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### Testing the bogie

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### A status report on *FLEXX* Speed bogies for *ZEFIRO* 380 trains

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# Testing the bogie

The bogie is a unique critical subsystem of most railway vehicles. Such criticality and relevance implies that very thorough validation and verification programmes must be performed in order to prove functionality, guarantee reliability and, most importantly of all, ensure safety. For these reasons, extensive test campaigns are performed on the bogie subsystem. This article highlights the testing work that CETEST performs on key sub-elements and components of the bogie subsystem. It also contains a presentation of the 'Instrumented Bogie' – a measurement solution tailored for preventive maintenance that incorporates CETEST's unique know-how and experience in railway testing.

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 diversity of customers ranging from railway undertakings (operators), system integrators (vehicle manufacturers) to equipment sub-suppliers. As leaders in the railway sector, testing of the bogie and its sub-elements is a core part of CETEST's business.

The bogie subsystem interfaces with the infrastructure and is directly responsible for fundamental roles such as guidance, comfort or traction and braking. It incorporates the following series of components:

- Wheels and axles, bearings, brake discs, brake calipers and all associated piping
- Gearboxes, traction motors (in some designs)
- Suspension (primary and secondary) with a wide variety and combination of sub-elements such as springs, dampers, restraints, roll bars, etc
- The bogie frame itself.

The following explains in more detail some of the tests (both test bench and on-track testing) that we perform at CETEST.

## Wheels and axles

We perform fatigue and endurance tests according to main international standards EN 13260, EN 13261 and EN 13262 in a multi-purpose test bench specifically designed for

wheel and axle verification. This test bench can subject the test specimen to loads up to 200,000 Nm via a frequency controlled eccentric load application. We also perform bi-axial testing of wheels in a modular test bench.

## Bearings

We offer two test benches in our specialised bearing laboratory for the functional and life compliance tests in EN 12082. Bearings

are brought to operating speeds and then vertical and lateral loading is applied with values of up to 200 kN and 100 kN respectively per wheel bearing.

## Gearboxes

We have a special laboratory for functional and endurance testing of gearbox design verification. In this laboratory, we have one test bench for no-load studies. These include flush, grease/oil distribution and grease/oil and water tightness.

We also have another test bench for load application studies in 4-square configuration which we can test gearboxes up to 1MW nominal power in speed ranges up to 6,000 rpm and torque ranges up to 10,000 Nm.

## Suspension elements

Tests on suspension elements are normally carried out by sub-suppliers in their design and



Figure 1: Wheel and axle test bench

quality laboratories. Qualifying a spring, characterising a damper or checking a ball joint is a typical test that is usually performed in-house. However, there are times when sub-suppliers will demand special testing of suspension elements due to internal test bench availability conflicts. Other times, the test

***The bogie frame is subjected to a combination of vertical, longitudinal, lateral and other particular forces (roll, yaw, etc.) throughout its operational lifetime***

complexity, necessary load application and control and/or instrumentation, are beyond the sub-supplier's capacity and so these tests are subcontracted out. At CETEST, we work closely with our customers to satisfy their test needs which can range from proof of concept testing to testing under real loads or more complex reliability testing such as accelerated life testing.

#### Bogie frame

The bogie frame is subjected to a combination of vertical, longitudinal, lateral and other particular forces (roll, yaw, etc.) throughout its



Figure 2: Control room for bogie frame test benches

operational lifetime. The bogie frame is not only a support for all the components we have already mentioned but it is also a structural and guidance element in itself, and so exhaustive

investigations of the durability of this structure must be performed.

CETEST engineers perform quasi static and fatigue structural tests according to main



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Figure 3: Instrumented Bogie for Metro de Madrid

international standards EN 13749, UIC 513, etc. CETEST offers three test benches for testing bogie frames.

These tests typically consist of two phases. First, the bogie frame is subjected to a series of combinations of all extreme loading conditions that are most demanding on the structure. During this phase, stresses on the structure are monitored via strain gauges that are installed on the most critical points according to numerical simulations and our own experience.

Secondly, the bogie frame enters the fatigue phase of the test which consists of the application of loads corresponding to the full lifetime of the vehicle (10 million cycles) in an accelerated manner. The bogie frame test benches are installed over isolated universal suspended test bases. This isolation guarantees

### **CETEST offers three test benches for testing bogie frames**

that heavy load vibrations are not transmitted to the structures of our main test facility.

