Change in soft magnetic properties during forming technology production

Florian Poltschak[a]

[a] *Johannes Kepler University Linz, Austria*

The process of forming is a widely used method for mass production especially of magnetic solenoid cores. Recently this method of manufacturing gains attraction as a cost-efficient way to manufacture components for electrical machines of any type. While it is well known that plastic deformation alters the magnetic properties of the steel, this fact is often ignored during the machines design process due to the lack of available material data for the respective zones. This paper presents a comparably simple, but accurate, methods to identify the required B/H-curve of the plastically deformed zones.

Keywords: soft magnetic material properties; plastic deformation; cold forming; core loss separation; magnetic hysteresis properties

1. Introduction

Cold metal forming offers a cost-efficient method for mass production of components used in the magnetic circuits of magnets or electrical machines [1]. Previous analyses identified a significant change in hysteresis properties resulting from plastic deformation at the edges during the manufacturing process of punching the core lamination steel [2, 3]. An interesting application of this effect is, that the locally distributed changes in soft magnetic properties due to plastic deformation during the manufacturing process, can even be used as finger print in non-destructive material identification [4], what illustrates its significance.

The focus of this paper lies on the identification of the altered material properties in the formed regions to derive the B/H curve of these deteriorated material sections. The result can be used during the machine or actuator design process e.g. in an FE analysis. Flat as well as folded ring samples of different steel grades typically used for solenoids have been manufactured. Their magnetic characteristics have been analysed in detail and compared against each other. This results in a method to derive the significantly modified B/H characteristics of the plastically deformed regions.

2. Results and discussion

To achieve a comparably simple method to analyse the influence of plastic deformation a multiple bent ring sample has been developed. This sample, illustrated in Fig. 1 allows to identify plastically deformed and non-modified regions.

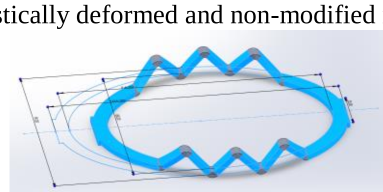
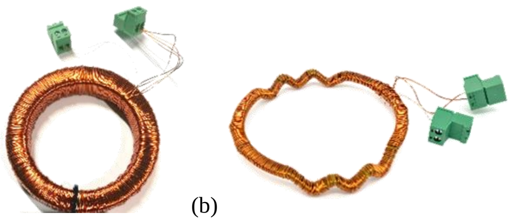


Figure 1: Design of the ring sample consisting of plastic deformed regions (grey) and not modified regions (blue).

Several effects need to be considered to successfully simplify the applied winding as shown in Fig. 2. As second step hysteresis measurements of a plastically deformed and an unmodified ring sample are carried out.



(a) (b)

Figure 2: Twice the same folded ring sample: (a) with cylindrical rapid prototyping cover for an easier manufacturing of the winding and (b) a directly would sample for comparison.

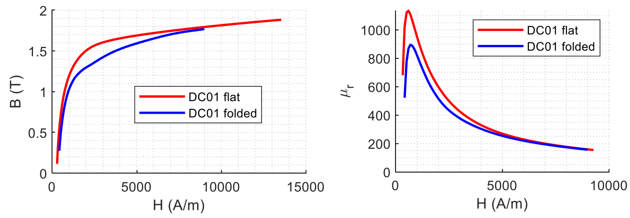


Figure 3: Derived material characteristic of the original (red) and formed (blue) DC01 metal sheet. Flux density vs. field strength (left) and relative permeability vs. field strength (right).

From the comparison of a flat and folded sample made from the same metal sheet, the magnetic characteristics of the plastically deformed region can be derived.

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