AUGUST 2015

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ECUC
www.ecuc-project.eu

OVERVIEW OF ECUC AND ITS OBJECTIVES

The EU-funded ECUC project – Eddy Current Brake Compatibility – aimed to prove that Eddy Current Brake (ECB) is a highly effective and applicable solution for increasing the braking capacity of new high-speed trains. Moreover it aims to solve the concerns raised by infrastructure managers by proposing concrete and realistic solutions to overcome any possible drawbacks that ECB has experienced on some lines.

Co-funded by the European Commission under the FP7 Programme (contract 314244), ECUC is composed of eight partners, two large enterprises (Knorr-Bremse and Alstom), one small-medium enterprise (Frauscher Sensor Technology), one European association (UNIFE), one research centre (CEIT), two railway operators (DB and SNCF) and one infrastructure manager (Network Rail). These partners have gained extensive knowledge whilst working in key positions in the development of ECB during recent years. This positive starting point means that progress beyond the state of the art has been facilitated through an improved understanding of the interaction between ECB, track and trackside signalling equipment.

This newsletter wants to offer the reader an accurate overview on the main results achieved by the ECUC partners during three years of intense cooperative work – namely the main results of the ECB test run in Germany, ECB engineering and testing guidelines, ECB compatibility with signalling devices, engineering guidelines for tracks and a new generation of ECB.

For more information on ECUC please visit: the official website www.ecuc-project.eu
or contact the Coordinator dvalderas@ceit.es
or Communication Leader andrea.demadonna@unife.org

ECB TEST RUN IN GERMANY – RELEVANT OUTCOMES

For the validation of the different simulation models, the assessment of the influence of ECB on the infrastructure and the numerous braking behavior tests runs (approx. 86) were carried out with an ICE 3 train - equipped with different types of ECBs - on the Nürnberg-Ingolstadt high-speed line in Germany.

For this, extensive measurements with different operation conditions were carried out on board the ICE 3 train. These included current flow and supply voltage of the ECBs from two wagons. On the infrastructure side, measurements of magnetic field emissions, output signals of axle counter detectors, rail temperature and rail stress were captured.

RAIL TEMPERATURE AND RAIL STRESS

Along the observed rail section, three locations (distance to each other approx. 23 m) were selected for measurements concerning rail temperature and rail stress. Rail temperature was measured at four points around the rail profile at each location (see picture below):

- Two points at the rail head
- One at the web
- One at the foot

These four locations allow the evaluation of the propagation of temperatures across the section of the rail. Rail stress was measured at one point around the profile at each location.

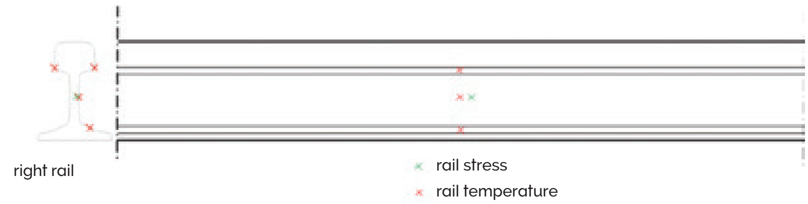


Figure 1: Measurement points for rail stress and rail temperature

A weather station was also installed to obtain information about weather conditions (ambient temperature, wind speed, etc).

The temperature of the rail was measured before, during and after each test run. Measurements during the test runs show that the rail temperature increases due to the use of ECB. Measurements before and after each test run provide information about the cooling of rails and the evolution of temperature over time. The table and figure (right) show an example of temperature measurements during the night of 4th of November 2014.

Case N°	type	date	start time	end time	normal speed	braking force (kN)
63	ambiente	04/11/2015	0:29:59	0:37:59		
63	test-run	04/11/2015	0:38:04	0:43:20	300km/h	139
64	ambiente	04/11/2015	0:44:54	1:04:51		
64	test-run	04/11/2015	1:06:08	1:11:36	300km/h	26.2
65	ambiente	04/11/2015	1:12:58	1:41:21		
65	test-run	04/11/2015	1:42:09	1:47:37	120km/h	142.1
66	ambiente	04/11/2015	1:49:12	2:21:57		
66	test-run	04/11/2015	2:22:20	2:27:48	300km/h	26.2
67	ambiente	04/11/2015	2:29:44	2:49:46		
67	test-run	04/11/2015	2:50:27	2:55:55	120km/h	169
68	ambiente	04/11/2015	2:58:04	3:16:31		
67	test-run	04/11/2015	3:17:45	3:23:13	300km/h	139
68	ambiente	04/11/2015	3:24:40	3:44:03		

