DESIGN OF A LOW-COST SYSTEM FOR THE MEASUREMENT OF THE RADIAL DISPLACEMENTS OF A CYLINDRICAL METAL TARGET

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1. INTRODUCTION

This study aims to implement an acquisition system for monitoring and measuring the radial displacement of a cylindrical metal target. Traditional methods often use capacitance or inductive sensors [1, 3, 4, 5, 6]; however, this research presents a novel application of inductive sensors exploiting flexible planar coils placed on curved surfaces and combined with low-cost inductance-to-digital converters (LDCs). This solution allows for high sampling rates and submicrometric resolution, making it suitable for applications requiring accurate radial displacement such as vibration monitoring. The experimental setup, including custom planar coils and a dedicated test bench, was implemented to measure radial displacement and to assess the system's accuracy and effectiveness.

2. MATERIALS AND METHODS

An inductive sensor consisting of an L-C resonant circuit, together with the LDC1101 converter (by Texas Instruments), is used. The latter allows both to keep the coil oscillating and to measure its equivalent parallel parasitic AC (alternate current) resistance value R_P or inductance L, whose variation is proportional to the distance of the sensor from the target. Three planar inductive coils were positioned at equal intervals along a circumference surrounding the target cylinder with a fixed gap at 120° from each other in the configuration shown in Figure 1. The proposed configuration enables the derivation of radial displacement from the distances measured by these position sensors. For an arbitrary sensor placement with orientation α_i, (1) can be obtained. where R is the distance between the centre of the cylinder and the i-th sensor mid-point, s_i is the sensor reading distance, r is the radius of the cylinder, and $(x_0,\, y_0)$ is the cylinder centre position in the plane shown in Figure 1.

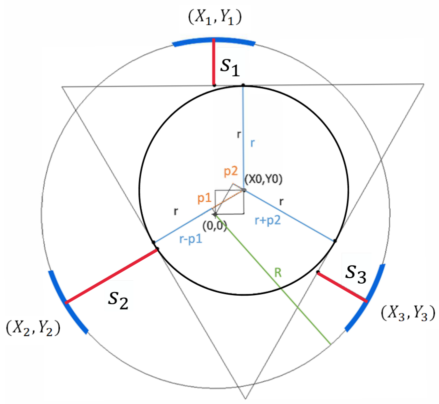

Figure 1: Configuration with 3 inductive sensors placed at equal intervals along the circumference of the target cylinder. The figure represent a section perpendicular to the cylinder's axis.

$$R = s_i + r + \cos(\alpha_i) \cdot x_0 + \sin(\alpha_i) \cdot y_0 \tag{1}$$

Form the Euclidean distance between the origin $(0,\, 0)$ and the cylinder centre position, the expression (2) can be obtained.

$$d = \frac{\sqrt{(s_2 - 2s_1 + s_3)^2 + 3\,(s_2 - s_3)^2}}{3} \tag{2}$$

Then, the uncertainty associated to the radial displacement measurement was derived exploiting the JCGM's Guide to the expression of uncertainty in the measurement [2]. A re-configurable test bench was set up to allow calibration and comparison tests between different coil and target configurations. A stepper motor, with a theoretical linear full-step of $165\,\mathrm{nm}$, is used to move a carriage back and forth, where test targets are placed. The LK-G5001P laser displacement sensor with the LK-H800W sensor head (by Keyence) is used as position reference.

3. PRELIMINARY RESULTS

Calibration of the eddy-current sensors was carried out, and a preliminary measurement of the radial displacement was obtained. Then, the uncertainty related to the displacement from origin d was derived, as shown in Figure 2.

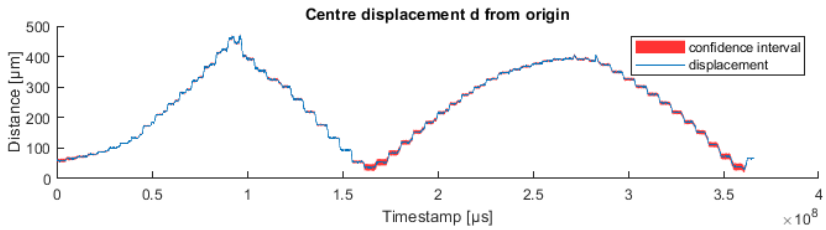

Figure 2: Centre displacement d from origin and associated uncertainty.

4. CONCLUSIONS

A test bench for calibrating custom flexible planar coils has been realised. A methodology was proposed to estimate the displacement of a cylindrical metal target. To estimate the target centre position, the test bench has been designed to examine three curved sensors placed on a circumference around it. In this work, the measurement accuracy of the target centre displacement from the origin is evaluated. The use of both R_P and L information could improve the measurement accuracy, exploiting optimisation algorithms for multi output calibration problems.

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