Railway-vehicle Technologies for European Railways

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OVERVIEW: At Hitachi, Ltd. a bulk order was received for 174 railway cars to run from 2009 on the Channel Tunnel Rail Link connecting London and the Straits of Dover in the UK. In August 2007, the first prototype train (consisting of six cars) arrived in the UK, and it is due to continue undergoing operational tests in the months ahead. To adapt technologies acquired in Japan to European train systems, it is important to satisfy local standards as well as the demands of customers. In this report, on the one hand, standards that presented a challenge to meet while developing this train are introduced in comparison to Japanese standards; while on the other hand, as examples of application of these technologies to European standards, our efforts regarding assurance of safety during collisions are presented.

INTRODUCTION

HITACHI received orders for 174 cars (i.e. 29 train sets with 6 cars per set) of our Class 395 high-speed train (with a maximum speed of 225 km/h) for operating on the CTRL (Channel Tunnel Rail Link) line between London and the Channel Tunnel — which crosses the Straits of Dover. It was the first time a Japanese rolling-stock manufacturer had received a bulk order for a high-speed train for operation in Europe including the UK. The train will start commercial operation in 2009 on train lines currently under high-standardization construction aiming for completion in time for the opening of the London Olympics in 2012.

Between August 2007 and January 2008, a total of 18 cars arrived (in increments of prototype train sets) to the UK, and they were received at the Ashford rail depos (operated by Hitachi's on-site maintenance company HiRaM). At the dedication of the rail yards in October, in the presence of the Secretary of State for Transport, the Right Honourable Ruth Kelly, and the Japanese Ambassador to the UK, Mr. Yoshiji Nogami, and at a commemorative ceremony marking completion of the refurbishment of St. Pancreas Station in November, in the presence of Her Majesty the Queen, the train was unveiled. From now onwards, it is planned to continue running tests on the train and confirm additional reliability.

The Class 395 — based on the "A-train" concept(1) — adapts lightweight, high-speed technologies

Fig. 1—High-speed Trains for European Railways (Class 395 in the UK).
Hitachi has developed and delivered high-speed rolling stock — based on the concept and technology of the high-speed, lightweight "A-train" acquired in Japan — for the Channel Tunnel Rail Link connecting London and the Straits of Dover in the UK. From now onwards, we will develop railway vehicles in accordance with the needs of European railways.

acquired in Japan to the UK's railway system. Naturally, providing a layout that meets the demands of British passengers and building a train in compliance with local standards were significant challenges.

In the rest of this report, as Hitachi's vehicle technologies for European railways, national technical standards that presented the major challenge in development of the Class 395 train are introduced, and particular measures taken in regard to crashworthiness are described.

ACCOMMODATING SPECIFICATIONS

As a specification that must be satisfied for the Class 395 to operate in the UK, technical standards have been established by the UK and Europe. Of the standards with contents significantly different compared to those in Japan, certain main ones are listed in Table 1. As the main technical standards, RGS (Railway Group Standard)[2] in the UK and TSI (Technical Specifications for Interoperability)[3] in Europe are quoted. TSI and RGS were developed for respective independent railways; the former is stipulated by EU Directive and the latter is stipulated by the UK's RSSB (Rail Safety and Standards Board). RGS covers railway systems established up to now in the UK. Meanwhile, for systemizing open railways between regions of each country in Europe, TSI assumes interoperability between countries. That is to say, satisfying both sets of standards in each country and in Europe made it possible to assure both compliance with conventional technical standards and versatility across the regions of Europe.

TABLE 1. Specifications of Railway Vehicles in the UK
In the UK and Europe, contents according to multiple specifications are prescribed in detail.

	UK	Europe	Japan
Collision	RGS, ATOC	TSI (EU Directive)	None
Body-structure behavior load	RGS	EN	JIS
Material strength	BS	EN (BS)	JIS
Aerodynamics	RGS	TSI (EU Directive)	None (customer spec. sheet)
Noise	RGS	TSI (EU Directive)	Environment Agency announcement
Fire resistance	BS, RGS, ATOC	None	Ministry of Land, Infrastructure, Transport and Tourism

RGS: Railway Group Standard
ATOC: Association of Train Operating Companies
TSI: Technical Specifications for Interoperability
BS: British Standards
EN: European Norm
JIS: Japanese Industrial Standards

Crash Performance

In Europe, if by chance there is a collision between railway vehicles, crashworthiness for assuring safety of passengers and crew is demanded by society. Consequently, research on crashworthiness has been going on from long ago, and in the UK, technical standards covering crashworthiness were already established over ten years ago.

Loading Conditions

Under the JIS (Japanese Industrial Standards), three loading conditions acting on a train body during normal operation are assumed; under RGS, 21 are assumed. In addition, loading conditions that are equally or more stringent than those under JIS are stipulated under RGS.