Figure 2: Table and graph showing example of temperature measurements

SIGNALLING DEVICES

INTERMITTENT TRAIN CONTROL SYSTEM (PZB AND GPE)

The German intermittent train control systems 'PZB' and 'GPE' were also taken into consideration. No critical influence could be evaluated that could have been assigned especially to the ECB.

SIGNALLING DEVICES

AXLE COUNTER DETECTORS AND WHEEL SENSORS

A variety of axle counter detectors and wheel sensors known to be compatible with the ECB Type EWB 154 R /L4 and EWB 154 R /L5,which are already installed on German high-speed trains ICE3 and Velaro D, were included in these tests. Several test runs were performed, combined with:

- The speeds 70, 120, 160 and 300 km/h
- The air gaps 5 mm and 7 mm
- Different currents inside the ECB coils: 20 %, 50 %, 82 % and 100 % of Imax (95 A)

Furthermore, test runs with a passive lowered ECB (air gap 5 mm and 7 mm) were performed to obtain information about the passive influence. As expected, the ECB influenced the signalling devices. Moreover, the influence of the ECB type EWB 154 R /L4 and EWB 154 R /L5 was comparable, showing that the EWB 154 R /L5 was even better.

SIGNALING DEVICES

CONTINUOUS TRAIN CONTROL SYSTEM (LZB)

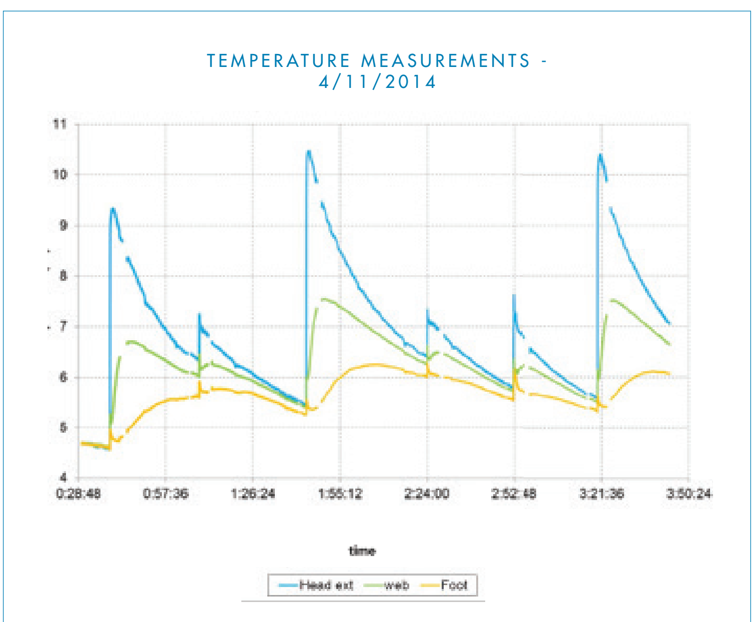
These test runs are scheduled for 11th to 13th August. To examine possible influences, the following two parameters will be measured, evaluated and compared with train runs without active ECB:

- Level measurement of the supply voltage of the line cable
- Error telegrams

SIGNALLING DEVICES

TRACK CIRCUITS

These test runs have been perfomed on the 11th and 12th August, 2015. To examine possible influences, the voltage of the motor relay will be measured, evaluated and compared with train runs without active ECB.



Temperature was measured at each test run and, thus, plenty of results regarding the increase and evolution of rail temperature as a function of braking force and speed of trains were obtained. These data proved to be useful when validating the thermal models developed within ECUC project.

