IOP Conf. Series: Materials Science and Engineering **200** (2017) 012045 doi:10.1088/1757-899X/200/1/012045

Study of the shielding performances of different materials regarding Electromagnetic Field Interference

Conecici L M, Munteanu C and Purcar I M

Technical University of Cluj-Napoca, Cluj-Napoca – 400020, Romania

E-mail: conecici.madalin@gmail.com

Abstract. This paper presents a computer-aided comparison of some of the most used electromagnetic shielding materials. Computer-aided design (CAD) model and the computer aided engineering (CAE) simulation technologies are used for the analysis of the electromagnetic field shielding performances of each material individually and a comparison will be established. The main topic of this comparison is to establish a proper shielding material for ElectroMagnetic Interference (EMI) sources. A three-dimensional (CAD) model of the circuit breaker coil designed in PTC Creo Elements v.18.1 environment was analyzed in Ansoft Maxwell v.15 environment in order to compute the electromagnetic field distribution. The residual (EMI) values are compared to one another and the best shielding material will be presented for this circumstances.

1. Introduction

Except for the superconductors no other materials is able to block completely a magnetic field without it being attracted to its magnetic force. The most efficient method to protect against magnetic fields is to redirect them, they cannot be removed. In order to redirect magnetic fields, shielding alloys with high-permeability are used. NETIC-AA, NETIC S3-6 and MuMETAL are one of a kind shielding materials with a highly guarded alloy composition, these materials were developed by Magnetic Shield Corp, after years of research and applications [1].

However, shielded enclosures are a poor substitute for good EMC design at the board level. Effective enclosures can add significant cost and weight to a product and a single breach of the enclosure (e.g. an unfiltered cable penetration) can completely eliminate any benefit the enclosure would otherwise provide. In many cases, a product in a poorly designed shielded enclosure will radiate more (or be more susceptible) than the same product without the enclosure [2]. Choosing a proper location, orientation, and material for a shield requires a knowledge of the type of field being shielded and the objectives of the shield. The following sections will describe basic shielding theory and provide several examples of good shielding in various situations.

2. The study domain

The standard European design of a DIN-rail mounted MCB includes the following components as shown in Figure 1:

1. Actuator lever – trips and resets the MCB manually;

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

2. Mechanism – a tension based system that forces the contacts together or apart;

3. Contacts – moving parts that either allows current to flow, when they are closed or do not allow current to flow when they are separated;

4. Terminals – the contact points of the MCB;

5. Bimetallic strip – used as a tripping system for longer term tripping currents;

6. Calibration screw – set up of the tripping current;

7. Solenoid – used for the short-term, high overcurrent tripping;

8. Extinguish chamber – used to guide the arc flow without damaging the MCB [3].

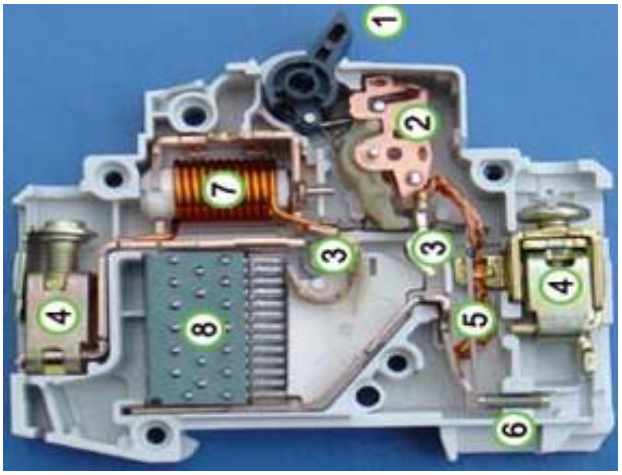

Figure 1. The MCB components design

As a domain for our study, the coil of the MCB will be used, mainly because the magnetic field reaches a high density in this area. Also, MCB's are often used mounted on rails side by side, the space between the two coils is filled only by the polyurethane casing on both MCB's[4], thus one fault in one MCB can be transmitted to the neighboring MCB via the Electromagnetic interference.

