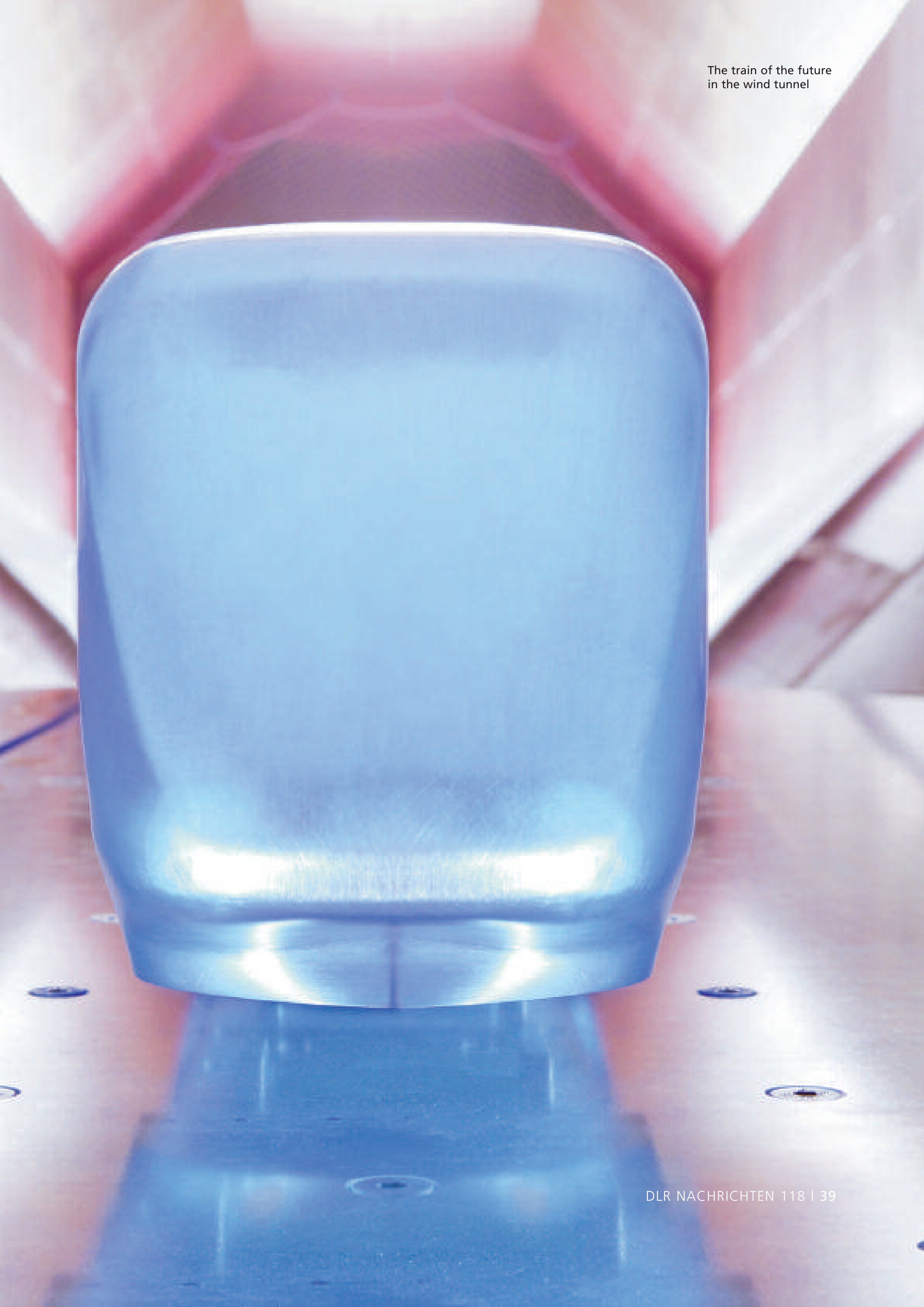
WITHOUT MUCH OF A STIR

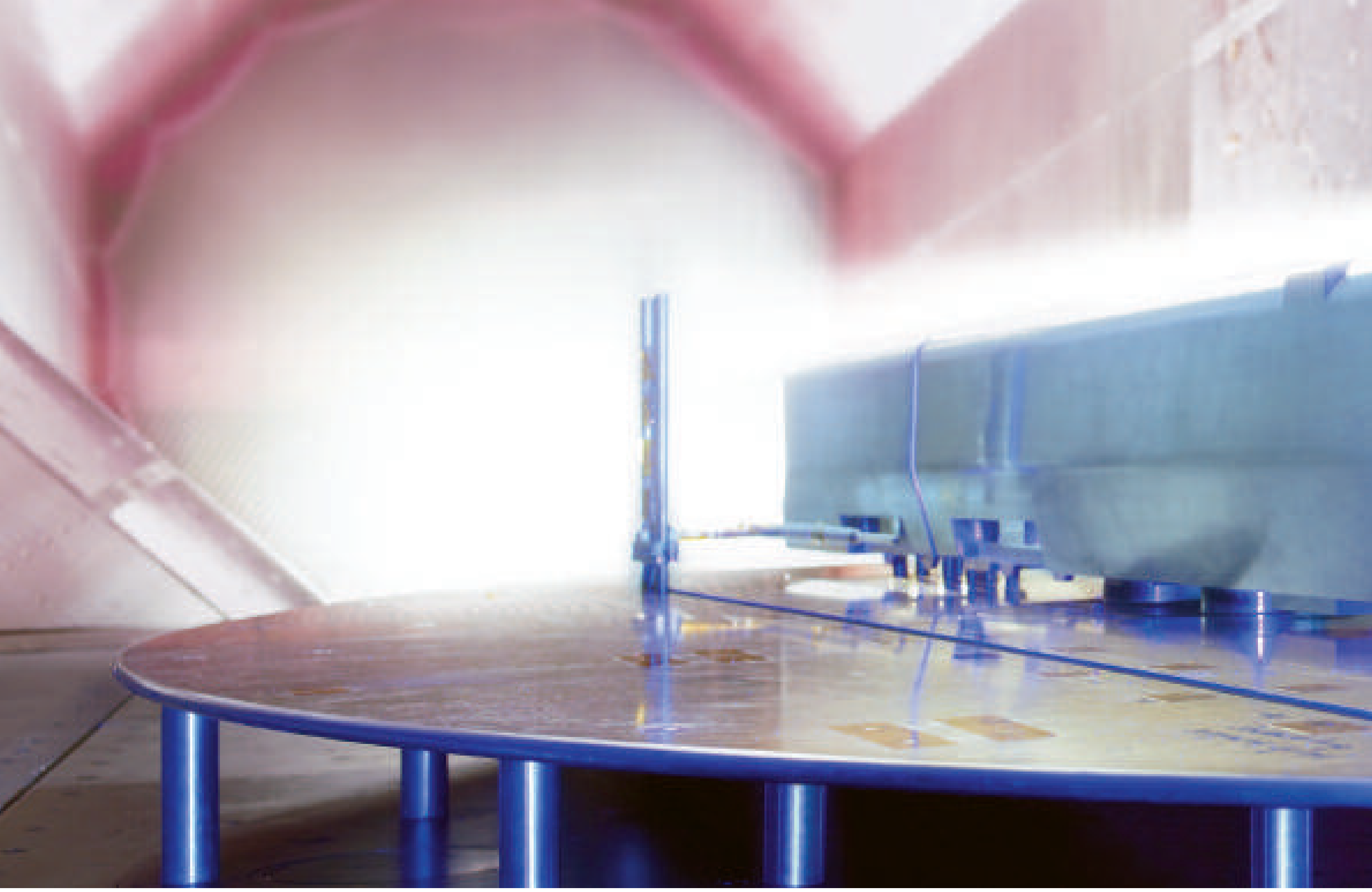
The Train of the Future is Light and Fast – and, Above All, Safe

