Approval testing and certification of high-speed trains

Italcertifer tests the Frecciarossa ETR 1000 with imc measurement solutions

Fig. 1: The ETR 1000 high-speed train

For the railway and transportation sector, Italcertifer offers a wide range of certification, inspection and, more generally, compliance verification in the railway sector. As an affiliated company of Gruppo Ferrovie dello Stato Italiane, Italcertifer is a central institution in Italy and abroad when it comes to railway conformity testing and safety assessments. For certification of the high speed train Frecciarossa 1000 (also known as ETR 1000), Italcertifer chose imc test and measurement solutions.

Getting the green light

The European standard EN14363 incorporates a variety of testing scenarios including high acceleration testing and maximum speeds up to 400 km/h.

The tests were carried out under extreme operating conditions – even exceeding those of regular operation. For example, testing was conducted at about 110% of nominal maximum speed and acceleration levels.

Distributed DAQ for high channel counts

For simultaneous data acquisition of approximately 300 channels, Italcertifer chose the imc CRONOS*flex* and imc CRONOS*compact* modular high performance measurement systems. The spatially distributable imc CRONOS*flex* modules allow digitizing inputs close to the sensor location, solving problems of noise and interference and resulting in high signal quality. With up to 100 kSample/s per channel, high bandwidth, precision signal conditioning and integrated sensor power supply, the imc CRONOS*flex* system was ideal for challenging data acquisition requirements. Furthermore, 3 imc CRONOS*compact* systems were used for synchronous acquisition of additional analog signals such as strain gauge data, voltage and temperature information, IEPE accelerometers, etc.

Fig. 2: imc CRONOS*flex* and imc CRONOS*compact*

System overview:

imc measurement devices	Qty.
imc CRONOS*compact* (CRC)	3
imc CRONOS*flex* (CRFX)	1
Amplifiers	
CRFX/UNI-4 4 universal channels for analog sensors, e.g., voltage, current, temperature, strain gauges, IEPE accelerometers	18
CRC/SC2-32 32 channels for voltage signals	4
CRC/LV-16 16 channels for voltage signals	1
CRC/ICPU2-8 8 channels for IEPE / ICP accelerometers	1
CRC/B-8 8 channels for strain gauge measurements	5
CRC/C-8 8 channels for temperature sensors and voltage	1
CRC/DI2-16 16 channels for discrete digital signals	2
CRC/DI8-DO8-ENC4 4 tachometer / incremental encoder inputs	1
imc software	
imc Online FAMOS Pro Real time data analysis framework running on imc CRONOS devices	
imc STUDIO Pro Comprehensive test & measurement software for the entire testing process: measurement, visualization, automation, data analysis	
imc FAMOS Enterprise + imc FAMOS Pro Data post processing, analysis and visualization	

Fig. 3: Utilizing a variety of signal conditioners, the imc measurement systems cover a wide spectrum of testing requirements.

Multi-channel synchronous data acquisition was performed with sampling rates of up to 100 kS/s per channel and data rates of up to 400 kS/s per device, where multiple synchronized devices operated in a distributed network. Precision amplifier front ends provided digitization with high A/D resolution of 24 bit; incorporating individual anti-aliasing filters.

The imc CRONOS systems include a built-in DSP that runs imc Online FAMOS; a real-time

data analysis framework allowing processing of custom specific algorithms. Data storage of both primary acquisition and live calculated results is simultaneously supported via onboard mass storage (such as Flash or HDD) and on one or more PCs on the network. Real-time graphs of different test parameters can also be viewed on multiple connected monitoring PCs.

Transducers and measurement sensors

The main physical quantities being measured were accelerations, forces, position displacements and speed of the vehicle.

For this purpose, the following transducers and sensors were applied:

- Accelerometers, mainly MEMS
- Strain gauges
- Potentiometric position and displacement transducers
- Laser sensors
- PDL system for progressive speed and position values
- Phonic (toothed) wheel to derive speed and distance traveled
- GPS receiver for redundant measurements of speed and position

imc systems and TEDS capability

An additional benefit provided by imc systems is that the amplifier channels feature TEDS capability. This allows for direct identification of sensor information, such as sensor type, location, supply, scaling factor, measurement range, sampling rate, etc. – automatically carried out. This proved to be a major advantage when safely handling and administrating large configurations with hundreds of channels and sensors.

Acceleration and displacement measurements

The train was instrumented with about 100 accelerometers in order to characterize the dynamic behavior and passenger comfort in addition to monitoring vehicle stability during travel.