3. 3d model used for the study and considerations

The only reliable way, known at this moment, to reduce EMI generated by parts of the circuit that are influencing other parts of the same or other circuits, is by shielding either the emitter or the receptor against electromagnetic fields [5]. Electromagnetic shielding is composed out of barriers made of conductive or magnetic materials.

The metallic or magnetic shielding can reduce the emitting and receive of radio waves, electromagnetic fields, and electrostatic fields. Also known as a Faraday cage, any enclosure composed of a conductive material is used to block electrostatic fields. The material used in the building of the enclosure severely affects the efficiency of the shielding capacity [6]. Other characteristics that influence the shielding performance are the frequency, size of the shielding enclosure, shape and orientation of the shield.

As a setup used for our study, the coil is situated between the two shields made out of different shielding material, and the study and the graphs are plotted onto two axes situated parallel to the coil, in the same place where the neighboring coil would normally be situated [7], as shown in Figure 2.

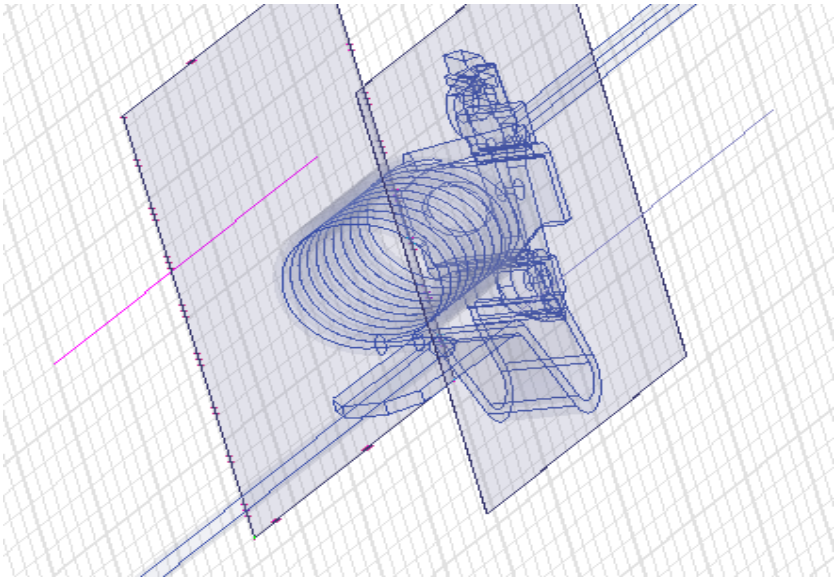

Figure 2. Coil, shielding material and plotting axis

Also as a parallel study, the thicknesses of the shields will differ. The study will take into consideration two thicknesses. One is 0,01mm, a very thin foil, in order to keep costs and space at a minimum. And the second thickness is 0.8 mm plate material which is the maximum width available in the MCB.

4. Materials studied

Electromagnetic Interference (EMI) shielding defines the absorption and/or reflection of electromagnetic radiation due to a material positioned in the way of the electromagnetic interference.

EMI shielding is rapidly becoming a strongly needed resource in the electronics and energetics industry, due to a fast increasing usage of electronics, their reliability and the rapid growth of radiation sources [8].

There is a difference though between Electromagnetic interference (EMI) shielding and Magnetic shielding. For example, magnetic shielding refers to shielding at magnetic fields that have a low frequency (e.g., 60Hz).

On the left side, the materials used for this study are presented with their Electrical proprieties as are the ones introduced in MAXWELL.

- $\boldsymbol{\sigma_r}$ -conductivity relative to copper
- $\boldsymbol{\mu_r}$ - the relative magnetic permeability

Table 1.

Material	σ_r	μ_r	$\sigma_r\mu_r$	σ_r/μ_r
Silver	1.05	1	1.05	1.05
Copper	1	1	1	1
Gold	0.7	1	0.7	0.7
Aluminum	0.61	1	0.61	0.61
Brass	0.26	1	0.26	0.26
Bronze	0.18	1	0.18	0.18
Lead	0.08	1	0.08	0.08
Nickel	0.2	100	20	2x10-3
Stainless steel	0.02	500	10	4x10-5
MUMetal	0.03	20000	600	1.5x10-6

5. 3d numerical simulation (CAE) and results

5.1. Simulation consideration

Adaptive Mesh Process was used for the simulation in question. This process is working with numerous passes over the model, and refining the mesh with every pass. There are numerous factors that can influence the meshing process, factors like the geometry of the model, field solutions, also a factor is a percent refinement number which in our case was set to 30%. As for Excitation of the solenoid, we used a current of 500A and 60Hz.