A typical bogie frame test will be subjected to a combination of 8-12 simultaneous loads applied via hydraulic actuators during the mentioned 10 million cycles. The test length will vary depending on the actuation frequency, but we are speaking of 6-8 weeks of non-stop 24 hour testing. Non-destructive inspection via visual and magnetic particles is conducted every two million cycles for potential crack detection and growth and propagation analysis.

Additionally, the customer may ask for the measurement of stresses calculated on

the bogie frame during real operational conditions running on-track (the European standard also calls for this for certain applications). In this case, CETEST technicians will install strain gauges on the frame following special instructions in order to protect the sensors from the harsh conditions under the car body. Measurements will provide information as to the real stresses and fatigue studies can also be performed.

### **Instrumented Bogie: ride dynamics evaluation and preventive maintenance**

At CETEST, we call an Instrumented Bogie a very special type of 'test product'.

As already explained, bogie testing involves the evaluation of many sub-elements and components. Much of this testing can be

#### **FURTHER INFORMATION**

CETEST Rail is a world reference in railway testing. We offer more than 40 years of experience through a dynamic team of highly skilled engineers and technical staff, combining state-of-the-art facilities and test benches with a flexible global field testing deployment capacity.

CETEST customers include vehicle manufacturers, equipment suppliers and system operators.

#### **Project references**

##### **Auto cargo freight wagon - Talleres Alegria**

Ride dynamics evaluation, noise and test verification of design weight.

##### **ORARIS very high-speed prototype - CAF**

Integral homologation of vehicle. Test campaigns included: carbody structural integrity, bogie fatigue, ride dynamics evaluation with instrumented wheel sets, pantograph dynamics measurement, noise, aerodynamics, EMC, etc.

##### **Dual traction freight locomotive - Ingeteam, CFD, EuskoKargo**

Noise certification, temperature characterisation in drivers cab and optimisation of the suspension through operational modal testing.

##### **Regional diesel train - CAF**

Integral homologation of vehicle. Test campaigns included: carbody structural integrity, bogie fatigue, ride dynamics evaluation, noise, etc.

##### **Metro de Madrid**

Instrumented Wheel Set and fully instrumented bogie turn-key project.

##### **VIEWLINER 8400 - Amtrak**

Qualification testing and simulation studies of passenger vehicle ride dynamics.

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performed in test benches especially fit for each of the components. Also, sometimes we install sensors on an operating vehicle to measure real behaviour, as also already commented. All of these testing methods focus on the validation and verification of the sub-elements part of the design and acceptance of a new vehicle and or component.

An Instrumented Bogie builds on the concept of Instrumented Wheel Set transforming the bogie into a full sensing system. As previously published in *European Railway Review*<sup>1</sup>, CETEST's Instrumented Wheel Set is a 'sensing system that is capable of measuring, in an uncoupled manner, the contact forces (vertical, lateral, and longitudinal) between the wheel and the rail. This system, based on extensometric gauge instrumentation, measures the contact forces through the direct measurement of stresses experienced by the wheel'.

How does an Instrumented Bogie work? We take a new or existing bogie and equip it with dozens of sensors and sensing systems to create a very special measurement bogie. The installed

equipment can include strain gauges, and accelerometers in all suspension stages and all primary orientations, gyroscopes, as well as two Instrumented Wheel Sets.

All instrumentation uses special robust sensors and is installed in a quasi-permanent manner in order to ensure full reliability throughout the longest possible period of time.

From a vehicle point-of-view, the Instrumented Bogie can be used by the operator to perform periodic ride dynamics evaluations from passenger comfort to running safety.

From a track maintenance point-of-view, the Instrumented Bogie goes beyond typical geometric measurements provided by existing measurement cars for corrective maintenance offering dynamic measurements of force levels. These can complement geometric measurements for necessary corrective maintenance, but can also provide a more advanced understanding in order to design preventive actions and filter down locations allowing for effective savings in operational maintenance.

## Reference

1. *European Railway Review*, Volume 17, Issue 6, 2011, page 58

## FURTHER INFORMATION



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## BIOGRAPHY



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With much excitement, this wheelset press will arrive on our doorstep at the end of 2012 and will be ready for production in February 2013.

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# Independent test laboratory enhances safety

The market for air spring systems for rail vehicles is a heavily contested one, with more and more providers forcing their way onto the market. However, products that at first glance look like the original are frequently no match for the hard conditions of everyday work in the rail industry. ContiTech Railway Engineering (CRE), one of the world's leading providers of air spring systems in railway technology, has more than 50 years of experience, which is why companies such as Bombardier place their trust in this expertise. It is underpinned by an independent test laboratory in-house.



