MÁV Central Rail and Track Inspection Ltd.

PATER TRACK DIAGNOSTIC EXPERT SYSTEM

Besides the quality information, the safe and economical maintenance of railway tracks plays an increasingly important role these days. For its preparation and planning, the „PATER" track diagnostic expert software is available.

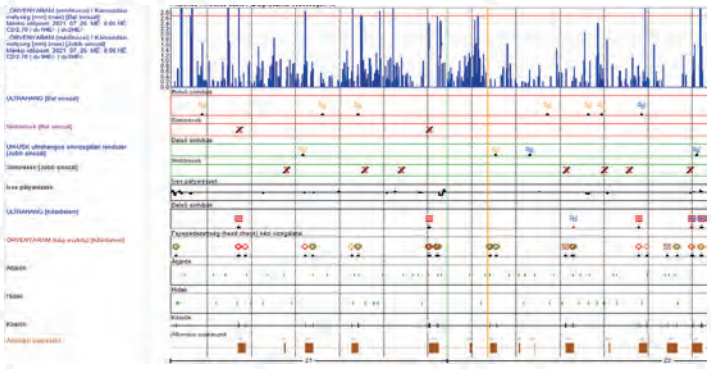
In order to achieve the above-mentioned goal, the PATER expert system ensures the registration of the railway track data and its diagnostic results, enabling the permanent condition-monitoring and maintenance planning. It gives support to the track maintenance professionals in managing and analysing the data of the technical and measurement systems, presenting the condition of the track, planning track maintenance jobs depending on track conditions, selecting the appropriate technology and performing cost estimates.

Expert system

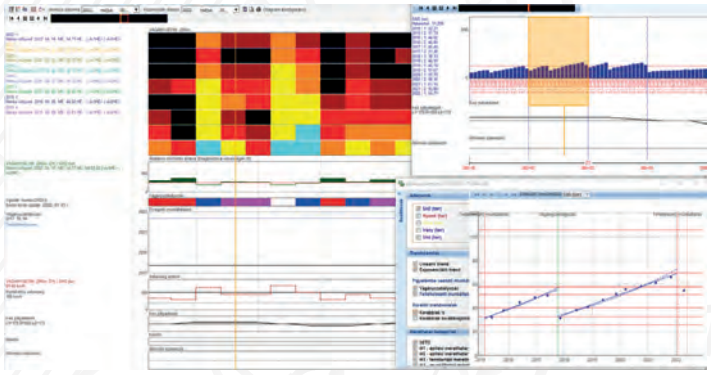
PATER is a client-server based program that ensures that data stored in the database can be accessed from anywhere and client users can use them through the internet in case of sufficient authorisation. This model has made it possible that all data is stored and updated in one location therefore the data available to users is always up-to-date.

In the engineering practice the values of the local defects and general quality indices are analysed and these values are sufficient to judge the traffic safety and quality. Nowadays we use track geometrical, ultrasonic, Head Checking, rail profile and rail corrugation measuring devices. The PATER program flexibly adapts to the requirements of any railway company: unlimited count of new measuring system, parameter, measuring limit etc. can be integrated.

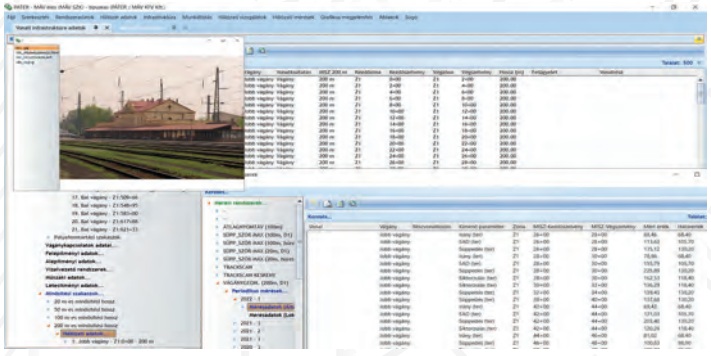
In case of all measuring systems real measurement data and their limit values are registered. Based on the built-in algorithms, the system recommends the location, time and the type of maintenance work to be performed. The program can prepare different sorts of reports, statistics and time-series based analyses from the registered technical and measurement data. The life of the rail flaws can be followed from discovery to reparation. The effects by changing the permitted speed can be simulated. The analysis and interpretation of data series and locations are supported by map view as well.



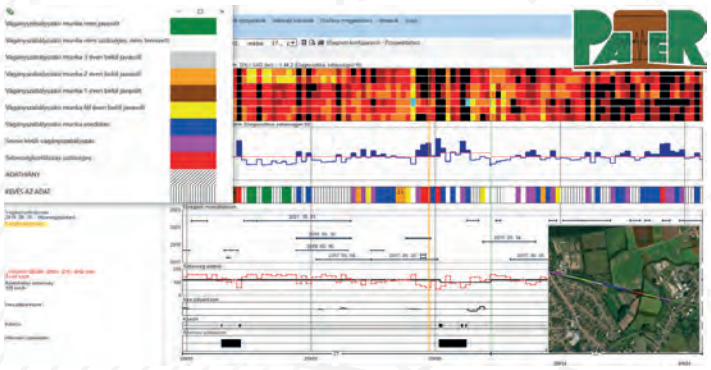
Rail defects revealed by various inspections and their qualification



