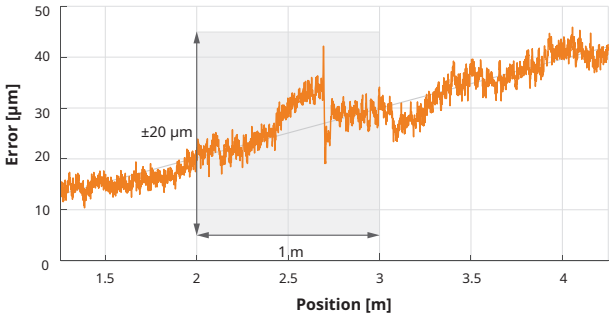
Accuracy of incremental linear encoder systems

The accuracy class is a sum of Sub-Divisional Error (SDE) and magnetisation error. The extreme values of the measurement curves over any one-meter section of the measuring length are within the accuracy class, as shown on the right. If measuring length is shorter than one meter, the accuracy class corresponds to this length. Magnetic scales are produced in four accuracy classes:

- Class D: ±10 µm/m
- Class A: ±20 µm/m
- Class B: ±40 µm/m
- Class C: ±100 µm/m

For accuracy class D (±10 µm/m) a special packaging is provided to ensure the performance of the scale (see more information in MSD01 at **RLS Media center**).

All figures below are for representation purpose only.



Example for accuracy class A.

Encoder-specific errors

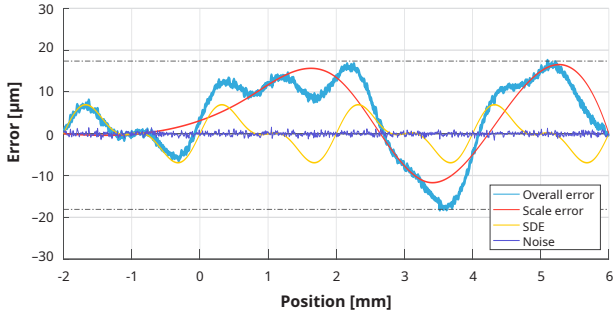
The accuracy of the linear encoder measurement is influenced by the encoder-specific errors and the installation-dependent error. To evaluate the overall accuracy, each of the significant errors must be taken into account.

Magnetisation error

The magnetisation error is caused by imperfections in the elasto-ferrite material and possible deviations resulting from the magnetisation process.

The following factors influence the result:

- Magnetic inhomogeneity of the elasto-ferrite layer,
- Oscillations in the elasto-ferrite thickness,
- Measurement uncertainty of the magnetisation system during manufacturing process



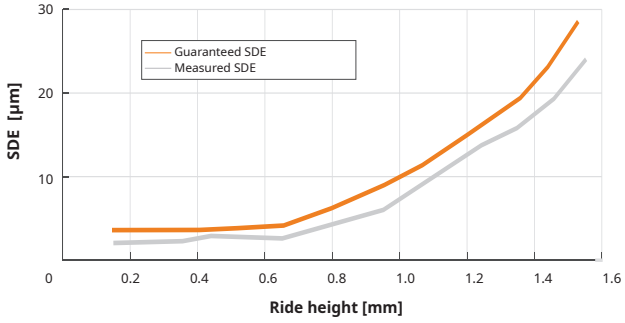
Typical error plot representation.

Sub-divisional error (SDE)

The sub-divisional or interpolation error is a periodic accuracy error. It is influenced by the following factors:

- Inhomogeneity and cycle definition of magnetic poles,
- Sensing distance (ride height) of the installed readhead,
- Quality of signal processing,
- Properties of the sensor.

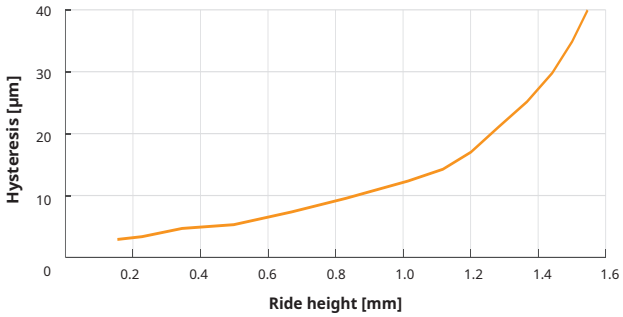
The SDE leads to speed undulations in applications where the encoder is used as a feedback, e.g. in speed control loops.



