A PLATFORM FOR CHINA'S SMOOTH RIDE TO THE FUTURE

A CSU team designed the world's fastest experimental system to study aerodynamic performance of trains at speeds of up to 500 km/h.

China's 32,000km high-speed rail network is the world's largest. Its streamlined trains already operate at an astonishing speed of 350 km/h. Now there are plans to expand the network by adding new lines, with even faster trains.

Behind this rapid expansion of speed and scope lies a huge effort by many scientists and technologists, and Central South University (CSU) researchers play a key role.

With its origins in the Hunan Advanced Industrial College, established in 1903, CSU's rail transit academic cluster includes transport and civil engineering programmes. New technologies and systems developed by its researchers range from train structure design and safety testing systems, to railway bridge and subgrade design. Their work underpins the safety of high-speed trains, increases their speed, and extends their service life.

KEEPING THINGS ON TRACK

When a train is travelling at high speed, the sudden change in air pressure, induced by the train crossing and going through tunnels, poses a safety concern because of risk of damage to train compartments, tunnel walls, and the surrounding environment. Easing the change in pressure to improve passenger experience and railroad efficiency is a strong focus of CSU's rail safety research team.

Led by Tian Hongqi, CSU president, who is also a member of the Chinese Academy of Engineering (CAE), the CSU team has designed experimental systems to study aerodynamic performance, including a world-first testing system for trains travelling at 500 km/h.

The key challenge is quick acceleration within a distance of just 60 metres. After many trials, the team designed a slingshot-like device that can quickly boost the speed to 500 km/h. Their invention also features a braking system that can quickly bring the high-speed train to a halt. Testing results can inform design of high-speed trains and tunnels, such as the tunnel hood shape and wall construction.

Almost all models of China's high-speed trains were tested at CSU's Laboratory of Traffic Safety on Track. The streamlined train design proposed by Tian's team reduced air resistance by up to 50%, and air pressure fluctuation at crossings by 25%. The experimental system is now being upgraded for testing 600-800 km/h Maglev trains.

Tian's team also designed the world's only system for testing train crashworthiness using full-size trains travelling on tracks. The system can quickly increase the speed of a 60-tonne train to 120 km/h within 10 metres, and allows emergency braking, a key innovation. In this system, if the train is not running at the desired speed or fails to meet certain parameters during the test, there is a control to halt it, preventing unnecessary test crashes. The countermand function helps to substantially lower the cost and improve the efficiency of crash tests.

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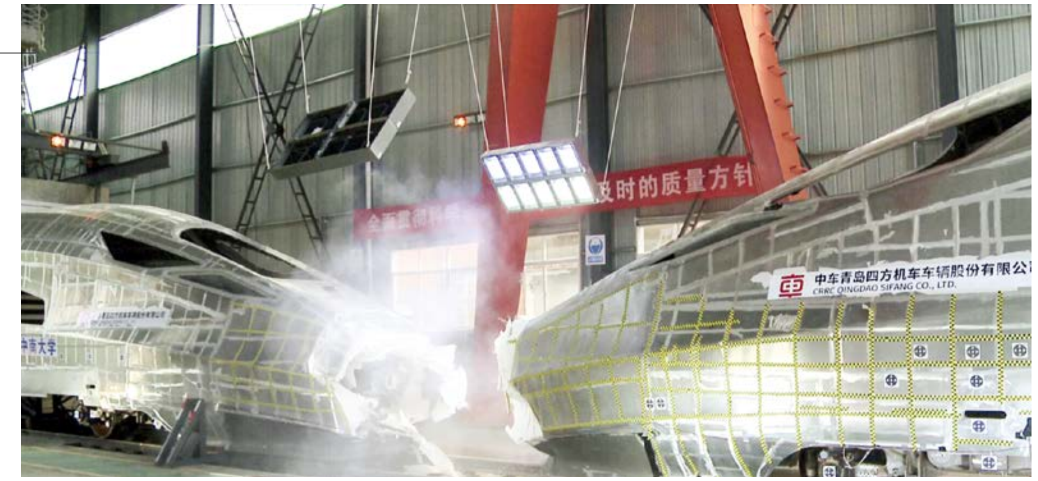

The internationally unique system for simulating train crashes using full-size real cars was designed at CSU.

The system's testing wall is unique, with large energy-absorbing capacity and the ability to withstand huge impact forces from train crashes. These tests improve the design of trains that can better absorb energy on impact, increasing high-speed train safety.

Other CSU inventions include a warning and transit command system that guides a train based on real-time monitoring of heavy winds and other adverse environmental factors. The system is now being used on the Qinghai-Tibet railway, which is built on the world's highest plateau and vulnerable to strong winds.

CEMENTING THE BASE OF DEVELOPMENT

Railway bridges occupy more than half of China's high-speed railway lines, and their safety is a high priority. In complex systems of trains, tracks and bridges, train safety control is a big challenge, particularly during natural disasters such as earthquakes and strong winds.

Researchers at the CSU school of civil engineering have developed stochastic simulation methods for reflecting seismic behaviours of the complex train-track-bridge systems under earthquakes and cross winds, breaking the bottleneck in rail safety evaluation and control. They developed an advanced shaking-table array system and wind tunnels to test the dynamic responses of high-speed trains and bridges under the combined impact of the passing trains and earthquakes or cross winds. These devices help to reveal the patterns of damage to key components of railway bridges. The results improved the wind- and earthquake- resistant design of railway bridges and were adopted as China's design standards.

These technologies have been applied in strong wind and high-risk earthquake areas, bringing significant economic benefits. The CSU team has conducted most of the running safety analyses for railway bridges, playing an essential role in the development of high-speed rails, and making China a leader in the field.

Ballasted tracks provide resilience and have low initial construction cost, but significantly limit operation speed. The bedrock of ballastless tracks is normally composed of concrete slabs instead of gravel, and while such slab tracks are used for 80% of China's high-speed railway lines, their use on long-span bridges still need careful investigation — due to the effects on the track-bridge interaction and vibration. The CSU national engineering laboratory for high-speed railway construction conducted fatigue tests, track-bridge interaction tests, and dynamic performance tests of long-span, cable-stayed bridges with ballastless tracks, making a breakthrough in the installation of ballastless track on long-span railway bridges. Their technologies contribute to the construction of China's first 300-metre, long-span, cable-stayed high-speed railway bridge.

Ballastless tracks demand high-quality concrete materials, and CSU researchers led the development of engineering materials for slab tracks by creating a composite called cement asphalt mortar. Tweaking the proportion of cement and asphalt brings variant ductility to the composite material, improving resilience and compression resistance according to the demands of the structure. The team also designed a novel self-compacting concrete, a highly flowable mix, which has high stability and resistance to cracking. CSU's preparation technology for concrete-based engineering materials is widely applied in China's ballastless tracks and has significantly improved track stability, durability and smoothness, enhancing passenger comfort, as well as track service life.

Frost damage to railway embankments poses another engineering challenge. A CSU research team has identified a new frost heave mechanism in porous materials, called vapour transfer and vapour-ice desublimation process, which is analogous to the ice accumulation process in an old-style freezer. Not explained by earlier literature, this new finding by CSU researchers will change the current practice in frost damage prevention, and has profound impact on high-speed railway design in cold regions. ■

A high speed railway wind tunnel with two test sections (wind speed ranges from 0-94 m/s)