Material Strength

In the case of JIS, although static strength is specified, fatigue strength is not. On the other hand, in the case of BS (British Standards), both static strength and fatigue strength are specified. Furthermore, in developing the Class 395 train, the evaluation method of JIS was applied for static strength, while that of BS was applied for fatigue strength.

Aerodynamics

Under RGS, an upper limit on pressure pulses generated while a train is running is prescribed. Under TSI, standards regarding pressure change when a train passes through a tunnel are prescribed. On the other hand, in Japan, although such standards do not exist per se, they are in essence set out in the customer's specification sheet.

External Noise

In Japan, in regard to external train noise generated during train operation, environmental standards covering bullet trains are stipulated by Environment Agency announcements. In contrast, in Europe, in accordance with an EU Directive on environmental noise enacted in 2002, noise-regulation values were incorporated into TSI standards, and reviews of domestic regulations within countries across the EU (including the UK) are presently being undertaken.

Fire Resistance

In Japan, the details regarding fire-prevention measures for trains are prescribed as ministerial ordinances by the Ministry of Land, Infrastructure, Transport and Tourism. In the UK, however, fire-resistance criteria are set out in multiple standards given by the BS, RGS, and ATOC (Association of Train Operating Companies) standardization bodies.

CRASHWORTHINESS

Of the standards introduced above, that covering crashworthiness involves completely different circumstances in the UK and Japan, in spite of the importance of assuring the safety of passengers. Given these facts, as cases in point of technologies that accommodate these standards, the following approaches for assuring crashworthiness have been taken.

Specifications

The details of the crashworthiness specifications are listed in Table 2. The RGS standard in the UK focuses on the train-car body; it specifies that energy of over 1 MJ is absorbed within 1 m of the body structure and that load generated during collapse is less than 3,000 kN. Moreover, collision mode specifies head-on collision and override collision for the driver's cab and front end collision for intermediate end structure.

On the other hand, in correlation with RGS, TSI (the European railway standard based on an EU Directive) focuses on behavior of a raked train and specifies that the maximum acceleration during collision is 5 g (gravity). Collision mode covers three situations: collision between two identical trains at a relative speed of 36 km/h (with vertical offset of 40 mm); collision with a buffered railway vehicle at 36 km/h; and collision with a lorry at 110 km/h.

Concept of Vehicle Structure

To assure safety during a collision, it is necessary to suppress the deformation of the units carrying passengers and crew, absorb kinetic energy possessed by the train compartment itself during collision, and lessen the acceleration acting on carbody as much as possible. Accordingly, in the case of the crashworthy structure developed for the Class 395 train, crashworthiness is assured by modularization of the train body into passenger sections separated from sections for absorbing energy. To start with, the passenger sections are made of aluminum hollow extrusions, and an adequately robust structure is attained by low-heat-input joining using FSW (friction stir welding)(4).

Moreover, the sections in which passengers and crew do not board are composed of structures that absorb collision energy (referred to as crumple zones hereafter), and kinetic energy is absorbed by plastic deformation of materials during collision. In this way, acceleration acting on passengers and the train crew during a collision was made as small as possible.

Overview of Crashworthy Structure

To satisfy the specifications listed in Table 2, it is necessary to absorb as much of the great deal of energy generated during a collision and reduce the acceleration. On top of that, it is necessary to take measures for weight-saving and against pressure

TABLE 2. Specifications for Crashworthiness

Crashworthiness in accordance with both an RGS (a proprietary British standard) and TSI (a European standard) is assured.

Object	Collision mode	Energy absorption amount	Peak load (kN)	Permissible length
Cab	Front end collision	Above 1.0 MJ	Below 3,000	Below 1.0 m
Cab	Override	Above 0.5 MJ	Below 3,000	Below 1.0 m
Interme-diate	Front end collision	Above 1.0 MJ	Below 3,000	Below 1.0 m

(a) RGS

Senario	Collision mode	Accel-eration	Others
1	18 km/h → ← 18 km/h, 40 mm (Vertical offset of 40 mm)	Below 5.0 g	Assuring survival space for driver
2	80-t wagon ← 36 km/h	Below 5.0 g	Assuring survival space for driver
3	15-t lorry ← 110 km/h	Below 5.0 g	Assuring survival space for driver

(b) TSI

variations that occur when a train passes through a tunnel at high speed.

In regard to the absorbance of energy, energy-absorbing materials that can efficiently absorb energy in compact and lightweight structures have been developed. The collapse behavior of such developed materials is described schematically in Fig. 2. The figure clearly shows that while collapse continues, regular local buckling deformations occur as energy is absorbed. Moreover, the simulation results successfully express the same behavior, so the predictive accuracy can be considered high enough.

