
White paper

Position transducers for hydraulic cylinders

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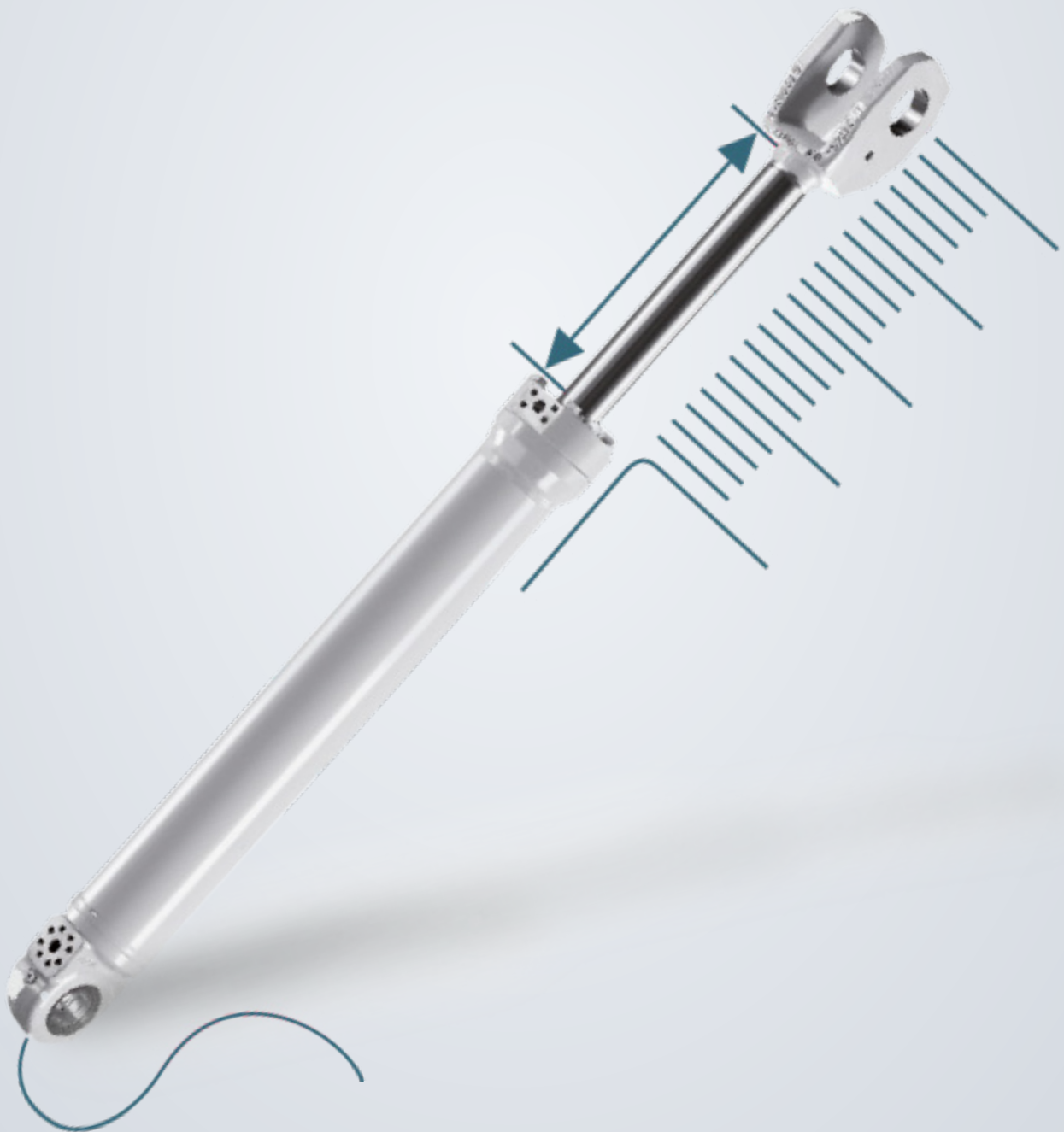
LIEBHERR

Control technology and electronics



Sensors and position transducers

This white paper analyses the most widely used position transducers for hydraulic cylinders. The focus is on the advantages and disadvantages of these systems based on defined requirements.



Introduction and definition

Over the course of time, an increasing number of different distance measuring systems have entered the market. In automation technology, these are used for position detection and distance measurement. In order to be able to record an increase in efficiency, it is important for companies to determine the most suitable system for their specific area of application.

