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ROLLING STOCK DESIGN SUPPLEMENT

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The Next Generation Train project

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Credit: DLR

The Next Generation Train project

How can rail transport be made safer, more efficient and environmentally-friendly? How must the trains of tomorrow be designed? Rail transport researchers at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt – DLR) are addressing these questions. In the 'Next Generation Train' (NGT) project, researchers from nine DLR institutes are using an interdisciplinary approach to tackle the key questions of how the trains of the future can be safe, comfortable, environmentally-friendly and can significantly reduce travel times. The project started in 2007 and is financed until the end of 2013 under supervision of the Helmholtz Society.

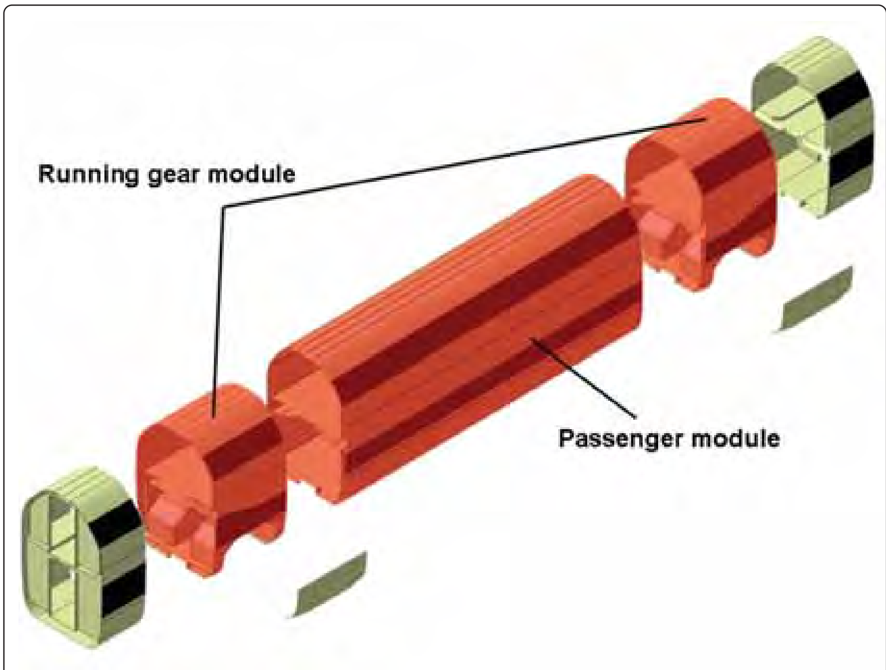
The requirements for railway vehicles have changed a great deal over the last 10 years. This development is being driven by the rise in energy costs, the increasing importance of the life cycle costs of a vehicle in comparison to its acquisition costs, stringent requirements regarding the safety of future vehicles, competition with other modes of transport, and rising expectations for passenger comfort. The NGT project brings together the DLR's existing skills in railway vehicle engineering[1]. Related areas, such as the design of the track and of automatic train control systems are taken into account in this research. Above all, value is added through the whole-system treatment of design issues and through the great potential for synergy. Networking among the partners allows for integrated treatment of the various topics, from conceptual design and materials qualification, through to detailed design and simulation to verification based on near production-ready components. Nevertheless, the DLR is not developing products; we are cooperating with manufactures of rail vehicles and suppliers to allow information flow during the runtime of the project.

Our research objectives are focused on innovative rail vehicle concepts, computer based and experimental development processes as well as technical solutions for global high-speed transport. Until now we have concentrated on the following two passenger rail vehicles:

- A high-speed feeder train running at 230km/h – NGT LINK
- An ultra-high-speed train running at 400km/h – NGT HGV.

We want to realise significant reductions in energy demand, for example, by introducing new technologies in light weight construction, propulsion and braking, as well as aerodynamic design. Furthermore, we are working on improved passenger comfort and reduced noise and wear. The operational processes for production, certification, maintenance and repair are also addressed. All technologies used are evaluated concerning their contribution to life cycle costs and pollution of the environment.

At the beginning of our research, we collected all legal, technical and potential customers' requirements into a functional specification. The desired vehicle was then described in all its operational and technical aspects. To write a technical specification for the optimal solution, we investigated, analysed and evaluated several alternative concepts of rail vehicles, propulsion, braking and crash protection. Different, systematically derived rail vehicle concepts could be found by variation of the wheel sets, the car-body volume and the related number of passenger seats, as well as passenger flow. With this approach, we obtained a set of parameters describing the target vehicle. From this, we developed the subsystems and components along with their production.

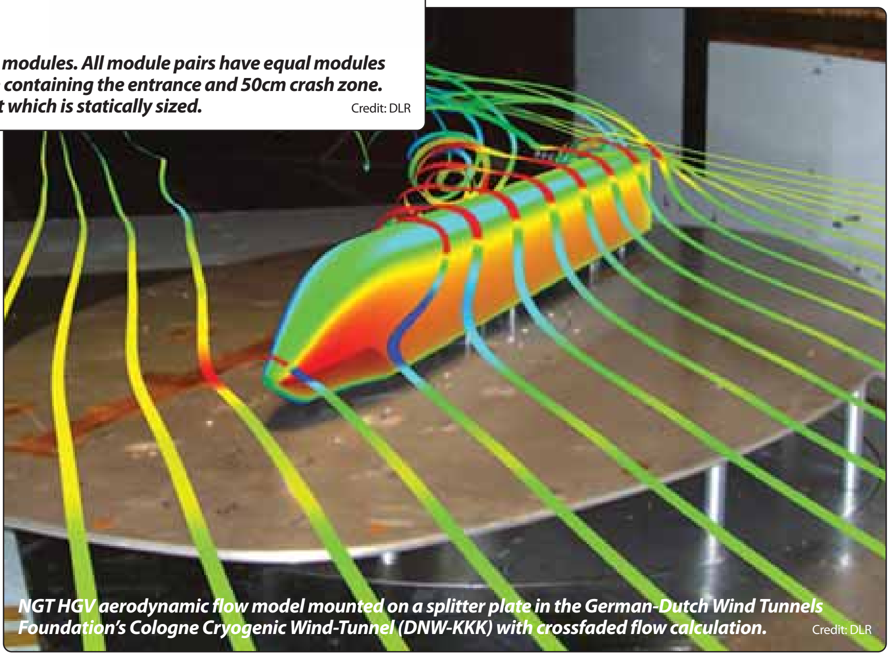


CAD-sketch of the NGT HGV intermediate car building modules. All module pairs have equal modules with regard to the vertical axis. The outer modules are containing the entrance and 50cm crash zone. The red modules are the passenger safety car segment which is statically sized. Credit: DLR

