Success Story
COMET

ASSIC
Austrian Smart Systems Integration Research Center
Programme: COMET – Competence Centers for Excellent Technologies
Programme line: K1-Centres
COMET subproject, duration and type of project:
New MEMS Sensors for Harsh Environment, 07/2015 – 12/2018, strategic

Powerful Analytics for Speed Sensing Technology

Integrated vehicle electronics that improve driving comfort and driving safety heavily rely on the output of sensors of the automobiles. One important example are wheel speed sensors that detect the rotary velocity of individual wheels to provide anti-lock braking system (ABS) and the electronic stability program (ESP) with reliable information. CTR developed an innovative analytical solution for magnetic wheel speed sensors which describes the influence of eddy currents that develop in such systems. Within the formulas a novel approach to suppress eddy influences was found, offering an opportunity for the development of distortion-free sensors with higher resolutions.

Background: Magnetic Speed Sensors

Wheel speed sensors measure the angular velocity of rotating axles. In the automotive industry they are used to feed data to intelligent vehicle electronics for the Anti-lock Braking System (ABS), the Traction Control System (TCS) and the Electronic Stability Program (ESP). New ideas focus on obtaining more information from the speed signal like tire pressure and wear, road conditions and other information to improve driving safety, driving comfort and driving dynamics. Several of those applications benefit from high resolutions and are critical for passenger safety that requires a high level of reliability of the sensor system, which is the reason for this study.

The most common realization of speed sensor systems is based on magnetic sensors and has been used in cars for decades. A so-called back-bias implementation is sketched in Fig. 1. It features a ferromagnetic cogwheel which is mounted on the rotating axle, a permanent magnet next to it generates the field and a magnetic sensor that is placed in-between the two. The sensor detects the modulation of the magnetic field when the cogwheel rotates and the angular velocity can be determined from it.

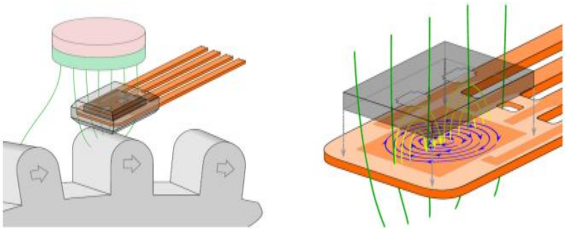

Fig. 1: Magnetic wheel speed sensor system and eddy influence.

Such an implementation has all the advantages of magnetic sensor systems, which include contact-free and thus wear-free operation, low cost, robustness against temperature and dirt as well as low power requirements, all highly sought for properties for industrial application.

However, modern sensor chips are mounted on top of metallic lead frames. By placing the sensor inside the oscillating magnetic field eddy

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currents develop in the conductive lead frame, distort the field and thus the output of the sensor system. It was shown in previous FEM simulations that this effect cannot be neglected for frequencies above 10 kHz for state-of-the-art magnetic sensors. Such frequencies are easily reached in applications so that this effect must be studied in detail and methods to suppress, or compensate it must be found.

The Analytical Solution

Time-dependent magnetic fields generate an electrical voltage according to Faraday's law of induction. When they penetrate a conductive medium the electrons inside the medium follow the voltage - a current is generated. This so-called eddy current produces a magnetic field itself that is, by Lentz's rule, opposed to the original field which then becomes suppressed, see Fig. 1.

This behavior is described by a differential equation which must be solved on the respective system geometry that includes the magnet size, shape and magnetization, the detailed description of the cogwheel as well as the sensor chip and lead frame. The absolute eddy influences strongly depend on this geometry.

However, the solution shows that there is a strong connection between the eddy effects and two critical ratios that do not depend on the system geometry but include the penetration depth, the lead frame thickness as well as the spatial extent of the field, see Fig. 2. It was possible to isolate these major influences and to make general statements about eddies in speed sensor systems that were then confirmed by FEM simulations.

A puzzling Effect

While working on the solution a puzzling effect was observed. It seemed that at high frequencies, when a maximal distortion is expected, the eddy influence itself could be suppressed by moving the sensitive element closer to the lead frame. In fact, the equations predicted, that the distortion would disappear exactly on the lead frame surface.

At first it was thought that such an effect cannot exist and must be a so-called artefact, a remnant of a mathematical approximation used in the derivation. But it was shown by subsequent FEM simulation that the effect could be reproduced and must therefore be of a physical nature.

While it is not fully understood at this point the effect implies that the sensitive elements in a magnetic sensor can be shielded from eddy influences on the lead frame by positioning them as close as possible to the latter rather than further away.

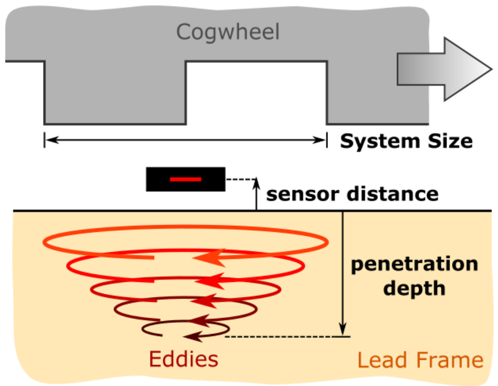

Fig. 2: Sketch of the three critical parameters inherent to all lead frame based magnetic speed sensor systems.

The results of this work were published in three subsequent journal papers. One mark of regard for this work is that one paper was chosen for the title page of the IEEE Magnetic Transactions journal. Future work is dedicated to improve understanding of the strange effect found by the analytical method and to extend the formalism to the intermediate frequency regime.

Contact and information
K1-Centre ASSIC

CTR Carinthian Tech Research AG
Europastraße 12, 9524 Villach
T +43 (0) 4242-56300-0
E info@ctr.at, www.ctr.at

Project coordinator
Dr. Michael Ortner