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DEGRADATION OF MAGNETIC PROPERTIES OF ELECTRICAL STEEL SHEETS DUE TO DIFFERENT CUTTING TECHNIQUES

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Introduction

The magnetic properties of electrical steel sheets, such as those typically used in electric machines, are adversely affected by cutting. The most common cutting technique in industry is punching. Laser cutting has been increasingly used, too, especially for small production batches and prototypes. The degrading effect of laser cutting on the material's magnetic characteristics is much less understood than that of mechanical cutting. We summarize key results on the influence of different process parameters on the material degradation and present a modeling approach that can be used as tool for electric machine design.

Influence of cutting techniques on the magnetic properties

The degrading effect of the cutting process on the magnetic properties depends on many parameters, notably the material investigated (chemical composition and grain size) and the settings of the cutting technology (e.g., clearance, blade radii, tool wear, cutting speed, cutting mode, power). In the following, the main results of an extensive analysis of three different electrical steel sheet materials, cut both mechanically as well as by laser cutting, investigated at different frequencies *f*, and over a wide range of magnetic flux densities *B*, are summarized. The measurements are carried out by Epstein frame measurements according to the standards IEC 60404-2 and IEC 60404-10 [1, 2].

At small magnetic flux densities, mechanical cutting typically has a smaller degrading influence in the specific losses than laser cutting. At medium or elevated magnetic flux densities, the effect of laser-cutting may be smaller. The relative difference between these two effects and the point of intersection depend on the amount of degraded material, i.e., the specimen's shape, and on the respective material and frequency investigated. With increasing frequency and specific cutting length, this point of intersection moves to smaller magnetic flux densities. (e.g. Fig. 1)

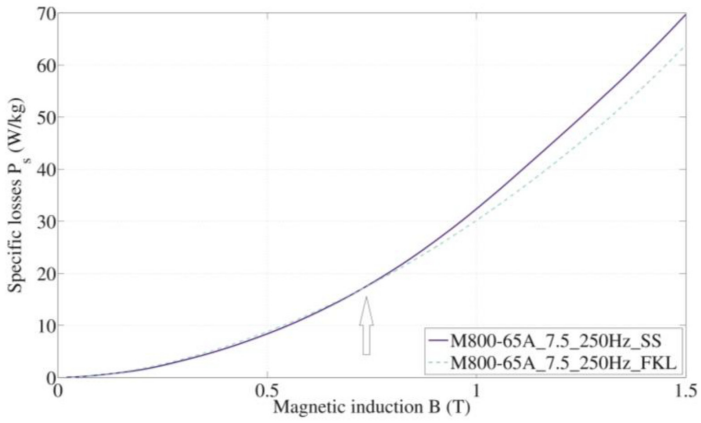

Figure 1: Exemplary point of intersection of specific losses of mechanically-cut and laser-cut samples [3, 5]

Both cutting techniques decrease the relative permeability of the electrical steel sheets. Especially at low magnetic flux densities, the detrimental effect of laser-cutting is larger than that of mechanical cutting. Here again, a point of intersection occurs after which the permeability of the laser-cut samples is better than the one of the mechanically-cut samples.

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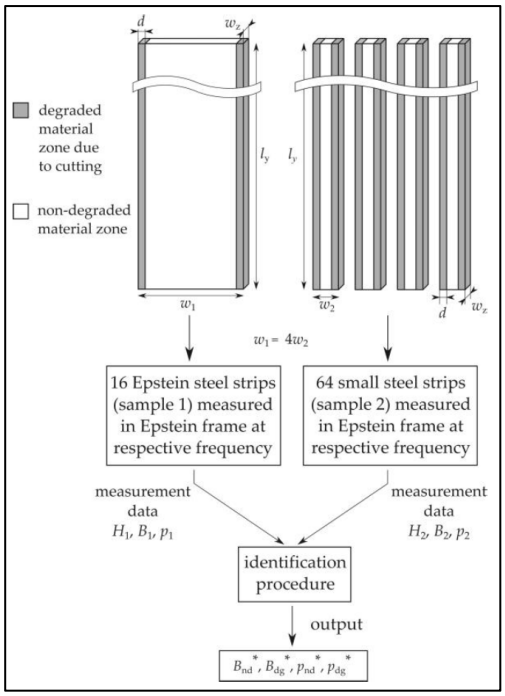
Modeling the influence of cutting



The influence of cutting may be considered in the design and analysis of an electric machine by a straightforward modeling approach, that is applicable to arbitrary geometries and which considers, at least indirectly, the influences of different materials and settings. It is based on measurement data obtained by the standardized, widespread and fast-to-perform Epstein frame method (see Fig. 2). It does not require information on specific material characteristics such as (changed) grain size and chemical composition, as this can be indirectly inferred from the measurement data. The losses computed for different stator cores corresponded well with the measured ones, both for mechanical and for laser cutting, and for different materials and frequencies (e.g. Fig. 3).

Figure 2: Schematic procedure to identify loss data to model the degradation effect due to cutting. [4, 5]

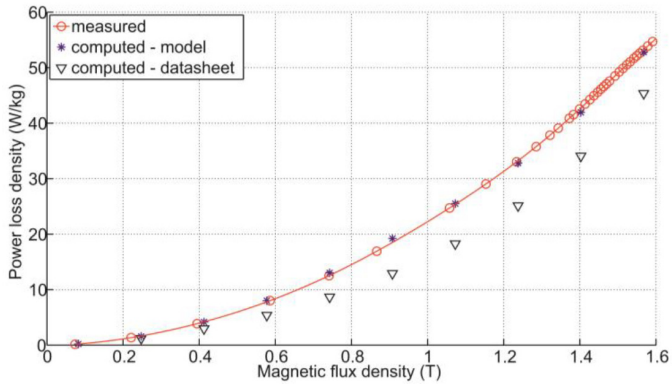


Figure 3: Specific losses of a stator core stack, material M400-50A, 250 Hz: measured, computed by the proposed approach, and computed from the datasheet provided by the manufacturer [4, 5].

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