There are eight higher level objectives to be singled out in the foreground for the design of the Next Generation Train. These are in addition to other important requirements[2,3]:

- Increase in the permitted speed to 400km/h
- Halving the specific energy demand compared with the 300km/h operating speed of the ICE 3
- Reduction of running and aero-dynamic noise
- Increase in passenger comfort
- Improvement in vehicle safety
- Reduction of wear and life cycle costs
- Use of modularisation and system integration for cost-efficient construction
- Improving the efficiency of development and approval processes.

The NGT HGV – the 202m double-deck electrical multiple unit (EMU) train set – is capable of running at up to 460km/h. The propulsion system has a performance of 18 MW, of which approximately 5 MW is provided by eight motors in each end car, and 8 MW distributed over eight intermediate cars with four wheel motors each. In normal operation the train slows by coasting and generative braking can then be used for greater deceleration. In an emergency at high-speed, the train applies aerodynamic brakes, and at lower speeds of around 250km/h, eddy-current brakes as well. For stand-still there is a friction-based brake.



NGT HGV aerodynamic flow model mounted on a splitter plate in the German-Dutch Wind Tunnels Foundation's Cologne Cryogenic Wind-Tunnel (DNW-KKK) with crossfaded flow calculation. Credit: DLR

The aerodynamic design culminates with a super-elliptic shell surface between the nose and the roof of the end car, fully covered wheel sets and car connections, no pantograph and a seamless undercarriage. The drag, and therefore noise, is very low. Thus the specific energy demand is more than halved compared with an ICE 3 train at 300km/h.

The complex control system for 32 mechatronic single wheel single running gears and four single wheel double running gears is in the design phase. The experimental evaluation can be performed on a roller rig in size 1:5. It can be shown that, in comparison to conventional bogies, the driving dynamics are improved and the wear is significantly reduced.

> ***'The requirements for railway vehicles have changed a great deal over the last 10 years'***

Driving full speed into a tunnel assumes some special measures which are the subject of investigations in our unique wind-tunnel. The front of the end car is designed with medium fineness ratio because it is assumed that in the future the tunnel portal will be constructed to cope with the train pressure head wave. We are currently developing the calculation tools for the transient aerodynamic effects to keep pace with the experimental equipment.

The cross wind stability seems to be critical, especially at the first intermediate car. Compared with the end car, this one is lighter because of less, or smaller, propulsion equipment. We are currently investigating whether it is possible to use inductive actuators to stabilise the train.

View on DLR worldwide unique tunnel (in front) and crosswind (in the rear) wind-tunnel. The crosswind wind-tunnel can be moved in longitudinal direction. Credit: DLR

Creating extraordinary passenger comfort is achieved by low noise, vibration and pressure variations and improved air conditioning, the introduction of passenger information, as well as easy access to reserved seats. Baggage is taken care of by an autonomous baggage handling system. Passengers check-in their baggage at a machine, for example in the car parking area, and get it back at their destination railway station. During the train run, the baggage sorting system in the end car sorts the baggage disembarking at the next station.

For investigations on air conditioning and noise emissions, we bought a Bombardier Transportation *TALENT* 2 end car and we are currently building a 'standard room', which is a section of the NGT HGV double-deck intermediate car. This generic laboratory will allow us, on the one hand, to investigate and qualify air conditioning devices for rail vehicle manufacturers and suppliers, and on the other hand, we can develop innovative heating, ventilation and air conditioning (HVAC) concepts. To host both laboratories, we will build a new hall in Göttingen, Germany.

Following our investigation of the potential for an ultra-high-speed train in Europe, we came to the conclusion that the Trans-European Network (TEN) would make an ideal substitute for intra-European flight services. This is in line with the latest White Book of the European Commission issued in April 2011.

In other areas of the world there are megacities within distances of 800-1,500km of each other. This situation calls for reasonably priced mass transport. For this reason, China is building a large high-speed railway network with EMU trains running at top speeds of 350-380km/h. The on-going planning of such a network in Australia is being supported by our software tools in cooperation with the University of Melbourne.

> ***'The NGT project brings together the DLR's existing skills in railway vehicle engineering'***

To significantly shorten the travel times for as many travellers as possible, a fast feeder service for ultra-high-speed lines is imperative. Since 2010, the scientific results from NGT HGV have been transferred to the development of an innovative fast double-deck feeder train called NGT LINK. The manufacturer-evaluated specification has been available since the end of 2010. The hybrid electrical multiple unit is set to a total length of 120m with 17m car-bodies. Currently, the work-packages concerning the propulsion and braking concepts are underway.

Investigating the flexibility of services is further increased by the ability to split and couple train-sets while serving different destinations. Following the introduction of flexible train spacing as a principle of train protection, it would be possible to further increase line capacity. Therefore, several EMUs can be coupled together by tele-controlled coupling. By observing the distance between two trains, the train speed is automatically controlled. The train-set driver simultaneously controls, via radio communication, the propulsion and braking systems of the whole train, so that the weakest link of the train determines the longitudinal dynamics. Besides the train safety issue of having two vehicles in one block, we are investigating the aerodynamic effects of running two or more trains in close proximity, and of having them in two-way traffic.