- The simulation is preceded by validation of the model. This will find and present any issues with the model and will give a report of the found issues;
- Once all parameters are set, the software is ready to start. Depending on the solution setup (refinement of the solution), and on the hardware used, analyzing the problem can take up to a few hours;
- When the software finishes analyzing the problem the results are represented, as field overlaid plots, graphic plots or numerical values. In this figure, the electromagnetic field generated into the vacuum.

5.2. Graphs and color scheme

- A 2D graph with the values of the magnetic field and the induced current overlaid is presented in the graph from above Figure 3.
- The Green and red graphs represent the intensity of the magnetic field on the left and right side of the MCB's Coil Figure 4.
- For the sake of the experiment, only the maximal values are used.

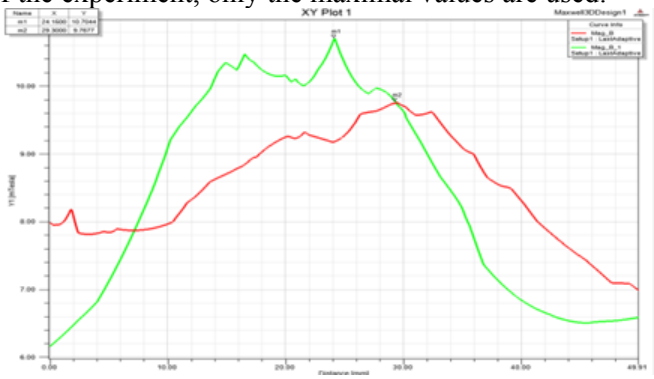

Figure 3. 2D graph with the values of the magnetic field alongside the measuring axis