Since January 2012, ContiTech Air Spring Systems has had at its disposal the world's only test laboratory for rail vehicle air spring systems that has been officially certified as independent with an accreditation certificate. Twelve test procedures of importance to the rail industry have been accredited in accordance with DIN EN ISO / IEC 17025.

"Compliance with DIN constitutes a major step towards ensuring credibility," says Friedrich Hoppmann, Head of the ContiTech Railway Engineering segment. "OEMs and manufacturers frequently require test data from an accredited laboratory. We can now provide this." The certificate was necessary for continued involvement in providing equipment for the high-speed train, BOMBARDIER ZEFIRO, in China, as the Chinese Ministry of Railways had requested accreditation.

"This accreditation underlines the fact that the test laboratory employees come up with trustworthy measurement results, just like those

that can also be provided by external test facilities," says Hoppmann. For this reason, all segments of ContiTech Air Spring Systems have been considered to be external customers since accreditation. With ISO 9001, TS 16949 and IRIS certification, the test laboratory has already been meeting the strictest of requirements for many years.

This expertise also impresses the customers. In recent months, ContiTech received orders for several major projects worth millions from its long-standing business partner, Bombardier. ContiTech is producing the air spring systems for the new generation of double-decker carriages for Deutsche Bahn. The first parts will be leaving the plant in the middle of this year.

In the spare part market, ContiTech works closely with Bombardier in Great Britain. Over the next five years, the company will provide spare parts for the Electrostar. "With this framework agreement, the successful cooperation that we had experienced on the OEM

market was continued on the spare part market," says Britta Jurgilas, Key Account Manager for Bombardier at ContiTech. In addition, ContiTech is taking on responsibility for delivery for a further OEM order for this train type from October 2012 onwards.

Bombardier India orders the air spring systems for Metro Delhi RS7 from ContiTech, and these parts are assembled in the plant in India. ContiTech is also involved in the high-speed class. Conti air spring systems are installed in the ZEFIRO in Italy, Bombardier's first high-speed train in Europe. Series delivery will start in August.

"ContiTech has been providing proof of its air spring expertise for over 50 years. Our expertise is in demand in many challenging projects," says Hoppmann. "At InnoTrans 2012, we will not only show our OEM expertise but also our spare part business. Customers can be fully certain that they are in safe hands with our spare products, which fully match the original parts. After all, these parts come from the same plants."

## BIOGRAPHY



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# Minimise downtime. Get back on track faster

Having recently celebrated 60 years of service in the Australian Manufacturing Industry, Andrew Engineering, rather than resting on its laurels, has expanded and diversified to solidify its proven reputation in an increasingly demanding global market. Consolidating its experience in the Automotive, Mining and Defence Industries, Andrew Engineering made a strategic business decision to focus its knowledge to create a flexible and reliable Bogie Exchange System (BES).



After identifying a market place need for improvements to the existing BES technology, Andrew Engineering's in-house design team created a unique streamlined solution, overcoming the historical challenges of rolling stock maintenance. With the BES currently servicing major metropolitan rail networks within Australia, Andrew Engineering is expanding to provide this proven technology to the BES market.

The BES provides a unique solution to rolling stock maintenance. Designed for installation in any facility with minimal civil costs incurred, this system is ideal for upgrading existing equipment or for achieving significant cost savings in the construction of a new plant.

The modular design of the BES allows it to be used as a single station, or for an entire car-set change-out solution. With automation being a key feature, an eight car-set can be changed out in as little as 12 hours using only a four man crew. Requiring a car body lift of only 50mm the BES allows other rolling stock maintenance procedures to be conducted simultaneously

with the bogie exchange, which when added to the short cycle time can provide significant cost savings in both maintenance hours and out-of-service downtime.

The BES is comprised of the following four major components:

## Drop Machine

The Drop Machine is designed to traverse along a standard depot pit with elevated rail. It is controlled by a secure RF pendant allowing for easy movement between stations. When in position the Drop Machine becomes the control centre, linking all the BES components together. With a 10.5T lifting capacity and a vertical traverse of 695mm, the Drop Machine can be used on a wide variety of rolling stock.

