

Taking Demagnetization into Account in Permanent Magnets Using Flux®

Abdessamed Soualmi, Patrick Lombard - CEDRAT.

Materials can be classified according to their magnetic property into two main categories:

Soft magnetic materials: which exhibit magnetic properties with the presence of external excitation.

Hard magnetic materials: exhibit magnetic properties in the absence of magnetic excitation. Permanent magnets are part of this family.

A wide variety of materials are used in permanent magnets (see table I).

	Br (T)	Hc (Ka/m)	Tc (C°)
Ferrites	0.2 to 0.4	200	300
Alnico	0.5	50	750 to 850
Samarium Cobalt	1.2	800	700 to 800
Neodymium Fer Bore	1.3	1500	310

Table I: Different families of permanent magnets.

Br: the magnetic induction that exists in the material in the absence of current.

Hc: the coercive magnetic field.

Tc: temperature at which material loses its magnetization (remanent flux density).

In practice, permanent magnets are used to create a field in localized, small-gap dimensions. With technological progress permanent magnets are used in many branches of industry (electric motors, sensors, magnetic recording, etc.) Permanent magnets are used to obtain magnetic fields without loss of power via the Joule effect. One of the major drawbacks of permanent magnets is irreversible demagnetization (when the magnet loses its properties, and can't return to its initial state).

The paper presents a method that takes into account the demagnetization of permanent magnets in Flux® software. In the following example, the method is applied to 3-phase permanent-magnet (PM) synchronous machines (PMSM) with distributed windings.

Principle of demagnetization with Flux during a solving process

A permanent magnet is characterized by its hysteresis cycle, and more specifically the second quadrant of the cycle called the demagnetization curve (see Figure 1), which gives lends the magnet its characteristics:

- remanent induction (Br)
- coercive field (Hc)
- energy density (BH)max

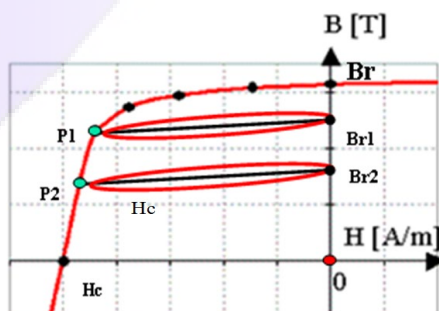


Figure 1: Demagnetization of Permanent Magnets.

The intersection between the characteristic of the permanent magnet and the load line is the permanent magnet's operating point. When H decreases to point P1, there is no return to initial magnetization Br, but along Br1 => local demagnetization of the permanent magnet.

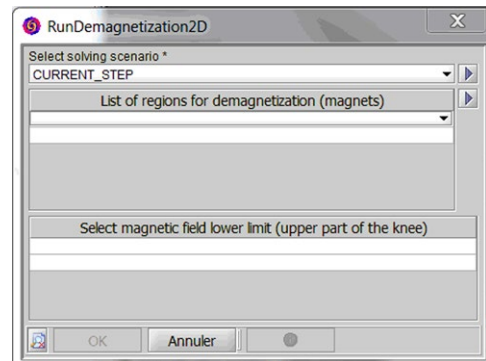


Figure 2: Interface of the macro in Flux.

The goal is to be able to modify remanent flux density in the permanent magnet versus time depending on the load on each point. To do this, we need:

- spatial definition of magnet
- at the end of each time step, a new value of Br is defined
- this new value of Br is assigned to the magnet definition
- a macro is used to automate the process

To execute the macro we select:

- list of regions for demagnetization
- the magnetic field lower limit

Application example

The studied machine (figure 3) is a synchronous machine with mounted surface permanent magnets whose characteristics are given in the table II.

Characteristics	Value
Number of poles	4
Number of phases	3
Frequency (Hz)	50
Stator slot	24
Stator outer diameter (mm)	48
Rotor outer diameter (mm)	25
Stator inner diameter (mm)	25.66
Rotor inner diameter (mm)	9
Length of stator (mm)	50.308

Table II: Characteristics of the study machine.

Figure 4 shows a comparison of the flux density iso values inside the magnets, with and without demagnetization. In figure a) the iso values are still the same in the magnets compared to when we take demagnetization into account; we observe that the iso values are not the same.

(see continued on page 11)

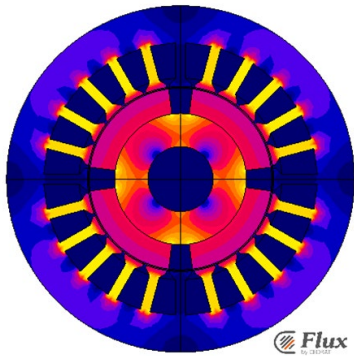
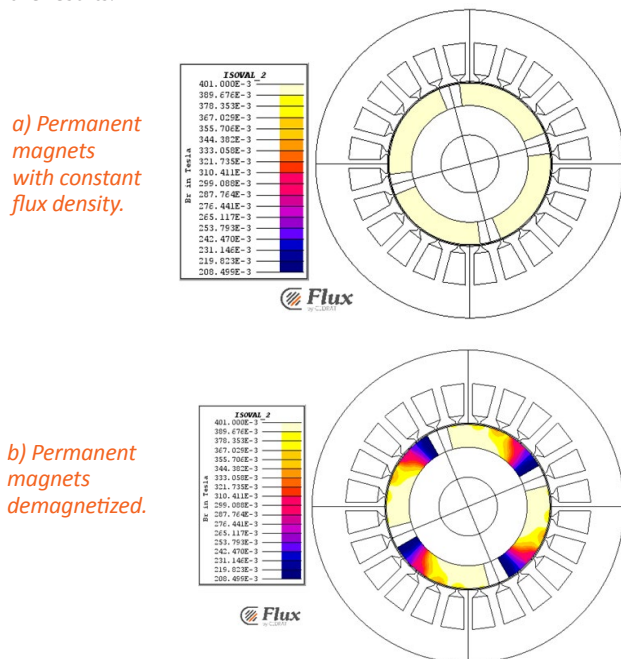


Figure 3: Flux density in the synchronous permanent magnets machine.

