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POSITIONSMESSUNG

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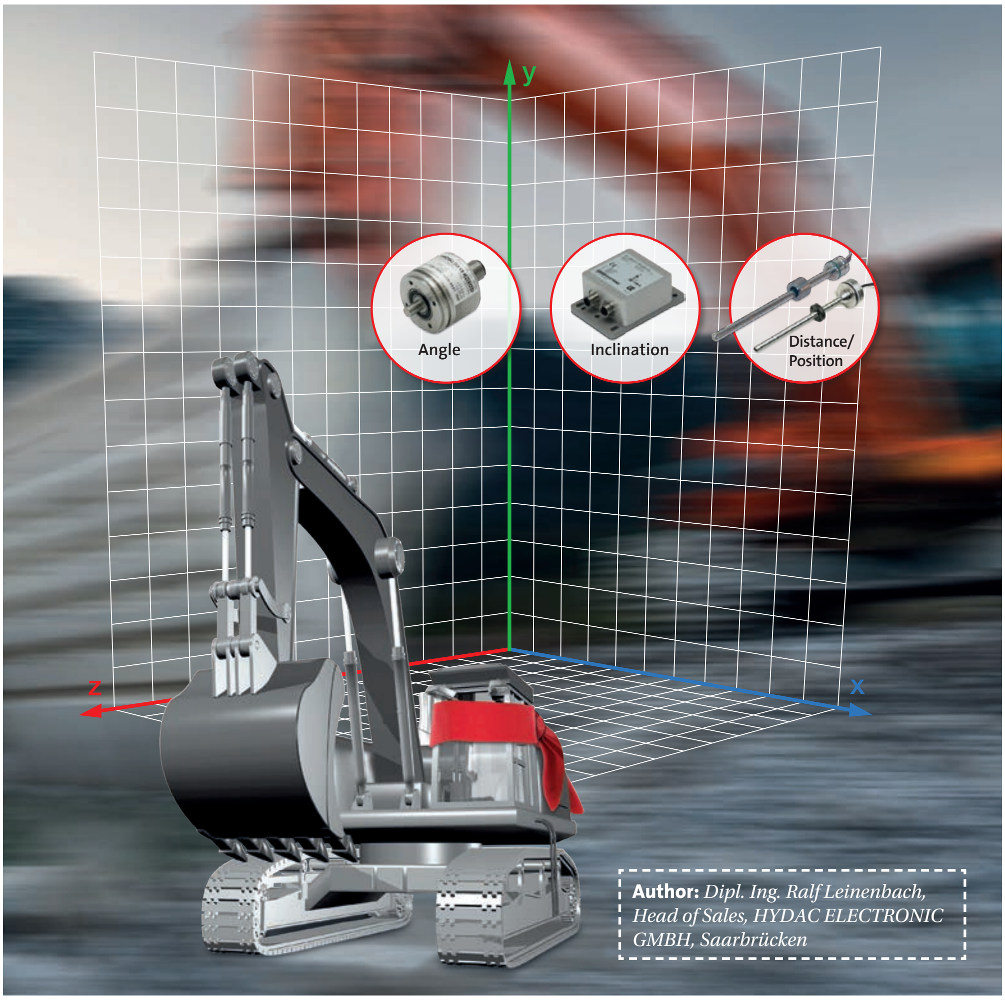
POSITION MEASUREMENT: VARIOUS APPROACHES IN MOBILE MACHINERY



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As developments in mobile machinery continue to progress, machine functions need to be executed with increasing speed and precision. This is vital if the specified development goals are to be achieved, such as increasing productivity and work quality or reduction of workload for the machine operator. It is clear that sensors in the closed-loop control circuits of individual machine functions play an crucial role in this regard.

HYDAC have been involved in these developments both as a manufacturer of sensors and as a provider of system solutions, and have thus acquired extensive expertise. This article draws on HYDAC's expertise to discuss sensors for measuring positions and movements in mobile machinery and to present various alternatives.

