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# A Mathematical Method to Describe Recoil Behavior of Nd-Fe-B-Material

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## I. Introduction

PERMANENT magnet machines are carefully designed to keep their magnetization. However, in some fault situations, the permanent magnets in a permanent magnet machine can be partly demagnetized. This will degrade the properties of the machine by increasing cogging and lowering the power factor.

In many cases it is interesting to know the machine behavior after a partial demagnetization. That is why a good model to describe Nd-Fe-B-magnet recoil behavior is needed. The model must also be implemented in FEM analysis.

## II. Recoil Behavior

Nd-Fe-B-magnet material shows interesting recoil behavior: For small demagnetization, the recoil curve is almost a straight line. For larger demagnetization, the recoil line bends clearly upwards near B-axis (Fig. 1.) The bending is larger for large demagnetization. The reason for the bending is most likely the existence of multi-domain grains like described in [1].

If the recoil operation stays in the second quadrant, only small insignificant minor loops can be detected on large demagnetization. Larger minor loops are only formed, if recoil operation goes deep into the first quadrant. Interesting phenomenon to be noticed is, that the minor loops in that case are not symmetric.

Traditional hysteresis models for magnetic materials, like Preisach Model, generate wide and symmetric minor loops [2], which mean that these traditional models, which have been mostly developed for soft iron, cannot be used to model recoil behavior of Nd-Fe-B-magnet material.

## III. The Model

The recoil curves of Nd-Fe-B-magnet material follow accurately third degree polynomial in the second quadrant:

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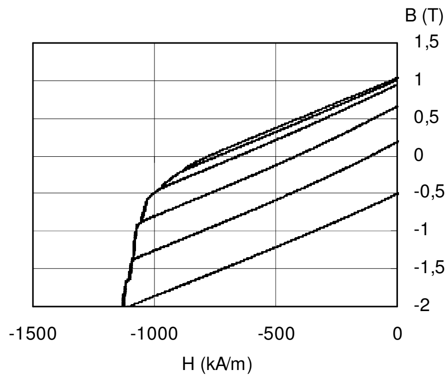


Fig. 1. Recoil curves of a high coercivity Nd-Fe-B magnet grade at 100ºC.

$$B = A_0 + A_1 H + A_2 H^2 + A_3 H^3 . \qquad (1)$$

The term multipliers $A_0$, $A_1$, $A_2$ and $A_3$ are linear functions of demagnetization:

$$A_i = a_{i0} + a_{i1} D , \quad i = 0,1,2,3 \qquad (2)$$

where D is for demagnetization: D = [-100%…0%].

## IV. Discussion

This kind of model based on third degree polynomial can easily be implemented in FEM analysis. The only problem is that there are many parameters to be recognized. Thus, the model recognition requires many measurements and curve fittings for the material in the temperature of interest.

The presented model describes the recoil curve of Nd-Fe-B-material accurately, when the demagnetization is between 0% and some -75 %. If the demagnetization is only small, between 0% and -5%, the recoil curve can be treated as a straight line.

## References

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