Space and time based graphical analysis of track geometry data



Tabular data management and attachment visualization



Planning of maintenance works

TRACK DIAGNOSTICS

Track diagnostics

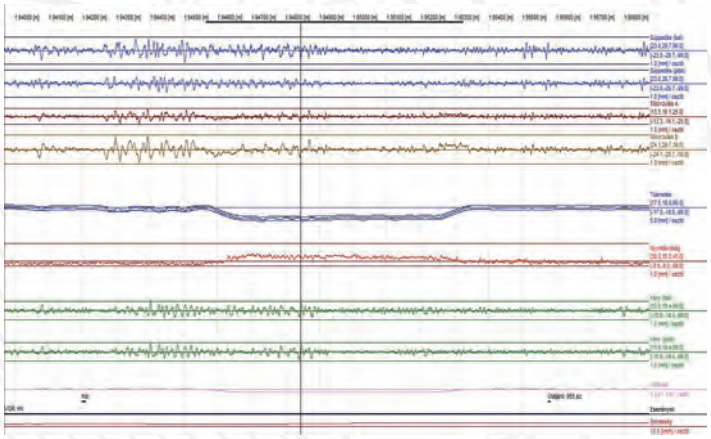
During periodic monitoring of railway track geometry condition, track maintenance specialists can make an accurate view about the current quality of the tracks. The track geometry measuring trains of our company are suitable for carrying out periodic track inspections of railway companies, as well as acceptance measurements of newly built tracks.

The track geometry measurement systems provide the parameters in accordance with the EN 13848 European standard family: track gauge, alignment and longitudinal level (conventional chord offset or distortion free data filtered to the D1, D2 wavelength ranges), cant, twist, curvature. Alongside with the measurement, the systems also provide a measurement graph, a local defect list, qualifying indices, as well as statistical list for assessing the general track condition. In the field of measurement results' analysis, professionals can choose from a variety of data processing methods, which provide assistance in the general assessment of quality of tracks, and thus the traffic safety for each longer track section. For this, a graphic and numerical evaluation is made for each track, and time series analyzes are also possible.

The FMK-007 measuring car perform vehicle dynamic measurements too. This measuring system is based on accelerometers placed on the car body, bogie frames and axle boxes of the measuring car. Among its services, derailment safety and track overload data calculated from measured wheel-rail forces, as well as values characterizing passenger comfort can be found.

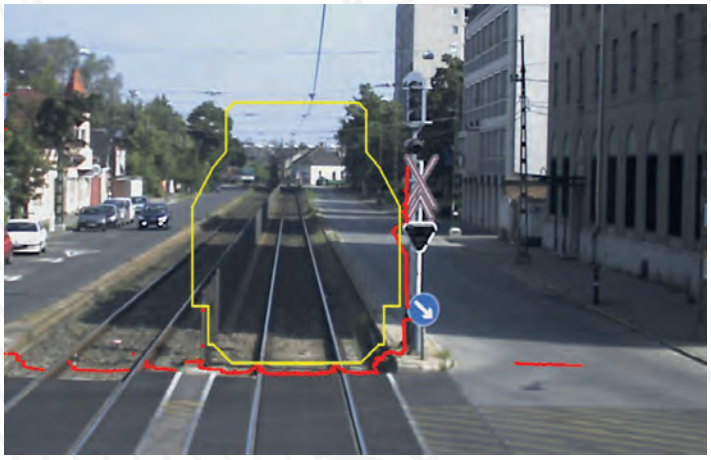
In addition to the track geometry measurement, the FMK-004 measuring train also performs clearance gauge measurement. The system is based on laser distance measurement, the identification of the laser point cloud is supported by video recording. The measurement data can be reviewed in an office evaluation software that gives a list of obstacles intersecting the chosen clearance gauge profile. Moreover, as a result of further processing of the laser point cloud, a data service is performed, which gives support for the registration of objects around the track that are relevant in the perspective of oversized shipment forwarding.

Track geometry measuring train (FMK-004)



Sample of track geometry measurement graph

Track geometry measuring car (FMK-007)



Evaluation of clearance gauge measurement

SUBSTRUCTURE DIAGNOSTICS

Substructure diagnostics

The GPR measuring system is suitable for inspection of thickness, homogeneity and relative humidity of railway sub-ballast and the structural layers below it, as well as for determination of ballast fouling index, mounted on a railway vehicle or by manual measurement.

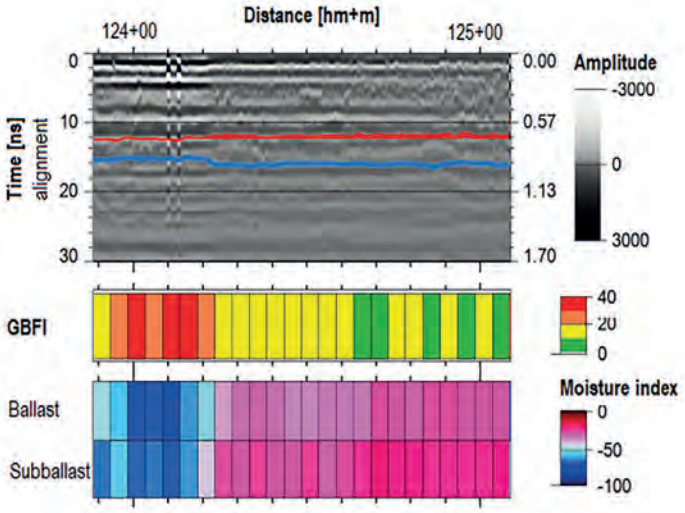
We apply 100, 400 and 1000 MHz radar-antennas in terms of inspected depth. The evaluation of the measuring results is supported by the data served by a laserscanner (LIDAR), an accelerometer and a video camera.

