Validation Ensures Trains Are on Track

to Meet European Safety Standards

Numerical simulation aids in the **design** of **passive safety systems** to **minimize** passenger **injury** during railway accidents.

by **Patrick Sicot** and **Pierre Huss**

The European Union (EU) and Member States are diligently working to build a single European railway system by 2020. To help meet this goal, the EU has issued various Directives – and their related Technical Specifications for Interoperability – to gradually align technical regulations and establish common safety objectives that all Europe's railways must achieve.

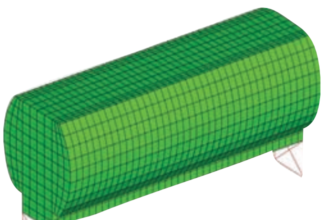
ALSTOM Transport, with more than 28,000 employees in 60 countries, serves private and public railway operators in Europe, Asia/Pacific, the Americas, the Middle East and Africa. It offers a range of products and services including high-speed trains, electrical and diesel multiple units, tramways and metros. One of its most recent projects is a high-speed train known as the ALSTOM Grande Vitesse (AGV). Currently under development, this fourth-generation train will achieve a maximum standard operating speed of up to 217 mph and carry as many as 460 passengers.

To ensure that the AGV conforms to passive safety requirements defined in Directives related to high-speed trains, ALSTOM engineers have carried out rigorous validation. Because it is not possible to validate the objectives through physical collision tests made on complete train sets, final validation has been performed through numerical simulation.

AGV Illustration: ALSTOM Transport/Design & Styling

Safety Matters

Compared to other modes of transport, rail transport is already considered the safest. And since safety has also been identified as a key objective in the different railway Directives and Technical Specifications for Interoperability, harmonization of the rail system should not lead to reduced safety levels.



European standard deformable obstacle.

At ALSTOM, passenger safety and cargo protection have always been a chief concern. To achieve this, ALSTOM associates three complementary means: active safety, in order to reduce the risk of accident; passive safety, to reduce the consequence of an accident if it occurs; and occupant protection, in the event of a secondary impact against the surroundings.

For the validation of the passive safety objectives, the ALSTOM team applies numerical simulation.

The high-speed Technical Specifications for Interoperability define several passive safety objectives to be met by trans-European high-speed trains in case of a collision. These include limiting deceleration, maintaining survival space and structural integrity of the occupied areas, reducing the risk of derailment and reducing the risk of overriding (one train riding up over the top of another).

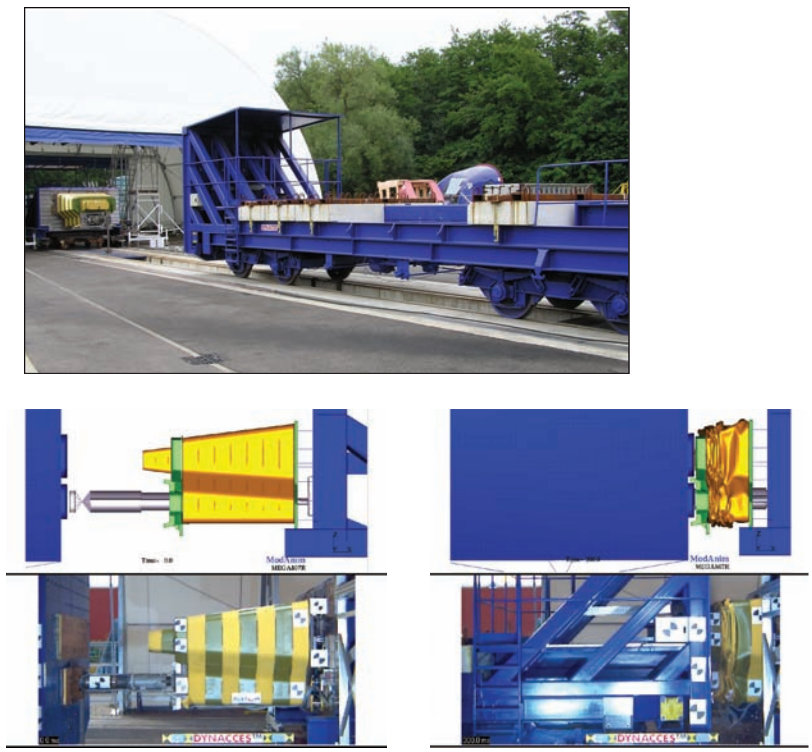
To validate each of these objectives, design scenarios consistent with the probable collision risks and with the most common types of collision-causing injuries and fatalities are specified. The first scenario involves the collision between two identical high-speed train sets at a relative speed of 22 mph.

