FlexIN™

Magnetic Scale System for Large Diameters

WIDE INSTALLATION TOLERANCES

WIDE TEMPERATURE RANGE

FLEXIBLE SHAFT DIAMETERS

FlexIN is a rubber-supported magnetic scale system with built-in tensioning mechanism compatible with LM10 or LM15 incremental encoders.
It is designed for installation onto large shafts as an element of the position and speed control loop. The compact readhead has wide installation tolerances and offers industry standard output types and a reference pulse for relative position. The non-contact measuring principle ensures high reliability in demanding applications.

Features and benefits

- Rubber spring profile supported scale with built-in tensioning mechanism
- Wide operating temperatures
- For external diameter installation
- For diameters from 350 mm to 3,500 mm
- Full circle measurements
- Substrate thermal expansion compensation
- Large allowable shaft diameter tolerance ±0.2 mm

WIND TURBINES | RADIO TELESCOPE | SOLAR PANELS | CT SCANNING | HARSH ENVIRONMENT

General information

The FlexIN magnetic scale system is compatible with RLS standard LM10 and LM15 readheads, which ensure reliable operation due to the non-contact design.

The choice of read head depends on the user's specific requirements. The LM10 read head is ideal for applications requiring high accuracy and resolution as it operates with a pole length of 2 mm. However, it requires a smaller sensing distance (ride height). In contrast, the LM15 readhead supports a more robust installation with a significantly wider sensing distance, but offers lower accuracy compared to the LM10.

Choose your FlexIN system

FlexIN scale

LM10 readhead

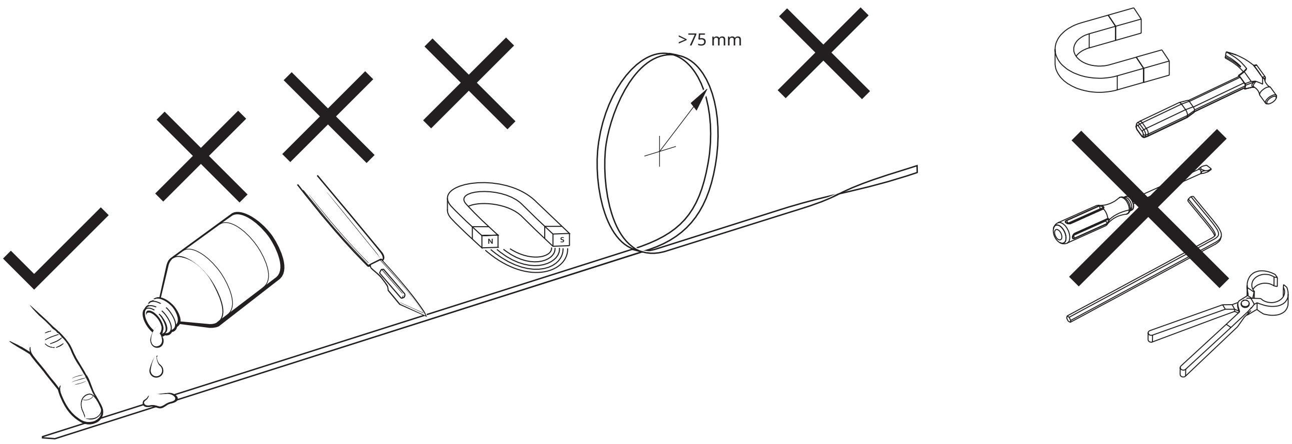
LM10 works with the FlexIN scale with 2 mm pole pitch. Choose the LM10 readhead if you need better accuracy, hysteresis and higher resolution. More about the LM10 readhead can be found in the LM10D01 at **RLS Media center**.

LM15 readhead

LM15 works with the FlexIN scale with 5 mm pole pitch. Choose the LM15 readhead if you need a more robust system in terms of installation tolerances and higher rotational speed. More about the LM15 readhead can be found in the LM15D01 at **RLS Media center**.

Storage and handling

Storage temperature	Operating temperature	Humidity
–40 °C to +60 °C (without readhead)	–40 °C to +85 °C (without readhead)	85% non-condensing



HANDLE WITH CARE. FlexIN system is a high performance metrology product and should be handled with the same care as any other precision instrument. The use of industrial tools during installation or exposure to strong magnets such as a magnetic base is not recommended as it carries the risk of damaging parts of the system which as a result might not perform in accordance with specifications.

