Bogie condition monitoring

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Bogie condition monitoring

Bogie condition monitoring offers new opportunities to increase reliability and safety, and to achieve lower maintenance costs. Using condition detection systems and applying sophisticated algorithms for data processing can detect incipient damage and allow sufficient time for repairs before significant mechanical failures occur.

LCC reduction

The railway industry is constantly looking for methods and technologies to significantly reduce life cycle cost (LCC) and total cost of ownership (TCO). For more than 150 years, even before the economic terms LCC and TCO were invented, fragmented reporting systems were used for railway vehicle’s cost tracking. Purchasing cost, coal consumption for steam locomotives, workshop man-hours per operating mileage, and spare part costs were some of the main indicators for efficient railway operation, although reporting was rarely consolidated.

From the early beginnings of railway technology, there was always a strong focus on reliability and safety, and traditional on-the-spot repair was quickly replaced by maintenance schedules based on mileage and/or time. This resulted sometimes in maintenance intervals being too short, with the consequence of lost revenue opportunity from unused remaining operational time including still available mileage on rolling stock.

In other cases, reduced maintenance intervals were required, typically for railway vehicles operated on specific challenging lines, like in the alpine regions, or on very poorly maintained tracks, under extreme weather conditions, or when derailments went unreported during shunting operations.
Lessons from wind energy

Today, there is a continuously increasing demand for reliability and safety as well as for reduction in maintenance costs. Condition monitoring is a mature technology and the railway industry has benefited from such advances. In other industries, like wind energy for example, maintenance schedules have been based for years on condition monitoring results. Wind farm operators take a proactive approach to maintenance, thereby reducing operating costs.

The SKF WindCon online condition monitoring system collects and analyses a wide range of data, compiles them, and provides a reliable performance overview. This helps to identify incipient damage and predict failures before they occur, to plan maintenance activities more effectively and to extend the time between costly tower climbs.

Data is presented using an Internet browser and the information is up-to-the-minute. The web-based version takes advantage of WebCon – SKF’s data warehousing and web hosting services. This tool helps to shorten lead-time from alarm to solution, since authorized personnel can undertake monitoring from any location with a computer or hand-held device with Internet access. The simplified maintenance and increased reliability that SKF WindCon provides can be enhanced with a SKF Windlub centralized automatic lubrication system for wind turbines.

A team of SKF engineers is dedicated exclusively to wind turbine condition monitoring issues and the management of installed systems. SKF WindCon is approved by Allianz and certified by Germanischer Lloyd. The main drivers for implementing condition monitoring into the wind power industry are the requirements of leading insurance companies.
Bogie monitoring

While there are similarities between the basic reliability and maintenance requirements of wind turbines and railway vehicles, there are also some significant differences. Wind turbines are stationary while railway vehicles are mobile, operating over vast areas and sometimes covering several countries. This means not only different geographical locations but also different technical requirements. Even the very basic technical regulatory standards can be very different. The average life expectancy time of railway rolling stock can be much longer than a wind turbine, which makes the threshold for entry of new technology into the railway industry higher and more difficult, and takes a longer time, particularly if one wants significant benefits in reliability and safety, and reduction in cost of operation.

The design, construction or assembly, maintenance and monitoring of safety-critical components, and more particularly of the components involved in train movements must be such as to provide safety at a level corresponding to the aims of the network, including those for specific degraded situations. The parameters involved in the wheel/rail contact must meet the stability requirements needed to provide safe movement at the maximum authorized speed.

The monitoring and maintenance of fixed or movable components that are involved in train movements must be such as to maintain their operation under the intended conditions.