Sensor

A sensor is a technical component that determines various physical parameters (eg.-temperature and pressure) and converts them into electrical signals.

Position transducer

A position measuring system, also known as a displacement sensor or position transducer, can use sensors to calculate the distance between two points - for example, the distance covered by the cylinder piston. The calculated distance is emitted as a signal and transmitted to a control system, for example. Position sensors are used in numerous industries.

Position transducer application examples

Working space and load moment limitation

A position measuring system enables the precise determination of the boom position. This allows the operator to define a working area in which the boom is allowed to move. If the boom reaches a limit, the machine warns the operator or automatically intervenes in the control system. This is helpful for working safely under overhead lines, for example.

Information about the exact position of the support is important to prevent the machine from tipping. The position measuring system provides exact position data for the implementation of a load moment limitation. This ensures increased working safety.

Automation and teach-in

Data on the exact position and speed of the piston are the basis for reliable automation. A position measuring system enables precise control of the cylinder movement. For example, assisted grading can be implemented. This relieves the driver and increases productivity.

If the driver repeatedly approaches certain loading or unloading points, he stores the position of the pistons once only. The driver can then approach these points quickly and accurately with the aid of the system. This semi-automatic positioning of the tool increases productivity.



Measurement types, methods and principles

Measurement type

Basically, there are two types of position measurement:

- **Linear** position measuring systems record a linear distance covered.
- **Rotative** systems record rotating movements, which they then emit as analogue or digital signals.

Measurement method

The measurement can be measured with an absolute or incremental scale:

- With an **absolute measuring method**, measurements are taken directly between a defined starting point and a reference point. When the power supply is activated, an absolute signal with the measured value is emitted immediately. A good example for the absolute measuring principle is a clock: the time is calculated from the reference value 0.
- The **incremental measuring method** uses a relative instead of an absolute scale. This means that only the difference between two points is measured. An example: a stopwatch that counts the seconds from the start of measurement. To obtain absolute values, a reference point to the measured object must first be defined via a reference run. This reference point to the measured object is also called the zero position. The distance between the measured object and the zero position is broken down into individual units, known as increment. These are counted and together form the measuring distance.

Measurement principles

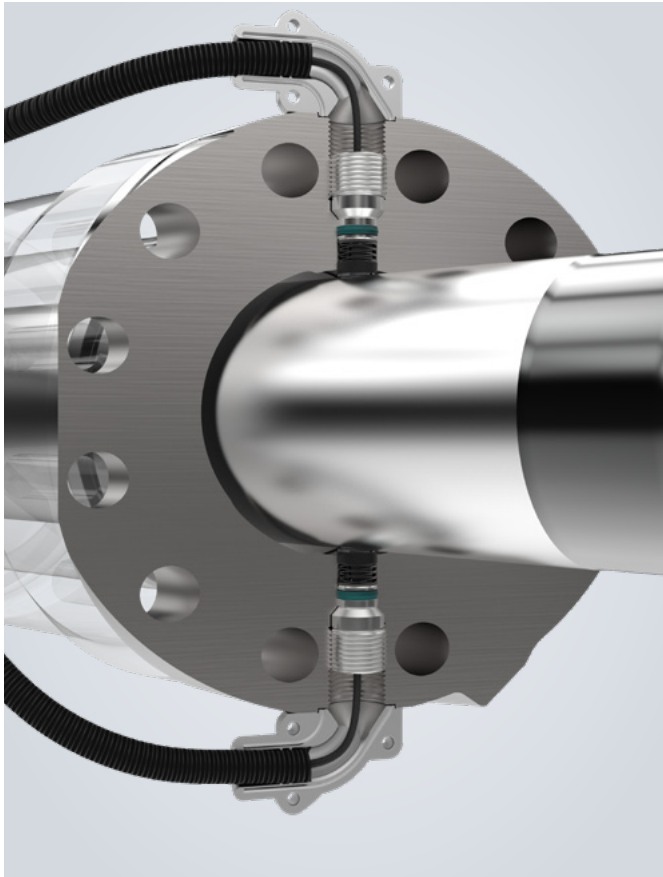
Based on these measurement methods, there are several principles for measuring the piston position in the hydraulic cylinder. For example, draw-wire systems, magnetostrictive displacement transducers and high frequency measurement systems.

High frequency measurement

The absolute principle of high frequency systems measures linear movements. Whereas with draw-wire and magnetostrictive sensors, a measured value is available on the CAN bus approx. every 5 to 40 ms, with such a measurement principle of this kind a new measured value is displayed with an internal sampling rate of approx. 330 µs – about 10 times as often.