With the auxiliary units, even the close environment of the railway track is inspectable, thus the exact position of the different objects can be obtained by the interpretation of radargrams.

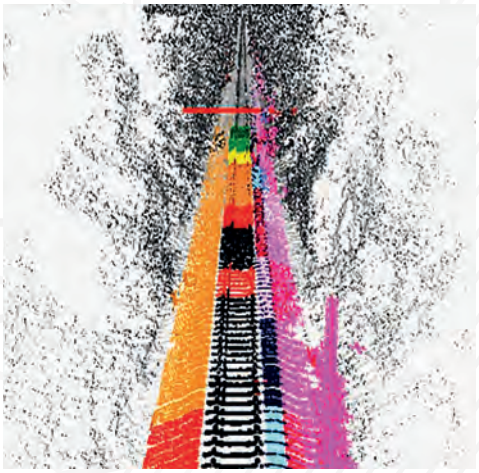
The measuring system can be easily and quickly installed on any railway vehicle, the optimal inspection speed is 80 km/h.

The evaluated data of GPR measuring system can easily be supplemented with the historical results of longitudinal level sliding average, which combined give a comprehensive view about the railway super- and substructure condition. Based on the delimitation of homogeneous and inhomogeneous parts established during the evaluation of the measurement results, the specific locations of more detailed geophysical and soil mechanical tests can be determined.

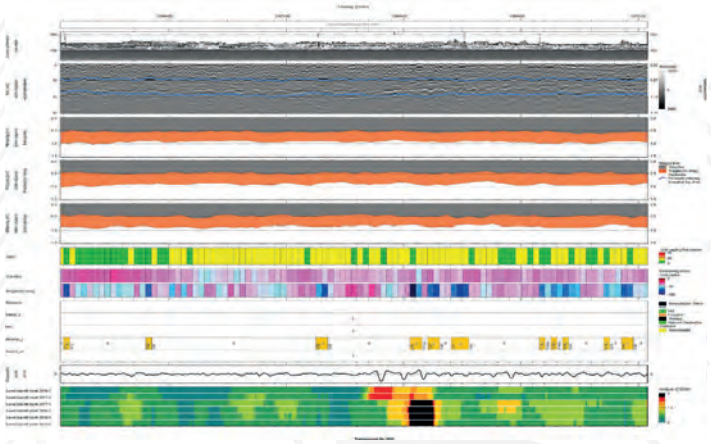
A GPR measuring system mounted on a measuring train



Interpreted layer-order, ballast fouling (GBFI) and humidity data



Point-cloud display



Radar-measurement results from top to bottom: laserscanner result, a radargram, real layer-order measured by the three radars with layer-borders and correct thickness-data, ballast fouling calculated on a 5 meter long basis (red-yellow-green), humidity of the ballast and bottom layer (pink and purple), position of structures, longitudinal level sliding average results of track geometry measurements.

BRIDGE- TUNNEL- AND OTHER STRUCTURE DIAGNOSTICS

Bridge-tunnel diagnostics

We provide our service under the guidance of our engineers (with expert license) and experts with several decades of experience in the inspection of bridges tunnels and other structures.

With the development of our tools, the inspections have become extendable to entire structures including their visible and hidden parts. During the detailed, full-scale target inspections covering all structural elements, in addition to manual tools, various modern, digital results providing diagnostic equipment help to discover and learn changes, as well as to measure the extent of defects and accurately record the condition-changes.

On site measurements

The basic task is the performance and evaluation of the measurements in an objective and consistent manner with our instrumental and data recording bridge diagnostics system, developed for on-site measurements.

The determination and service of basic data and measurement results for the bridge condition qualification system are performed using consistent measuring devices.

Furthermore, we carry out the load testing measurements of bridge superstructures under traffic considering effective loads, load intensity, speeds and dynamical effects.

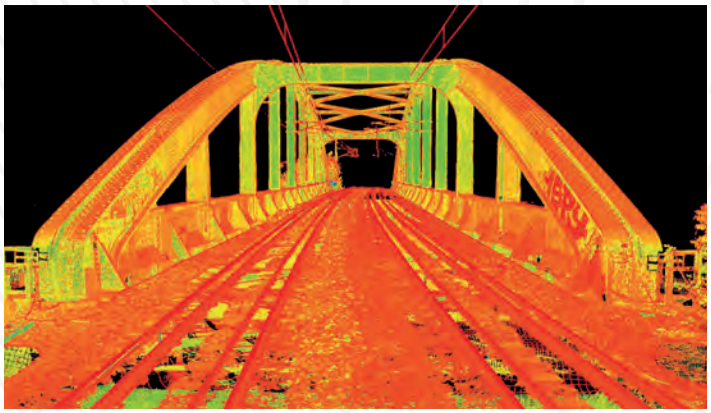
For bridge diagnostic inspections, we also have a system applied for complex geodetic surveying of structures, which is based on a modern, high-resolution 3D laser scanner. The system is used to inspect the condition of tunnels, vaults, substructure and geotechnical structures, check the conformity of their position and shape to the implementation plan, as well as to reveal surface defects and deficiencies, provide and evaluate basic data for movement tests.