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BIOGRAPHY

Joachim Winter Studied Mechanical Engineering with a specialisation in Aerospace Technologies at Technical University Braunschweig. He then became Scientific Assistant Professor at the Institute of Mechanics at Mercator-University Duisburg. Between 1987 and 2001, Joachim worked at the DaimlerChrysler Group in different positions of aeronautical engineering and vehicle research. From 1998 he was Head of Systems Engineering of DaimlerChrysler Rail Systems (Signal) – Adtranz in Braunschweig as well as Head of the Competence Centre Satellite Navigation at the site in Ulm. In parallel to this between 1998 and 2000, Joachim was Head of Marketing & Sales Central Europe at the site in Braunschweig. When Bombardier took over the business in 2001, Joachim became Head of the Profit Centre Satellite Navigation of Bombardier Transportation (Signal) Germany in Ulm. From 2004 to 2006 he was Director Signalling Technology of Central Engineering in Stockholm and then from 2007 was Director Telematics of Business Unit Central Europe and Site Manager at the site in Mannheim. Since February 2008, Joachim has been Project Manager for the Next Generation Train at the Institute of Vehicle Concepts of Deutschen Zentrums für Luft- und Raumfahrt (DLR) in Stuttgart.

Igor Alonso-Portillo
Director for Strategy and
Business Development, CETEST

Home delivery: a new paradigm in rolling stock testing

Most of the components of rolling stock undergo design verification and functional qualification tests by the suppliers themselves in order to check correct performance as well as operational endurance. This is also the case for fully-finished rail vehicles, except for the fact that many of the tests have to be performed on track. In many cases, component suppliers and vehicle manufacturers do not have the capacity, know-how or facilities to perform these tests. Hence components and vehicles are taken to special test laboratories. This causes an extra burden on planning, time and cost. Could the laboratory be moved to the supplier or manufacturer instead of shipping the components and vehicles? CETEST provides a breakthrough approach to railway testing that challenges the current status quo.

The CETEST Test and Analysis Centre is an independent accredited laboratory focusing on the testing of railway vehicles. With headquarters in Northern Spain, we are a global company serving a variety of customers ranging from railway undertakings (operators), system integrators (manufacturers) to equipment sub-suppliers. As leaders in the railway sector, we have developed a series of so-called 'portable' test benches which allow us to deploy a unique mobile test capacity to customers' premises with the associated savings in time, cost and complexity associated to shipping equipment and components to test laboratories.

Figure 1: Modular data acquisition system with portable carbody structure test rig in background Photo Credit: CETEST

At CETEST, we have more than 40 years of experience in the test and qualification of carbody frames, crash energy management modules, bogie frames, bolsters, wheels, axles, gearboxes, bearings, suspension elements and pantographs. What is more, at fully-finished vehicle level, we measure and characterise suspension behaviour, ride quality, noise, EMC, wheel-rail interaction (through our own Instrumented Wheel Sets), brake performance and energy consumption, etc.[1]

Our experience, together with a thorough analysis of the feedback from our customers and other market players, convinced us that a new concept was needed in order to break the boundaries of the realm of railway testing. The goal: to provide a new paradigm to our customers in terms of flexibility, control and of course reduction in time and cost when it comes to testing railway components for rolling stock or vehicles as a whole. Test laboratories have been too 'self-centred' and we wanted to change this by placing the customer at the heart of our work.

With this in mind, we studied all tests that were conducted and asked ourselves the following question: which of these tests could we potentially perform at the customer's premises? This would of course require the design and manufacturing of new special dismountable devices: 'portable' test benches that would be deployed locally for a new level of customer experience.

Our research and hard work has paid off and today we are proud to offer the breakthrough we were looking for with several 'portable' test benches, including:

- Carbody structure test rig
- Instrumented Wheel Set calibration test bench
- Instrumented Pantograph calibration test bench
- Suspension characterisation test platforms.

We are also currently working on additional devices, but the goal remains the same: to keep moving towards a bigger portable offering, to keep the customer at the centre of our research and development. The challenge is big since some rolling stock components

