Accuracy of linear encoder systems

The accuracy of the ring encoder measurement is influenced by **encoder-specific errors** and **installation-dependent errors**. In order to evaluate the total accuracy, each of the significant errors must be considered. Fig. 1 shows a typical accuracy error plot with marked particular influences.

Encoder-specific errors

System error consists of a magnetisation error, crosstalk and SDE.

Ring	System error [°]
	Over the entire RH
MR020C	±0.31
MR024C	±0.25
MR026C* ID12	±0.23
MR026C ID16	±0.23

Ring	System error [°]
	Over the entire RH
MR034C	±0.17
MR045C	±0.13
MR049N	±0.11
MR050C*	±0.11

Ring	System error [°]
	Over the entire RH
MR061C*	±0.09
MR080N	±0.07
MR100S	±0.05

* Significant installation error expected due to coarse inner diameter tolerance.

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:

- the magnetic inhomogeneity of the elasto-ferrite layer,
- the ring installation tolerances during the magnetisation process,
- the measurement uncertainty of the magnetisation system during manufacturing process
- the quality of the magnetisation system.

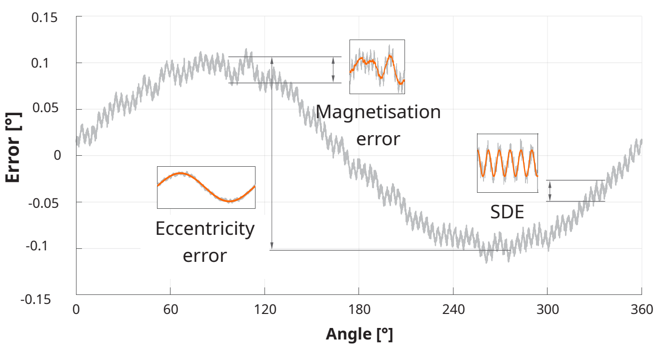

Fig. 1. Typical accuracy error plot.

The magnetisation accuracy A_M can be calculated by the following formula:

$$A_M = \pm \frac{4.6}{D}$$

where *D* is the outer ring diameter in [mm].

D [mm]	A_M [°]
20	±0.229
40	±0.115
60	±0.076

Crosstalk

Crosstalk is an undesirable effect of reference mark magnetisation on the incremental track magnetisation, which leads to accuracy peaks. It depends on both the ride height and the lateral offset.

An example of crosstalk is shown in Fig. 2.

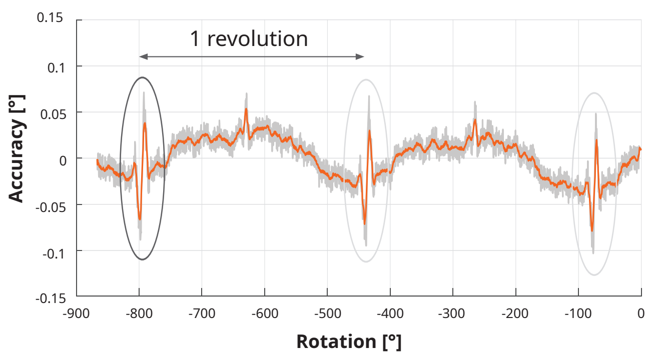

Fig. 2. Crosstalk representation. The crosstalk (Ri magnetisation) is circled.

Fig. 1 to Fig. 4 are for representation purpose only.

Sub divisional error (SDE) or interpolation error

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

- the length of poles,
- the homogeneity and cycle definition of magnetic poles,
- the sensing distance (ride height) of the installed readhead,
- the quality of the signal processing,
- the characteristics of the internal AMR sensor.

The SDE leads to speed ripples in applications where the encoder is used as speed feedback, e.g. in speed control loops. For axial rings, SDE is strongly influenced by ride height.

The maximum SDE at optimal sensing distance can be calculated by the following formula:

$$\mathbf{SDE} = \pm \frac{0.58 \times K}{OD}$$

where:
SDE is Sub divisional error (°)
OD is the outer ring diameter in (mm)
K = 1 for magnetic rings with oouter diameter >30
K = 2 for magnetic rings with outer diameter <30

OD (mm)	SDE (°)
20	±0.029
40	±0.014
60	±0.009

Hysteresis

Hysteresis is the difference in result of measuring the same point when approached from different directions.
It is known that ferromagnetic materials maintain their magnetised state in response to external fields, trying to change their direction.
The hysteresis in encoder systems depends on the strength of the magnetic field. A stronger magnetic field leads to a smaller hysteresis and vice versa. Therefore the hysteresis is strongly influenced by the ride height at which the readhead is installed (Fig. 3).

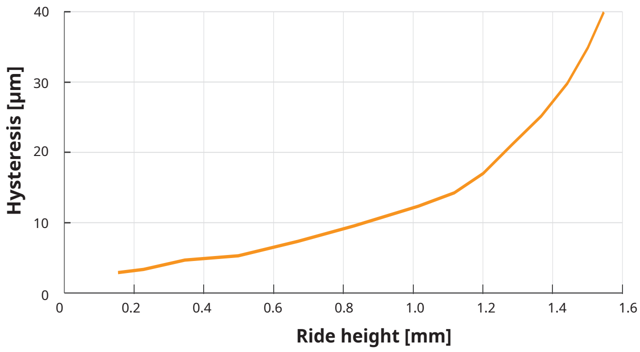

Fig. 3. Hysteresis vs. ride height (for encoder systems with 2 mm pole length).

Installation-dependent errors

Installation and adjustment of the ring and the readhead, in addition to the given encoder-specific error, normally have a significant effect on the overall accuracy of a system. Of particular importance are the installation eccentricity and the effect of deformations resulting from the ring installation.

Installation eccentricity

Eccentricity can be caused by the misalignment of the ring's center towards the rotational axis, as can be seen on Fig. 4.
The error caused by eccentricity can be calculated by the following formula

$$E_{accuracy} = \pm 0.114 \frac{e}{D}$$

where $E_{accuracy}$ is eccentricity error in [°], *e* is misalignment of ring's center towards the rotational axis in [µm] and *D* is the outer ring diameter in [mm].

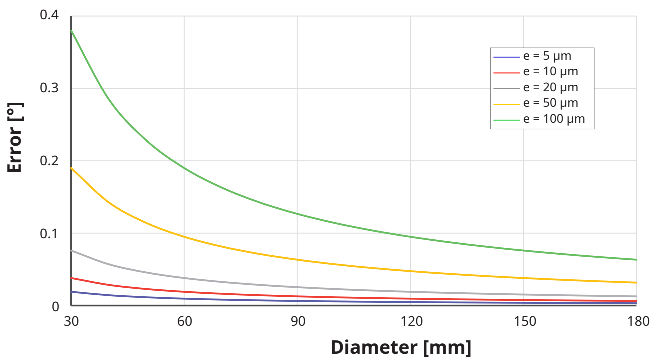

Fig. 4. Influence of installation eccentricity on accuracy.

Deformations of the ring during installation

By installing a ring to a non-ideally circular shaft, possible deformations can occur. These can have a significant influence on the system accuracy error.