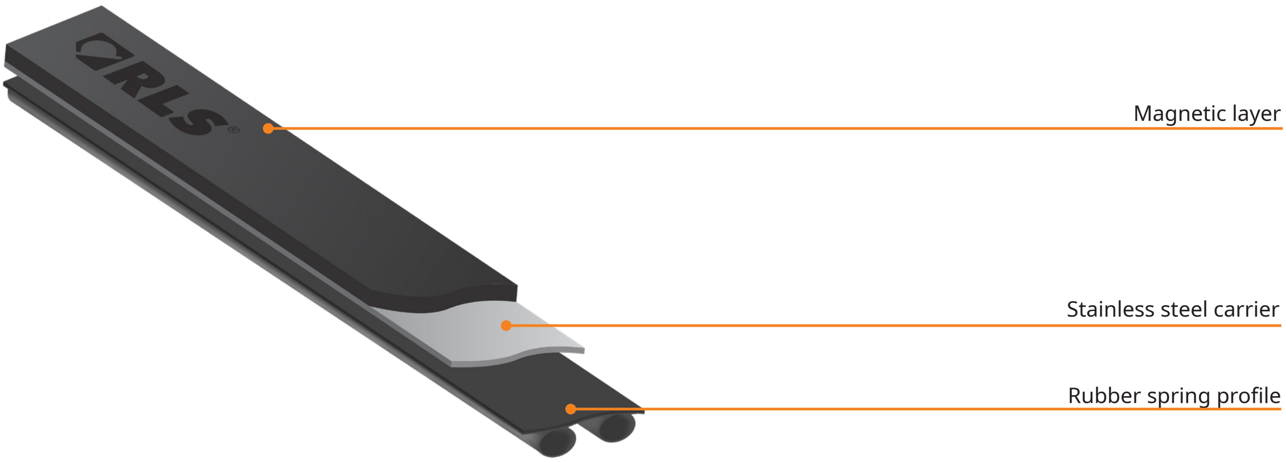
Packaging

Each magnetic scale is packed and rolled in a cardboard box.

All FlexIN magnetic scales have 12 months shelf life and should be installed within this period.

FlexIN magnetic scale design

Structure



Appearance and print

The orientation of the magnetised reference mark and the incremental track is always the same, relative to the scale print as shown in the figure below.

The shape of the reference mark may vary. The image is for representation purposes only.

The dotted line shows the reference side of the scale.
The vertical line indicates the reference mark.

Scale surface print description

Scale surface print appears every 100 mm and contains the RLS logo and a unique code.

FI 2000 A WW YY BB NNN

- FI – Magnetic scale
- 2000 – Scale type
- A – Accuracy class
- WW – Week of scale production
- YY – Year of scale production
- BB – Batch number
- NNN – Counter designator (100 mm = +1 count)

Accuracy of FlexIN system

The accuracy of the FlexIN system is affected by the accuracy errors of the encoder (magnetic scale and readhead) and by installation-related errors. In order to assess the overall accuracy of the system, each of these errors must be taken into account. This document explains all the errors and gives an example of how to calculate each error based on the shaft diameter and the eccentricity introduced in your system. The accuracy and hysteresis can also be calculated on **the RLS website**.

Contributing factors to the inaccuracy of the system

The system error consists of a:

- Magnetization error (Mag. error)
- Joint error
- Eccentricity error (Ecc. error)
- Crosstalk error due to the magnetisation of reference mark
- Sub-divisional error (SDE)

Figure 1 shows a typical accuracy error plot with marked contributions to the inaccuracy of the system.

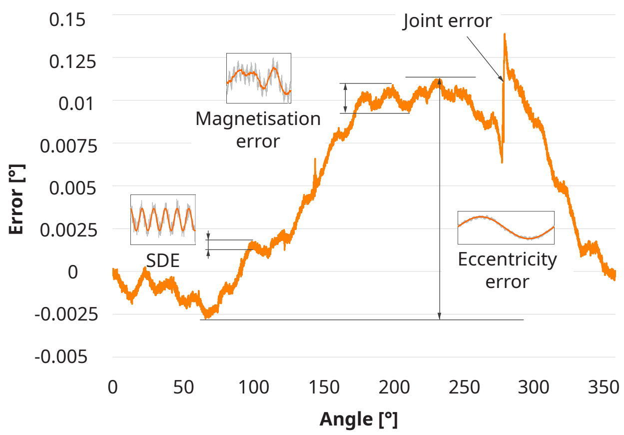


Fig. 1. Typical accuracy error plot.

Magnetization error

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

The following factors influence the result:

- The magnetic inhomogeneity of the elasto-ferrite layer
- The quality of the magnetisation system
- The size of magnetic poles (2 mm or 5 mm pole pitch)

This value is a constant that is determined by the accuracy of the magnetic scale. The 2 mm pole pitch magnetic scale is more accurate than the 5 mm pole pitch magnetic scale. The magnetisation error contribution based on the pole pitch is:

$$\textbf{Mag. error (2 mm pole pitch) [°]} = \pm \frac{7200}{\text{CIRC [µm]}}$$

$$\textbf{Mag. error (5 mm pole pitch) [°]} = \pm \frac{36000}{\text{CIRC [µm]}}$$

CIRC = Circumference in [µm]. It can be calculated based on the PN parameters of the FlexIN system (FI**XXXX**A**YYYY**B0000A100).

CIRC [µm] = XXXX × YYYY

XXXX = Pole pitch (2000 or 5000)

YYYY = Number of magnetic poles per circumference

Example of the FlexIN magnetic scale with a diameter of 1 m and a magnetic pole pitch 2 mm. The PN of the FlexIN scale would be FI**2000**A**1584**B0000A100

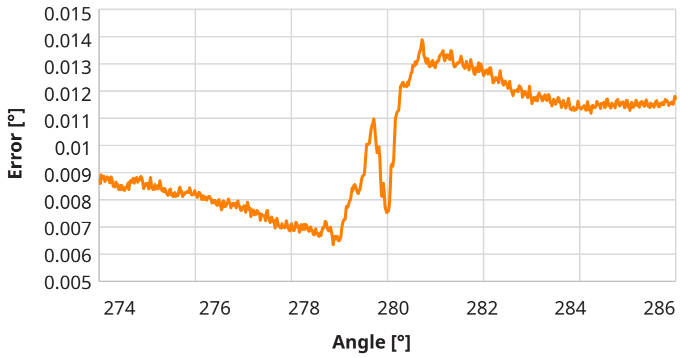
CIRC = 2000 * 1584 = 3168000 µm

$$\text{Mag. error (2 mm pole pitch)} = \pm \frac{7200}{3168000\ \mu m} = \pm 0.0023°$$

The contribution to the inaccuracy due to the magnetisation error would be ±0.0023° or ±2.3 mdeg or ±8.3 arcsec.