Monitoring systems

The emergence and application of modern monitoring systems made it possible to continuously monitor changes in the condition of bridge structures.

We get a more detailed and more accurate view about deterioration processes, structure behaviours with the help of long term installed and maintained devices (monitoring systems), which can even be made capable of providing real time data service, analysis and alert, making the monitoring system much more reliable and supporting the maintenance of traffic safety as well as the timely introduction of necessary restrictions.

Inspection of Northern Danube rail bridge



3D laserscanner survey of Langer-beam arch bridge

Tunnel inspection of Great Hárs-hill

VEHICLE TESTING

The spectrum of vehicle testing activities ranges from type tests of newly built or refurbished railway vehicles to research & development tests with measurements which aim to detect the reasons and assist in the solution of problems which arose during the operation or maintenance of rail vehicles. The gains from vehicle tests range from unmonetizable life & property protection resulting from the direct prevention of the danger of derailments/accidents to significant cost savings achieved thanks to newly introduced maintenance/operation instructions based on the test results and their assessment.

Type (homologation) tests serve to confirm the conformance of the features of the vehicle relevant to traffic safety:

- Static (loading rig) and dynamic (buffing) strength tests serve to confirm that the vehicle will not suffer permanent deformation in case of the highest expected collective load (as specified in the relevant regulations).
- Quasi-static tests of safety against derailment involve the evaluation of the yaw moment of the bogies, the torsional stiffness of the vehicle body and underframe and the appropriate interaction of the couplers and buffers.
- For dynamic derailment tests, the wheel–rail contact forces have to be recorded continuously. The targeted evaluation of these signals is the basis for the assessment of the vehicle's safety against derailment, but it is also possible to determine the vertical loading of the railway track or the safety against the permanent lateral track displacement.
- The lateral running stability and ride comfort characteristics of a tested vehicle can also be mapped in the framework of on-track tests.
- The proper functionality of brake systems is a basic requirement of traffic safety:
  - Slip or train-braking tests with stopping distance and/or deceleration measurement serve to determine the braking performance of a rail vehicle.
  - Wheel slip protection (WSP) tests serve to confirm that the vehicle can stop safely and without any damage even under dismal ambient conditions.
  - An interesting sub-field of dynamic brake tests is the monitoring of the thermal load on the friction parts of the brake system.
- In traction and energetics tests, beyond the experimental determination of the rolling resistance and the rotating mass coefficient, one can also derive the characteristic curves and efficiency factor surfaces of traction vehicles, the power coefficient and the consumed and regenerated electric energy for electric traction vehicles, and the specific fuel consumption for diesel vehicles.
- External standby, starting and pass-by, as well as internal standby and running noise tests serve to determine the operational noise emission level of railway vehicles, the keeping of which under a stipulated level is a sub-task

Vehicle testing

Static strength test of a carbody

Yaw moment test of the bogie of a wagon

Safety against derailment test of a rail transport wagon consist

Slip test of an IC coach

of environmental protection with ever increasing emphasis.

With the exception of dynamic strength tests, for the above activities, MÁV KFV Kft. acquired accreditation status according to EN ISO/IEC 17025 in 2022.

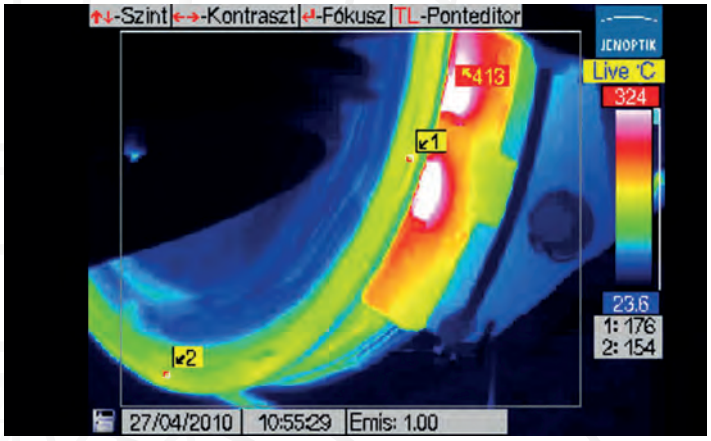
Two examples of our diverse research & development tests with measurements:

- A narrow-gauge diesel locomotive type showed large-amplitude roll vibrations and multiple derailments on certain track sections in service. With the help of a vertical running dynamics test and a computer simulation based on its results, we identified the barely damped vibration modes responsible for the derailments via wheel unloading, as well as the track geometric & operational profile parameters responsible for the excitation of these modes, then we determined the relevant parameters of the vertical dampers to be added to the primary suspension. The mounting of the dampers resulted in a radical improvement of the safety against derailment, as attested by a control test we also conducted.
- In the case of a low-floor EMU type with wheels much smaller than normal heavy rail vehicles, a traffic safety concern arose regarding safety against derailment when traversing the unguided section in the crossing part of a double slip switch. We conducted simultaneous measurements of the angles of attack and the lateral axle box forces, the results of which showed that these EMUs can run safely across the crossing centres.