Condition monitoring benefits

- reduced maintenance cost for the operator:
  - operational cost reduction because of damage detection in a very early stage which enables an optimized schedule of maintenance
  - reduction of vehicle standstills
  - reduced need for maintenance
  - reduction of maintenance overtime work
- increased vehicle reliability
- optimization of spare part logistics
Capabilities
SKF Multilog on-board axlebox condition monitoring system IMx-R may be part of the train’s bogie condition monitoring system or may work as a stand-alone system. This system also fulfils the requirements of the European Technical Specification for Interoperability (TSI) Directive 96/48 EC. This standard stipulates that the equipment shall be able to detect a deterioration of the condition of an axlebox bearing, either by monitoring the temperature, and/or its dynamic frequencies. The maintenance requirement shall be generated by the system and the system shall indicate the need for operational restrictions when necessary, depending on the extent of the bearing damage. The detection system operates fully independently on-board the train and the diagnosis messages are communicated to the driver. This system complies with EN 15437-2.

TSI requirements
Bogie condition monitoring includes sensors for the detection of running instability according to the requirements of the European Technical Specification for Interoperability (TSI) Directive 96/48 EC. The ERA Technical Specifications for Interoperability (TSI) are specifications created by the European Railway Agency to ensure the interoperability of the trans-European rail system. The interoperability issues apply to the lines within the Trans-European Rail network. This TSI stipulates that the monitoring of the running stability shall be continuous, or at a frequency to provide reliable and early detection of damage for high-speed rail applications. This TSI also defines different classes of rolling stock:

- Class 1: Rolling stock having a maximum speed equal to or greater than 250 km/h.
- Class 2: Rolling stock having a maximum speed of at least 190 km/h, but less than 250 km/h.
- Rolling stock having a maximum speed higher than 351 km/h. This TSI applies, but additional specifications are necessary, which have not been developed so far. These additional specifications are considered by TSI as open and therefore covered by national rules.

### Bogie condition monitoring capabilities

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Detection parameters</th>
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</thead>
<tbody>
<tr>
<td>Wheel Axlebox bearing</td>
<td>Out-of-roundness, Temperature, Relative temperature in comparison with other axlebox bearings, Vibration levels</td>
</tr>
<tr>
<td>Gearbox</td>
<td>Bearing temperature, bearing vibration levels, unbalance, alignment, shaft bending, loose part, bearing damage, damaged gear wheel and resonances</td>
</tr>
<tr>
<td>Gearbox oil</td>
<td>Oil temperature, oil level, oil condition</td>
</tr>
<tr>
<td>Traction motor</td>
<td>Bearing temperature, bearing vibration levels</td>
</tr>
</tbody>
</table>
The assessed rolling stock is a group of vehicles that are indivisible in service or single vehicles that are within defined formations of powered and non-powered vehicles. It includes both passenger and/or non-passenger carrying vehicles. For Class 1 trains, the system shall also be linked to the on-board diagnosis data recorder to enable traceability.

Access to lines is not solely dependent on fulfilment of the technical requirements of this TSI. Other requirements in Directive 2004/49 and Directive 2001/14 shall also be taken into account in permitting a railway to operate this rolling stock on a specific line [33].

### Wheelset monitoring

Wheelset condition monitoring is implemented by a vibration sensor mounted on the axlebox housing or integrated into the axlebox bearing. This provides information that can be used to determine the condition of the wheelset such as wheel flats and wheel shape. The real time calculation is also utilizing information about the shaft speed. Wheel maintenance is very costly and time consuming. With bogie condition based maintenance, the timing of these operations can be scheduled by optimizing the operating mileage of wheelsets without any compromise to reliability and safety.

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**Table: TSI requirements**

<table>
<thead>
<tr>
<th>Monitoring</th>
<th>Detection parameters</th>
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<tbody>
<tr>
<td>Hotbox detection</td>
<td>Axlebox temperature measurement on each axlebox</td>
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<tr>
<td>Bogie hunting detection</td>
<td>Acceleration measurement in accordance with UIC 515-1</td>
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</tbody>
</table>

**Table: TSI function enhancement**

<table>
<thead>
<tr>
<th>Monitoring</th>
<th>Detection parameters</th>
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<tr>
<td>Derailment detection</td>
<td>Acceleration measurement on each axlebox</td>
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<tr>
<td></td>
<td>Algorithm to be defined</td>
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</table>
Axlebox bearing monitoring