Error on the joint

The joint error must be taken into account when calculating the system error. The joint error is caused by the phase mismatch and the damage of the magnetic pattern during the cutting process of the scale. The phase mismatch is the physical gap between both ends of the scale.



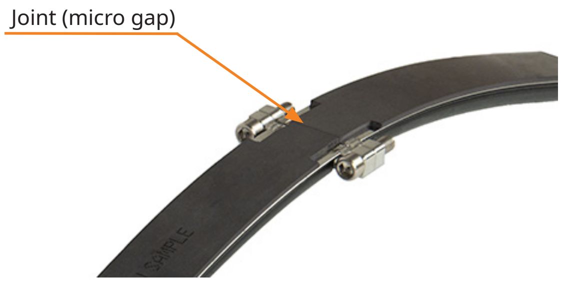


Fig. 2. Junction error plot.

The joint error is determined with a constant independent of the magnetic pole pitch (for LM10 and LM15):

$$\textbf{Joint error [°]} = \pm \frac{\textbf{18000}}{\textbf{CIRC [µm]}}$$

Example of the FlexIN magnetic scale with a diameter of 1 m and a magnetic pole pitch 2 mm. The PN of the FlexIN scale would be FI**2000**A**1584**B0000A100

CIRC = 2000 * 1584 = 3168000 µm

$$\text{Joint error [°]} = \pm \frac{18000}{3168000\ \mu m} = \pm 0.0057°$$

The contribution to the inaccuracy due to the error at the joint would be ±0.0057° or ±5.7 mdeg or ±20.5 arcsec.

Eccentricity error

The installation and adjustment of the FlexIN scale has a significant influence on the overall accuracy of the system. The eccentricity error is caused by the uneven distribution of the rubber spring during the installation process of the FlexIN. The eccentricity error contributes significantly to the inaccuracy of the system and can be reduced by correct and optimised installation. Please follow **the installation instructions** shown in the video.

The eccentricity error is determined with a constant and varies between 2 mm and 5 mm magnetic pole pitch.

The drawing below shows the dial gauge indicator measuring the radial runout on the circumference of the installed FlexIN scale.

To simplify the calculation of the contribution of the radial runout to the inaccuracy of the system, two constants were determined based on the maximum rideheight of the LM10 and LM15 encoder systems.

Maximum allowed radial runout:

LM10 (2 mm pole pitch) = ±0.3 mm

LM15 (5 mm pole pitch) = ±0.4 mm

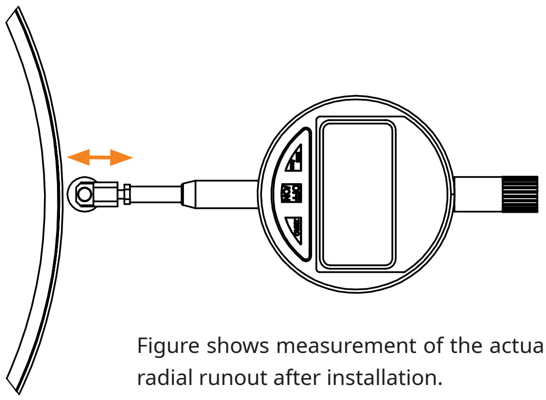


Figure shows measurement of the actual radial runout after installation.

$$\textbf{Ecc. error (2 mm pole pitch) [°]} = \pm \frac{\textbf{108000}}{\textbf{CIRC [µm]}}$$

$$\textbf{Ecc. error (5 mm pole pitch) [°]} = \pm \frac{\textbf{144000}}{\textbf{CIRC [µm]}}$$

First example of the FlexIN magnetic scale with a diameter of 1 m and a magnetic pole pitch 2 mm. The PN of the FlexIN scale would be

FI**2000**A**1584**B0000A100

CIRC = 2000 * 1584 = 3168000 µm

$$\text{Ecc. error (2 mm pole pitch)} = \pm \frac{108000}{3168000\ \mu m} = \pm 0.0341°$$

The contribution to the inaccuracy due to the eccentricity error would be ±0.0341° or ±34.1 mdeg or ±122.8 arcsec.

For a more accurate calculation of the eccentricity error, it is recommended to measure the actual radial runout with a dial gauge indicator once the FlexIN is installed (as shown in the drawing above).

Second example on the FlexIN magnetic scale with a diameter of 1 m and a magnetic pole pitch of 2 mm, but with a measured radial runout of ±100 µm:

$$\text{Ecc. error (LM10/LM15)} = \pm \frac{360000 \times E\ [mm]}{CIRC\ [\mu m]} = \pm \frac{360000 \times 0.1}{3168000\ \mu m} = \pm 0.0114°$$

E is measured radial runout in mm.

The contribution to the inaccuracy due to the eccentricity error would be ±0.0114° or ±11.4 mdeg or ±41 arcsec.

Crosstalk error

Crosstalk is an undesirable effect of the magnetisation of the reference mark on the magnetisation of the incremental track, which leads to inaccuracy spikes. It depends on both the ride height and the lateral offset. To simplify the calculation of the system accuracy, the crosstalk error is already included in the magnetisation error and can be ignored.

