The highly accurate measurement of oscillations and vibrations on vehicles and infrastructure is the basic requirement for safe, comfortable rail transport. Sensors play a central role in the development, construction and operation of trains and in systems for monitoring tracks, switches and bridges.

Also, the optimization of line capacities and the increasing volume of traffic in rail operations of the future require measures to react more quickly in the event of train disruptions. The evaluation of oscillations and vibrations is not only used to record the actual condition of the vehicles: Intelligent sensor solutions also enable the early detection of future material weaknesses. Corrective measures can be initiated before cost-intensive damage occurs. This information can be transmitted in real time and is always available in the digital twin. The basis for this are powerful sensor solutions and self-learning, intelligent algorithms for post-processing the measurement data obtained.

The challenge

Rail vehicles, especially the bogie, axles, brakes and wheel bearings, are subject to extreme loads and are designed and tested in accordance with the EN 13749 standard. To test the operational strength of vehicle components, the trains travel thousands of kilometers under harsh conditions which impacts up to 400 g, this is not uncommon when testing wheelsets and bogies. Since the high mechanical forces also act on the sensors, they must be extremely robust, long-term stable and reliable.

The previous sensor requirement in rail traffic was shaped by the equipment of test trains. For example, track position data is recorded and geometric errors in the track superstructure are determined. This route monitoring enables maintenance measures to be better planned and carried out in good time. Among other things, test & measurement sensors are used here to precisely measure vertical accelerations. However, the implementation of regular test drives and subsequent evaluation of the results has a decisive disadvantage: It always only shows the condition of the routes or the vehicles themselves with a corresponding delay. Continuous investigations of the operational stability in regular operation can identify possible weak points on trains at an early stage and make a decisive contribution to the safety and reliability of rail vehicles.

The use of digital technologies in the entire rail sector will significantly increase the capacity, effectiveness and quality of the rail network. In addition to real-time transmission and decentralized availability of the results, sensors form the basis for tracking the exact status of the fleet and infrastructure at any time. Furthermore, these are no longer used exclusively in test trains, but are an integral part of high-speed trains, regional trains, trams, as well as underground or suburban railways and are therefore subject to the requirements of the DIN EN 50155 / IEC 60751. This means that the need for cost-effective, mass-market and thus industrial sensors is increasing.

Partnership

The construction and development of an industrial piezoelectric IEPE acceleration sensor with railway approval unites two leading sensor manufacturers from Test & Measurement, and industrial environment in a project.