The second is a collision at a speed of 22 mph between a high-speed train set and a railway vehicle equipped with side buffers. The railway vehicle is a four-axle freight wagon UIC 571-2 with an 80-ton mass.

The third scenario is a collision at a speed of 68 mph, at a level crossing, with a heavy road obstacle. Although the current Technical Specifications for Interoperability call for the use of a 15-ton rigid reference obstacle, a future revision specifies a deformable obstacle, which is more representative of the behavior of a heavy road obstacle. This is particularly true to highlight intrusion within the cabin and the rollover phenomenon of the obstacle on the train's front end.

ALSTOM's AGV is designed to comply with the revised Technical Specifications for Interoperability.

Due to the prohibitive costs and complexities associated with physically validating complete train sets, ALSTOM engineers used numerical simulation of the design scenarios, including RADIOSS for explicit analysis to virtually validate



The physical MEGA system crash test takes place in Reichshoffen, France (top). The comparison of the behavior observed during simulation and test is shown below.

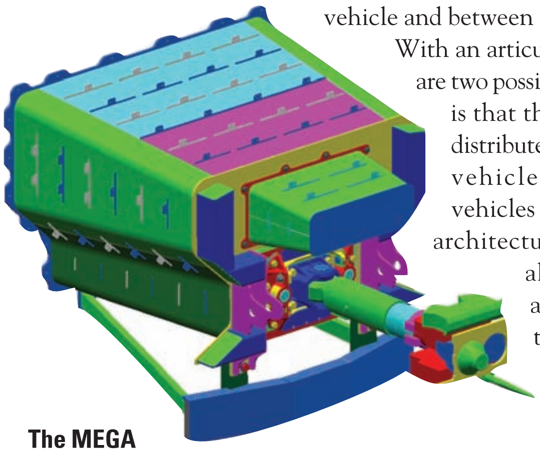
these systems. Part of the Altair HyperWorks suite, RADIOSS is transient, nonlinear CAE technology designed to simulate safety-related performance as well as other impact events.

The numerical simulation alone is sufficient for accurate prediction of structural behavior in areas where the deformation is limited. For the crumple zones, the validation program includes the calibration of numerical models through comparison with appropriate test results. This is called the "combined method" and is described in the high-speed Technical Specifications for Interoperability and in the standard prEN15227 (Railway Applications – Crashworthiness Requirements for Railway Vehicle Bodies).

Distribution of Energy Absorption along the Train Set

With a conventional train set architecture, the passive absorbing devices are distributed throughout the entire train set – at the front of the first vehicle and between the vehicles.

With an articulated architecture, there are two possible alternatives. The first is that the absorbing devices are distributed at the front of the first vehicle and between the vehicles (just as in conventional architecture). The second is that all the absorbing devices are located in front of the first vehicle.



The MEGA system.

A parametric study focused on the inter-trailer behavior has shown that, for an articulated train set, the optimized solution is to locate the total capacity of energy absorption at the front of the first vehicle, under the condition that the stroke force level is relatively low. This is usually possible for high-speed trains having a long "nose cone" due to their aerodynamic design. This is the solution that ALSTOM engineers used for the AGV.

This crash management solution provides major safety advantages compared to other high-speed trains. For instance, the passengers and the train staff are located in secured areas, even if they are standing in the cabin or in the gangways. In addition, the decelerations are homogeneous along the train set. That is, whether they are located in the end car or in an intermediate car, all the occupants are submitted to rather low decelerations. Also, the connections between the vehicles are maintained, preventing the risk of derailment and overriding.

The AGV: 217-mph Links Between Medium-Sized Towns

ALSTOM Transport offers a range of innovative products and services in more than 60 countries. It is known for its TGV and tilting Pendolino trains, Citadis tramcars and the Metropolis metro trains.

The ALSTOM Grande Vitesse (AGV), a fourth-generation, very high-speed train currently under development, is a rapid regional transport solution geared for links between medium-sized towns. Capable of transporting up to 460 passengers, the AGV complements the higher-capacity offering, the TGV Duplex.

The AGV will be the first single-deck articulated train of its capacity to achieve a maximum standard operating speed of 217 mph, compared to the TGV's 198 mph. Key elements of the TGV, including articulation and articulated bogies, will be retained in the AGV.

However, the new AGVs will use distributed traction rather than power cars at each end in order to offer greater comfort and mobility to passengers. They will raise the bar in energy efficiency due to massive weight reduction. Fewer bogies will be required, resulting in lower maintenance costs.