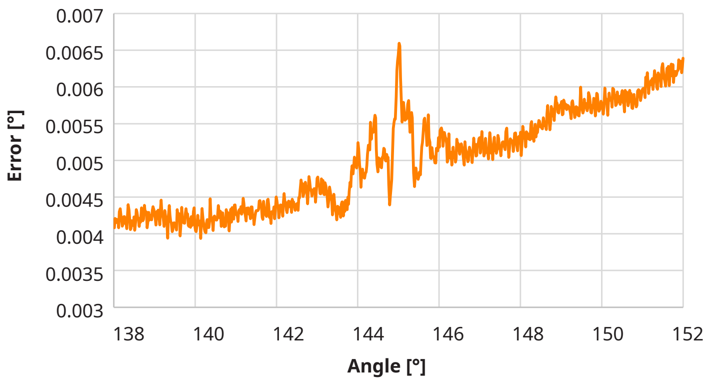


Fig. 3. Crosstalk error plot.

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 the poles,
- the homogeneity and cycle definition of the 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.

The SDE contribution was determined as a constant over the entire installation range and varies between 2 mm (LM10) and 5 mm (LM15) pole pitch.

$$\textbf{SDE error (2 mm pole pitch) [°]} = \pm \frac{\textbf{1800}}{\textbf{CIRC [µm]}}$$

$$\textbf{SDE error (5 mm pole pitch) [°]} = \pm \frac{\textbf{3600}}{\textbf{CIRC [µm]}}$$

Example of the FlexIN magnetic scale with a diameter of 1 m and a magnetic pole pitch 2 mm (LM10 readhead). The PN of the FlexIN scale would be FI**2000**A**1584**B0000A100

CIRC = 2000 × 1584 = 3168000 µm

$$\text{SDE error (2 mm pole pitch)} = \pm \frac{1800}{3168000\ \mu m} = \pm 0.0006°$$

The contribution to the inaccuracy due to the SDE error would be ±0.0006° or ±0.6 mdeg or ±2.2 arcsec.

System error (SUM value)

The system error results from the sum of all contributions described on the previous pages. The result is an expected accuracy value of the FlexIN system based on the shaft diameter and the eccentricity error. Most of the inaccuracy is an eccentricity error. It is therefore recommended to install the FlexIN scale as optimally as possible in order to achieve better results. Installation instructions can be found **here**.

Sys. error = ± (Mag. error + Joint error + Ecc. error + SDE error)

$$LM10 = \pm \frac{7200 + 18000 + 108000 + 1800}{CIRC} = \pm \frac{135000}{CIRC} \qquad LM15 = \pm \frac{36000 + 18000 + 144000 + 3600}{CIRC} = \pm \frac{201600}{CIRC}$$

For example, on the FlexIN magnetic scale from the previous examples for each contribution, the system error would be as follows:

Sys. error = ± (0.0023° + 0.0057° + 0.0341° + 0.0006°) = ±0.0427°

The system accuracy would be ±0.0427° or ±42.7 mdeg or ±154 arc-sec.

For a more precise calculation of the system error, it is recommended to use **the calculator** on the RLS website.

Hysteresis

Hysteresis is the difference in the result of measuring the same point when approaching it from different directions.
It is known that ferromagnetic materials maintain their magnetised state in response to external fields and attempt to change 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).

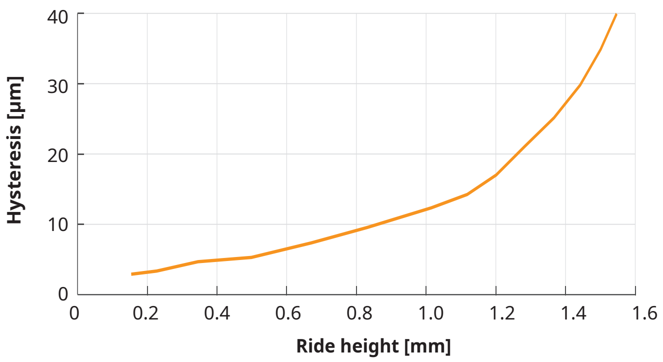
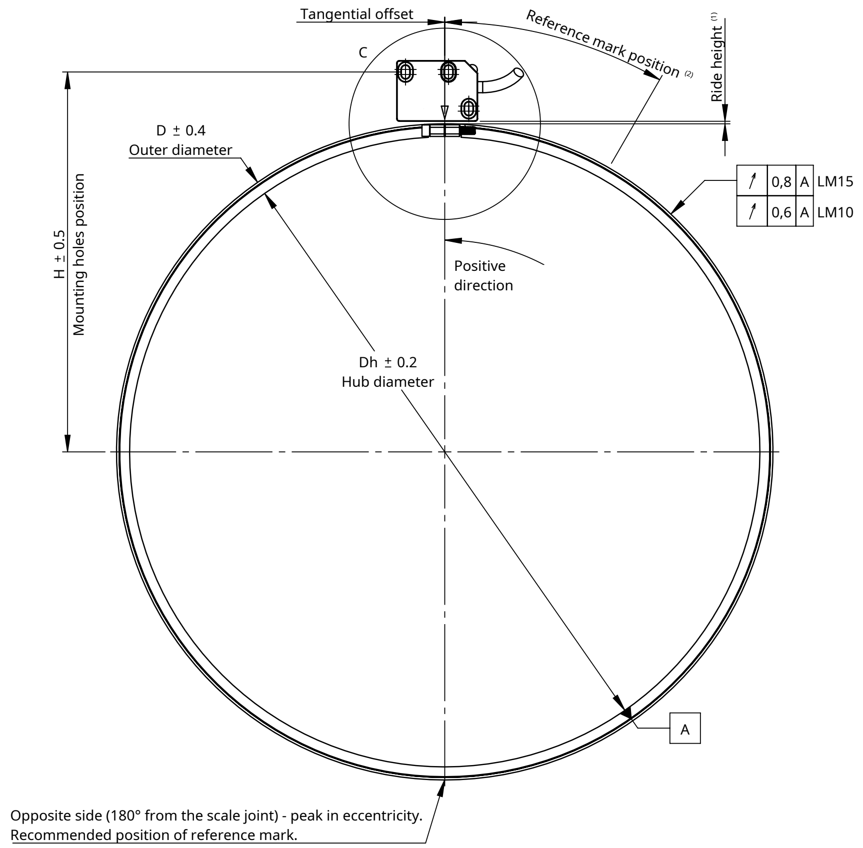