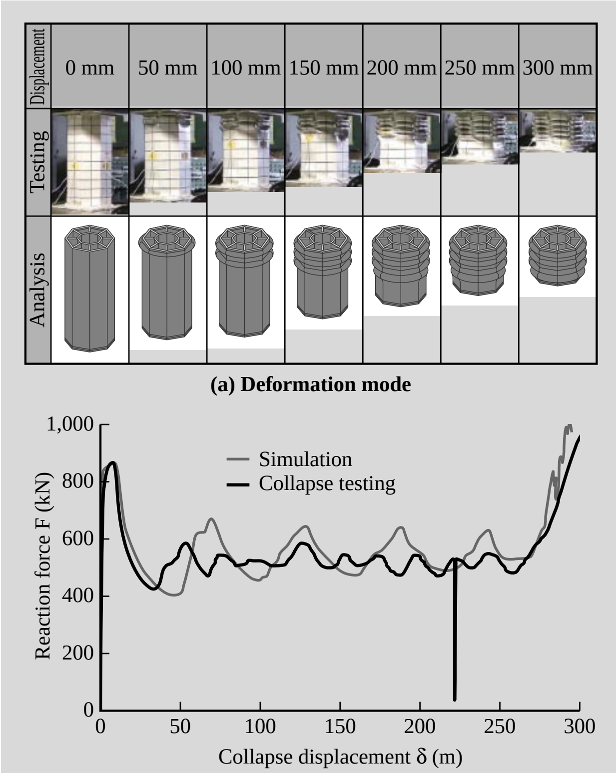
In addition, to follow Hitachi's "A-train" concept, the crashworthy structure satisfies other conditions. According to our computer simulations, a structure that satisfies demands for light weight, good collision characteristics, and strength was accomplished.

The crashworthy structure is an important component directly linked to safety; therefore, in regard to RGS, collapse testing with real objects is performed in order to verify the crashworthy characteristic. At the same time, in regard to TSI, such verification is difficult with real vehicles, so simulation is used to reveal collision behavior instead.

Behavior During Collisions

The conditions of deformation of the crashworthy structure that satisfies both the UK's RGS standard and the EU's TSI standard are described below.

Fig. 3 shows (a) a schematic of the front end of the crashworthy train-body structure as well as (b) testing results on an actual structure under RGS head-on collision targeting the structure, and (c) the corresponding simulation results. It is clear that deformation is limited to the crashworthy structure only, and the driver's cab and other sections are not deformed. What's more, the simulation results—which reproduce the testing results well—well express the load during collapse and deformation mode. That is,



(a) Deformation mode

(b) Collapse characteristics

Fig. 2—Collapse Behavior of Energy-absorbing Materials.
It can be understood that energy is absorbed by buckling and creasing (top: experimental-test results; bottom: simulation results). And energy is absorbed under stable load during collapse.

(a) Front crashworthiness-structure crumple zone (original shape)

(b) Testing results

(c) Simulation results

Fig. 3—Deformation of Front Crashworthy Crumple Zone under RGS Head-on-collision Test Condition.
It is clear that only the members for absorbing energy are deformed, and the simulation results are in good agreement with the testing results.

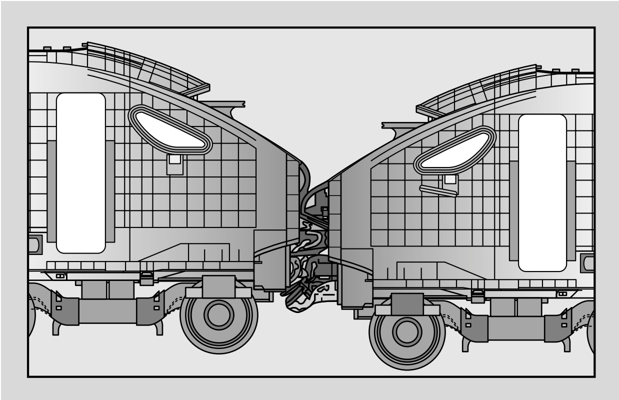


Fig. 4—Deformation under TSI Scenario 1 (Head-on Collision). It is clear that only the crashworthiness-structure crumple zone deforms, and the survival space for the driver is assured.

the load during collapse is lower than the specified value of 3,000 kN given in the standards, and the absorbed-energy value (i.e. 1.1 MJ) exceeds the specification value (i.e. 1.0 MJ).

As an example of the TSI standard, Fig. 4 shows deformation of the cab section under TSI Scenario 1 (specifying collision of similar trains). It is clear that in either of the front train sections, the deformation is limited to the crashworthy structure, and even around the driver's cab (where the largest deformation is generated), the survival space for the driver is adequately secured. This result confirms that the passenger sections are protected against deformation during collisions. In addition, the highest deceleration generated during the collision is 0.9 g—which is significantly below the specified value of 5 g.

CONCLUSIONS

In this article, in terms of vehicle technologies for European railways, dealing with national standards—which presented a major challenge to successful delivery of Hitachi's Class 395 train—and the assurance of crashworthiness, in particular, were described. From here on, Hitachi will continue to develop vehicles that keep in accordance with customer specification sheets and European standards.

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