MAGNETIC FIELDS

10 KHZ TO 1.3 MHZ

Magnetic fields emitted from a traversing ECB between 10 kHz and 1.3 MHz were measured at a typical wheel sensor mounting position and recorded using a Magnetic Noise Receiver (MNR) – both in accordance with CLC/TS 50238-3. The data were analysed either by applying a windowed FFT or according to the analysis methodology defined in CLC/TS 50238-3. The FFT offers a detailed insight into the frequency content of the magnetic field emission of the passing ECB over time (location), as shown in Figure 3, while the bandpass analysis described in the CLC/TS 50238-3 shows if a particular wheel sensor is compatible with the magnetic field emission.

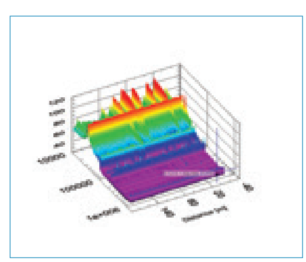


Figure 3: Typical FFT analysis of several ECBs passing the MNR recorder

ECB ENGINEERING AND TESTING

GUIDELINES AND PROJECT RECOMMENDATIONS

Multiple interferences between the ECB of rolling stock and the stationary infrastructure can be observed. For the design of the ECB, operational aspects also have to be taken into account.

	Brake System/ECB	Train/bogie	Infrastructure	Operation
Electrical	• Power consumption • EMC with signalling systems • isolation requirements	• Power supply of ECB • EMC with signalling systems • Earthing concept	• EMC of signalling systems with ECB	• Diagnosis (earth fault, insulation) • Service and maintenace
Mechanical	• Dimensions of ECB • Air gap (incl. adjustm.) • Forces • Mass of ECB • Pneumatic load relief	• Design of bogie • Kind of wheel set • Load collectives at interfaces • Pneumatic supply	• Rail type/gauges • Non-magnetic switches • Load cases for track/track equipment	• Air gap adjustment • Management of rail temperature • Maintenance
Functional	• Service brake • Emergency brake • Control of ECB • Brake blending (brake steps ECB)	• Control of train • Range of speed • Number of ECBs	Approval for use of ECB for emergency and/or service brake	• Operational cycle • Enable signals for use of ECB • Service and maintenance

Figure 4: Overview of ECB component relationships

For the development of guidelines, the identification of the performance requirements, in conjunction with their mutual relationship, design parameters and the identification of representative worst case conditions, are mandatory. These aspects have been investigated in work packages 2 and 4. Furthermore, the improvements of the compatibility model from work package 3 are considered.

The ECB guideline is related to other engineering guidelines:

- The installation of the ECB in the vehicle
- Signalling systems and for tracks
- Recommendations regarding ECB's new requirements
- Definition of a test procedure for ECB in the vehicle
- Advice for the compatibility of the rest of the systems which can be influenced by ECB

In this constellation, the determined interfaces can be split into two groups describing relevant aspects for rolling stock and infrastructure.

The first group, rolling stock, includes interfaces for the brake control system, the pneumatic control system, the electric power supply and control system and the mechanical system of bogie and ECB.

The second group, infrastructure, contains interfaces for the signalling devices, the track, the rail equipment and the operation.

The definition of interfaces should be elaborated on the basis of nominal values. Tolerances and worst case conditions should be charged with an additional safety value.

Derived from the definition of interfaces, the design requirements of ECB have been determined.

The main design requirements of ECB are:

- Brake performance
- Cycles of brake application
- Installation in and interaction with bogie
- Power supply and power control
- EMC
- Climate conditions
- Safety

Exemplified in exclusive components of the new generation of ECB, the closed development process from the initial idea through to validation has been carried out.

As a result, a verification of requirements was performed on the basis of laboratory tests with regard to the latter type of test procedure. Worst case conditions have been measured in the laboratory as far as possible. Therefore, additional loads are applied and related to the nominal values for the verification of the thresholds.

The validation of functionality was carried out and the results were benchmarked with the weighted additional loads of worst case conditions from laboratory test. The recommendations listed below are derived from the experience obtained from project work:

- The requirements regarding the interfaces should be based on nominal values
- Tolerances and worst case conditions should be charged with additional safety values
- Running tests should evaluate the functionality at nominal operation and verify the load factor of the interface
- Methods and test procedures are available to determine values in case of incomplete definitions of interfaces
- Present evaluations by manufacturers of signalling devices should be integrated in European Standards in future and prospectively could define EMC requirements for the design of ECB
- The track-related requirements of ECB's limitation of brake force should differ between ballasted and un-ballasted tracks
- The engineering guideline of ECB should follow the structure of EN16207 for magnetic track brakes

ECB COMPATIBILITY WITH SIGNALLING DEVICES

The recommendations are a result of analysing a number of physical effects, either measured or simulated, that are associated with an actively braking ECB and are accountable for the interference a wheel sensor or axle counter can experience.