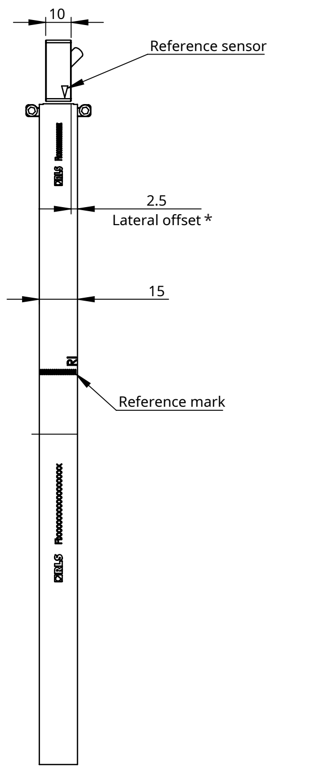
Fig. 3. Hysteresis vs. ride height (for encoder systems with 2 mm pole length).

For a more precise calculation of the hysteresis, it is recommended to use **the calculator** on the RLS website.

Dimensions and installation drawings

Dimensions and tolerances are in mm. Dimensions without tolerance values are in accordance with ISO 2768-m.

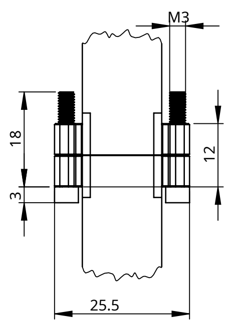




* Check tolerances on **page 12**.

(1) Ride height needs to be adjusted on the opposite side of the magnetic scale joint.
(2) The recommended position of the reference mark is at the opposite side of the magnetic scale joint (more details in the "**Mechanical data**" table).

Scale joint detail



Scale length	Hub diameter	Outer diameter	Mounting holes position
$L_S = n \cdot p$	$D_h = \frac{Ls}{\pi} - 8.4$	$D = \frac{Ls}{\pi} + 2.3$	$LM10\text{:}\ \ H = \frac{L_S}{2 \cdot \pi} + 21$
			$LM15\text{:}\ \ H = \frac{L_S}{2 \cdot \pi} + 22$

n - Number of magnetic poles
p - Magnetic pole length (2 mm or 5 mm)

The fasteners are M3x18, based on DIN912, with reduced shank and head (custom screws).

General tolerances for linear dimensions according to ISO 2768-m

Tolerance class	up to 6	6-30	30-120
m (medium)	±0.1	±0.2	±0.3

The orientation of the readhead and magnetic scale is essential. Please make sure that orientation is as specified.

Technical specifications

System data		With LM10	With LM15
Substrate diameter		350 mm to 3,500 mm	350 mm to 3,500 mm
Number of magnetic poles		564 – 5510	226 – 2204
Accuracy (at 1 m diameter) - see chapter **Accuracy**		±0.043°	±0.064°
Resolution		0.244140625 µm	0.6103515625 µm
Hysteresis		< 3 µm at 0.3 mm ride height	< 12.5 µm at 1 mm ride height
Maximum permissible speed (mechanical limit)** (for higher speed **contact RLS**)	D < 900 mm	rpm = 210/D* [m]	rpm = 210/D* [m]
	D > 900 mm	rpm = 325/D* [m]	rpm = 325/D* [m]

* D stands for the outside diameter of the mounted scale.
** The electrical limit values are determined by the selected readhead configuration. Please check **the calculator** for the maximum speed on the RLS website.

Mechanical data

Material	Carrier		1.4310 stainless steel
	Magnetic scale		NBR elasto-ferrite
	Rubber spring profile		EPDM rubber, black
	Joint		1.4301 stainless steel
Thickness	Magnetic scale (relaxed rubber state)		6.25 ±0.6 mm
Mass	Magnetic scale and carrier		93 g/m
	Rubber spring profile		33 g/m
	Connecting element (two used in a joint)		4 g
	Fastener M3 (two used in a joint)		1 g
Width			$15^{+0.15}_{-0.05}$ mm
Length		Minimum	1.1 m
		Maximum	11 m
Reference mark position (position of scale joint is 0°)		Recommended value	At 180°
		Minimum	5°
		Maximum	355°
Reference mark position tolerance [°]		LM10	±1 mm × 360° / Ls (scale length in mm)
		LM15	±2.5 mm × 360° / Ls (scale length in mm)
Thermal expansion coefficient (CTE)			11.2×10^{-6} K^{-1}

Environmental data

Operating temperature	–40 °C to +85 °C (without readhead)
Storage temperature	–40 °C to +60 °C (without readhead)
Maximum non-operational external magnetic field	25 mT
Vibrations (55Hz to 2000 Hz)	300 m/s² (IEC 60068-2-6)
Shocks (6 ms)	300 m/s² (IEC 60068-2-27)
Environmental sealing	Up to 85 % humidity non-condensing

Reference mark options

Unique reference mark

The readhead must be ordered with reference mark option A. For further details, please refer to the “Part numbering” chapter in the **LM10** or **LM15** data sheet, which is available from the **RLS Media center**.