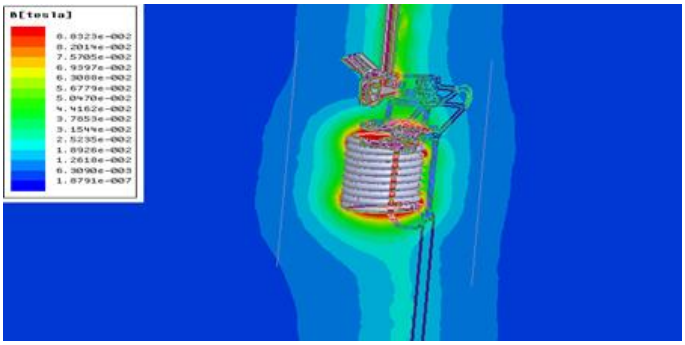

Figure 4. Color scheme representation of the magnetic field

5.3. Comparison of the obtained values

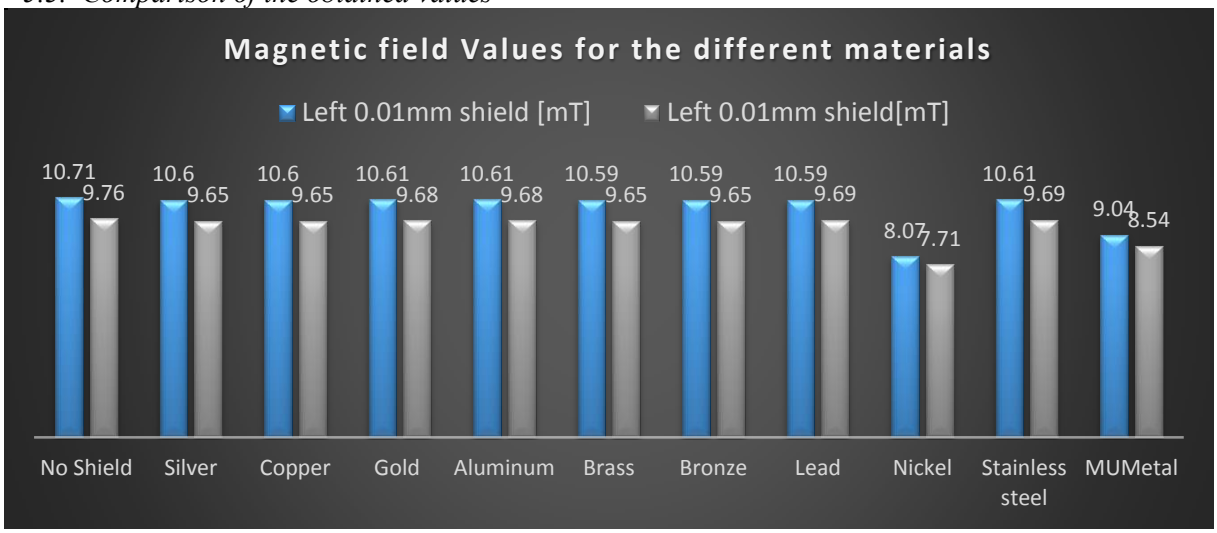

Figure 5. Results of the magnetic field simulation for all different Shielding materials, Values for the 0.01mm shield material

In Figure 5, the results of the simulations are shown, where the shields were made out of 0.01mm thick foil. Immediately it is visible that there are two materials that stand out regarding their shielding abilities. These two materials are Nickel and the Branded MuMetal. Considering these results another simulation is executed but the thickness is 0.8mm, the maximum space available for the application.

In this simulation, though, only Nickel and Mumetal at a thickness of 0.8mm, because all other materials have, as we can see from Figure 5 similar shielding proprieties.

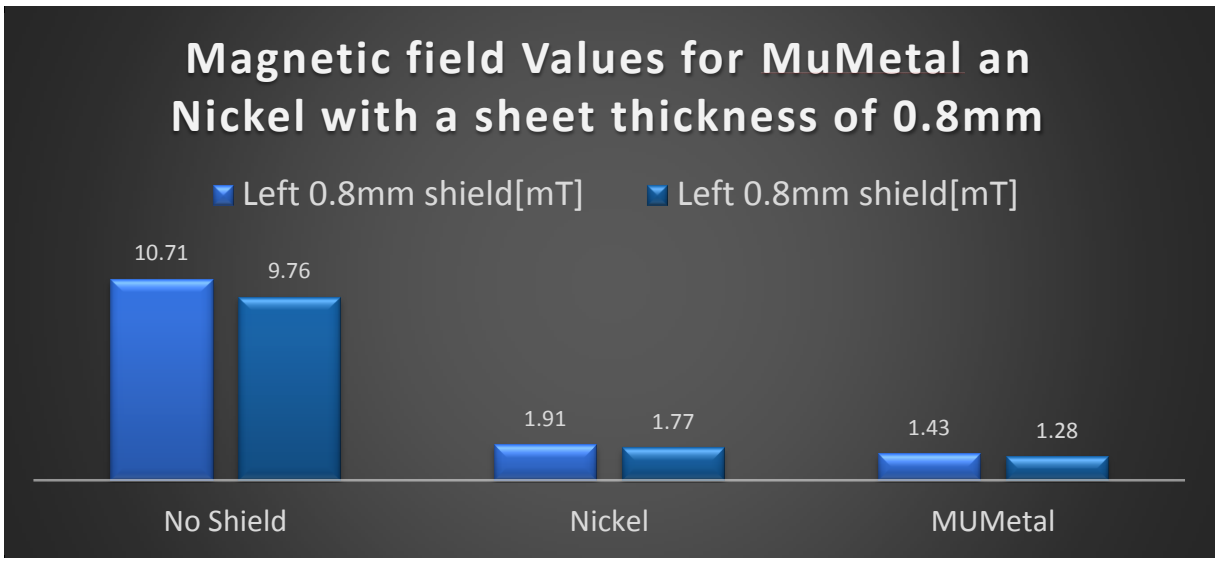

Figure 6. Results of the magnetic field simulation for Nickel and MuMetal, Values for the 0.8mm shield material