Equivalent conicity

EQUIVALENT CONICITY is a quantity characterising the kinematic relationship of a given railway wheelset and a given pair of rails. Its value is an indication of the possibility of the emergence of unstable lateral running (the situation when a wheelset resp. rail vehicle is locked into a non-decaying, large-energy hunting motion). Among other factors in the track–vehicle system, the magnitude of the upper speed limit of stable lateral running, the so-called critical speed, is influenced by the geometric conditions of the contact surfaces of the wheels and rails, which can be characterised from this viewpoint with the equivalent conicity. In this field, MÁV CRTI Ltd. can conduct the following tasks:

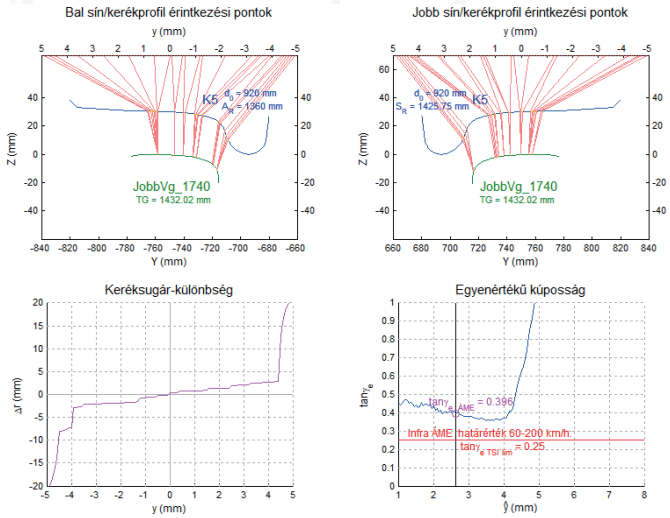
- assessment of given track sections from the viewpoint of equivalent conicity (for this, for the calculation, we pair profile measurement results for worn rails with standard wheelsets);
- assessment of a given vehicle from the viewpoint of equivalent conicity (for this, for the calculation, we pair profile measurement results for worn wheels with standard rail pairs);
- assessment of a given track–vehicle system from the viewpoint of equivalent conicity (for this, for the calculation, we pair rail profile measurement results with wheel profile measurement results).



Thermal distribution during a dynamic brake test

Unguided distance test

Measurement of wheel profile & diameter



Calculation of equivalent conicity

INSPECTIONS DONE BY MEASURING TRAINS

Besides the checking of track geometry, the other determinant area of railway diagnostics is the regular inspection of the rails, which are the primary bearing elements of the superstructure. This guarantees the keeping of the transport safety on a high-level, and ensures the necessary data for the track maintenance and for the planning of the economical rail attending work. The constant rising of the loads on the railway track is the consequence of the more and more modern, high performance - traction vehicles capable of high speed, the increasing train traffic, the developments of the railway system. This tendency emphasizes the importance of rail diagnostic inspections.

The diagnostic services on the railway infrastructure core network are performed by two measuring trains (FMK-008 and SDS) of the MÁV Central Rail and Track Inspection Ltd. Both of the measuring trains are equipped with ultrasonic, eddy-current, rail corrugation and rail profile measuring systems. The measuring systems are controlled from a central computer interface that can supply all sub-systems with measuring instructions and synchronized position identification data. Every detected rail flaw is linked with GNSS data that is provided by a high-accuracy GNSS based positioning system.

Rail diagnostics

Ultrasonic inspection

The detection of the inner material discontinuity of rails is done by the ultrasonic measuring system, which works with 12 ultrasonic inspecting channels per rail and special probe arrangement making it possible to radiate almost all of the cross-section of the rail. The measuring bogie and the measuring beam that is led through between its axles assure the precise positioning of the measuring probes and safe passage over the turnouts. The ultrasonic evaluation from “A” and “B” scans is supported with good quality video images. The qualification of the rail flaws are based on the EN 17397-1:2020 standard. The measuring system meets the requirements of the EN 16729-1:2016, the maximum inspection speed is 70 km/h.

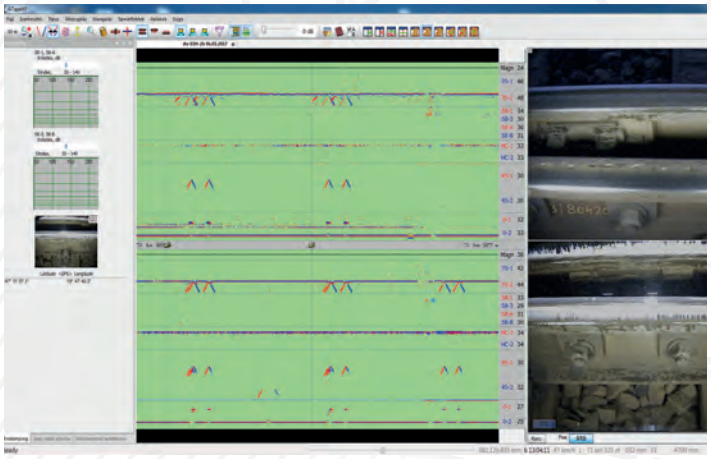
Eddy-current inspection

The detection of the head-check defects resulting from the rising of the rolling contact fatigue on the railway network is provided by the eddy-current technology. The measuring system contains four probes per rail inspecting those lanes of the running surface which are the most exposed to rail head cracking. The measuring system provides the maximal defect depth of the running surface cracks per meter in the interval of 0,1 to 3,0 mm,

Rail diagnostic train (FMK-008)

Measuring room

Measuring bogie with ultrasonic inspection heads



Ultrasonic register (“B” scan) with video images of the rails

Rail diagnostics

using a previously determined evaluation angle. The inspection records contain the number of cracks per meter as an informative value. The measuring system meets the requirements of the EN 16729-2:2018, the maximum inspection speed is 70 km/h.