The magnetic scale must be ordered with reference mark.
The readhead must be ordered with the reference mark option A.

Periodic reference mark

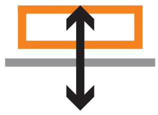
The readhead must be ordered with reference mark option C. For further details, please refer to the “Part numbering” chapter in the **LM10** or **LM15** data sheet, which is available from the **RLS Media center**.

The magnetic scale must be ordered without reference mark option. The position information is output in incremental quadrature format with periodic reference pulses every 2 mm (LM10) or 5 mm (LM15).

Installation tolerances

Ride height / radial offset

Values in mm.	LM10	LM15
No Ri	$0.3^{+1.2}_{-0.2}$	$0.5^{+3.5}_{-0.4}$
Magnetised Ri	$0.3^{+0.5}_{-0.2}$	$0.5^{+2}_{-0.4}$

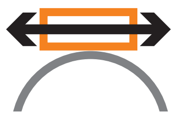


Axial offset

Values in mm.	LM10	LM15
No Ri	0 ±1	0 ±1
Magnetised Ri	0 ±0.7	0 ±0.7

Tangential offset

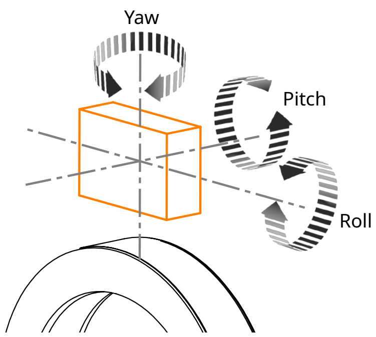
Values in mm.	LM10	LM15
No Ri	0 ±1	0 ±1
Magnetised Ri	0 ±0.7	0 ±0.7



Readhead — Magnetic scale

Readhead to scale

Roll	±3°
Yaw	±3°
Pitch	±3°



At lower ride height the readhead can come into contact with the magnetic scale within the roll-pitch-yaw tolerances.

Installation instructions

Installation of the scale

Before starting the installation process, please make sure that you use **the rolling tool (ACC089)** and the **mounting fluid (ACC077)** for the correct installation of the FlexIN scale. These two accessories are essential to achieve the best alignment and system performance and to ensure a secure and accurate fit.
The following installation instructions for the FlexIN scale describe step by step the installation of the scale, the preparation of the surface, the alignment and the final adjustment. You can also follow the installation instructions shown in the video.

FlexIN installation video

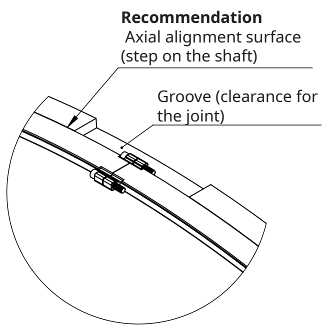
Method for axial alignment of the scale

Depending on the mounting surface, there are two options for the axial alignment of the scale to ensure optimum system performance. Both methods are designed to enable accurate and efficient installation of the scale and integrate seamlessly into your system.

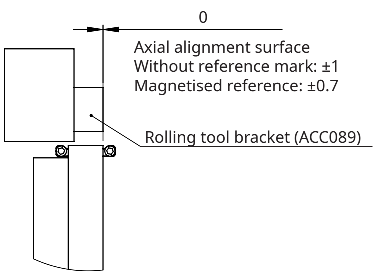
Option 1
Step on the shaft acts as a stop barrier for accurate lateral positioning of the scale. A groove must be milled into the mounting surface to ensure enough room for scale joint. Groove must allow enough space for fastener mounting. This method provides a physical guide that ensures the scale is perfectly aligned with the axis of the machine.

Option 2
The surface of the rolling tool bracket is used as a reference point. By aligning the scale to the surface of the rolling tool bracket, you can achieve precise positioning without additional machining.

Option 1
Recommended



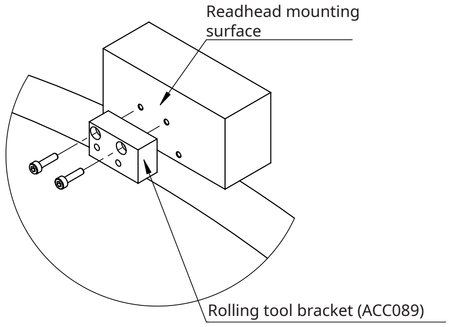
Option 2



Installation process

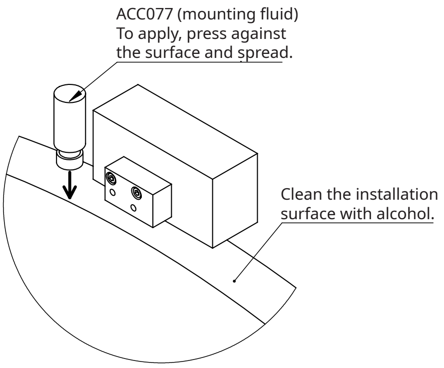
1. Preparation for the installation of the rolling tool

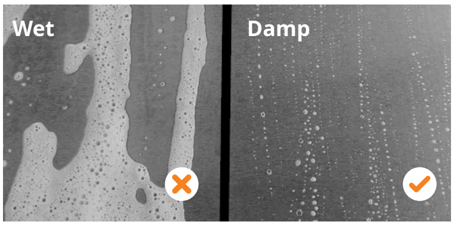
Prepare the readhead mounting surface. Install the rolling tool bracket by using the mounting holes where the readhead will be installed.



