successive brake applications by several trains over the same stretch of track could overheat the rail, resulting in operational restrictions. In addition, they apply upward forces on the track, which is not designed for such loads.

A prototype of a magnetic induction brake was built and underwent testing on a TGV Réseau train set; it provided up to 16 % of the braking effort. In stowed position, the brake shoe (mounted under the power car's truck side frames) rides 10 cm (4 in) above the rail; when applied, it skims a few cm above the rail without actually touching it. Currents generated by the traction motors create a magnetic field, and the motion of the train causes circular currents to flow inside the rail. These currents produce a retarding force on the train, and are turned into heat by the internal resistance of the rail. (This is Faraday’s law in action!)

The disk brakes are also in need of supplemental thermal capacity to sustain longer applications; this can be achieved through the use of new materials. A carbon disk/carbon pad architecture is under consideration, although such systems experience large variations in effectiveness and wear, in addition to being prone to oxidation problems. Another design is inspired by the disk brakes of airliners, using a rotor disk sandwiched between two stator disks by hydraulic pressure. This runs into problems of braking effectiveness as a function of speed, requiring sophisticated active control of another league than the simple antilock system used today. It also poses problems for maintenance, requiring disassembly for inspection. Yet another direction of research is a high-pressure carbon/carbon brake, using contact pressures an order of magnitude higher than in other designs. This technology is touted to increase the thermal capacity of each disk from the current 18.5 MJ to 45 MJ, while decreasing the weight of each truck by 500 kg (1100 lb). Finally, the «furthest out» designs call on ceramic/ceramic brake systems.

3. Weight reduction

Axle loads become a critical constraint at high speeds, in order for maintenance costs of track and train to be reasonable. It is the reason why the keeping weight down is one of the biggest challenges for the design of the next TGV generations.

The first approach to reduce weight is new materials. For the TGV Duplex car bodies, aluminium is used. The trailers are a monocoque design assembled out of extrusions, yielding a weight reduction of 20 % over an equivalent steel structure. The frame of the power cars is made of high tensile strength steel, as in the TGV

Atlantique units, for a weight reduction of 10 % over lower grade steel. Stainless steel could also make an entry into the new train sets, as well as composites. Composite materials are not used on the TGV Duplex's main structural components for reasons of cost, and also because the technology was not deemed sufficiently mature. Future TGV generations, however, could be built with a composite main structure assembled with glue. There is a research effort to explore the resistance of composite materials to the wear and tear encountered over 30 years of high-speed operation. Other weight reductions are achieved by using better paints, electrical wires with thinner insulation, and many other small measures that become significant when added together.

4. Noise reduction

Noise is another major concern of high speed rail technology, not only for the passengers but also for those living near high speed tracks. The interior noise level of the new TGVs, in particular, suffers from all the weight-reducing measures described above. The solution adopted is to isolate the interior from the structure, using flexible blocks as well as a sound-deadening composite laminate.

Outside of the train, aerodynamic noise begins to dominate wheel noise at high speeds. Better aerodynamics not only reduces the emitted noise, but also moderates the energy consumption of the train. Field measurements via laser velocimetry, wind tunnel tests, as well as computer models have been used to investigate the flow characteristics in the vicinity of the car bodies. Much attention centres on the nose profile, and shrouding of the trucks; data is being shared with Japanese researchers who are pursuing similar matters. While the TGV NG power car looks much like a 3rd generation power car, exterior shapes for future designs are being further optimized. The fifth generation TGV, currently under the form of the MX100 research project, will have a radically streamlined nose profile. This is because at the speeds envisioned, aerodynamic drag dwarfs every other source of resistance to motion; improving the aerodynamic characteristics of the train therefore has a big payoff.

Other points of interest are the study of the interaction of the train with nearby obstacles, such as in a tunnel. Special shapes can reduce the strength of pressure waves generated by the train, thus improving passenger comfort. An early result of this research was the profile of Eurostar´s nose, which is optimized for running in the Channel tunnel.

Trackside noise reduction has also been a focus, with passive and active solutions. Acoustic walls can be built (and have been built in many places) to shield noise-sensitive areas from the track, yielding reductions of overall train noise on the order of 10 to 15 dB. Active systems using loudspeakers embedded in the walls are also under consideration.

5. Crashworthiness

Following recent trends in the auto industry, there is significant effort going into passive security of TGV train sets.

Using new software for railroad crash simulation, called 'Pamcrash', the TGV Duplex structure was optimized on a supercomputer. The trailers have extremely rigid bodies with deformable, energy absorbing crush zones at the ends. The coupling between the power cars and trailers has also been reviewed; it still uses screw-link couplers with buffers, but the buffers have structural fuses built in so that they fold away under crash loads. The car ends have been reviewed to prevent the power car from climbing onto the first trailer. For multiple unit operation, the Scharfenberg couplers in the noses of the train set have been designed to collapse under heavy loads, so that two power cars coupled nose to nose can make firm contact with each other to prevent telescoping. This is in addition to the energy absorbing ram shield already mounted in the nose of all TGV power cars to defend the cab cubicle.

6. Signalling

As regards the signalling in TGV systems, it is the *exclusive* use of in-cab signalling for high speed running. TGV lines do not have line side signals; they are too difficult to read at speed. All signalling information is transmitted to the train through the rails, and appears to the engineer in the cab. In general, TGV train sets are heavily computerized, and many important functions are controlled digitally.

7. Tracks

Dedicated TGV lines use no special technology - just welded rails laid on hybrid steel and concrete ties, over a thicker than usual bed of ballast. The greatest difference lies in the combination of curve radii and super elevation that make high speed possible; a 5 km (3 mi) radius would be considered tight. The track centres are spaced further apart than usual, to reduce the blast of two crossing trains. Signalling blocks measure 1500 m (5000 ft) and certain lines allow one train every three minutes. The catenary is of completely standard design, essentially identical to 25 kV equipment on other French lines. The track and catenary are aligned and tuned specially for high speed.

Conclusion

With pushing up the speed limits of the TGV train systems, there are many problems arising as regards the design, used materials and safety. Solutions to these problems demand heavy investments from the SNCF company into research and development projects. As such investments must be profitable in a longer term, new TGV lines have to be established between places where there is a sufficient need for long distance travel able to bring reasonable profit to the TGV train system operator.

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