APPLICATION NOTE

Bogie Monitoring

Bogie monitoring analyses the vibrations produced by a system's components through measurement of the vibrations in real time. As an effect, it allows a great reduction in maintenance cost: repairs no longer depend on a routine maintenance review, but on the results obtained by sensors. Moreover, such processes ensure the security of passengers while travelling.

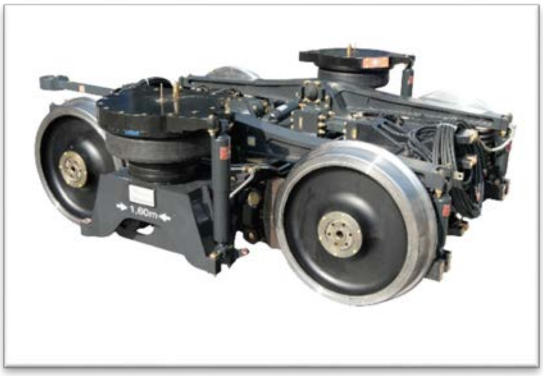

Figure 1: A bogie developed by Siemens SA

The load on a railway wagon may reach a hundred tonnes, generating a lot of stress on support elements. Monitoring can be applied to the several structures present on a bogie to keep track with the state of each component, including:

- Gearboxes
- Bearings
- Axle boxes
- Brakes
- Traction motors
- Any static structure

The bogies allow the train to move smoothly and are a critical component for both the security and comfort of the passengers. In general, there are two bogies per wagon, each bogie bearing a set of four wheels.

Architecture of the System

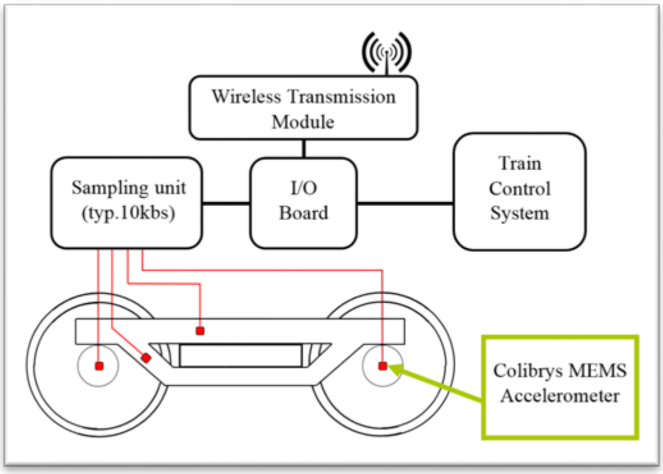

Figure 2: An example of bogie monitoring configuration

The accelerometer system is placed in a small metallic container that is fixed to a structure. Once its output values are sampled via an A/D converter, the data are directly transmitted to the train control panel and optionally to any external networks.

A defect or impairment in a structure causes vibrations, which inevitably increase the deterioration of the system. These vibrations are detected either by a permanent increase in output values, or by frequency analysis. The second possibility requires an FFT operation to obtain a frequency spectrum. The graph is then compared to the corresponding component's default spectrum in order to check the component's state.

Condition Analysis

Bogie monitoring enables preventive maintenance, as long as some conditions are respected. Durability and reliability primarily must be considered. The vibration generated by the friction of the wheels on the rails are low frequency, typically from DC 0 Hz to 1000 Hz. In addition, the accelerometer must be adapted for any kind of travel, speed and temperature. It is required that the sensors withstand the shocks caused by small stones.

The number of sensors installed on the bogies depends on the critical areas that are exposed to fatigue. Other parameters such as the speed of the train, the condition of the railway tracks, the quality of the components (including the accelerometers) and the direction of the vibrations help to determine the correct number of sensors. The use of 3-axis accelerometers is strongly recommended.

Performance Required

Noise detection is the most important technical point of the sensors used in this application. Damage in a structure could be identified as random noise at first; the less noise the sensor itself generates, the earlier any dysfunction may be detected. Therefore, a high performance sensor, featuring a low-noise capability, enables the earliest preventive maintenance for any non-random noise detected

High precision has a huge impact on spectral frequency analysis. It could even differentiate between two different components mounted on the bogie, for example a gear bearing and an axle bearing. Being able to perform precision monitoring consequently reduces the operational costs drastically.