2. Preparation of the installation surface

Start by thoroughly cleaning the installation surface to remove dirt, debris and contaminants. This will ensure a clean bonding environment for the scale. After cleaning, evenly apply a layer of the recommended mounting fluid to the surface. Make sure that the entire surface is damp. This will make it easier to position and adjust the scale during installation.

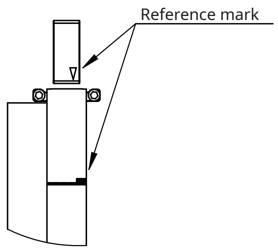


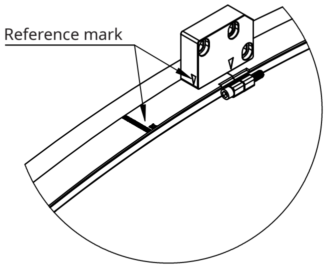


The use of a lubricant is required for all diameters. A moderate amount of mounting fluid ACC077 must be applied, as shown in the picture. The surface must be damp, not wet.

3. Setting up the scale

Carefully place the scale with the rubber side on the prepared installation surface without twisting or bending it.

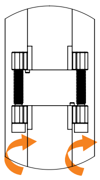




Make sure that the alignment of the scale and the readhead is correct.

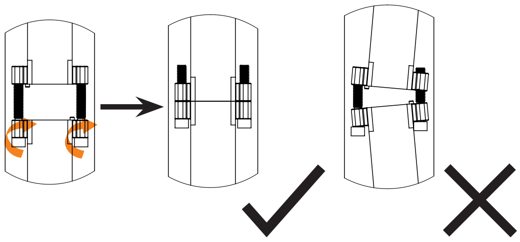
4. Securing the scale ends and axial aligning

Loosely connect the ends of the scale with the specified fasteners by leading them through the threads located in the adjacent connecting element. Align the scale in the axial direction on a reference surface around the entire circumference.



5. Connect the scale ends

Tighten the two fasteners alternately and gradually, no more than one full turn at a time. The maximum torque is 0.6 Nm. Make sure that the connecting elements remain parallel during the process.



Maximum torque is 0.6 Nm. No more than a full turn at a time.

Always make sure that the scale is axially aligned and has not moved from the required position.

6. Installing the rolling tool (ACC089)

Mount the rolling tool on the bracket. (Fig. 1.) Press the rolling tool down so that the connecting elements touch the installation surface. (Fig. 2.) Secure the roller in position by tightening the fasteners on the rolling tool.

Fig. 1

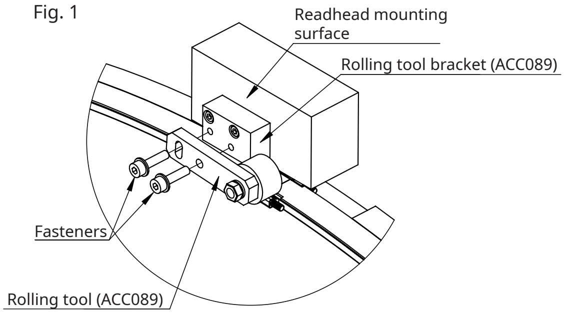
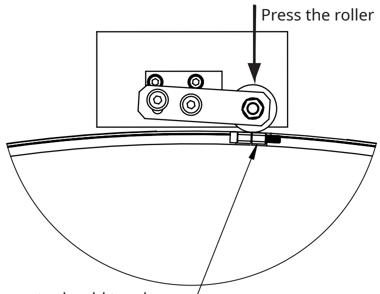


Fig. 2



If the rotation of the hub is not possible and ACC089 cannot be used, another rolling tool can be used to roll around the circumference manually.

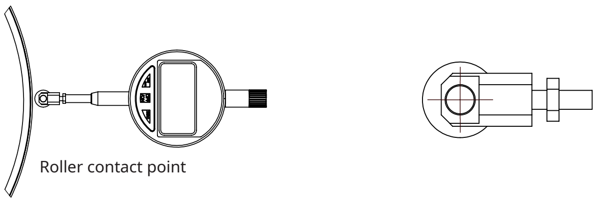
The magnetic scale can easily be damaged by sharp edges, so use a smooth and soft roller.

The roller should be pressed onto the magnetic scale with enough force to bend the scale and compress the rubber spring profile under the scale.

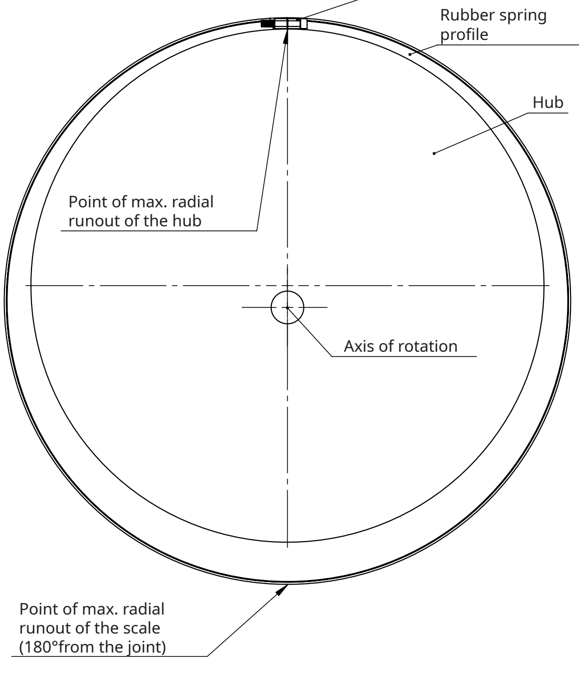
7. Improving radial runout circumference

This step is important to reduce eccentricity.