Rail corrugation measuring

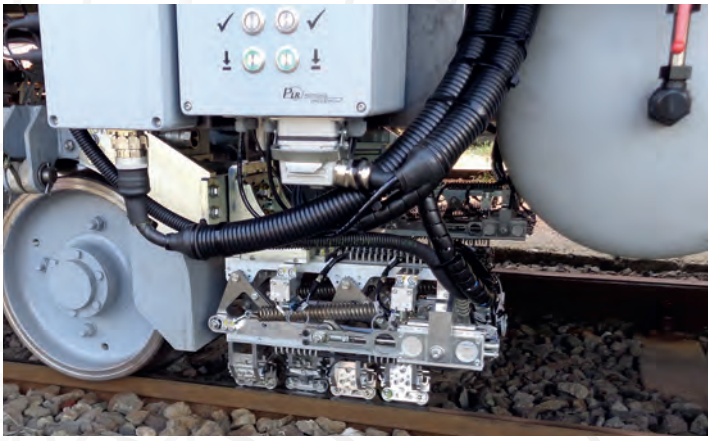
Besides the vertical and lateral wear of the rail, most commonly on the inner rail of curves with small radius can the rail corrugation of the running surface be detected.

The measuring systems of the rail diagnostic trains are able to measure the extent of the rail corrugation, which means the detection of the amplitude (A) and the wave length (W) on the scale of 30 to 300 mm (short wavelength rail corrugation). During the measuring, high resolution inductive sensors are used to record the distance between the base plane and the running surface. The measuring range of each of the sensors is 5 mm. In this range the resolution of the measuring heads is smaller than 1µm, which makes it possible to measure on high-speed railway lines.

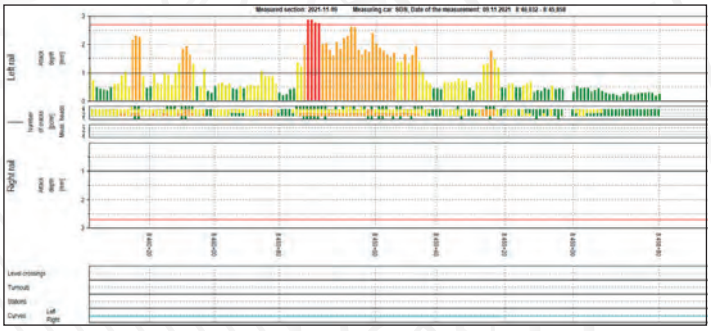
There are two ways for the qualification of the measured values; one of these is based on the peak-to-peak principle according to the MÁV D.54. directive and the other one is calculating the RMS value based on the EN 13231-3 standard.

Rail profile measuring

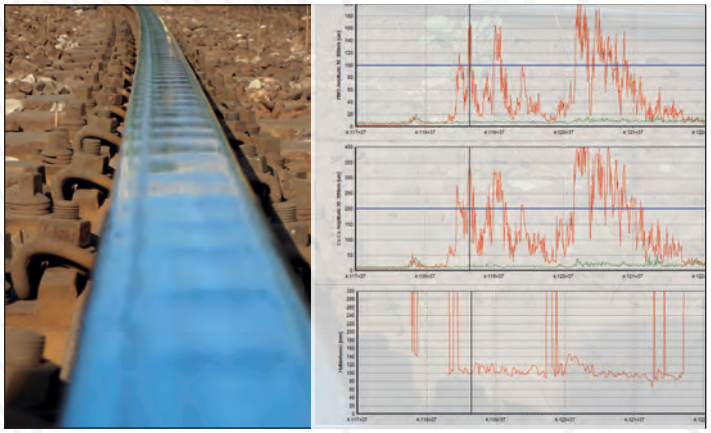
The checking of the shapes and wearing of the rails, the tracking of the wearing process and the filtering out of the values over the limit are important parts of the rail diagnostic measurement. This is the role of the rail profile measuring. The measuring system is equipped with 2-2 laser units and camera groups per rail. The picture of the laser beams that are projected to the rails is detected and fit on the standard rail type by an optical camera group and on this basis the wear parameters can be calculated. Accordingly, this principle provides contactless measuring with the maximum inspection speed of 120 km/h. The most important rail wearing parameters during the rail profile measuring process: vertical wear, lateral wear and the equalized vertical wear that is calculated based on these two values. Besides the ones that are mentioned above, other rail wearing characteristics can be listed too, such as outer lateral wear, rail inclination, railhead width, railhead height. Connected to the rail profile measuring, based on the wheel profile parameters, the equivalent conicity parameter can also be calculated according to the EN 15302:2008 standard.