## Side Shifter

Nested upon the Drop Machine, the Side Shifter provides an adjustable lifting platform for a range of Bogies. It can accommodate various wheel centers with minimal manual intervention, and the wheel chocks can be adjusted

for different gauges. The Side Shifter is guided by a keyway cast into the concrete and is driven from underneath the rolling stock, carrying the bogie out to the service road for change over.

## Removable Rails

Locked into position and providing tractive return when rolling stock is driven into the depot, the rails are then opened to allow the side shifter to traverse to the service road. The rails are designed to bridge standards and are available in two lengths; the standard 3,800mm and an extra-long measuring 4,620mm. With a crossover load rating of 30.5T, the removable rails can handle most rolling stock currently in service.

## Car Body Jacks

The Car Body Jacks provide a fail safe synchronous lifting system for the Car Body. With inbuilt load sensors and dual encoders, the Jacks can detect if they are in the jacking points correctly and halt lifting to prevent rolling stock damage. Combining digital and analogue encoders ensures that the car body is always lifted evenly, without constant visual inspection from operators.

Andrew Engineering's BES, sets a new standard in safety, reliability, flexibility and cost reduction.

## BIOGRAPHY



**Chris Muir** has 22 years of experience in the Manufacturing Industry and was the QA Manager of the first product BES project. His current position is in Technical Sales and Marketing.

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# A status report on *FLEXX* Speed bogies for *ZEFIRO* 380 trains

The design approach and bogie architecture of the **BOMBARDIER\* FLEXX\* Speed bogie** for the **BOMBARDIER\* ZEFIRO\* 380** was previously explained in *European Railway Review Issue 5 2010*<sup>1</sup>. Now, almost two years later, this article will provide a summary of the progress made.

Within the Bombardier bogie portfolio, the *FLEXX* Speed platform is approaching speeds of 250km/h and above. The design of these bogies was based on those by Siemens/Bombardier for ICE\*\* 3<sup>rd</sup>. The main goal was to use already proven solutions – as described in *European Railway Review Issue 2 2009*<sup>2</sup> – but to also introduce new features in order to meet the requirements of being able to operate at a top speed of 380km/h (the Chinese Ministry of Railways decided to reduce the maximum operational speed of high-speed trains by 50km/h, but still the contractually agreed top speed is 380km/h) and to reach an annual operating-distance of one million kilometres.

The first *FLEXX* Speed bogies for this project have now been produced (see **Figure 1** and **Figure 2**, page 10) and the first *ZEFIRO* trains are in the commissioning phase.

As published in *European Railway Review Issue 5 2010*<sup>1</sup>, the bogie validation covers four levels: the validation of bogie components (i.e. testing of certain elements mounted in the bogie); the validation of the bogie itself (mainly performed on a roller rig in order to reveal critical vibration phenomena); the validation on

car level, and last but not least, the validation on train level during on-track testing.

Level 1 validation is almost complete – except for the ongoing fatigue tests of frames and traverse beams and validation tests on car level. An important milestone was recently reached when bogies passed the roller rig tests performed at Chengdu University.

## Car level tests

Car level tests focus on validating the global vehicle characteristics which are significant to the dynamic performance of the bogie, as well

as the dynamic interaction between the car body and bogie. These tests include:

- Torsional stiffness of car body shell and complete car body
- Stiffness of yaw damper brackets
- Lateral stiffness of suspension
- $\Delta Q/Q$  test
- Flexibility coefficient
- Car body natural frequency
- Roller rig test of complete car.

These tests have been performed to a large extent at the Bombardier Sifang Transportation production facility and at the Sifang Rolling Stock Research Institute, both located in Qingdao, China. The torsional stiffness of the completed car body is a parameter which contributes to wheel unloading in track twists



Figure 1: Motor bogie

which is globally verified in the  $\Delta Q/Q$  test. The yaw damper bracket stiffness is an important parameter, considering the damping rates and force levels needed to ensure running stability at operational speeds of up to 380km/h. This test was performed on the completed car to take into account the stiffness of the connection

- **Modal analysis:** a series of step functions is used to excite bogie and car body bounce, pitch, yaw and sway modes
- **Stability map:** the running speed is increased stepwise up to 420km/h and stability limits are assessed after a short set of track excitations has been applied



**Figure 2: Trailer bogie**

between the bolster beam and the car body connection, as well as the stiffness of the complete car body itself. The car body's natural frequency test is important to validate the design concept with respect to the ride comfort requirements of the customer. Lateral stiffness and flexibility coefficient tests are used to validate the behaviour of primary and secondary suspension on vehicle level.