MORE THAN JUST STANDARD SOLUTIONS

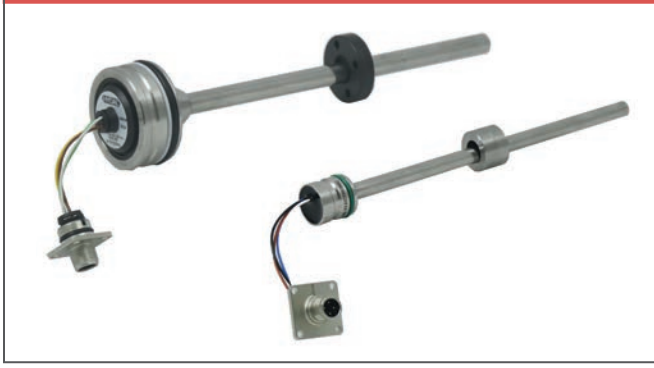
On the basis of modern or new sensor technologies, sensors for position measurement have been developed in recent years that provide significantly better performance with regard to accuracy, dynamics and adequate robustness for particular applications. Applications where position or movement measurement is required include vibration damping, load moment limitation, fully and partially automated operating functions, work area limitation, support, speed control and path control. These applications are typically relevant in agricultural machinery, construction machinery, municipal machinery and hoisting and conveying machinery. Many operating functions need to have elevated functional safety in accordance with the risk assessment. For sensors, this means that versions with increased functional safety are required in addition to a standard version.

Given that requirements for measurement accuracy and measuring dynamics can vary and that different applications call for different mounting options, it is clear that there is no perfect position measurement sensor that suits all purposes. From the large range of products with different measurement methods, each of which has its own strengths and weaknesses, at present mainly recommended are cylinder-integrated linear position sensors, angle sensors and inclination sensors, all of which have their individual pros and cons in the above-mentioned applications.

WHAT ARE THE DIFFERENCES?

The individual sensor measurement principles are presented below, with a comparison of the performance characteristics based on application-related criteria.

01 Linear position sensors HLT 1100 HLT 724



for full integration into hydraulic cylinders	
HLT 724 Magneto-inductive	HLT 1100 Magnetostrictive
Non-contact, with target magnet	Non-contact, with target magnet
Measuring ranges: 5 cm to 40 cm	Measuring ranges: 5 cm to 2 500 cm
Resolution: 0.5 mm	Resolution: 0.1 mm
Head diameter:: 20 mm / 24 mm Rod: 8 mm	Head diameter: 48 mm Rod: 10 mm
	SIL 2 / PLd in Categories 2 and 3

02 Angle sensors HAT 1000 HAT 3000

HAT 1000 / HAT 3000
Magnetic, non-contact Hall sensors
Measuring ranges: up to 360°
Resolution: 12 bit to 18 bit
SIL 2 / PLd in Categories 2 and 3

Linear position sensors are mainly integrated into hydraulic cylinders, with full integration (where the entire sensor is located inside the cylinder) being preferred as this provides greater robustness. The measurement signal is transmitted to the outside via a cable connection or a flange connector mounted on the cylinder.

Different measurement principles are used for the measurement function. At present, it is mainly magnetostrictive, magnetic, magneto-inductive or inductive measurement methods that are used in linear position sensors in the various machine functions. Greater measurement lengths (typically up to 3 m) are generally measured with magnetostrictive linear position sensors. For shorter measurement lengths and small cylinders with small diameters, the most suitable measurement principles are magneto-inductive or magnetic (e.g. measurement based on Hall sensors) **(fig. 01)**. Potentiometric measurement principles tend to result in wear and have been less popular for many years now because of their lack of robustness.

Angle sensors mostly work on potentiometric, visual or magnetic measurement principles. Here too, sensors working on a potentiometric basis are becoming less popular because of robustness considerations. Visual measurement methods are also often eliminated because of environmental conditions (e.g. condensation). Angle sensors with a magnetic measurement method, using Hall sensor elements, have proved to be highly robust. Such sensors offer resolutions ranging from 12 to 14 bit as standard. For more demanding applications, sensors are now available with resolutions of 16 bit and more, which in the past was only possible with visual sensors **(fig. 02)**.