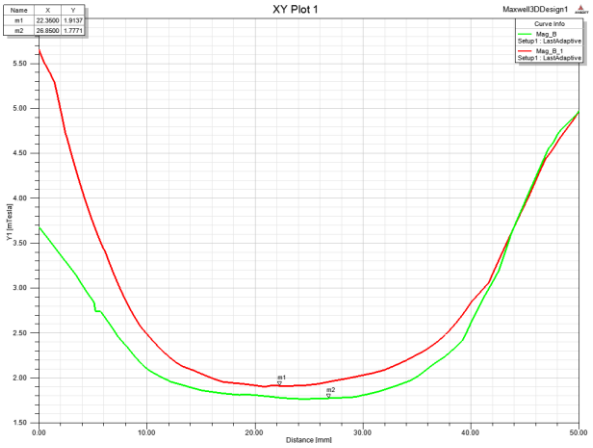

Figure 7. Results of the simulation with proper shielding materials

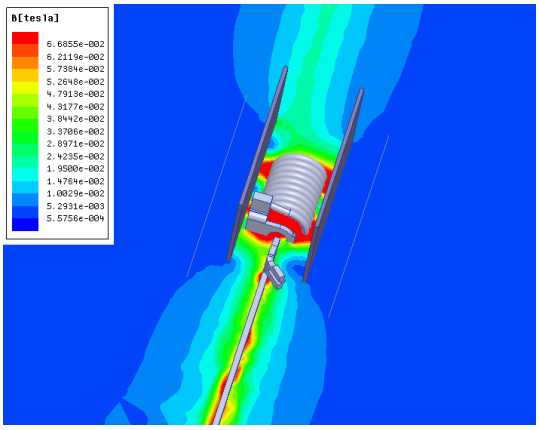

Figure 8. Color scheme representation of the magnetic field with proper shielding

In Figures 6, 7 and 8 The simulation results show the effectiveness of the thicker shielding for the Nickel and MuMetal shields, while Figure 6 shows also a comparison to a no shield situation.

6. Conclusions

Depending on the shape, the size, the composition and the distance to the shielded object, the shielding strategy can be effective or not. For example, if the shields are positioned very close to the shielded object, they will attract the magnetic field. In this case, the MuMetal can get oversaturated and it reacts by increasing the magnetic field surrounding it.

As presented in Figure 5. It is visible that Nickel and Nickel based materials, as the MuMetal is, are the best shielding material for low-frequency applications.

The paper presents a potent solution for the shielding of MCB's, a more reliable shielding solution would be entirely made out of metal, but while the MCB is an Electric protection device it cannot be made out of any conductive material. To bypass this problem, some shielding solutions are implemented at the Distribution Panel level. This shielding solution is designed to protect the devices from the outside interferences, but not from the short circuit faults generated inside MCB's components level.

References

[1] Luo Y, Lu J G and Li Z G 2002 *Study of Reliability Test and Analysis for Miniature Circuit Breakers*, Electrical Apparatus Institute 323# Hebei University of Technology, pp 80-81
[2] Conway J T 2001 Exact Solutions for the Magnetic Fields of Axisymmetric Solenoids and Current Distributions, *IEEE Transactions On Magnetics* **37**(4) 2977-2988
[3] Dwight H B 1931 The magnetic field of a circular cylindrical coil, *Phil. Mag.* **38** 948-957
[4] Conecici L M, Munteanu C and Purcar I M 2015 *Magnetic Field Simulation of a Miniature Circuit Breaker's Coil*, Moden Power Systems MPS 2015, Technical University of Cluj-Napoca
[5] Wu Y, Rong M, Li J and Lou J Y 2006 *Calculation of Electric and Magnetic Fields in Simplified Chambers of Low-Voltage Circuit Breakers*, State Key Laboratory of Electrical Insulation for Power Equipment, Xi'an Jiaotong University, Xi'an, China, 710049
[6] Pop D, Neamt L, Tirnovan R and Sabou D 2013 *3D Finite Element Analysis of a Miniature Circuit Breaker*, Technical University of Cluj-Napoca
[7] Marandi S R 1996 The Magnetic Near-Field Of A Solenoid, *Canadian Space Agency* **1** pp 1-4
[8] ***SIEMENS Primer Miniature Circuit Breakers

[9] ***Metal shields and encryption for US passports, Newscientist.com. Retrieved 18 November 2012
[10] ***MuMETAL Magnetic Shield Corp. 2012 Catalog MU-2. Retrieved 26 June 2016