### Roller rig test

The roller rig test was performed at the Traction Power State Key Laboratory of Southwest Jiatong Technical University (SWJTU) in Chengdu from the end of February 2012 to the beginning of May 2012, which marked an important milestone in the validation phase. The test consisted of two phases – first, the so called investigation test and afterwards the type test, where contractual requirements were checked. During the investigation test, the supplier defined test procedures and instrumentation freely, and the type test was performed by a certified test institute and the results were reported to the customer. For the roller rig test, an intermediate motor car was used (see Figure 3).

The aim of the investigation test is to verify the dynamic behaviour of the vehicle with special focus on the interaction of the car body and bogie and involves the following three main components:

- **Running test:** running safety, running behaviour and ride comfort values are evaluated for running speeds between 160km/h to 420km/h for different track excitation types for time periods of one to two minutes.

The usual test procedure on the SWJTU roller rig is defined in the Chinese railway industry standard TB/T 3115-2005. This requires the measurement of accelerations and displacements on axle box, bogie frame and car body levels. Wheel-rail forces are not measured and the rollers are not instrumented to this effect. However, for anticipating restrictions governing track access time and test scope during main line tests, Bombardier opted to measure track forces with instrumented wheel sets during the roller rig investigation test. These wheel sets are equipped with IWT<sup>4</sup> instrumentation developed by Interfleet Technology, and are capable of measuring lateral and vertical wheel forces as well as the contact point position on the wheel profile (see Figure 4 opposite).

A comprehensive test matrix has been set up involving:

- Tests with motor bogies and trailer bogies
- Tests with nominal and worn wheel-rail contact conditions
- Tests on inflated and deflated secondary suspension
- Reduced damper characteristics, complete damper failures and orifice variants in the air spring system.



**Figure 3: ZEFIRO\* 380 intermediate motor car being prepared for tests on a SWJTU roller rig**





Figure 4: Instrumented motor bogie underneath the test coach

Furthermore, the roller rig test programme is accompanied by test cases intended to verify the function of the instability monitoring system (IMS box), to verify the acoustic vibration isolation requirements and to measure acoustic transfer functions.

The type test follows the same structure as the investigation test. However, the investigation test bogies are replaced by regular production bogies. A special requirement for roller rig testing, according to the TB/T 3115-2005 standard, is that the maximum test speed must be 15% higher than the maximum track test speed, which itself is 10% higher than the highest operational speed. In the case of the ZEFIRO 380 vehicle, a speed of 420km/h is required for track tests and therefore a speed of 483km/h is required for the roller rig test.

All-in-all, a distance of 12,308km was accumulated. More than 300 signals (wheel/rail forces; accelerations; displacements, temperatures and running speeds) were being recorded. The basis for evaluation of the test results is the European standard EN 14363 and the Chinese national standard GB 5599-85. The main test results are:

- Under nominal conditions stability limits are maintained up to 483km/h. Running safety

and running behaviour values satisfy the GB and EN standards up to 420km/h. Ride comfort values meet customer requirements up to 380km/h

- On deflated air springs the stability limits were maintained up to the maximum test speed of 380km/h
- With both yaw dampers, each 25% degraded, the stability limit was maintained up to the maximum test speed of 380km/h
- With one yaw damper 50% degraded, the stability limit was maintained up to 280km/h
- With one yaw damper completely failed, the stability limit was maintained up to 230km/h.

#### What's next?

In terms of bogie validation 3, on-track test campaigns are foreseen. In June 2012 the test runs on the so-called Beijing loop with speeds up to 160km/h started. At the end of July 2012, the high-speed test runs on future service lines will be performed. Afterwards, an examination period of 600,000km is planned, to be supervised by the Chinese Ministry of Railways. This exercise will be finalised by the disassembling of bogies.

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 \*\* Trademark of third parties.

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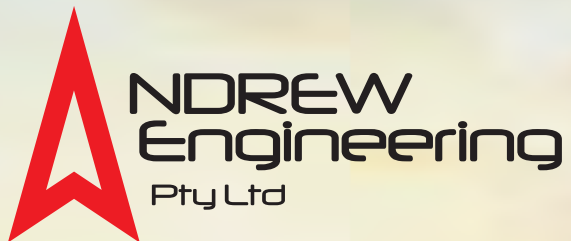
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#### BIOGRAPHY



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