Stress Zone Imaging in Steel Plates using Multi
Coil Array Sensors

M. Neumayer1, D. Watzenig1, and B. Brandstätter2
1Institute of Electrical Measurement and Measurement Signal Processing,
Graz University of Technology, Kopernikusgasse 24/IV, A-8010 Graz, Austria.
2Elin Motoren GmbH, Elinmotorenstrasse 1, A-8160 Preding/Weiz, Austria.
E-mail: neumayer@TUGraz.at

Abstract—Stress zones in electrical steel are referred to as parts
of steel sheets of electrical machines which have seen severely
mechanical stress during the production process of the machine.
The mechanical stress (cutting punching, etc.) causes decreased
electrical material properties in the active part volumina leading
to increased losses. In this paper we will extend the latest
developments of stress zone imaging - this is an imaging technique
to determine spatial material properties of the sheet by the use
coil sensors - towards the use industrial sensors in order to image
the properties close to the cutting edge.

Index Terms—Eddy current, inverse problem, optimization,
electrical machines, steel

I. INTRODUCTION

By providing the magnetic path for the flux inside electrical
machines, steel sheets are the central components of the stator
and rotor in any rotating electrical drive. Electro steels are
produced in steel companies and provided to the machine
factory in form of rolls. Then the parts parts of the stator
and the rotor a cut out to obtain the slices of the later machin-
ery parts. During the manufacturing process the steel sheet
receives severely mechanical stress due to the different steps
of the production process like cutting, punching and bending.
These processes effects the electromagnetic properties of the
steel sheet in a negative way (increased losses). Figure 1 shows
two figures of steel sheets during the production process.

(a) Steel sheet with punching burrs.
(b) Steel sheet with removed punch-
ing burrs. Additional isolation is re-
quired.

Figure 1. Steel sheet during the production process.

In the works of Nakata [1], Saito [2] and Ossart [3] the
effects of stress due to cutting, punching and bending of
the sheets are reported. Even the last two production processes
showed similar effects as cutting. The significance of this
topic is due to the fact, that decreased magnetic properties
cause increased iron losses in the active parts volumina of
the machine. The impact of these losses (eddy current and
hysteresis) even becomes more important to the fact that the
power densities steadily increase.

An early method to determine local electromagnetic
properties of the sheets was invented by the Austrian E.
Werner in the late fifties of the last century [4]. For the so
called needle probe method, electric currents are injected into
the steel sheet by two needles. A magnetic field probe (i.e.
a Hall probe) is used to measure the magnetic field strength
at the surface of the steel sheet. As the magnetic properties
modulate the field strength at the surface, the sensor signal
can be used to quantify the material properties. In 2000 Senda
et al. proposed a modified version using several needles.
However, as needle probe based systems offer drawbacks like
the destruction of the insulation layer. Also the measurement
process is of time consuming nature, as these methods only
take local measurements.

A contrary model based approach to determine local
material parameter deviations in the steel sheets was
presented by the authors in 2010 [5]. In this work a coil array
was placed above a steel sheet. Figure 2 depicts the simulated
arrangement. Using measurements from the coil array an
inverse problem [6] is solved, which allows a reconstruc-
tion of the spatial material parameters. The work was a simulation
feasibility study for stress zone imaging using a coil array.

In this paper we will present further develops on the idea of
stress zone imaging using coil array sensors and consider the
reconstruction of material parameters in the region of the edges
of the steel sheet. In contrast to the initial publication presented
in [5] we will consider the use of commercial available multi
coil array sensors in order to push the development of the
sensor system.

A. Idea of the Model based Approach

Model based approaches for solving indirect or inverse
measurement problems are based on the use of a computer
model, or forward map, $F : x \mapsto y, x \in \mathbb{R}^N, y \in \mathbb{R}^M$,
which simulates the physical measurement process $P : x \mapsto \tilde{d}$.
Hereby $\tilde{d} \in \mathbb{R}^M$ are the measurements which are corrupted
by noise. The parameters of interest are summarized into the parameter vector \( x \). The measurement problem is to find \( x \) given the data \( \tilde{d} \). Classical deterministic solution approaches are formed by the way of optimization problems. Typical approaches are given by the form

\[
\xi^* = \arg \min_x \left\{ \|y(x) - \tilde{d}\|^2 + \alpha \|R(x)\|^2 \right\}.
\]

(1)

The first term in equation (1) minimizes the data misfit between the measurement \( \tilde{d} \) and the model output \( y \). The second term is a regularization which is required to stabilize the problem due to its numerical instability caused by its ill-posed nature [8],[5].

The forward map \( F \) for solving the inverse problem of stress zone imaging is an eddy current problem which aims on the computation of coil parameters given the geometry and the parameter vector \( x \). Various standard approaches for solving the underlying eddy current problem are summarized in [7]. Methods for solving (1) are found in numerical optimization theory [9].

For the physical measurements we consider the use of a an industrial available multi coil probe sensor as depicted in figure ?? The sensor head delivers the measurements \( \tilde{d} \). Such sensor heads were originally developed for non-destructive material testing.

B. Outlook

The final paper will include a detailed description about the use of industrial multi coil array eddy current sensors for stress zone imaging at the cutting edges of steel sheets. The paper will present the results from simulation studies, as well as an analysis of the system properties in order to further develop the measurement system.

REFERENCES