A scattering parameter measurement determines piston position and speed. A probe excites the cylinder with a high frequency signal at different frequencies. The signal moves in the cylinder, from the piston rod bearing to the piston, and is reflected there. Another probe reads this response signal. The electronic module checks the response signal for changes in phase and amplitude. The system uses these changes to calculate the position and speed data of the cylinder. And that's it – finally the results are put on the CAN bus interface and can be transferred. The high frequency ensures that the measurement of piston position and speed is very accurate.

Type of measurement	High frequency	Draw-wire	Optics	Magnetostrictive
Measurement method	linear	linear	linear	linear
Measurement principles	absolute	absolute and incremental	absolute	absolute



Various approaches

The operating modes of the position measuring systems are different. In high frequency measurement, for example, the signal is fed in and read out via probes integrated in the piston rod bearing.

Draw-wire sensor

A draw-wire sensor is also called a string potentiometer. It is a rotary displacement encoder. The position can be measured either absolutely or incrementally. The measuring cable is clamped between the two eyes of the hydraulic cylinder. When the cylinder extends, the spool rotates and the measured value is emitted as a signal. This can happen via a rotary encoder or an angle sensor.

Optics system

The optical system uses optical sensors to determine the stroke of the cylinder. Here, a binary code is mapped onto the piston rod. The sensor is able to determine the current position of the rod as an absolute value. For the sensor to be able to analyse the bar code, a high contrast of the code to the surface is required. This contrast can be ensured by means of laser marking or selective coating through black chrome plating. Due to high corrosion resistance, as well as abrasion resistance, black chrome plating is also suitable for extreme conditions.

Magnetostrictive system

Magnetostrictive displacement transducers are also called magnetostrictive sensors. They are linear and absolute displacement measuring systems with their own measuring distance. Their mode of operation is based on the physical principle of magnetostriction: if ferromagnetic material, such as iron, is in the vicinity of a magnetic field, it deforms and changes its volume. The sensors contain three components: a waveguide – the measuring element – made of ferromagnetic material, a permanent magnet and a pulse converter. The permanent magnet is typically located on the moving component of the machine, for example the cylinder piston.

An electrical impulse conducted into the waveguide triggers the measuring process. This current pulse builds up a magnetic field that reacts with the field of the permanent magnet. Magnetostriction generates a wave that propagates at ultrasonic speed in the conductor. As soon as the wave reaches the end of the conductor, a pulse or signal converter generates an electrical signal. The time difference between the triggering and reception of the pulse indicates the absolute position of the permanent magnet and thus that of the hydraulic cylinder. The sensors are integrated into the cylinder by means of a deep-hole bore.

Requirements for position detection



The requirements you should consider for position sensing can basically be grouped into three categories - measurement technology, mechanics, and costs.

Measurement technology

Within the category of measurement technology, the requirements accuracy, hysteresis and sampling rate are used. A perfect position transducer should have sufficient accuracy, the lowest possible hysteresis and a sufficient sampling rate.

Mechanics

Among other things, the mechanics category checks whether the system has the necessary robustness and mechanical integration capability for the application.

Costs

From the point of view of costs, other costs are taken into account in addition to those incurred for manufacturing and assembly expenses. There are further costs of varying amounts depending on the degree of difficulty of carrying out a service or retrofit. These are also taken into account in this category.



Clarification of terms

Accuracy

Describes the difference between the actual and the determined position.

Hysteresis

Describes a system behaviour, in which the output variable also depends on its previous state.

Sampling rate

Describes the frequency with which a signal is sampled per time interval.

An analysis

The most widely position transducers

Various systems are suitable for displacement measurement in hydraulic cylinders. The existing position transducers differ in terms of their measurement types, measurement methods and measurement principles.

To help you choose the most suitable position measurement system for your application, we have evaluated the most widely used systems for you. We made our assessment based on the position sensing requirement already mentioned.