Use a rolling tool to roll along the length of the scale while rotating the axis for at least 10 full rotations. Unfasten the wheel of the rolling tool and lift it from the scale. It is necessary to measure the radial runout with a dial indicator. If the radial runout of the magnetic scale does not meet the requirements, you can improve it by rolling another 10 full rotations or more.



Maximum allowed radial runout of the magnetic scale	
LM10	±0.3 mm
LM15	±0.4 mm



Use a dial indicator with low exertion force to avoid scratching the scale surface. A digital indicator with a roller is recommended.

If the required radial runout cannot be achieved, check the radial runout of the hub with a dial indicator.

The radial runout of the hub and the magnetic scale can be subtracted if the scale joint is placed at the point of max. radial runout the scale.

8. Uninstalling / Removing the rolling tool

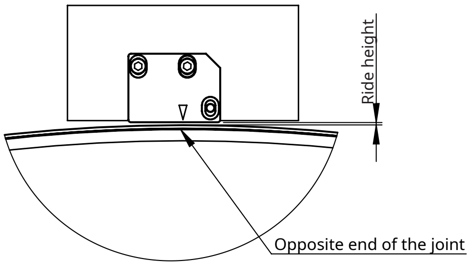
Once you have successfully improved the radial runout of the scale, you can uninstall and remove the rolling tool.

9. Axial alignment

After radial alignment, the belt must be checked for lateral alignment using the method selected at the beginning of the installation. The permissible axial deviation is ±0.7 mm.

10. Installing the readhead

Set the ride height according to the specifications in the data sheet of the readhead. The rideheight must be set on the opposite side of the joint element where the eccentricity is highest. The LED on the readhead immediately indicates whether the installation was successful or adjustments are required. The properly installed FlexIN scale is ready for use after 1 hour. After 24 hours it is suitable for use under maximum load.



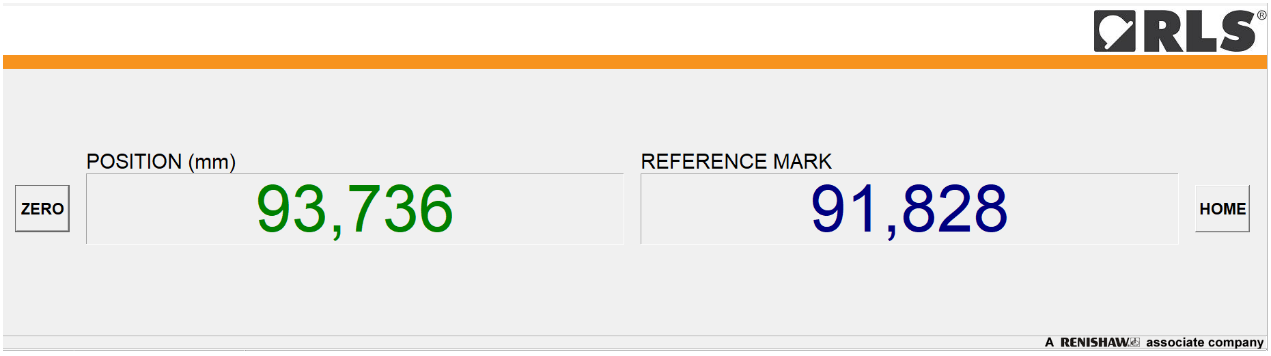
Ride height	LM10	LM15
Values in mm.	0.1 - 0.8 (recommended 0.3 mm)	0.1 - 2.5 (recommended 0.5 mm)

The ride height should be set on the opposite side of the scale joint.

11. Steps to control the system when required radial runout is not achievable

If we do not achieve the required radial runout, the system can be checked using the E201 interface. Connect the readhead to the E201 interface and observe the LED display on the readhead. If the LED indicator lights up green during the entire rotation, the system is working correctly.

The reference mark must be checked in both directions and over at least 10°. If the position value of the reference mark is the same in both directions, the system is working correctly. Check the display of the reference mark indicator on the monitor - see picture below.



Part numbering

FI 2000 A 5500 A 5500 A1 00

Pole length

2000 - 2 mm pole length (for use with LM10 readhead)
5000 - 5 mm pole length (for use with LM15 readhead)

Accuracy class

A - ±20 µm/m (for use with LM10 readhead)
C - ±100 µm/m (for use with LM15 readhead)

Scale length *

xxxx - Where xxxx equals scale length in poles

* Maximum scale length is 11,000 mm. To calculate the scale length and the number of poles, please use the **online calculator**.

Reference mark

A - Unique reference mark
B - No reference mark

Reference position

xxxx - Where xxxx equals scale position in poles, calculated from angle position from the scale joint
0000 - No reference mark

Readhead compatibility

A1 - LM10
A2 - LM15

Special requirements

00 - No special requirements (standard)

Table of available combinations

Series	Pole length	Accuracy class	Scale length	Reference mark	Reference position	Readhead compatibility	Special requirements
FI	2000	A	xxxx	A	xxxx	A1	00
				B	0000		
	5000	C		A	xxxx	A2	
				B	0000		

Accessories

Rolling tool (including fasteners)
ACC089

Mounting fluid
ACC077

Magnet viewer
MM0001

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Document issues

Issue	Date	Page	Description
1	10. 9. 2024	–	New document
2	7. 10. 2024	13	Accessories added to installation description