By Sigfried Loose

Safely operating rail vehicles means taking numerous components into consideration. The vehicle is naturally the first aspect. However, there are also the passengers, staff, residents, other vehicles, and, last but not least, the infrastructure to take into account if new materials and production techniques are to be introduced. Contemporary means of transport have to satisfy both economical and ecological requirements. These invariably require the use of lightweight materials. At the same time, the demand for short traveling times is also to be taken into account. For the next generation of rail vehicles, this means that the vehicles need to be lighter and be operated at higher speeds with greater acceleration. With the project "Next Generation Train," DLR scientists are tackling this challenge while making sure that safety is not left along the wayside.



The train of the future
in the wind tunnel



THE LATERAL FORCE ON THE VEHICLE AND LIFT COULD RESULT IN AN UNWANTED CHANGE IN THE LOAD BALANCE

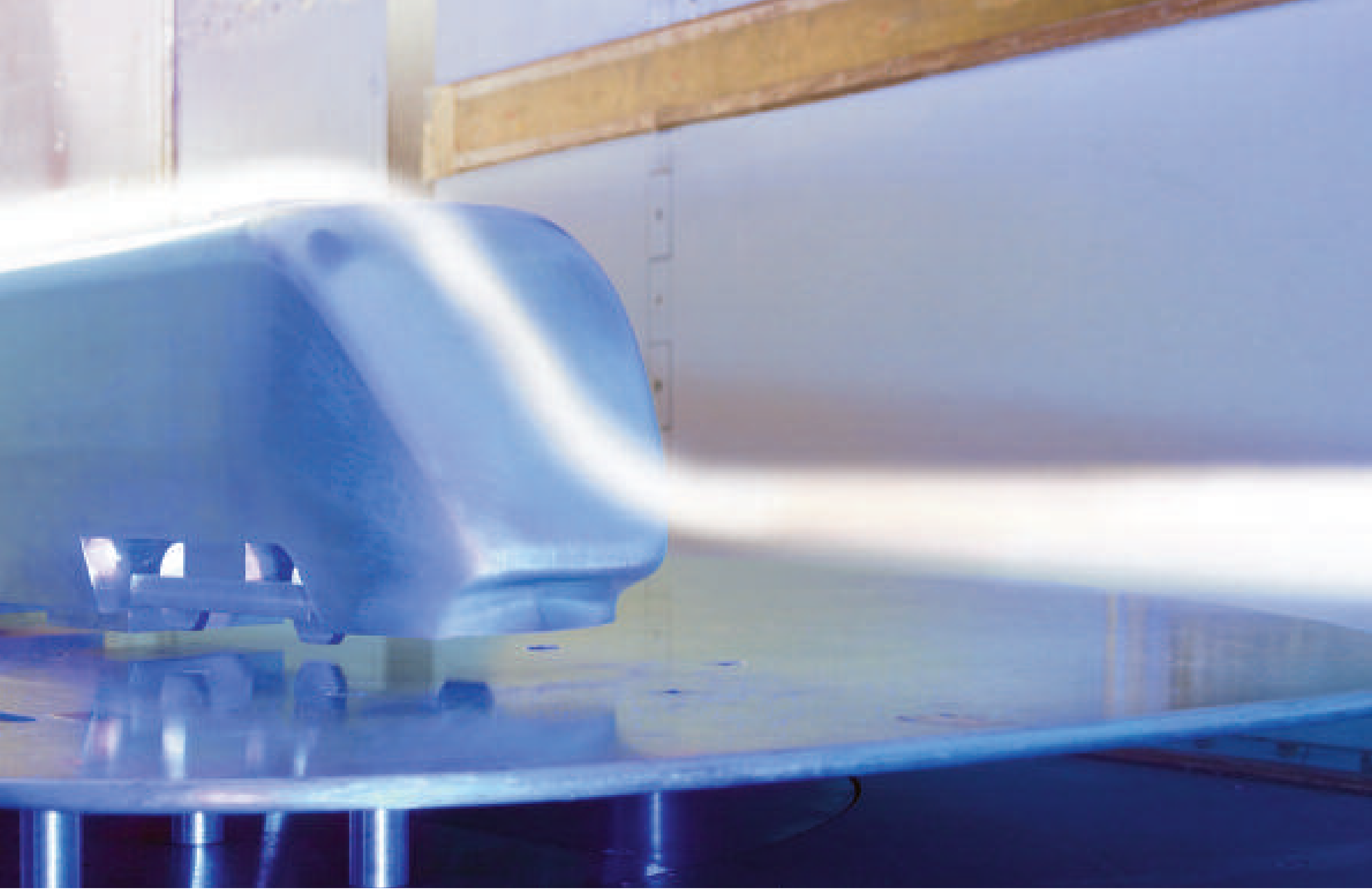
For a new lighter and faster train, above all stability against crosswinds needs to be examined from the point of view of safety. The higher the speed and the lower the weight of the train (in particular the traction unit), the more problematic is the susceptibility towards crosswind. The developers and, in particular, the aerodynamic engineers working on the use of a control car (without drive) for the transition from the first to the generation of high speed trains in Germany (ICE 1 to ICE 2) especially had to deal with this problem. The change that was made from the classical locomotive drive train to the rail car concept (distributed drive system) for the transition to the last generation of high speed trains, the ICE 3, further intensified these issues.

