Hall probe bench prototype
for closed magnetic structures

ALBA Synchrotron Light Source,
Engineering division, Transversal section

Llibert Ribo, Carles Colldelram, Liudmila Nilkitina, Pep Campmany
Summary

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• Validation
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• Conceptual design: and dimensions
• Materialization and Description
• FEA
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Requirements

- Upgrade to the ID lab to measure closed magnetic structures
- Long longitudinal Measuring ranges (up to 3 m)
- Vertical and transversal direction scans
- Small Guidance error on positioning the hall sensor (order of 0.05 mm)
- Very small angular deviations (order of 0.05 mrad)
**concept**

- Hall sensor attached on a string tensioned on a C shaped arc structure
- The string is passing through the closed magnetic structure
- The arc is moved by an accurate positioner

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**Simple Idea**

![Diagram of the concept](image)

**Arc length 2L**

**Length needed for the measurement 3L**

**THIS CAN WORK??...**

- We are able to materialize that arc and move it with a positioner of a precision level of a machining tool
- We will need a lot of space and we have it
- Is a string stable enough once it is tensioned?
Validation

The Vibrating string

A string under tension has a mode of vibration on the first harmonic which frequency depends on the **vibrating length**, the **tension** and the **linear mass**.

\[ f = \frac{1}{2L} \sqrt{\frac{T}{\mu}} \]

*When this is excited, will have direct impact on the positioning accuracy of the hall sensor.*

Calculation of the 1st harmonic vibration

- L ≈ 4000 mm
- Area 24x1,4 mm²
- Material Pultruded carbon fiber d=1600 Kg/m³
- Elastic limit 2800 Mpa

\[ T = 7,5kN \rightarrow f = 55 \text{ Hz} \rightarrow \text{stress} = 223 \text{ Mpa} \]

At ALBA environmental low frequencies are considered under 30 Hz. This value is taken as a reference when designing in a safe margin.
Validation

- Evaluate fundamental frequency modes of a tensioned strip of the same section calculated previously
- Inducing external excitation for amplification checking
- Very simple exercise to confirm the analytical values of the frequencies and the amplitude
Specification and parts

Ranges.

\[ X : \pm 125 \text{ mm} \]
\[ Z : \pm 50 \text{ mm} \]
\[ Y : 1200 \text{ mm} \]

Chamber allowance (“stay clear” area) = 600 mm

Longitudinal POSITIONING ERROR

\[ dX, dY, dZ < 0.05 \text{ mm} \]

Angular POSITIONING ERROR

Roll \( d\alpha \), Pitch \( d\beta \) < 0.05 mrad

Yaw \( d\phi \) < 0.1 mrad

Repeatability

\[ X, Y, Z \leq 0.03 \text{ mm} \]

Speed

\[ Y \sim 15 \text{ mm/s} \]
Dimensions

Side View

- 2600
- 1400
- 650
- 650
- 4300

Top View

- 1445(+125)
- 600

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Materialization: arc structure

Strip dimensioning

- Area 16x1.4 mm²
- Vibrating length 2600 mm
- \( d = 1600 \text{ Kg/m³} \)
- Tensioning force 0.5 TN

Results

- Stress = 223 Mpa
- Security factor = 13
- \( f_1 = 71 \text{ Hz} \)
- Elongation \( \sim 4 \text{ mm} \)

Arc structure

- Aluminium profile structure
- Two tensioning blocks one with stretching gauge
- Mass around 400 Kg
Z stage

- Double flexure system on a granite block
- Compact design: with a single step Z&pitch
- Allows Z range of 100 mm and tilt about 0.2º
- Flexures on high modulus material
- Preloaded guiding system and grinded spindles
- Movement for each flexure is encoded
- Mass of that assembly around 1.2 Tn
XY stage

• X stage: 2 actuators are implemented to avoid rotation on the vertical axis due to the long beam.
• Y stage: Measurement axis: All mounted on a granite block.
• Preloaded roller and matched guides.
• Separation between those guides affect on the vertical accuracy.
• Mass of the XY stage 5 Tn.
FEA calculation

F = 1000 Kg

Max = 0.94 mm

Max = 53 MPa

F = 1000 Kg

32 Hz

Max = 134 MPa

42.5 Hz

Max = 134 MPa
Mounting

XY stage

- Verification of the components with alignment and metrology group

- Big granite block is aligned flat on respect to the floor.

- Interface plate fitted in top. Checking the slots where the transversal guides are. Grinding was corrected several times

- Very accurate alignment of the sets of linear guides
Mounting II

- Hollowed granite block is located on top of the XY stage
- The assembly is stopped to test the motors and perform some measurements to test the actuator
Mounting III

Arc structure

- Stretching system
- Carbon fiber is cutted by water
- The assembly is stopped to test the motors and perform some measurements to test the actuator
- C structure and stretching system are mounted in parallel
- Carbon fiber is tensioned up to 1Tn
Results: Y Scan

LONGITUDINAL MOVEMENT – Measure of the straightness at 1200 mm scan (+ direction)

LONGITUDINAL MOVEMENT – Measure of the straightness at 1200 mm scan (- direction)
Results: Z Scan

VERTICAL MOVEMENT – Measurement of straightness 100 mm
(+ direction)

VERTICAL MOVEMENT – Measurement of straightness 100 mm
(- direction)
Angle evolution

ROLL EVOLUTION MOVING ALONG Y AXIS
Vibration static

![Graph showing vibration static analysis]

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Vibration on movement

Graph showing vibration spectrum with data from different channels. The graph indicates frequencies and their corresponding amplitudes.
Next steps and Conclusions

• Finish the measurements (X scans and repeatability) and prepare a performance report for the ID group is needed to inform the magnetic measurement group.

• Hall sensor integration and first measurements with a calibration magnet

Conclusions

• Specifications are almost guaranteed

• It can work for very narrow gap closed structures up to open conventional dipoles

• That solution tooks a big space for the operation range

• If this short prototype succeed, a 3 m range bench can be considered using this concept
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