It should be noted that general, sweeping remarks pertaining to all types of ECBs and wheel sensors on the market cannot be made since the interactions are specific to the technologies used in both the ECBs and wheel sensors studied. Despite these limitations, however, a number of recommendations and guidelines can be outlined, which provide a framework for future developments, a number of which are noted here.

GENERAL COUPLING MECHANISM

Excluding a specific frequency band that will be discussed below, the levels of harmonics do not significantly depend on the level of saturation of the magnetic parts of the system (mainly rail and pole cores) that the ECB DC current introduces. However, this current saturates the rail, which affects the axle counter signal even if the AC radiation from the ECB remains approximately the same. In this manner, the active ECB has an indirect impact on the axle counter through rail saturation effects. Therefore, it is recommended that, if possible, a compatibility test in the laboratory between ECB and the wheel sensor is performed on a rail of non-magnetic metal and similar conductivity to emulate worst case operation. conditions.

FREQUENCY OF OPERATION OF WHEEL SENSORS

Even if the main coupling mechanism is through rail saturation, reducing ECB emissions is also recommended. High-frequency magnetic fields emanating from on-board electronics can couple through the ECB to the wheel sensor. The frequency content of the emitted radiation in the range 10 kHz – 1.3 MHz has been measured and found to decrease with increasing frequency, as presented in figure 5. With respect to ECB, it seems therefore to be easier for axle counters working at higher frequencies (e.g. above 300 kHz).

Higher brake currents may generate increased frequency content in the 100 – 250 kHz range. Additionally, highest emissions within this band are likely to occur at braking speeds of approx. 120 km/h with an ICE3 train. Therefore interoperability test runs at the maximum braking force and at 120 km/h are recommended, particularly if the wheel sensor operates in the frequency range 100 – 250 kHz.

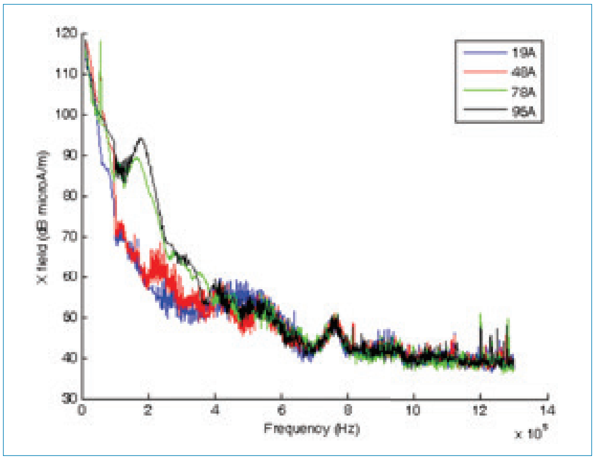


Figure 5: Typical frequency spectrum of magnetic fields for four different braking currents at 160 km/h.

LATERAL DISPLACEMENT

The ECB is mounted directly to the train bogie and any lateral movement of the bogie is translated into a lateral displacement of the ECB. The position of maximum interference for wheel rim detection sensors is when the ECB is directly above the sensor. Simulations show that an increase of 5 dB in emissions can be expected, therefore, an overhead of 5 dB from the nominal position is recommended to be included in any calculations of immunity limits.

INTERNAL WHEEL SENSOR TECHNOLOGY

Low-frequency magnetic fields can also alter the properties of magnetic components in the sensors themselves, thus having a dramatic effect on the signal. Although this has been known for a number of years, it is worthy of reiteration here. It is therefore recommended that no ferromagnetic components be used in construction of wheel sensors if they are to be ECB compatible.

By understanding the interaction between ECBs and wheel sensors, the recommendations noted above have been developed in the hope of alleviating potential hurdles in the design and testing of future wheel sensors and axle counters for use in conjunction with ECBs.