The crosswind that impacts on the vehicle and the lift it experiences from the diagonal airstream force resulting from the crosswind can, in particular, lead to an unwanted change in the load balance of the leading pivoted bogie. That is unless these forces and the resulting momentum are compensated by more weight or through forces that are induced by aerodynamic control surfaces.

Due to their weight, existing fast trains manage with relatively small passive (immovable) spoilers. If the weight of the trains is significantly reduced through lightweight construction (30 percent would be conceivable here), this would no longer be enough. Forces and momentum will also have to be controlled by active control elements in order to be able to safely operate the vehicle at all times and all circumstances.

In order to design and draft these control elements and processes you need to be precisely familiar with the transient flow field surrounding the train. In principal, the experimental and numerical tools that exist today enable a precise analysis of these time-dependent and partly time-limited occurrences. However, the use of special experimental facilities is necessary in order to gain an as realistic as possible simulation of the actual flow field. Highly precise simulations of the driving dynamics need to expand this procedure in order to arrive at reliable statements about the expected real behavior of the vehicle.

At DLR, extensive experimental investigations are being carried out

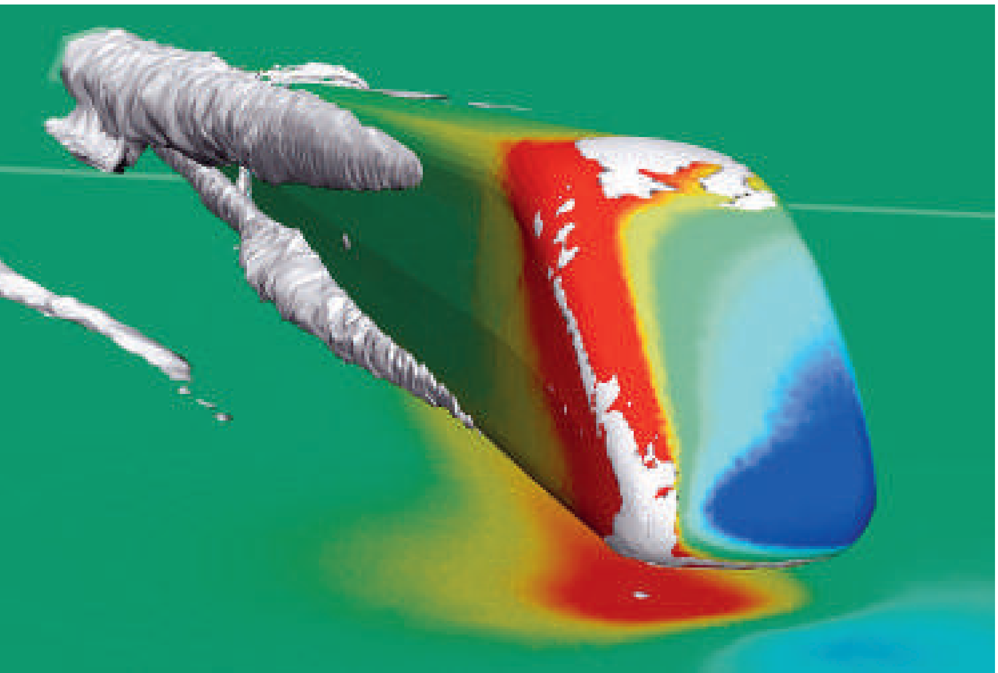


in various experimental facilities. Detailed numerical calculations are also being carried out. The turbulence structures of a generic train model subjected to incoming streams of strong crosswind force were studied in the cryogenic wind tunnel of the German-Dutch wind tunnel (DNW) in Cologne-Porz.

It was examined how the turbulence structure resulting from the surrounding airflow impacted on the time-related development of the forces and momentum. This turbulence structure can then be reduced by influencing the flow field in a targeted manner.

Another important issue is the impact of the vehicle on its environment. The issues that are being researched here include tunnel transits (pressure waves), the slip stream that is dragged along with the train, the head wave, and vehicle-track system interactions. When passing through tunnels, an increase in traveling speed causes the pressure wave amplitudes induced by the train to significantly increase.

