Multi-layered cutting of thin non-oriented electrical steel sheets

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Thin, non-oriented electrical steel laminations under 0.25 mm offer reduced high-frequency losses compared to thicker grades, due to a substantial decrease in classical eddy current losses. Cutting of electrical steel deteriorates the magnetic properties significantly. In this paper, electrical steel samples are not just cut individually, but as multi-layered stacks. The influence on the magnetic properties as well as on the cut-surface are studied in detail in order to enable future considerations concerning the best possible combination of cost, quality and quantity when cutting thin electrical steels.

Keywords: non-oriented electrical steel; cut-edge effect; thin electrical steel laminations

1. Introduction

In order to use electrical steel in rotor and stator components of electrical machines, the sheets need to be cut into the desired geometry. This is usually done in series production via sheet metal blanking/punching [1]. Unwanted induced residual stress remains within the components and alters the magnetic properties due to the magneto-mechanical coupling (i.e. Villari-Effect) [1,2]. The optimization of punching parameters to minimize the detrimental effects is part of ongoing studies [3].

Furthermore, sheet thicknesses of electrical steel are further reduced to minimize eddy current losses. Consequently, this results in an increased punching workload since more sheets need to be cut to reach the same rotor height, increasing process times, tool wear, and cost.

The presented study addresses these topics through a simultaneous multi-layer cutting approach. This requires no mechanical connection of the individual sheets (i.e. interlocking, packaging). The magnetic properties, as well as cut surface quality and residual stress, are examined.

2. Results and discussion

In this study, two industrial electrical steels with 0.1 mm and 0.2 mm thickness are cut on an industrial press BSTA 50-110 with varying layers. Conventional single sheet blanking (one-layer) is compared with stacking of two sheets (two-layered) and three sheets (three-layered) respectively while being cut as schematically displayed in Figure 1 (a). The cut sample strips have a geometry of 10 mm x 60 mm. Six of these strips are each taped together and measured on a 60 mm x 60 mm Single Sheet Tester, according to the established methods as described in [4]. The influence of cutting clearance (CCL) relative to sheet thickness as well as with varying stacking numbers are studied.

In Figure 1 (b) the comparison of cut surfaces for one-layered and two-layered cutting are displayed for the 0.2 mm steel sheet. The amount of shear and brake ratio changes in multi-layered cutting depending on the sheet position (bottom, top), when relative CCL is constant. In Figure 2, results of magnetic measurements at 50 Hz for the 0.2 mm steel sheet are displayed. For all cut samples, the magnetization deteriorates relative to the uncut samples, as expected. The effect of multi-layered cutting is in the same order of magnitude of CCL variations. Furthermore, it can be observed that bottom layers show distinctly less deterioration than top-layered laminations after two-layered cutting for this material. Furthermore, bottom sheets show less deterioration for the same relative CCL per sheet than the one-layer-cut sample. This aligns with optical analysis, as depicted in Fig. 1 b), since brake surfaces would expect less plastic deformation.

In the full paper, neutron grating interferometry will be added to analyse the residual stress and subsequent domain change, in the cut-edge region as in [5,6].

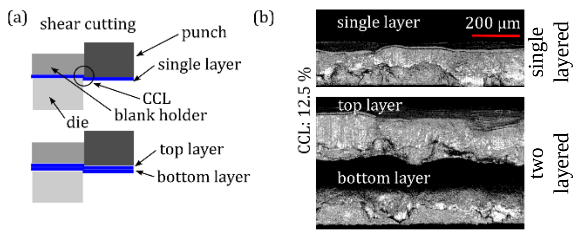

Figure 1: (a) Schematic description of multi-layered cutting, (b) cut-surfaces of 0.2 mm single/two-layered cutting with laser-optical microscopy at 25 µm CCL (single) and 50 µm CCL (two-layers) .

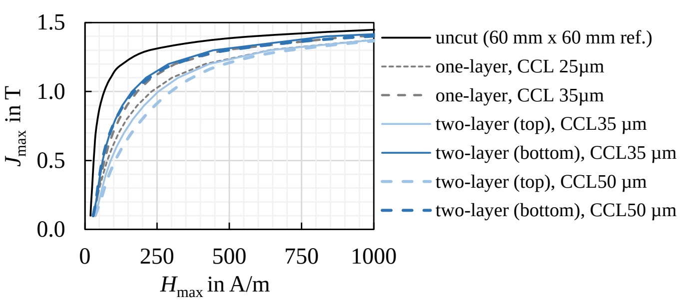

Figure 2: Magnetization curves for multi-layered cutting with different cutting clearances at 50 Hz.

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