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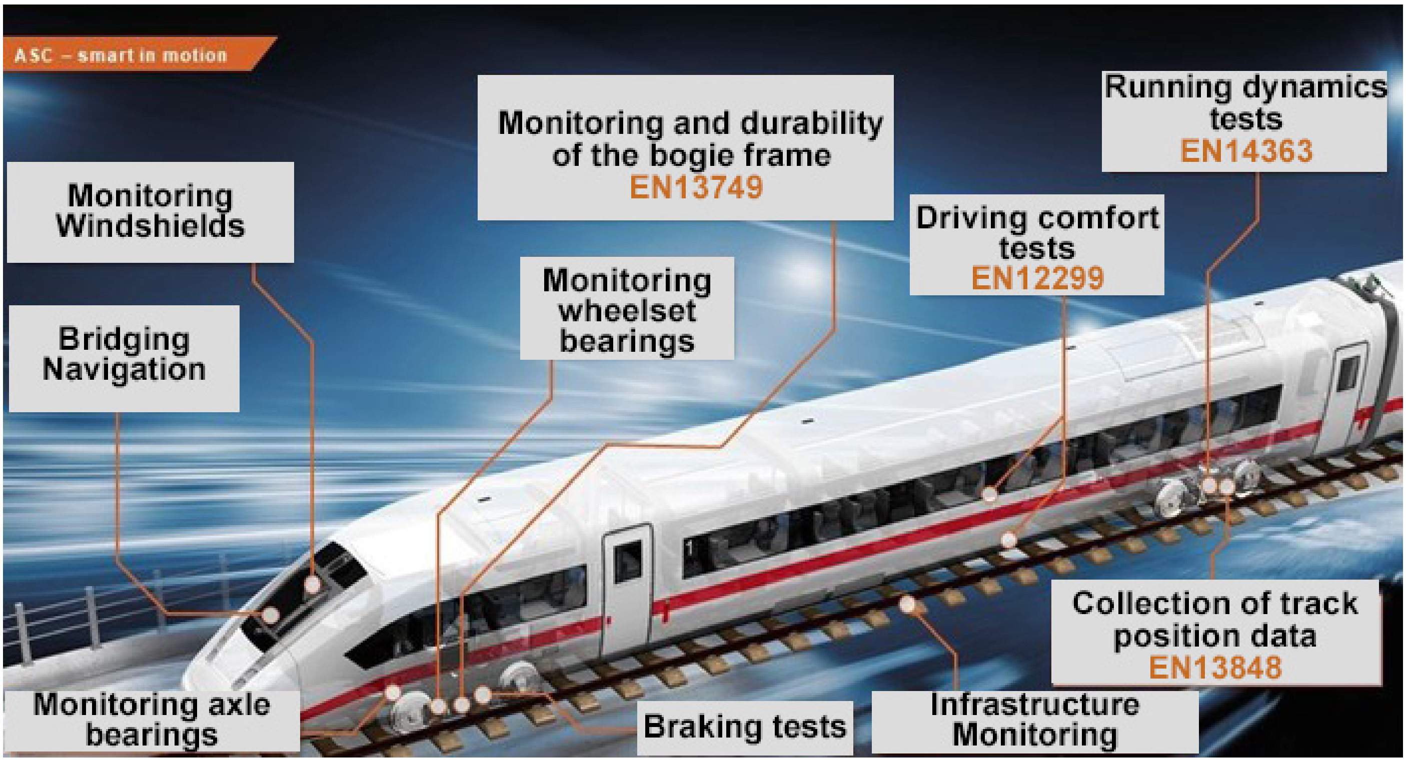


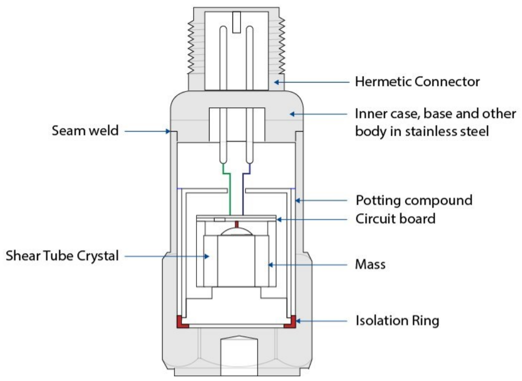
The challenge: The development of an industrial acceleration sensor with railway approval for the measurement of oscillations and vibrations on the bogie.

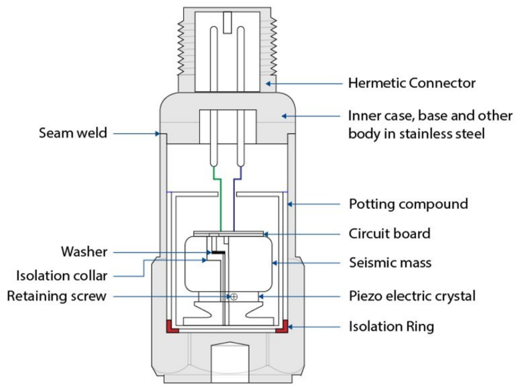
For demanding measurements in railway applications, ASC GmbH from Pfaffenhofen an der Ilm is one of the world's leading manufacturers of MEMS-based inertial sensors for demanding test and measurement applications, while Hansford Sensors, based in London, is an expert in design, development and manufacture industrial vibration sensors.

For ASC GmbH, Hansford Sensors offers a partnership and flexibility in the design of the sensor technology, so that a direct design of the sensor properties with regard to the rail approval is possible. While Hansford Sensors tailors the OEM technology of the measuring cell precisely to the needs of ASC, ASC can concentrate on the design, implementation and certification of the overall system.