This increases the mechanical strain on the components and structural elements of the vehicle and on the tunnel system. It also means a vital problem for the maintenance personnel of tunnel systems. The amount of the pressure amplitude which can be expected mainly scales with the train speed, the head shape and head length (design parameters), the tunnel cross-section, the tunnel length, and the composition/geometry of the tunnel (gravel, surfaces, etc.).

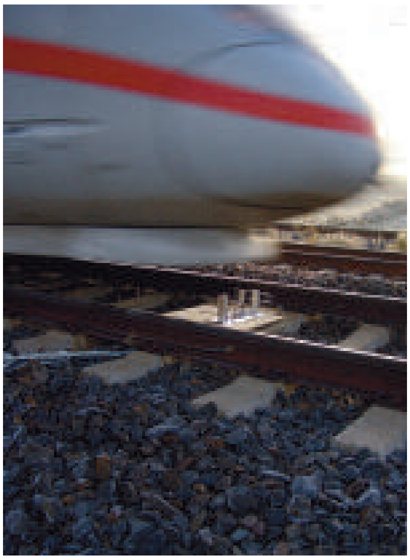


Numerical flow field calculation of a generic high-speed train with crosswind influence; the pressure is colored coded. Clearly identifiable: the leeward turbulence structure.

With the design, in other words the shape of the rail vehicle, it is possible to influence the behavior of the train when passing through tunnels and the pressure waves that are caused. Another possible method of influence is to change the geometry of the tunnel.

ANOTHER IMPORTANT ISSUE IS THE IMPACT OF THE VEHICLE ON ITS ENVIRONMENT

However, this second option is quickly reduced as infrastructural requirements determine these parameters to a large degree. With regard to the environment, the impact of the pressure waves consists of highly varying mechanical loads. These can result in damage to or even destruction of the tunnel infrastructure. A phenomenon which is equally to be taken into account is the so-called slip stream, a boundary layer dragged along by the train. Through the movement of the rail vehicle, air is displaced which, in combination with the boundary layer that forms around the vehicle, is manifested in a complex three dimensional flow induced by the vehicle. You are exposed to this flow when you are in the proximity of a passing train. When trains drive through train stations, the slip stream can be felt as a sudden gust of wind. The forces exerted by the flow field of the vehicle on the people are scaled with the flow speed, which is in turn dependent on the distances of the people to the train. The flow field that is induced by the train is determined by the length and speed of the train, the composition of the surface and the shape of the train, the type of train (passenger train; freight train; double-deck train, etc.), the local wind, and the environmental conditions.



