

Always on the right path

Rotation rate sensors from ASC provide for the safe transport of containers

The volume of worldwide freight transport is constantly growing, together with the demand for special vehicles to transport the containers in the harbour. A leading manufacturer of AGVs (automated guided vehicles) delivers the vehicles to terminals around the world. High-precision rotation rate sensors from ASC ensure precise navigation of AGVs.

In 2018, Europe's largest harbour, in Rotterdam, handled about 14.5 million standard containers; in Hamburg, the figure approached 9 million. The giant steel containers are transported from the wharf to the storage area primarily by AGVs (Automated Guided Vehicles). These systems are not controlled by humans, but instead receive their instructions from a control centre. While the automation of these processes enables extremely efficient loading and unloading, it involves very complex technology. One of the major challenges in the operation of AGVs is safe, collision-free navigation of the vehicles on the terminal grounds.

Successfully in use for more than 20 years

The AGVs of the ASC customer are about 15 metres long, 3 metres wide and 1.90 metres high. They can transport a 20, 30, 40 or 45-foot standard container with a weight of up to 40 t, or two 20-foot containers with a maximum total weight of 70 t. Six container terminals in Europe and the USA have been using the AGVs for more than 20 years in continuous operation – without a single malfunction. Some of the vehicles have completed 70,000 hours of operation. In comparison with smaller automated guided vehicles used worldwide in warehouses and logistics centres, the requirements with respect to safety, detection of the environment and localization are much more complex here.

The automated guided vehicles are controlled by a control centre on the terminal grounds. So that the central computer knows the location of the vehicles at all times, each AGV is equipped with a high-precision rotation rate sensor to determine its position. In 2017, the sensors originally used for this purpose were discontinued. The follow-up model no longer fulfilled the company's high technical requirements, which made it necessary to find an alternative. The AGV manufacturer then discovered the uniaxial rotation rate sensor from ASC on the Internet and ordered the prototype. The sensor was tested in different conditions, together with the other electronic components. After successful completion of the tests the decision was made to use the ASC 271 rotation rate sensor in all AGVs of that series.

High-precision data measurement with rotation rate sensors from ASC

The ASC 271 consists of robust MEMS silicon vibration ring elements and is available in measuring ranges of $\pm 75^\circ/\text{s}$, $\pm 150^\circ/\text{s}$, $\pm 300^\circ/\text{s}$ and $\pm 900^\circ/\text{s}$. The sensor measures the rotation rates by means of so-called Coriolis forces exerted on a moving object. These forces generate a radial motion on the ring circumference of the sensor. The intensity of these forces is proportional to the angular velocity of the rotation. As a result of the motion on the ring circumference, the rotation rate sensor generates an analogue stress signal that is linearly proportional to the angular velocity. The rotation rates measured by the ASC 271 are very precise, since the sensor has a

bias instability of only $9^\circ/\text{h}$ and a very low angular random walk of $0.2^\circ/\sqrt{\text{h}}$. The well-balanced design of the ring elements also means that the gyroscope is very robust: Vibrations and impacts to the AGVs that occur during transport cannot corrupt the readings.

AGVs are faster than comparable systems

The AGV manufacturer installs the rotation rate sensors from ASC together with the on-board electronics in a switch cabinet mounted directly on the AGV. Since the vehicles are flat and are equipped with an absolute position system the measurement of the rotation rates on the z axis is sufficient for determining the position. The manufacturer therefore uses the uniaxial version of the sensor. ASC also offers the gyroscope in a triaxial version that was specially developed for three-dimensional navigation.

On straight routes the AGVs reach speeds of up to 6 m/s (ca. 22 km/h), and up to 3.5 m/s even in curves. The highly dynamic behaviour of the vehicles is due in large part to the high-precision gyroscope from ASC. Without them the maximum speed of the AGVs in curves would be 2 m/s, due to the danger of excessive deviation from the route.

The ASC sensors also make the AGVs faster than automated guided vehicles of other manufacturers. Another advantage is that the ASC customer is the only manufacturer to offer a complete AGV bundle from a single source. All others use bought-in sensor components. This integral approach is also pursued by ASC: The company insists on in-house development and manufacturing of its sensors in close cooperation with the customers.

Precise navigation is a major challenge

Two factors are decisive for precise navigation of AGVs: high-precision rotation rate sensors and fast response behaviour. The analogue signal of the ASC 271 is sampled 50 times per second, processed by the proprietary electronic circuitry installed in the vehicle, and transmitted in digital form to the AGV on-board computer. The latter uses the data to compute a position value, which corresponds to the spatial orientation of the vehicle and which is sent to the control centre. On the basis of this data, a central computer in the control centre then determines the optimal route for each vehicle in real time.

This is very complex task, because some container terminals, with an area of 2 km by 150 metres, can have as many as 120 AGVs in use. They automatically follow routes that have been assigned to them by the control computer. This computer receives its instructions from a higher-level computer that is also responsible for the ship planning and assigns containers to be loaded or unloaded by the ship-to-shore cranes on the wharf.

The task of navigation is made difficult by the large number of AGVs moving about at the terminals. An additional hindrance is the limited space available to the vehicles, because the majority of the terminal area is occupied by containers. To ensure safe and smooth traffic flow in these circumstances, the automated guided vehicles are equipped with positioning accuracy of ± 25 mm.

ASC also to mobilize straddle loaders

Since ASC rotation rate sensors deliver outstanding performance in the AVGs, the customer is also planning to equip the company's straddle loaders with sensors from ASC. The straddle loaders are currently in use at the terminal storage areas, where the containers are transferred from the AGVs for unstacking. They could also be used in the immediate vicinity of the ship-to-shore cranes on the wharf – but this would require modification of the navigation system. As of now, the straddle loaders are controlled via GNSS signal, which however would be prone to interference from the large steel legs of the ship-to-shore cranes. The use of Inertial Measurement Units (IMUs), a combination of rotation rate and acceleration sensors, would allow safe and precise navigation. "Our new IMU 8 is ideal for this task", says Dipl.-Ing Markus Nowack of ASC. "It can easily achieve the required positioning accuracy of ± 0.5 m over a distance of 200 m." Initial tests with the IMUs are scheduled to begin in the near future.