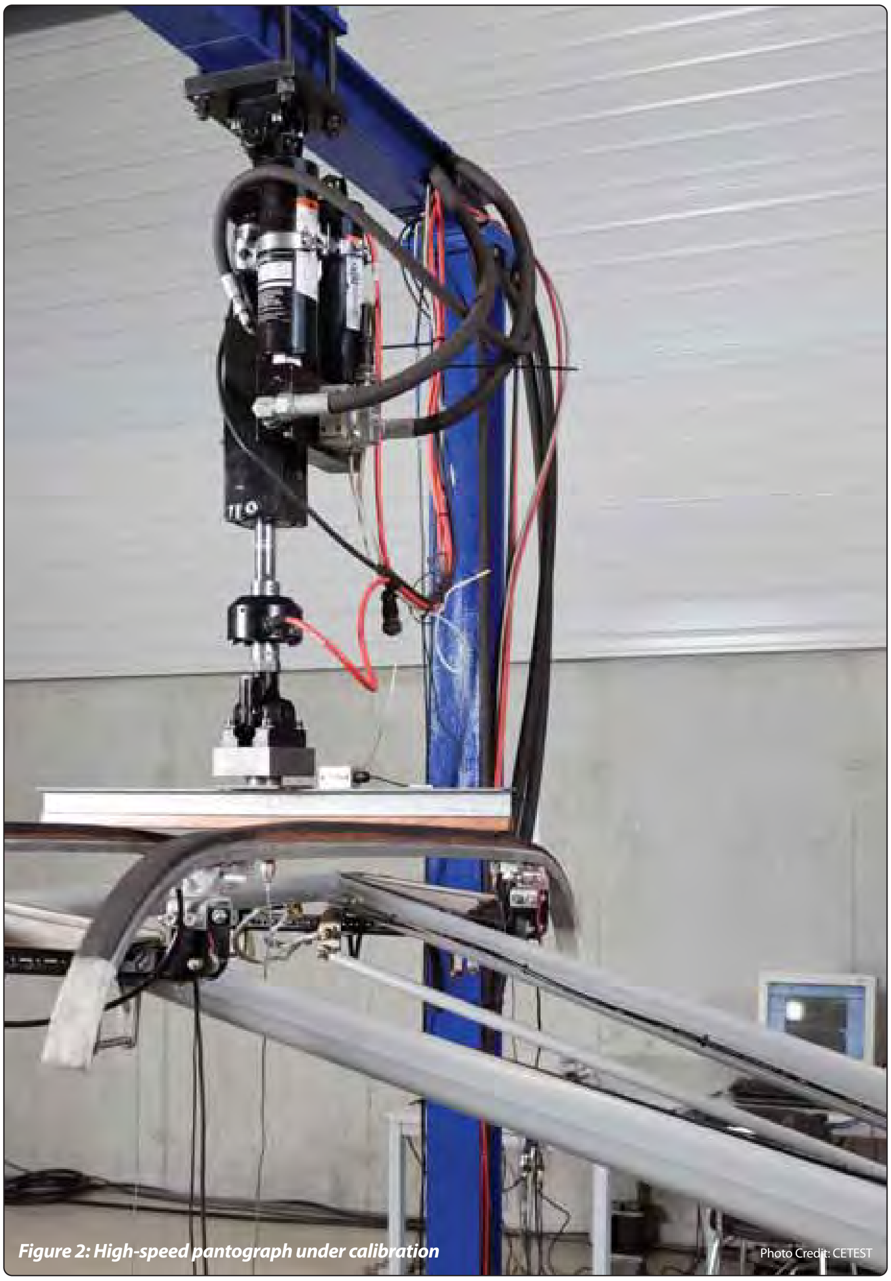

Figure 2: High-speed pantograph under calibration

Photo Credit: CETEST

must be tested at fixed facilities (e.g. wheels, axles, bogie frames)[2] due to the fact that high loads at high frequencies are applied. These test set-ups require special foundations able to withstand the dynamic forces the components are subjected to and very powerful hydraulic installations to apply the combined loading hypotheses required by standards.

Portable carbody structure test rig

All new rolling stock carbody frames/shells must undergo structural testing to check for their reliability and ensure that they will withstand longitudinal forces related to motor pull, brake, crash as well as vertical forces due to passenger loading. Also, jacking in case of derailment is a vertical condition that must be checked for.

Our portable carbody structure test capacity has been designed taking into account diverse international standards (e.g. EN norms, North American APTA standards, etc.).

The test bench is formed by an assembly of mechanical structural elements, a specific hydraulic actuation system and also a modular data acquisition system that monitors load application and provides all necessary data channels for the measurement of stresses and displacements, etc.

In line with our 'portable' philosophy, we ship the test bench to the customer's premises in standard shipping containers. Once it arrives, all we need are a couple of weeks for mounting the bench. We can instrument the car frame in parallel to the assembly of the test bench, therefore having both bench and frame ready at the same time.

The savings in time and cost are enormous as well as the avoidance of all planning associated with shipping a car frame. Today, car frames that are tested at laboratories must be shipped on long distances. This means a special shipment, for example from Spain to the Czech Republic or Germany or from California to New York or Colorado. With CETEST's portable carbody structure test rig, the paradigm has changed.

Instrumented Wheel Set calibration and Pantograph calibration test benches

These are two very different test benches, but both with the same philosophy of being fully portable. Who are the customers that buy an Instrumented Wheel Set? A wheelset supplier, a rolling stock manufacturer and/or also a rolling stock operator. Who are the customers of a

> ***'All new rolling stock carbody frames/shells must undergo structural testing to check for their reliability and ensure that they will withstand longitudinal forces related to motor pull, brake, crash as well as vertical forces due to passenger loading'***

special instrumentation for a pantograph qualification? Likewise, the supplier, the manufacturer and/or the operator. Why should any of them have to ship these components to a laboratory far away to have them instrumented and calibrated before installing on a rail car? The answer is: they shouldn't! And with CETEST's calibration test benches, they no longer have to!

Whilst a wheelset or a pantograph are not expensive components to ship compared to a carbody frame or a full vehicle, shipment costs and also additional time can still be incurred, which can be a burden when working to a tight project schedule.

CETEST's portable calibration test benches can be shipped with very short lead time notice (upon availability) and be up and ready in a matter of hours in order to check correct functioning of all instrumentation.

Our skilled engineers have developed

proprietary solutions to wheelset and pantograph instrumentation able to accurately measure contact forces and dynamic behaviour with infra and super structure respectively.

Figure 3: Rail vehicle under roll simulation test

Photo Credit: CETEST

These systems have been tested at speeds above 350km/h with satisfactory results. They are designed for accuracy and endurance.

All feedback on the concept from our customers so far is very positive. Therefore, why not offer them the possibility to have it all calibrated at home? Full control, full participation, and the lowest costs possible.

Portable suspension characterisation test platforms

Finished rolling stock cars must of course also undergo a series of tests prior to being allowed to enter tracks. Some of the most important tests are those related to the characterisation of the suspension in order to evaluate derailment behaviour (wheel offloading and x-factor) as well as flexibility while curving (lean testing / souplesse coefficient).

Again, our portable system is designed with diverse international standards in mind (e.g. EN norms, North American APTA standards, etc.).

The system is formed by a series of platforms that are placed in a full-modular manner so as to be able to support the fully-finished vehicle as if they were a track section. They are independently actuated per wheel with and integrated load sensor system for wheel load measurement. They also include inclinometers and displacement sensors for full control and monitoring of the suspension behaviour.

They can be shipped in one single container or even a small truck and can be set up in less than a week. A vehicle can be fully tested (unloaded and loaded conditions) at the manufacturer's plant in just a few days!

> ***'Our portable system is designed with diverse international standards in mind'***

CETEST has a set of portable devices that we believe mark a breakthrough in rolling stock testing, evaluation and qualification, both at component and vehicle level. All these benches are designed to be deployed anywhere in the world, making CETEST the only truly global railway test service supplier. We not only offer savings in time, cost and planning, but also full control and presence in every step of the test campaign to the customer – a new paradigm for design engineers and project managers in the world of railways.