String pots were used to measure the displacement of the hydraulic actuators and dampers in order to characterize the vehicle dynamics, suspension and the response of the different systems.

Fig. 4: String pots and accelerometers

Force measurements

One of the main measurements required by the EN14363 is the assessment of wheel-rail contact forces. For this measurement, wheel sets had to be instrumented with more than 100 strain gauges. Six axles were monitored, with each providing about twenty signals from strain gauges being transmitted via the MTP-NT telemetry system from KMT. The data were processed in real time using imc Online FAMOS to obtain the values of the contact forces on the 12 wheels.

Fig. 5: Instrumented wheel sets

In addition to force measurements taken at the wheels, other components on the train were instrumented to operate as real load cells for taking additional force measurements and studying their operation.

Fig. 6: Strain gauge outfitted components

Immediate test results in real time with imc Online FAMOS

A key component of imc measurement systems is the integrated real-time platform imc Online FAMOS. This tool, running on its own dedicated processor, allows synchronized, real-time data processing in order to deliver immediate analysis results, which are instantly available to the test engineers on site. This direct feedback allows for immediate evaluation, based on processed and thus intuitively understandable result data. Hence, it gives information about the progress of the test, for immediate reaction and even intervention.

A dedicated train car had been set up as an operations center. Here, all data to be acquired with the distributed measurement system was available for live monitoring and visual inspection by the test engineers. A total of over 300 mechanical and electrical parameters, variables and complex results were continuously monitored during testing on multiple PC stations. imc Online FAMOS was used to process, analyze and output the streaming data in real time according to mathematics and algorithms that had been defined by the customer and easily edited within imc STUDIO software. Test results included such information as the interaction forces between the wheels and rails, filtering according to the standard, calculations of speed and position, distance covered by integrating the speed information from a GPS receiver, etc.

Fig. 7: Measurement data via imc STUDIO

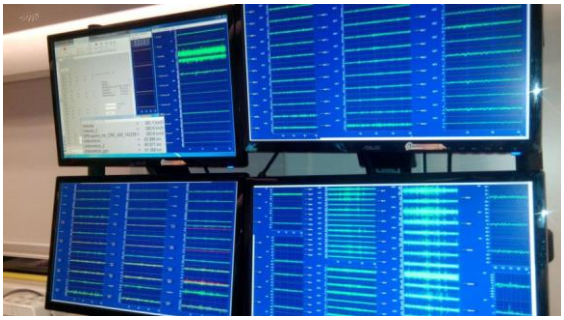

Fig. 8: Dedicated on-board work station

Post-processing

After each test session and before the next, the data were further analyzed and evaluated with the additional post processing tool imc FAMOS, on the basis of easily created sequences. Over 100 parameters were used from each run to characterize the interaction between wheel and rail. A realignment of the position signal along the known characteristics of the line was performed to minimize errors in the position measurement.

Graphs were produced that represented the trend lines of the various parameters of interest with a total of more than 600 charts for each report.

Conclusion

For this project, using imc's comprehensive solutions of measurement equipment and analysis software has proven to be flexible and reliable. For their demanding testing and certification campaigns, Italcertifer has been very satisfied using the imc CRONOS*compact* and imc CRONOS*flex* systems for several years now. They appreciate the ease and flexibility for configurations, as well as the benefits of versatile live analysis provided by imc Online FAMOS.

The combined use of live processing from imc Online FAMOS, data acquisition from imc STUDIO and post processing from imc FAMOS provides a quick, straight-forward and flexible solution. It allows for defining automatic acquisition, testing, sequencing, analysis and test report generation – based on a convenient drag & drop approach, without the need for any low level computer programming. This completely satisfies even the most particular application requirements from pre-test up to final certification.

A total number of 50 trains are planned to be tested, some of which have already entered service since the middle of 2015.

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imc Test & Measurement GmbH is a manufacturer and solution provider of productive test and measurement systems. imc implements metrological solutions for research, development, service and production. imc has particular expertise in the design and production of turnkey electric motor test benches. Precisely outfitted sensor and telemetry systems complement our customer applications.

Our customers from the fields of automotive engineering, mechanical engineering, railway, aerospace and energy use imc measurement devices, software solutions and test stands to validate prototypes, optimize products, monitor processes and gain insights from measurement data. As a solution provider, imc offers their customers an attractive and comprehensive range of services. These include project consulting, contracted measurements, data evaluation, specialist deployment, customer-specific software development and system integration. imc consistently pursues its claim of providing services for “productive testing”.

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