Technology

Nowadays, acceleration sensors with a piezoelectric operating principle are mainly constructed using the so-called shear principle. While the shear principle is preferable to the compression principle in many applications, the structure with compressing seismic mass shows its advantages in rail applications. Compression sensors are particularly suitable for continuous exposure to high-amplitude impacts. While shear sensors show their advantages with base strain effects, the "sandwich construction" of the compression technology is mechanically more robust and less sensitive to micro-cracks in the crystal-mass system.





The starting point for the developments were the piezo-electric acceleration sensors ASC P311A15 (side connector) and ASC P311A25 (top connector), which are already based on compression technology from Hansford Sensors. The cooperation gives ASC the opportunity to incorporate its many years of experience into the adaptation of the sensor characteristics and to ideally adapt the standard sensors from Hansford Sensors to fatigue tests in rail traffic.

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Conditions

Not only the dead weight of the rail vehicles, but also all forces acting on the bearings or wheels are absorbed by the bogie. Since trains are track-guided vehicles, material wear occurs in the form of defects on the rails or flat spots on the wheel tires. The wheel sets on bogies are also subject to enormous loads, especially when cornering at high speed. As a result, bearing friction occurs, which in turn can lead to increased wear. Between the track width of the rails and the track dimension of the axles, accelerations also occur due to sinusoidal pendulum movements. If these accelerations exceed critical values this can in the worst case lead to a train derailment.

By reliably determining the vibration behavior on the bogie, however, damage developments can be identified in good time, preventive maintenance measures can be taken and unexpected malfunctions can be avoided. Continuous monitoring of the bogie is therefore a significant added value for ongoing operations.

Construction and railway approval

The aim of ASC GmbH was the construction, certification and market-driven introduction of a mass-market, cost-effective IEPE acceleration sensor for use in traffic trains.

The "heart" of the acceleration sensor with rail approval is an OEM sensor capsule that is already used in industrial IEPE sensors. This technology offers an excellent basis, a wide frequency range from 0.5Hz to 17kHz (±10%), availability in different measuring ranges from ±16 g to ±800 g and a very high shock resistance of up to 5,000g .

Reliability and service life are essential for use in rail transport. With a calculated MTTF number (Mean Time To Failure) of 250,000 hours, which corresponds to approx. 28.5 years, the OEM technology meets the requirements for the design, which aims to check the functionality of the sensors 24 hours a day and provides for a period of 20 years.

The "body" of the acceleration sensor is an application-specific development with regard to the operating conditions in rail vehicles. The developed sensor housings are hermetically sealed and are made of extremely robust stainless steel. They meet the tough requirements of the vibration and shock test criteria and, thanks to the IP68 protection class, also withstand the harsh environmental conditions in terms of dirt, moisture, stone chips and temperature.

Further essential content for testing the equipment installed on rail vehicles is the technical design features. These are defined and fixed as part of the development. After successfully testing all criteria according to EN 50155, no more changes may be made to the components. The direct cooperation between the sensor manufacturers ASC and Hansford Sensors thus focused early on coordinating design measures and processes for integrating the OEM sensor capsules into the railway-specific housing.

The need to develop a housing arises from the fact that conventional IEPE sensors can usually only be fixed to the measurement object by means of 1-point screwing or gluing, which means that there is no redundancy. Furthermore, the use of railway-specific, permanently integrated cables is essential. These include fire-resistant, halogen-free, flame-retardant as well as temperature, UV and ozone-resistant.

Additional mechanical interfaces are to be avoided, especially with high-frequency vibration analyzes, since otherwise all material interfaces can lead to changes in the frequency response or represent an additional source of errors during adaptation. Therefore, the design of the housing also offers the possibility of integration to select the sensitive direction of the acceleration measurement, so that depending on the application, additional brackets or mounting adapters are not required.

Outlook

The market launch of the mass-market, cost-effective IEPE acceleration sensor for rail applications was planned for the first half of 2021. Know-how was based on the developments, which will also be incorporated into further projects. This applies to the implementation of additional functions, such as electrical interfaces or alternative supply voltages, as well as the completely new development of sensor solutions. With the jointly developed, rail-approved IEPE acceleration sensor, we are entering into an exchange with rail vehicle manufacturers and taking impulses as a guide for the continuous optimization of our portfolio in the rail sector.

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