And this is just the tip of the iceberg! Stay tuned for our developments in portable railway testing technology.

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FURTHER INFORMATION

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BIOGRAPHY

Igor Alonso-Portillo is Director for Strategy and Business Development at CETEST. He holds a Masters degree in Aerospace Engineering and has worked in railways, aerospace, defense and renewable energy. His career in the railways includes positions such as test engineer and researcher at Spanish manufacturer CAF. He also worked at UNIFE as Coordinator for joint research projects co-funded by the European Commission.

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Wheelchair space design in rolling stock to improve occupant crash safety

Approximately 20 years ago, wheelchair users were provided with a legal framework to travel by rail. In the UK, following the passing of the Disability Discrimination Act (DDA) 1995 (now incorporated into the Equality Act of 2010), the Rail Vehicle Accessibility Regulations (RVAR) of 1998 paved the way for wheelchair users to travel by rail in a regulated manner. The RVAR has since been replaced by RVAR 2010 to cover non-interoperable railway connections in the UK. At the EU level, the European standard for the accessibility of heavy rail vehicles, the Technical Specification for Interoperability for Persons with Reduced Mobility (PRM TSI), came into force on 1 July 2008. Following these legal frameworks, a number of regulations and codes of practice have been put in place to provide wheelchair users with greater access to rail.

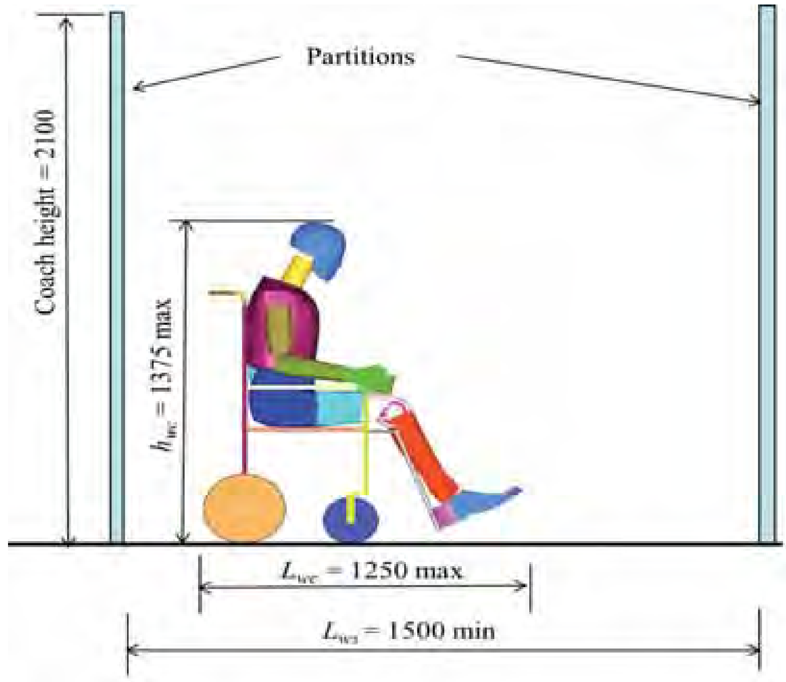

Figure 1: A typical open space designated wheelchair space

Currently, railways have great potential over other modes of transport in meeting sustainability development goals (economic, social and environmental). It is expected that railway capacity would increase at a higher rate than other modes of transport. This would result in a rise in the number of people travelling by rail. Wheelchair users are expected to be part of this population and, taking the UK as an example, are in fact increasingly choosing to travel by rail. According to the UK Association of Train Operating Companies (ATOC), disabled railcard journeys in the UK have trebled in the last 15 years. There are now 122,000 railcards in use by people with disabilities, an increase of more than 40,000 in just five years – thanks to the increasingly accessible infrastructure and rolling stock. To improve accessibility, vehicle interiors are now engineered to accommodate a wheelchair occupant.

Fixed seats on trains are designed to national and international standards as part of the vehicle dynamic system. By contrast, most wheelchairs are not intended for use as a vehicle seat and have not been designed or tested for crashworthiness. However, currently, there is a push for wheelchair manufacturers to design them to withstand high crash deceleration. In rolling stock, consideration of human factors and ergonomics has led to the development of standards to provide adequate space in the wheelchair area. To be deemed accessible, a railway vehicle should at least accommodate a reference wheelchair with dimensions as stipulated by the PRM TSI (the length of the wheelchair, $L_{wc} \leq$ 1,250mm, which includes foot protrusion and the maximum height $h_{wc} \leq$ 1,375mm – see **Figure 1** on page 77). When on board a railway vehicle, it is recommended that a wheelchair occupant transfers to a vehicle seat. However, the common practice is to park in a wheelchair space, either facing forward or rear, but not sideways. In the event of a crash, the main concern for occupant safety is secondary collision with interior furniture or features.

Wherever a designated wheelchair space is provided, the EC PRM TSI specification sets a length (L_{ws}) requirement of 1,500mm to 1,600mm (minimum) depending on the seating configuration (**Figure 1** on page 77 shows an Open Space Configuration). However, to allow for easy manoeuvrability, it is recommended that the area should be as large as possible. Nevertheless, train manufacturers build to maximise the number of fixed seats. Subsequently, the wheelchair space is typically minimised to between 1,500mm and 1,600mm long. It is important to note that crash-worthiness and wheelchair space requirements have already reduced the number of fixed seats by about 10 and six, respectively. The reduction in the number of seats is in contrast with the desire for train operators to run economically because increasing the number of seats maximises space utilisation. To this effect, train manufacturers tend to minimise the wheelchair space rather than maximise it beyond 1,600mm.

While much has been done to ensure that infrastructure and rolling stock are accessible, little has been done to design the interior of trains for reduced injury severity during secondary collision. This article discusses what factors ought to be considered by rolling stock interior design engineers when developing retrofitted or new-build railway vehicles to improve wheelchair occupant safety during a crash. The factors identified include human related factors, wheelchair design and railway interior design.