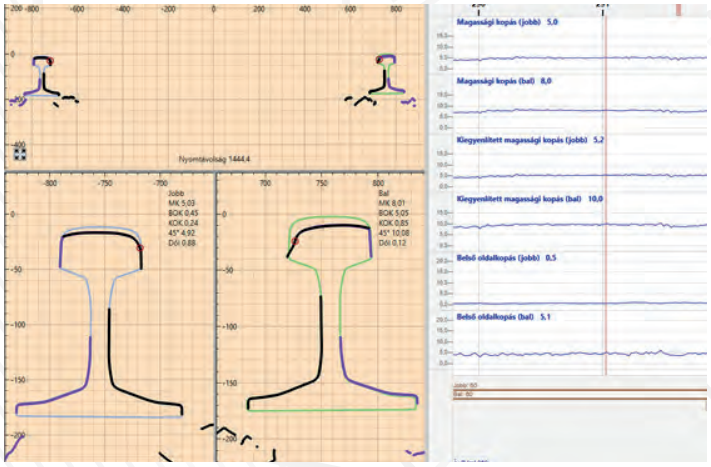
Eddy-current measuring probes



Eddy-current graph with Head Check defects



Visualization of the rail corrugation with measuring graph



Worn transversal rail profile and graph of wear parameters

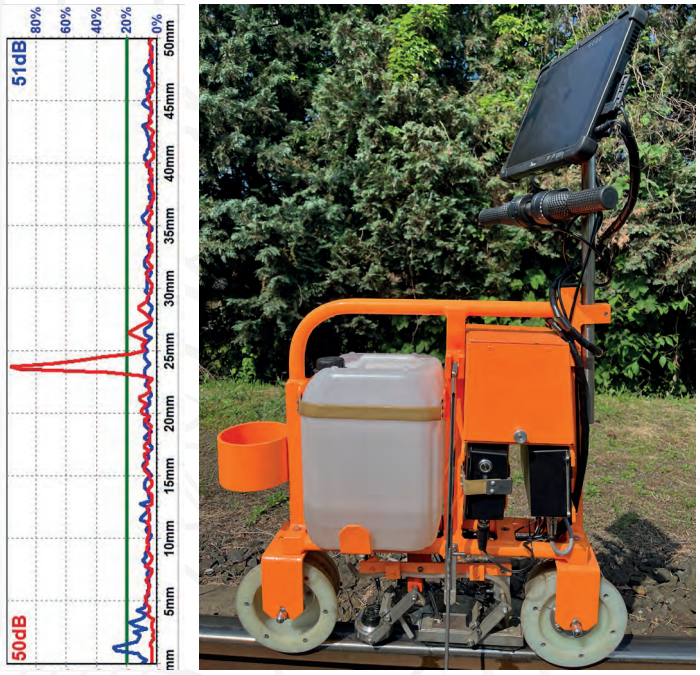
INSPECTIONS DONE BY MANUAL MEASURING DEVICES

Rail diagnostics

Besides the inspections, that are done in great volume by the measuring trains, the services by manual measuring devices are also widely present in the activity of MÁV CRTI Ltd. The scope of the inspections with manual measuring devices are typically secondary railway lines and stations-tracks, turnouts, metro and local railway lines, which are not inspected by the measuring trains. Furthermore, these manual inspections have a significant role in the secondary inspection of the flaws detected by the measuring trains. Thus, the measuring systems that are operated on the trains have an alternative with the manual measuring devices in the cases of ultrasonic, eddy-current, rail corrugation and rail profile inspections.

Ultrasonic inspection

The ultrasonic trolley can handle 5 channels at the same time, which allows it to scan the rail cross section with more ultrasonic probes in one pass. In case of the ultrasonic trolley, the indications can be analysed on „A" and „B" scans just like on the measuring trains. Furthermore there is the opportunity to record and save the registered ultrasonic data, the defect list handling and the protocol generation in the given inspection is done on the same interface. The results can be replayed and analysed in the office. The qualification of the rail flaws is done according to the EN 17397-1:2020 standard. The ultrasonic trolley meets the requirements of the EN 16729-1:2016 standard.



Ultrasonic trolley

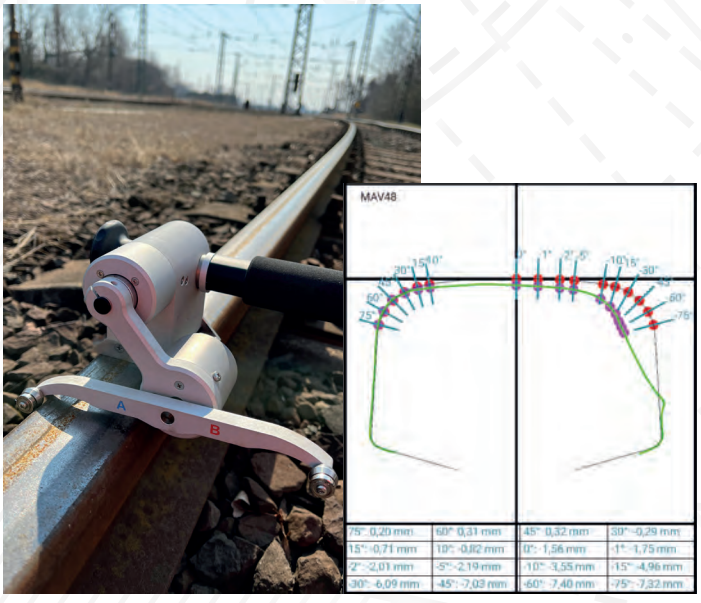
Eddy-current inspection

The number, position and shaping of the inspection probes of the eddy-current manual measuring device is the same as on the measuring trains, which means that the inspection of the Head Check flaws is done by 4 – 4 probes on both rails. The provided results are also the same as the results which are presented in the chapter about the eddy-current measuring system installed on the train. The ultrasonic trolley meets the requirements of the EN 16729-2:2018 standard.