New technologies have given rise to powerful inclination sensors in recent years that allow significant quality improvements to be made in certain applications, such as vibration-damped booms. New elec-

MAIN POINTS

SENSORS PLAY A MAJOR ROLE IN CLOSED-LOOP CONTROL CIRCUITS

MEASURING ACCURACY AND DYNAMICS REQUIREMENTS ARE CRUCIAL FACTORS

ALWAYS CONSIDER THE OVERALL COSTS IN THE DECISION-MAKING PROCESS

03 **Inclination sensor (IMU) HIT 1500**

	Highly dynamic, movement-compensated, reliable inclination measurement
	Dynamics: up to 50 Hz Resolution: 0.01°
	MEMS acceleration measurement in 3 axes MEMS angular rate measurement in 3 axes
	Movement-compensated inclination in 3 axes Acceleration and angular rate values in 3 axes
	SIL2 / PL d in Category 3

Table **Quality comparison of typical performance characteristics**

Performance characteristics	Linear position	Angle	Inclination	
	Cylinder-integrated	Magnetic	Classic damping	IMU(MEMS)
Mechanical robustness of sensor and connection	++	- (0)	+	+
Accuracy of position measurement	+/++	+/++	--	0/+
Influence of cinematics, play, etc.	-	-(0)	++	++
Influence of deflection, vibration, etc.	--	--	+	++
Dynamics	+	++	--	0/+
Cost of mechanical connection and integration	-	-	++	++
Retrofitting capability and option packages	--	-(0)	++	++

tronic components such as MEMS chips (microelectromechanical system) that are also used in smartphones and cars have revolutionised inclination sensors, drastically altering their price and size. Sensor fusion, such as fusing acceleration sensors with gyroscopes, has given rise to IMUs (inertial measuring units) that provide signals relating to the dynamic movement state in addition to movement-compensated angle signals. Compared with previous damped systems such as angle sensors with pendulum or liquid-filled capacitive sensors, MEMS-based inclination sensors have significantly better dynamic characteristics (fig. 3).

THE SPECIFIC APPLICATION DECIDES

When selecting a suitable sensor for position or motion detection, the particular application and the corresponding requirements, such as those for measuring accuracy or measuring dynamics, are crucial factors. To make the best possible choice, it is important to compare the technical and commercial characteristics of a cylinder-integrated linear position sensor, an angle sensor and a inclination sensor. If increased functional safety is required, there are designs in Cat2 or Cat3 architecture. **The table** provides a quality comparison of typical performance characteristics.

With regard to the sensor's mechanical robustness, for example its resistance to stone chipping, a cylinder-integrated position sensor scores points because of its ideal "packaging". When it comes to accuracy, linear position sensors and angle sensors have the best values. The greatest measurement accuracy for rotary movements is provided by angle sensors. If effects associated with the particular application need to be allowed for or excluded, such as kinematic influences, deflection or mechanical play, inclination sensors are the first choice (provided they can be mounted in the correct location). Inclination sensors also have the advantage in relation to retrofitting or use as a replacement part (plug-and-play).

The issue of costs is a much more complex matter. Designers often base their decisions solely on the price of the sensor. The decision-making process should, however, take into account the overall costs, including the costs of connecting or integrating the sensor. While linear position and angle sensors may initially seem less expensive than inclination sensors, in some cases they may result in costly mechanical or design measures being required, cancelling out the apparent saving.

THERE IS NO UNIVERSAL SOLUTION

In conclusion, there is no lack of modern and powerful sensors for measuring position or motion that meet the increasing demands made of machines, and thus machine functions. The preferred sensors at present are cylinder-integrated linear position sensors, angle sensors and inclination sensors. As there is no universal solution for the wide range of machine functions and environmental conditions, the question of which sensor best meets the technical and cost requirements must be examined on a case-by-case basis.

Photos: *HYDAC*

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