What's more, the AGV will be the first train to be equipped from the outset with ALSTOM's interoperable ATLAS control and signaling system. It will, therefore, be able to cross European borders and communicate with the signaling systems used in each country without having to be fitted with four or five different systems, as is the case today.

The MEGA System

The passive safety system installed in front of the cabin is named MEGA. It is the ALSTOM standard passive safety solution for high-speed trains and is already mounted on other ALSTOM high-speed trains.

The AGV system and the complete MEGA system were dynamically tested on the DYNACCESS test bench located in the ALSTOM-Reichshoffen Unit. All the objectives of the collision tests of the MEGA system were fulfilled:

- Chronology validation of the absorber's deformation;
- Integration validation of the coupler retreat

system in the absorber;
- Capacity validation of the absorbing devices; and
- Recording of data for the model calibration.

After adjusting (in the numerical model) the test parameters, such as the initial speed of the impacting test wagon and the masses of the test wagons, the behavior of the MEGA system and the physical data from the simulation were compared with those recorded during the collision test. All the criteria for the calibration acceptance of a numerical model prescribed in the high-speed Technical Specifications for Interoperability and in the standard prEN15227 were fulfilled.

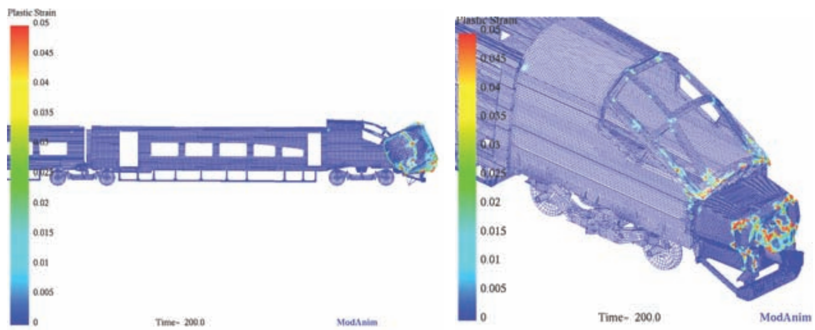
Final Validation

The calibrated model of the MEGA system was then installed in the numerical model of the AGV train set in order to perform the simulation of the design collision scenarios. The train set model consisted of 1.2 million elements, including 3D models of the two first vehicles with their bogies – the rolling base onto which the rail carriage or wagon is fixed – and connections as well as a 1D model (springs and lumped masses) for the rear part.

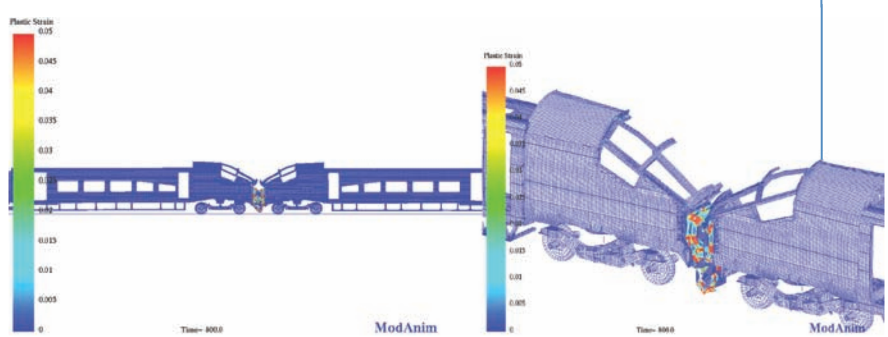
ALSTOM engineers ran the simulation, and all the criteria for evaluating the conformity of the passive safety function were fulfilled:
- Reducing the risk of overriding: The simulation of the design collision between two identical AGV train sets demonstrated that under the vertical offset condition of 40 mm, no bogie lifting occurred;
- Limiting deceleration: For all design scenarios, the mean deceleration is very low and clearly lower than the 5 g authorized;
- Maintaining survival space and structure integrity of the passenger-occupied areas: For all design scenarios, no deformation of the occupied areas was observed; and
- Protection against a low obstacle: An obstacle deflector is fitted on the leading end of the train on the MEGA system, reducing the risk of derailment.

The ALSTOM process for design and validation has demonstrated that the AGV conforms to the passive safety requirements defined in the Directives related to high speed. It provides safety in the event of a collision.

Through numerical simulation, engineers demonstrated that energy is not absorbed in the areas in which staff and passengers are standing (cabin or gangways). The simulation also shows that decelerations are very low, and the connections between the cars keep their integrity, therefore reducing risk of derailment and overriding. C2R



Simulation of the collision between an AGV train set and a heavy road obstacle at 68 mph.



Simulation of the collision between two AGV train sets at 22 mph.

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