The MEMS Revolution

MEMS sensors measure an acceleration by a variation of capacitance between two electrodes. These sensors are characterised by their small weight and size. Having a compact silicon structure, MEMS bring high durability, a strong resistance to fatigue, shocks, and an outstanding performance stability in temperatures varying from -55°C to +125°C.

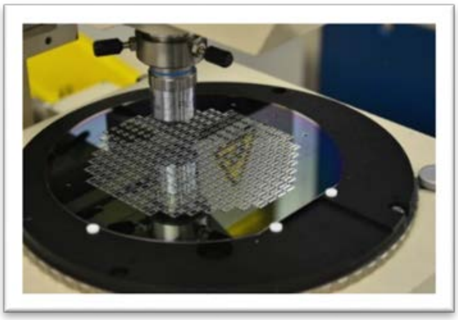

Figure 3: The inspection of the MEMS on a wafer

Two older types of sensors could be used for bogie monitoring:

- Accelerometers based on the piezoresistive effect (PR) are generally used for crash testing; however, the deterioration of the piezo crystals makes it difficult to provide a reliable long-term analysis. With varying temperatures, the PR stability is disrupted. In addition, the crystals suffer from a bad bias drift (zero shift), compared to the MEMS capacitive accelerometers.
- The piezoelectric sensors (PE) can resist very high temperatures (700°C) and have the largest frequency bandwidth, but they are relatively heavier as they need a larger mass for proper functioning. They also cannot measure low frequencies down to DC 0 Hz.

Safran Colibrys as a Proven Supplier

Unlike standard accelerometers where their numbers are proportional to their precision, high quality sensors reduces the number of spots measured, thus the number of sensors. Moreover, MEMS capacitive sensors are able to compensate for thermal bias derivation. Thanks to their integrated electronics, Safran Colibrys' sensors also provides a self-test function to check the integrity of the measurement system at any time.

Figure 4: The VS1000 Safran Colibrys sensor

Safran Colibrys produces a wide variety of MEMS sensors, all capable of working in any type of environment. Although the scaling factor is available from ±2g to ±200g[1], a typical range for this application would be around ±10g to achieve a good compromise between saturation and noise reduction. The vibration sensor family offers the best performance for this application, especially the VS1000, with a maximum noise bias of 7 µg/√Hz (typically at 2g), a non-linearity of 0.1% FS (typically), a linear frequency response from DC 0 Hz up to 2500 Hz at ±5% (typically), and 7000 Hz at ±3 dB (typically).

With over 25 years of experience, Safran Colibrys has mastered the domain of high precision MEMS accelerometers. The sensors are fabricated in Switzerland, using the bulk micro-machining technique to achieve both accuracy and stability. Furthermore, they are guaranteed to function effectively for many years, and have been qualified by the aerospace and defence industries.

[1] ±2g, ±5g, ±10g, ±30g, ±50g, ±100g, ±200g, and other ranges available upon request.

A Remarkable Achievement

Siemens and Safran Colibrys have been successfully qualified for the latest generation of German ICE high speed trains. The Velaro D train is the fourth generation of interoperable high-speed trains made by Siemens using distributed traction and the first innovative integrated bogie monitoring systems.

The system represents the latest state of the art safety monitoring using a combination of DC low frequency MEMS based vibration sensors coupled with high frequency piezo sensors. These two types of sensors are mounted on the bogie and axle to measure wheel, axle and bearing condition and wear.

The MEMS technology is constantly gaining more credibility from the transportation, aerospace and defence industries, allowing cost-effective solutions.

Figure 5: The Velaro D high speed train

Glossary:

- A/D: Analog to digital
- dB: Decibel
- DC: Direct current
- FFT: Fast Fourier transform
- FS: Full scale
- Hz: Hertz
- MEMS: Microelectromechanical systems
- PE: Piezoelectric
- PR: Piezoresistive