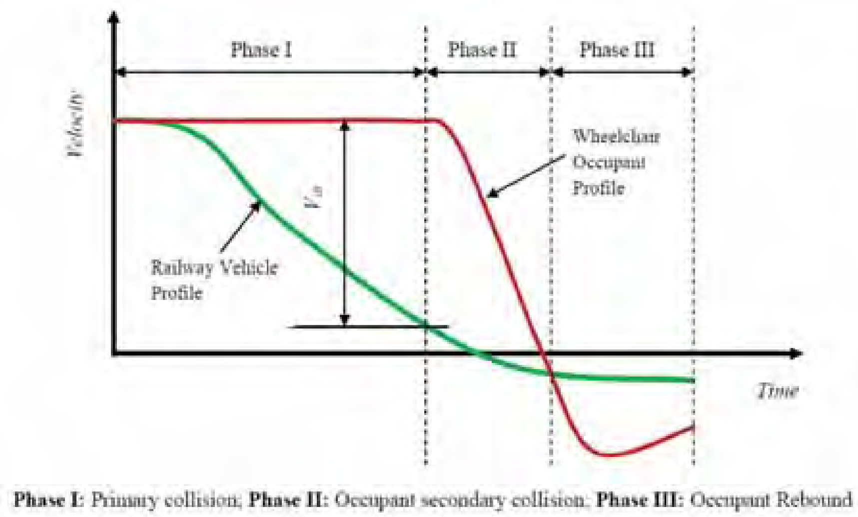

Figure 2: Railway vehicle and wheelchair occupant velocity history

Wheelchair occupant crash dynamics

During a train crash (primary collision), the occupant continues to travel with their initial motion (see **Figure 2**). This motion continues until the occupant makes contact with an object in their trajectory (referred to as secondary collision) at a relative velocity V_{iR}. Common secondary collision objects include furniture such as partitions, grab poles and tables.

Since wheelchairs are not secured and the occupant is not restrained, the higher the weight of the wheelchair and occupant, the higher the impact kinetic energy will be, and therefore the injury potential.

Human factors

When dealing with wheelchair occupant transportation in rolling stock, the starting point is to recognise that although a wheelchair is used as a seat on board a train, it is a mobility device used by people with disabilities as an assistive technology. This subsequently takes into account Human Factors Engineering (HFE). The basic premise of human factors and ergonomics is user-centred design, based on a fundamental understanding of user capabilities, needs, and preferences. These human-related factors include anthropometry, weight, personal preferences, medical condition, and the ability to interact with wheelchair and the interior environment.

The occupant's anthropometry is one of the most important factors affecting the occupant's crash kinematics behaviour in that it determines that mass moment of inertia. Missing or not fully developed limbs may influence whether the occupant uses footrests, a situation that determines the pre-crash posture. Wheelchair

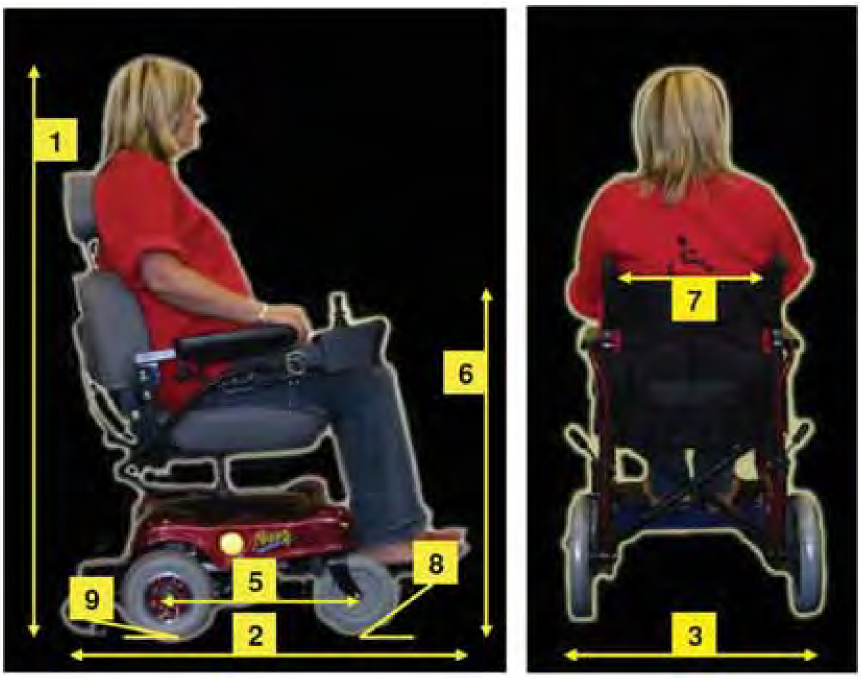

Figure 3: Some of the key parameters of wheelchair[1]

users with both lower extremities are likely to place their feet on the footrest. This, however, is a personal preference of the occupant. Crash tests conducted involving wheelchair occupants have shown that placing the feet on the footrest influenced the initial occupant posture and subsequently post-crash occupant kinematics and secondary collision characteristics. The occupant's weight influences the secondary collision kinetic energy. Their ability to interact with the wheelchair and vehicle environment determines the pre-crash orientation and subsequent crash kinematics. Therefore, an optimised crash-safe train environment should put human factors specific to wheelchair occupants at the centre of the design. These factors determine pre-crash occupant posture, which ultimately determines the occupant's secondary collision characteristics and potential injury severity.

Direction of travel

During a frontal crash, an occupant is projected forward with reference to the decelerating train. Therefore, the seating orientation and location is important in determining the occupant kinematics and which interior furniture/feature the occupant would impact in a secondary collision. A train is bi-directional; therefore, secondary collision would occur either with the front parts of the occupant's body if the wheelchair occupant is facing the direction of travel, or the rear parts of the occupant's body if they are facing the opposite direction. In some older vehicles, however, sideward facing is unavoidable due to lack of wheelchair turning space inside the vehicle.