Representation of an SDE as a function of the ride height.

Hysteresis

Hysteresis is a difference in the measurement results when approaching the same point from different directions. The ferromagnetic materials maintain the magnetised state in response to external fields and try to change their direction. Hysteresis in the encoder systems depends on the magnetic field strength. A stronger magnetic field leads to a smaller hysteresis and vice versa. Therefore hysteresis is strongly influenced by the sensing distance at which the readhead is installed.



Representation of a Hysteresis as a function of ride height (for 2 mm pole length only).

Installation and temperature-dependent errors

In addition to the given encoder-specific error, the installation of the encoder system has a considerable influence on the total accuracy of the encoder system. Of particular importance are the installation eccentricity and the effect of deformations caused by scale installation.

Temperature-dependent error

Temperature-dependent error is an effect of a thermal expansion coefficient α that can be used to calculate the thermal expansion coefficient (CTE) ΔL

$$\Delta L = L \cdot \alpha \cdot \Delta T$$

where L is an effective length of the magnetic scale in [m] and ΔT is a relative temperature difference in [K]. RLS offers steel with CTE ΔL = 17 x 106 [m/mK].

Influence of stress during installation

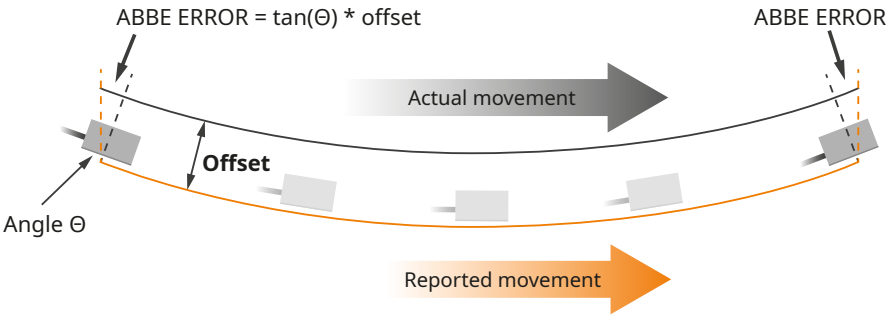
The accuracy of the system is influenced by the repeated cycling of the load. The tensile load of 1 kg causes the magnetic scale to expand for 17 µm. The linear expansion ΔL can be calculated as

$$\Delta L = \frac{F}{A \cdot E} L$$

where F is tensile force in [N], A cross-sectional area in [m2], E Young's modulus of elasticity in [Pa] and L scale length in [m].

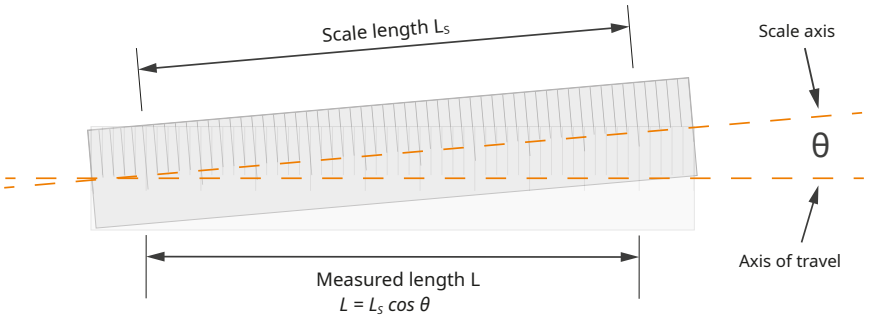
Abbe or sine error

Abbe or sine error occurs when the axis of measurement is offset from the axis to be measured. If the axis of linear movement is curved, the difference between the actual movement and the reported movement contains an error proportional to the offset and the tangent of the angle θ.



Cosine error

The cosine error results from an angular offset between the axis of motion and the position-giving element (encoder). The cosine error is as small as the angle θ.



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Document issues

Issue	Date	Page	Description
1	4. 3. 2022	General	New document (taken from MSD01)