Eddy current manual measuring device

Rail corrugation and rail profile measurement

In case of the inspection of shorter railway sections, our company carries out the rail corrugation measurement in the wavelength interval of 30 – 300 mm. The rail profile manual measuring device enables the measurement of selected cross-sections by mechanical roller scan, calculates the main wear parameters and visualizes the worn rail profile.



Rail profile manual measuring device

GNSS BASED POSITIONING SYSTEM

Positioning system

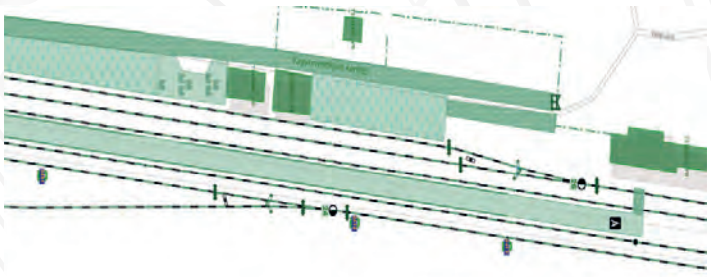
In addition to the development of measuring systems, the positioning of discovered defects and defect locations is a serious challenge. Thanks to the precise satellite positioning, our company can determine the railway sectioning within an accuracy of up to 1 meter at a measuring speed in real time. For this, it is essential that a so-called GNSS-chainage database is available for each railway line and track.

The new, satellite-aided solution is based on the traditional, encoder-dependent positioning method. In order to apply the new method, the construction of a meter-resolution virtual reference point network had to be created, which assigns the geographical (GNSS) coordinates to the positioning system defined by railway chainage markers.

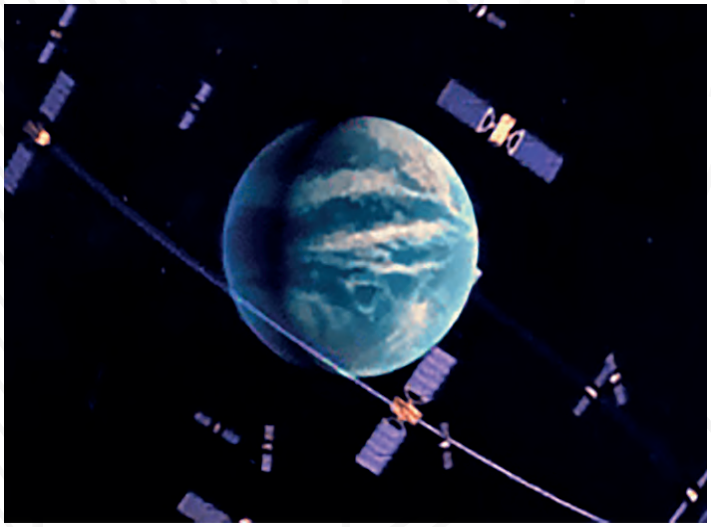
This database relies on the GNSS coordinate points of the theoretical track axis sections projected onto the track, based on the position of the surveyed hectometre marker stones. Based on this data, the positioning system determines the railway chainage value valid at the given time, and is able to automatically correct the encoder-based value in real time and regularly.

In order to ensure accurate base signals during the movement of the measuring train, the DGNSS correction applied in the GNSS receiver filters, based on the reference stations on the ground, the errors arising from atmospheric distortion of the signals coming from the satellite, as well as the errors in the satellites' orbits. Singularity-sensible locations mean an additional challenge. These are such places, where the moving vehicle is hidden from the satellites (such as tunnels, bridges over the tracks, or in a station hall). At these locations the system must not automatically correct the chainage value, because it would assign invalid data to the measuring results, which is why we set these locations under correction-ban. Of course, the measurement-managing operator will have the possibility in any cases to manually intervene and correct the automatically calculated chainage value.

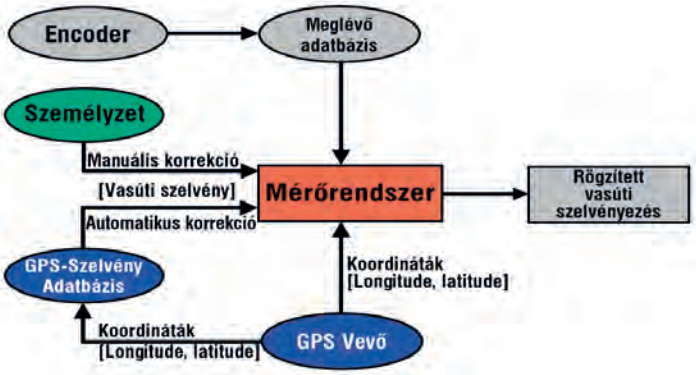
Antennas to receive DGNSS/RTK correction



Geoinformatic background-database with hectometre stones



Satellite positioning



Positioning system schema

MÁV Central Rail and Track Inspection Ltd.

H-1097 BUDAPEST, PÉCELI U. 2., POSTAL ADDRESS: H-1476 BUDAPEST PF. 136.
PHONE: (+36-1) 347-4010
E-mail: mavkfv@mavkfv.hu; Web: www.mavkfv.hu

e.com CERT
Certified by ISO 9001

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