Wheelchair characteristics

Figure 3 (opposite) shows some of the wheelchair parameters that influence user/ wheelchair and wheelchair/space interaction. Not indicated are three angles which are critical to the dynamic response of the wheelchair and its occupant during a crash. These are the angles of inclination of the footrest, seat and backrest. Wheelchair occupant crash displacement increases with decreasing footrest inclination, seat and backrest angles. In addition, wheelchair crash motion characteristics are influenced by the coefficient of friction between the wheels and the floor, particularly when the wheelchair brakes are applied.

Notably, compared to manually powered wheelchairs, electric powered wheelchairs offer superior control capabilities and have greater potential to address human factors concerns specific to the disabled. They have better control and therefore parking characteristics than manually powered ones. This determines pre-crash posture.

Figure 4: Wheelchair occupant secondary collision with a grab pole

Wheelchair securement and occupant restraints

Whether the wheelchair is secured and/or the occupant is restrained determines the occupant displacement relative to the interior furniture. Currently, Wheelchair Tie-down Occupant Restraint Systems (WTORS) are not provided in most trains. Introducing WTORS remains debatable and may have its own challenges to overcome because most wheelchair users feel that since restraints were not provided for other occupants on a train seat, neither should WTORS be fitted for wheelchair occupants. Many feel that fitting securement and restraint system may actually impede on their ability to egress in case of an emergency. Also, some occupants would not use restraints for medical reasons.

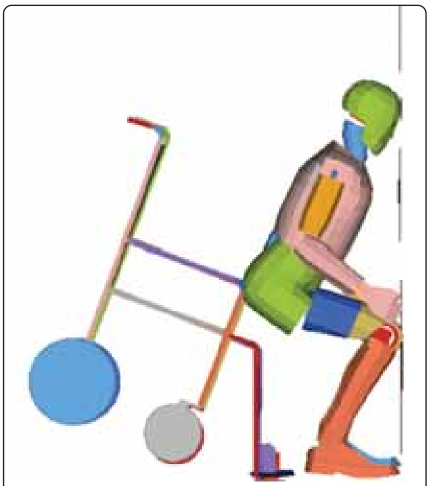

Figure 5: Wheelchair occupant secondary collision with a partition

In the UK, studies have found that various organisations and disability groups did not wish to use wheelchair securement and occupant restraint systems on board trains. Most were unwilling to use them because they were considered to be time-consuming, and posed potential difficulties with the release of such systems in an emergency. Therefore, any train interior design aimed at improved crash-worthiness should consider these challenges.

Figure 6: Wheelchair occupant secondary collision with a fixed bay table

Law and legislation

When developing future legislation and rolling stock interior design, wheelchair users expect a bottom-up approach – this would ensure that most human related factors are incorporated in the designs. Therefore, there is a need to effectively engage wheelchair users through information dissemination.

Secondary collision objects and occupant proximity

Rolling stock interior design furniture and features surrounding a wheelchair occupant constitute secondary collision objects in the event of a crash. The pre-crash proximity to the occupant, geometry and mechanical properties of these objects determine the potential injury severity created by secondary collision. **Figure 2** (page 78) implicitly shows that the higher the initial distance between the occupant and secondary collision object, the higher the (relative) impact velocity will be, leading to increased injury potential. Therefore, the pre-crash proximity of the occupant prior to the crash determines the relative impact velocity (V_{IR}), and injury potential.

The characteristics of occupant secondary collision are strongly dependent on the configuration of the wheelchair space. In the Open Space configuration, frontal collision secondary collision objects in the wheelchair parking space include partitions, grab poles and the floor. Where a fixed bay table is fitted, the main frontal collision object is the table itself. Positioning of furniture with respect to a wheelchair occupant influences how and where the furniture collides with an occupant. It also determines the occupant's displacement and impact velocity; therefore how much kinetic energy the occupant carries.

injury. Subsequently, the geometrical and material characteristics of the secondary collision object are key parameters when designing wheelchair space for minimised injury severity.

Flow chart of factors influencing design of wheelchair space

Figure 7 shows how design factors discussed above relate to the wheelchair occupant crash injury potential. It postulates that human factors specific to wheelchair users should be the centre

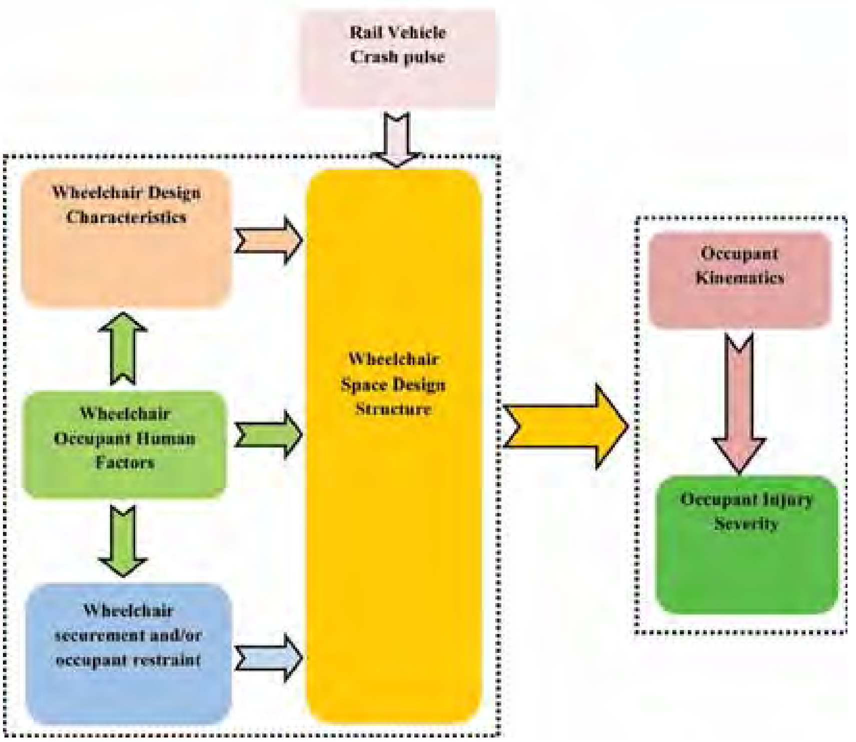

Figure 7: Interrelation between the factors that influence wheelchair space design and injury potential