Axlebox bearings have been monitored for decades in the railway industry, by means of stationary trackside mounted temperature and noise detection systems. This equipment is typically installed at certain intervals along the track or at strategic locations, such as ramps in the case of alpine railway lines. Such a system typically provides an indication of heavily worn or damaged components, requiring the train to stop and the faulty wagon replaced and sent to the next suitable workshop. This causes a lot of operational delays and costs. For example, axlebox bearing elements like rollers and inner ring raceways, as well as toothed wheels, all generate specific dynamic frequencies which can be detected and analysed with additional knowledge of certain geometry data and shaft speed. Minor geometry bearing differences, such as spalling, can also be identified very early through the analysis of the generated frequency spectra.

The two screen shots below were made during validation testing of the bogie condition monitoring system. By using bearings with spalling in different stages. In reality, bearing spalling would be detected in a much earlier stage.
Traction motor and gearbox monitoring

Traction motors and gearbox components like bearings and toothed wheels may also be monitored, as well as shafts and couplings, using vibration sensors as part of the bogie condition monitoring system. Gearbox oil temperature and level, and more recently, oil condition, can be included in the bogie condition monitoring system, or work as a stand-alone. Vibration signatures from propulsion components vary, depending on the actual traction effort applied.

Information about the train speed and load, therefore, has to be considered in the data processing, together with certain geometric parameters and gearbox ratio.

Schematic illustration of gearbox vibration measurement points. All rotating components of a bogie produce a typical vibration spectra. This makes it possible to identify each component via the frequency.
SKF Multilog online system IMx-R

The SKF Multilog online system IMx-R is the latest generation of powerful, cost-effective solutions for railway vehicles. Together with SKF @ptitude Observer software, IMx-R provides a complete system to improve machine reliability, availability and performance. This is done by providing early fault detection and automatic advice for correcting existing or impending conditions and advanced condition-based maintenance.

In addition to the analogue channels, four digital channels are used for measuring speed, trigger or digital status, such as indicating when a measurement can take place. Several measurement points may be attached to one channel and both AC and DC measurements can be measured on the same channel. Individual conditions for warning and alarm may be set for each point. Warning and alarm levels may be controlled by machine speed or load.

The IMx-R works as a mechanical condition monitoring and protection system with several other units in a network with the SKF @ptitude Observer monitor. The system can even run in an existing LAN, together with other computers, printers, servers, etc. or over the Internet.

The unit’s unique built-in hardware auto diagnosis system continuously checks all sensors, cabling and electronics for any faults, signal interruption, shortcuts or power failure. Any malfunction triggers an alarm. In the case of system power failure, the system will automatically restart when the power returns.

GPS track profiling

Information from axlebox vibration through the bogie condition monitoring system, linked with a global positioning system (GPS), facilitates sufficiently accurate

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**SKF Multilog online system IMx-R installation**

![SKF Multilog online system IMx-R installation diagram]

- **GSM (GSM-R, global system for mobile communications – railway)**
- **IMx-R**
  - Warning, alarm, system failure
  - Speed
  - Load
  - 24–120 V DC
  - Communication interface (GSM, etc.)
- **Driven wheelset**
- **Non-driven wheelset**

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profiling of the track to determine track deterioration as seen by the wheelsets over time. The system accommodates any type of sensor, but principally vibration sensors are used. To increase accuracy, an AXLETRONIC odometer sensor can be applied on one axlebox to determine deterioration of the track.

**IMx-R technical description**

The IMx-R is designed to operate worldwide in typical railway environments, as defined in customer specifications, railway operator standards and international standards. The IMx-R complies with EN 50155 regarding electromagnetic compatibility (EMC), shock and vibration levels as well as ambient temperatures.