When we compute the performances (electromagnetic torques) of the machine for both cases, the demagnetization of the magnets leads to a decrease in machine performance.

■ Magnetic field effect

In this section we vary the magnetic field and for each value we compute the electromagnetic torque. In the end, we compare the results.



a) Permanent magnets with constant flux density.

b) Permanent magnets demagnetized.

Figure 4: Comparison between permanent magnets without and with demagnetization.

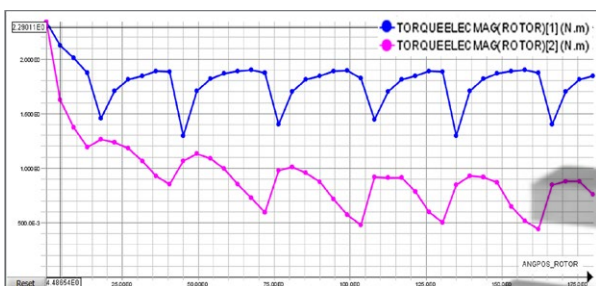


Figure 5: Torque vs position without and with demagnetization of permanent magnets.

Magnetic field (A/m)	H1	H2	H3
Value	3e4	1e5	2e5

Table III: Magnetic field values.

“ Numerical simulations are of major importance in the selection of magnetic materials while designing a machine. ”

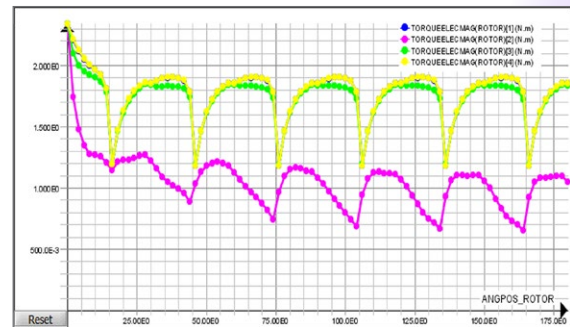


Figure 6: Magnetic field value effect on the demagnetization of the permanent magnets.

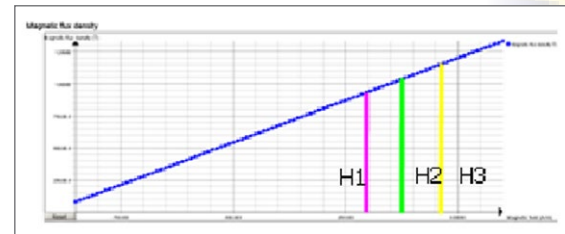


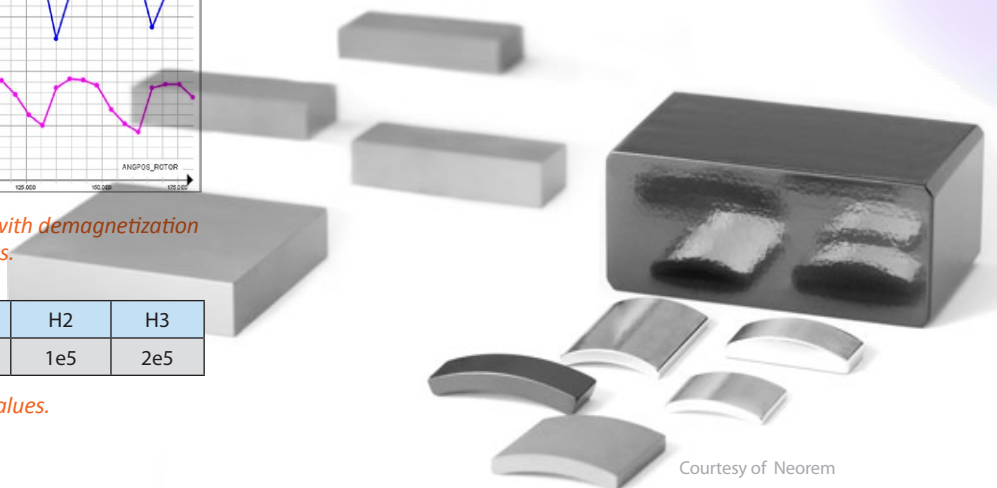
Figure 7: Curve B(H) of the material.

As we can see, when we increase the value of the coercive magnetic field (from H1 to H3, Figure 7) we reduce machine performance. This means that we demagnetize magnets more. And when we decrease the coercive magnetic field value, machine performances stay the same (we observe a little demagnetization of the magnets in the corners). After running the whole process, the state of the magnet can be used in another project to re-check the main characteristics of the motor (Back EMF, Torque, Ld and Lq...).

■ Conclusion

Demagnetization is critical:

- to check that magnets will survive a short-circuit or any default
- to check that magnet is not modified by starting current
- to check that the nominal working point will not damage magnet's properties.



Courtesy of Neorem