Figures 4, 5 and 6 (page 79) illustrate wheelchair occupant kinematics that may result from a secondary collision involving a wheelchair occupant and three common secondary collision objects. Occupant collision with a partition results in kinematics where the feet collide with the partition first, followed by the knees and finally the head. Collision with a grab pole, which is centrally located in the sagittal plane, results in different kinematics where the head makes the first secondary collision. Therefore, for the Open Space, the head is at highest risk of injury. On the other hand, when the occupant collides with a bay table, the occupant kinematics is totally different – with the torso (chest and/or abdomen) making the first contact. Therefore, in this configuration, the torso is at highest risk of

of the space design. These factors determine how the user interacts with:

- The wheelchair which also interacts with the wheelchair space
- Wheelchair securement and/or occupant restraint systems (if any). Such a system should fit with the wheelchair space design as well
- The actual wheelchair space design (the furniture and features).

This interaction affects the occupant's crash kinematics behaviour that ultimately determines secondary collision injury characteristics. Overall, the chart shows that in order to fully define wheelchair occupant railway vehicle crash safety, human related factors should be factored in – how they affect wheelchair choice and how the occupant interacts with the wheelchair and railway vehicle interior.

Conclusion

A crashworthy wheelchair railway vehicle space design should consider the complex interrelation between human factors, wheelchair design, train operations and secondary collision objects/furniture. For this reason, to comprehensively and effectively define occupant safety when transported by a train, it is imperative that the subject of crashworthiness incorporates wheelchair occupant human related factors. This will also assist in developing crash-safe future designs of carriage interior furniture, accident investigation and subsequent recommendations aimed at preventing wheelchair occupant injury. Incorporating wheelchair occupant-specific human factors would also enhance their acceptability of any legislative and technical measures that are aimed at increasing occupant safety.

To improve wheelchair railway vehicle crash safety, the design of the railway vehicle interiors should aim at optimising the dimensions of the wheelchair space rather than maximising them. It reflects a compromise between accessibility which tends to maximise the wheelchair space and crash safety which improves with reducing the initial distance between the occupant and secondary collision objects. Appropriate geometry and material properties of these objects should also be determined. This would result in an optimum design, which interior design engineers need to target. The design should also incorporate the operational constraints of train operators. As part of the PRM TSI, the EU needs to develop a standard that specifies a wheelchair environment that ensures the wheelchair space is maximised for accessibility, and also optimised for crashworthiness.

Reference

1. Images obtained from the Report '*A Survey of Occupied Wheelchairs and Scooters*' conducted in 2005. Research conducted on behalf of Mobility and Inclusion Unit of the Department for Transport, United Kingdom

BIOGRAPHY

Dr. Emmanuel Matsika, a mechanical engineer, is a Researcher at NewRail where he conducts research on EU Projects aimed at improving safety and security of passenger railway vehicles, and enhancing performance of railway freight vehicles. His PhD research was on railway vehicle crashworthiness, focusing on crash safety of wheelchair occupants.

Galea – connect and protect

Ahead of InnoTrans 2012, Rainer Krause, Head of Voith Turbo Scharfenberg Product Management, gives a technical insight into the company's Galea crash head module and how rail operators can benefit from its design.

Major structure and energy absorption elements are made from GFRP

What exactly is the Galea crash head?

The Galea crash head is a vehicle head incorporating a high percentage of GFRP (Glass Fibre Reinforced Plastics) components. It has been designed for rail vehicles with velocities of up to 200km/h, combining high safety and flexibility with low energy consumption and lightweight design. A train front end is heavily stressed and subjected to extreme loads in accidents, therefore, special structure and energy absorption elements have to be used. In order to guarantee the highest safety levels, the vehicle heads of the Galea series are designed in compliance with the European crash standard EN15227 and other specifications such as the prEN 45545 'Fire Protection on Railway Vehicles'.

Why did you choose GFRP as a base material?

With their lightweight mode of construction, fibre composite materials allow the design of complicated geometries and free-form surfaces required for modern design. The use of GFRP and GFRP sandwich materials make the Galea a lightweight solution compared with existing vehicle heads. Furthermore, the Galea was fitted with GFRP energy absorbers. Due to their high energy absorption capacities, these could be also be designed in a weight-saving way, in contrast to steel parts of comparable absorption characteristics. The GFRP energy absorbers show almost ideal deformation behaviour in case of a crash, while at the same time the design and manufacturing technologies allow for very good reproducibility.

How do operators benefit from Galea?

Lightweight vehicle heads reduce the transportation energy consumption, thus increasing the manufacturer's economic efficiency and eco-friendliness. Increasing the passenger volume also improves the transport efficiency of the traffic carrier. Also, the production of aerodynamic outer contours is simpler and more cost-efficient. Thanks to its variable design, the Galea series can be easily adapted to individual vehicle geometries. Operators can keep their brand identity and significantly stand out from their competitors. Furthermore, the modular design reduces mounting and replacement times, resulting in minimal costs.

Which manufacturers are you already in touch with to realise this concept?

Small and medium sized rail vehicle manufacturers which do not have huge development departments at their disposal will particularly benefit from Voith Turbo Scharfenberg's expertise in energy absorption systems. The Galea series can be individually adapted to any vehicle frame, and other parts of the Galea, e.g. single energy absorbing elements from fibre composite materials, can be integrated into already existing vehicle concepts.

The Galea will be the highlight of our stand at the InnoTrans 2012 trade show. We will present a full-size walk-in Galea vehicle head in Hall 1.2.

BIOGRAPHY

Rainer Krause is Head of Voith Turbo Scharfenberg Product Management.

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