When the rail temperature rises from the stress-free temperature, high compressive stresses will occur. As the continuous welded rail (CWR) is not allowed to expand in the longitudinal direction, any irregularity in the track may trigger lateral buckling. The use of ECBs raises rail temperature further. So, where a rail is already heated due to climate conditions, lateral stability of the track can be seriously compromised.

In order to avoid the lateral buckling phenomena, two actions might be taken:

1) increase of lateral resistance of tracks

2) and/or control of rail temperature, incorporating the effect of ECBs

The second solution requires no change to anything in pre-existing tracks. Knowledge of temperature increases in rails due to repetitive use of ECBs is however needed. The temperature increases would be added to other contributions and compared to the rail temperature threshold that has been established for a particular line, dependent on the characteristics of the track (especially type of ballast - a condition of lateral resistance).

Temperature increases due to repetitive use of ECBs have been obtained from simulations and tabulated in order to provide infrastructure managers with sufficient data to plan their braking strategies and accomplish lateral stability safety criteria. Other factors, such as different braking forces, time interval between trains and effect of wind have also been considered to provide steady temperature increases.

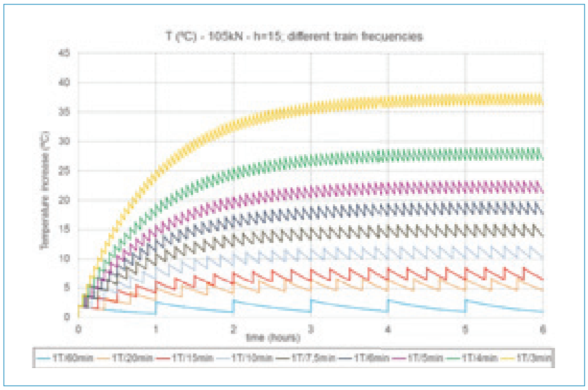


Figure 6: Temperature increases (°C) – 2/3 service braking; low speed air cooling the rails.

Tracks should have a high lateral resistance in order to allow a high frequency of trains (20 trains per hour) at high braking forces (full service braking – 180kN), as temperature increase is about 65°C. Especially on hot days, temperature increases due to climate conditions might be +20°C; tracks might already be at risk of buckling and the braking strategy should be changed. This could be done either by reducing the number of trains allowed to use ECBs or reducing the braking force.

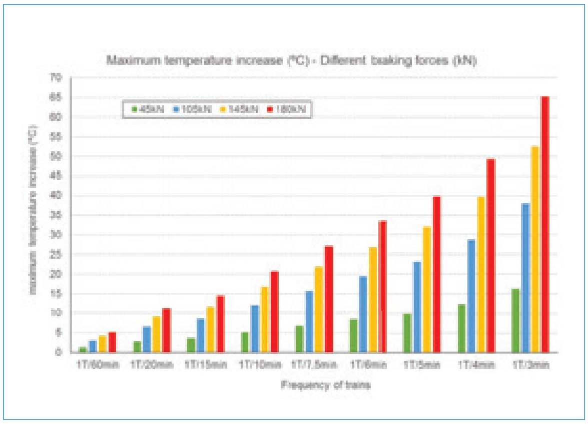


Figure 7: Graph showing different braking forces (kN), frequency of trains and maximum temperature increase (°C).

Design of repetitive use of ECBs for existing tracks should follow these steps:

1) Establishment of maximum allowable temperature or allowable temperature increase for a particular track

2) Evaluation of temperature increase due to climate conditions or other phenomena

3) Calculation of the margin left for use of ECBs

4) With that value in mind, using tabulated data, establish the braking force and the frequency of trains allowed in that particular track, and communicate to the train with ECTS or other modern signalling systems

As an example, imagine that the maximum allowable temperature increase for a particular track is +35°C. In case climate conditions are not hot and do not contribute to temperature increase of rails, a train frequency of 10 trains per hour might be allowed at full service braking capacity (180kN) and almost 20 trains per hour might be allowed at 2/3 service braking capacity (105kN).

Nevertheless, if solar gain produced a temperature increase of +19°C, the frequency of trains permitted to use ECBs should be reduced to only four trains per hour at full service braking capacity and eight trains per hour at 2/3 service braking capacity.

A NEW GENERATION OF ECB

Multiple interferences between the ECB of rolling stock and the stationary infrastructure can be observed. For the design of the ECB, operational aspects also have to be taken into account.