Transit of a high-speed ICE 3 type train over a sensor-equipped panel for determining the speed and pressure field in the undercarriage area of the train.

In combination with the so-called head wave – the pressure wave caused by the train – this flow which is induced by the train harbors a latent potential for danger. If the traveling speed is increased or if double-deck trains are used, this potential danger increases. This critical problem must be taken into account when designing the vehicle. A surface which is as smooth as possible and has no gaps will have a positive effect on the development of the induced speeds. Particular value must be placed on analyzing the wake of the vehicle. With the existing vehicles, this is what causes the highest speeds.

Further vital questions for both the vehicle and for the infrastructure and other vehicles concern vehicle-track system interactions. Depending on the composition of the track and the configuration of the train, “whirlwinds” of gravel stones may result from the gravel bed.

These stones can cause serious damage to the vehicle, the infrastructure, and to other vehicles. The decisive influential parameters here are the composition of the undercarriage, the clearance height, the speed, as well as the condition of the infrastructure and/or the track bed.

The same applies for dealing with this problem as mentioned above: Without being familiar with the time-dependent flow field, it is difficult to find solutions. To this end, DLR is developing a measuring system in the track bed for the transit of a French “Thalys” -type high-speed train. The work is being carried out in cooperation with the company Bombardier on various European high-speed sections in Germany, Spain, and Italy. The ground clearance and speed of the train are generally fixed parameters; the infrastructure can only be altered on a wide-scale in the very long-term.

The composition of the vehicle’s undercarriage is also subject to numerous requirement profiles. A dynamic design requires that certain components must be affixed due to the required weight distribution in the undercarriage area. However, this can potentially lead to the ground beneath the train becoming highly fissured, which in turn creates conditions which will cause gravel to be sprayed into the air.

As part of the DLR project “Next Generation Train,” solutions will also

In the control room of the cryogenic wind tunnel of the German-Dutch Wind Tunnels (DNW) at the DLR in Cologne-Porz: The behavior of generic train models under the influence of airflows is analyzed.

be found for this problem over the next few years. It will be a long time before all the questions have been answered for the lighter and, at the same time, fast train of the future. However, with the results of the DLR researchers there is one thing it will certainly be – aerodynamically safe. Without too much of a stir.

Author:
Sigfried Loose is a researcher at the Institute of Aerodynamics and Flow Technology in Göttingen. For many years he has been investigating the special problems posed by aerodynamic rail questions and is in charge of the project "Next Generation Train," which was launched in January 2007.

STRATEGIC PARTNERSHIP WITH BOMBARDIER TRANSPORTATION

By Dr. Tjark Siefkes, Senior Director Product Development, Centers of Competence and Knowledge Management of Bombardier Transportation GmbH

Rail is by far the safest form of transport and ensures environmentally friendly transport from A to B. However, we should not be complacent with what we have achieved today if we want to ensure sustainable mobility in Germany. We therefore need to firstly improve the performance and attractiveness of rail transport and secondly improve energy efficiency and resource conversation.

Bombardier Transportation chose DLR as its strategic research partner because it brings with it ideal requirements: proven competencies, many years of experience, interdisciplinary working approach and the necessary scale to be able to successfully overcome the enormous challenges in the rail transport sector. Our experiences so far through our cooperation with DLR are extremely positive and provide a fruitful basis upon which we can jointly build on, for example, with the project "Next Generation Train."