An overview of the most widely used position measurement systems:

- Magnetostrictive system
- Optics system
- Draw-wire sensors
- High frequency system

ely used ducers

Assessment of position measurement systems against the defined requirements:

- fulfilled above average (compared to the other systems)
- averagely fulfilled
- below average or not fulfilled

Requirements at a glance

Measurement technology

- Sufficient accuracy
- Low hysteresis
- High sampling rate

Mechanics

- Suitable for telescopic cylinders
- High installation flexibility
- High mechanical robustness

Costs

- Low production effort
- Low assembly effort
- Simple service
- Simple retrofitting

Magnetostrictive system analysis

- Accuracy
- Hysteresis
- Sampling rate
- Telescopic cylinder
- Installation flexibility
- Mechanical robustness
- Production effort
- Assembly effort
- Service
- Retrofittability



Magnetostrictive system

Measurement technology

This system works very accurately due to the mathematical principle of operation. It also has a low hysteresis. With a medium sampling rate, this system performs well in the measurement technology category.

Mechanics

The system is not suitable for telescopic cylinders, as only certain cylinders can be used for measurement. The system is not particularly flexible when it comes to installation. It is also mechanically robust to a limited extent only.

Costs

This system incurs high costs for manufacturing and assembly. A deep hole must be drilled in the piston rod to install the system, so there is a high mechanical integration cost. Service and retrofitting are also very cost-intensive. In the event of damage, the cylinder must be completely removed from the machine and disassembled, as the systems are installed internally.

Optics system

Measurement technology

The optics system on the outside provides sufficient accuracy. In addition, the hysteresis is low and the sampling rate is high.

Mechanics

The system is not suitable for telescopic cylinders. The installation flexibility as well as the mechanical robustness are in the midfield. A sensor evaluates an absolute binary code applied to the piston rod and thus determines the position of the cylinder. Since the system is installed in the cylinder structure, it is well protected from external influences.

Costs

The manufacturing effort of an optics system outside is very high and the retrofitting is very difficult. The assembly and service are also not easy to perform.

Optics system analysis

- Accuracy
- Hysteresis
- Sampling rate
- Telescopic cylinder
- Installation flexibility
- Mechanical robustness
- Production effort
- Assembly effort
- Service
- Retrofittability



Draw-wire sensor analysis

- Accuracy
- Hysteresis
- Sampling rate
- Telescopic cylinder
- Installation flexibility
- Mechanical robustness
- Production effort
- Assembly effort
- Service
- Retrofittability



Draw-wire sensors

Measurement technology

The external draw-wire sensor does not provide sufficient accuracy in some cases. It is important for the accuracy of this system that the rope rolls up correctly at all times. Therefore in the case of high mechanical shock stress, for example, when the machine receives a blow, there is a risk of low measurement accuracy. On the other hand, this system has a low hysteresis and a high sampling rate.

Mechanics

The external draw-wire sensor is also suitable for telescopic cylinders. Another positive feature is the high installation flexibility. However, this system is not particularly robust mechanically, as the rope can break and be damaged.

Costs

Low manufacturing and assembly costs, as well as easy retrofitting, have a positive effect on costs. Only the implementation of the service can generate higher costs.

High frequency system

Measurement technology

The LiView high frequency measurement system provides sufficient accuracy in many areas. The system has a low hysteresis and a high sampling rate.

Mechanics

The system is also particularly suitable for long cylinders. However, it is not suitable for telescopic cylinders. A positive aspect is the high flexibility during installation. Since the electronics can be installed flexibly and protected, the system also has a high mechanical robustness – also because the system uses the cylinder itself as the measuring distance.

Costs

The manufacturing and assembly costs are average. Retrofits, on the other hand, are difficult to implement. However servicing is very easy to perform, as errors can be found quickly with the help of the integrated self-diagnosis function (UDS).

High frequency system analysis

- Accuracy
- Hysteresis
- Sampling rate
- Telescopic cylinder
- Installation flexibility
- Mechanical robustness
- Production effort
- Assembly effort
- Service (UDS diagnostic function fast troubleshooting)
- Retrofittability



Your future position transducer

Which position transducer is most suitable for you depends largely on your application and requirements.

As a rule, all of the position measurement systems listed have sufficient accuracy to be used in mobile machines, for example. All systems also have a low hysteresis and a high sampling rate.

In the mechanics category, the draw-wire sensor and the high frequency system stand out positively. The LiView high frequency system is the clear favourite, especially in terms of robustness.

If we consider the manufacturing and installation costs, as well as the retrofitting options, the draw-wire sensor comes out on top from a cost perspective. However, if the service aspect is also taken into account, the high frequency system also scores positively in this category. Retrofitting, on the other hand, is only easy with the wire rope hoist system.

Do you have questions about our LiView high frequency measurement system, especially for your application?

Contact us, we will be glad to help you:

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