### IMx-R design details
- In accordance with TSI regulations UIC 515-1
- SIL Safety Integrity Level 2 capability (measurement of performance required for a safety instrumented function)
- Mounted in a 19” rack
- True simultaneous measurement of all channels
- Multi-parameter gating
- Digital peak enveloping (DPE)
- Adaptive alarm levels
- Data buffering in non-volatile memory when communication is down
- Output relay drivers
- Fully supported by SKF @ptitude Observer

### IMx-R reference standards

<table>
<thead>
<tr>
<th>Document number</th>
<th>Document title</th>
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<tbody>
<tr>
<td>TSI HS R5 Directive 96/48/EC, Version EN03, 23.06.2006</td>
<td>TSI, high-speed trains – working document on decision Railway applications: electronic equipment used on rolling stock</td>
</tr>
<tr>
<td>EN 50155</td>
<td>Railway applications – specification and demonstration of reliability, availability, maintainability and safety (RAMS)</td>
</tr>
<tr>
<td>EN 50126</td>
<td>Communication, signalling and processing system – software for railway control and protection systems</td>
</tr>
<tr>
<td>EN 50128</td>
<td>Railway applications – safety related electronic systems for signalling</td>
</tr>
<tr>
<td>EN 50129</td>
<td>Railway applications – rolling stock equipment – shock and vibration tests</td>
</tr>
<tr>
<td>EN 61373</td>
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</tbody>
</table>
AXLETRONIC sensors
In addition to the SKF Multilog IMx-R condition monitoring system and the SKF @ptitude Observer software, SKF offers a complete package including sensorized bearing units which are equipped with AXLETRONIC sensors. The sensors detect operational parameters for these condition monitoring systems like speed, sense of rotation, positioning, bearing temperature and vibration. For more information, refer to chapter 7.

SKF @ptitude Observer analyse tool
The main task for the IMx-R is to monitor and timely report axlebox bearing temperature detection and bogie hunting detection when observed in accordance with TSI. In addition, IMx-R is able to monitor the condition of wheelsets, axleboxes, traction motors, gearboxes and cardan shafts.

The hot box axlebox detection and bogie hunting detection and condition monitoring results are stored in the SKF @ptitude Observer database. Results from the IMx-R units are further processed by the SKF @ptitude Observer machine diagnostics into machine condition results such as trends and clear text messages showing detected machine faults. These results can be easily accessed using the SKF @ptitude Observer software.
Applications

The first bogie online condition monitoring application was introduced in 2001 with the installation of the earlier SKF MasCon16R system. SKF signed a long term contract to increase the reliability of 14 triple locomotives Dm3 type with the Swedish MTAB iron ore railway operator which serves the Swedish – Norwegian line Kiruna – Narvik. The aim was to increase reliability and to avoid unplanned stops caused by problems with equipment like axleboxes, traction motors and gearboxes. Before that, many mechanical breakdowns caused lost time and cost to haul the trains with the defect locomotive on the single track line. During the SKF monitoring and scheduled maintenance, not one unplanned stop was registered. The locomotives were taken out of service in 2005 when a new locomotive generation started operation (page 203). With the SKF contract, MTAB dramatically saved costs and increased reliability.

Global references

In the following years, several diesel and electrical locomotives, multiple units and high-speed trains were equipped with MasCon16R in Germany, Japan, Switzerland, Sweden and UK. The results confirmed the expectations of operators and manufacturers and enlarged the experience with the SKF bogie monitoring system.

In 2008, the first application of the new IMx-R generation was installed in one of the latest European high-speed trains. The experience confirmed expectations and soon the first serial order followed. From 2010 on, a larger number of European high-speed trains will be fully equipped with IMx-R.
The Power of Knowledge Engineering

Drawing on five areas of competence and application-specific expertise amassed over more than 100 years, SKF brings innovative solutions to OEMs and production facilities in every major industry worldwide. These five competence areas include bearings and units, seals, lubrication systems, mechatronics (combining mechanics and electronics into intelligent systems), and a wide range of services, from 3-D computer modelling to advanced condition monitoring and reliability and asset management systems. A global presence provides SKF customers uniform quality standards and worldwide product availability.

References