In combination with the technological advances achieved in recent years, the possibility to develop products with enhanced functionality has been provided by this project, such as mass reduction, lower interferences with signalling devices, longer lifetime and higher availability.

Furthermore, the progress in standardisation opens the way to simpler interfaces, modularisation and lower efforts. Within the scope of this project, a concept of a new ECB has been developed derived from the results of the systematic collection of previous experience, the identification of performance requirements and the relationship between design and performance requirements. The design concept of the new ECB is featured by modularisation, lower weight and full metal protection.

The modularisation can be divided in principle into main functional parts:

- Self-sustained magnet,
- attraction force support beam,
- angled screw coupling.

The attraction force support beam transmits the attraction force to the bogie interface. The adaption to the wheel distance and the longitudinal position of the magnet can be adjusted without changes to the magnet body.

The angle screw coupling enables the adaption of the lateral distance to the bogie interface. Thereby, already in the stage of design of ECB frame the kind of bogie with inside or outside bearings can be taken into account.

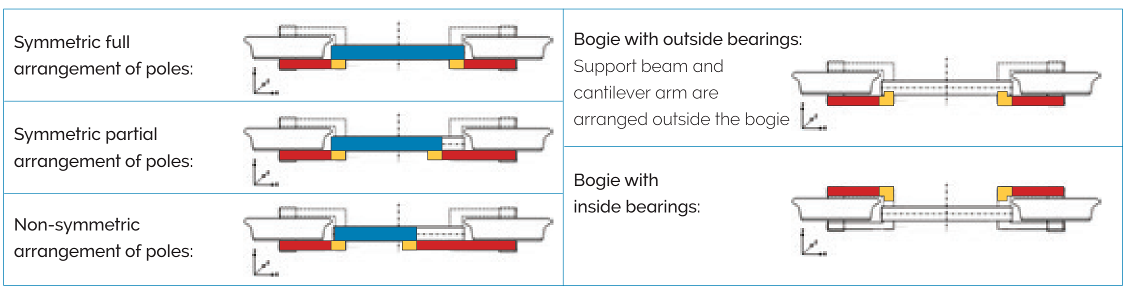


Figure 8: Examples of arrangement flexibility by modularisation.

The self-sustained magnet has two integrated functions. The first is the application as a beam to transmit the attraction and the brake forces. The second function is to hold and mechanically protect the magnetic parts which generate the magnetic field for braking application. Here, the possibility for modular design is also given. This self-sustained magnet can be equipped with electrically powered magnets similar to the existing ECB or with permanent magnets.

The advantages of the modularisation are a better integration of the power supply into the train, depending on the type of magnetisation (electrically powered or permanently magnetic), more flexibility for bogie integration and simplicity of manufacture.

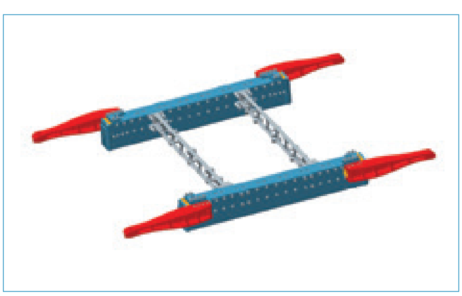


Figure 9: Model of a new ECB.

An additional advantage of modularisation is the reduction of mass by the use of specific materials adapted to their functionality. The specific ratio between brake performance and weight can be enhanced up to 25% compared with the existing ECB system.

A full metal cover protects the electric and magnetic parts of the magnet from excessive operational demands and shields high-frequency magnetic fields. Furthermore, solutions for the influence of electromagnetic field reflections and, thus, disturbances - induced by metal surfaces – on signalling devices has to be found. This is identified as the passive effect.

A multilayer compound of thin ferromagnetic sheets with a special 3D structure is most suitable for reducing the coupling interferences.
Another positive effect of the shielding of high-frequency magnetic fields is the simplification of the interface between power supply, signalling devices and ECB regarding the EMC. The high-frequency magnetic fields introduced by power supply are inside or introduced by signalling devices outside the metal cover and have not mutual interaction. Thereby the effort of approval is reduced.

PROJECT PARTNERS

ALSTOM

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