Magnetic field reduction screening system for a magnetic field source used in industrial applications

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Abstract. This paper presents the description of the design and solution given as magnetic screen for a 50Hz industrial application, combining different materials to obtain the optimum reduction of the field. Important ideas are presented on the magnetic field behaviour, the response of the different materials subjected to magnetic fields, the effects and variations (in the shape and intensity of the field), introduced by the screen, and also, the differences in these influences produced by the screen as a function of their material properties, dimensions or positions. Keeping the magnetic field within a certain region of the space without disturbing the field in the other regions is not an easy task. That is why simulation and real measurements have to be combined. With the digital model, a large number of simulations are carried out modifying the screen step by step to obtain the optimal field reduction. The final measurements have validated the improvements performed by the screen.

Keywords

Magnetic shielding, low frequency electromagnetic fields, human exposure, screen parameters, industrial application.

1. Introduction

During the last years, electromagnetic fields have been a permanent point of conflict due to the growing awareness of the health risks by the general public. Although lots of biomedical studies have been carried out on this domain, none of them has been able to establish a clear relation confirming electromagnetic fields as a cause of any kind of illness. However, it is clear there has to be limits in order to control possible exposures. European authorities have regulated these aspects fixing limits for the radiated emissions produced by different kind of electromagnetic sources [1]. These limits vary as a function of the frequency and, for the case of the industrial applications (50Hz) they are:

- For occupational exposure: 500µT
- For general public exposure: 100 µT

The application introduced in this paper deals with the magnetic screening performed in an industrial process trying to reduce the magnetic field emitted by one of the components below the established limits.

2. Problem description

Placed in an industrial environment, as a part of the productive process, an industrial coil is used to demagnetize the workpieces being fabricated which could keep a remanent magnetic fields on its inside as a result of the productive process manipulation and transformation. These fields existing in the workpieces are not useful at all, resulting even damaging for the correct functioning of the pieces once they are installed and have to start working. Therefore, they have to be eliminated.

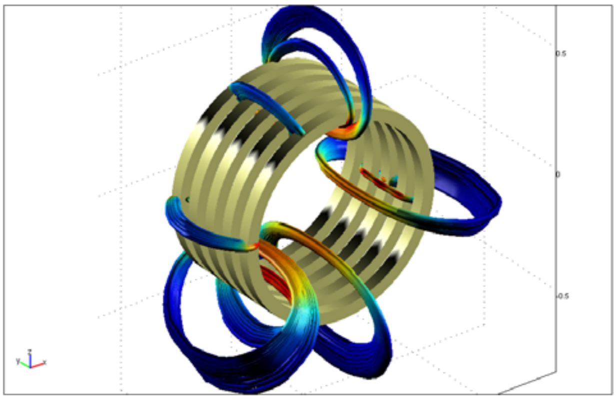

Figure 1 - Coil with workpiece and magnetic flux lines.

Demagnetization is the reduction of a magnetic field from its maximum magnetization intensity to almost zero, achieved by a repeated polarity reversal at a given frequency.

For demagnetization, the amplitude of an applied alternating field must be continuously reduced as shown in figure 2. The initial demagnetization field strength must be at least equal to the magnetization field strength existing in the sample. The reduction of field strength within the workpiece can be achieved electrically by reducing the magnetic field progressively while it circulates through the coil, or mechanically by slowly withdrawing the workpiece from the field of a constantly energized demagnetization coil. The figure below can give an idea of the procedure.

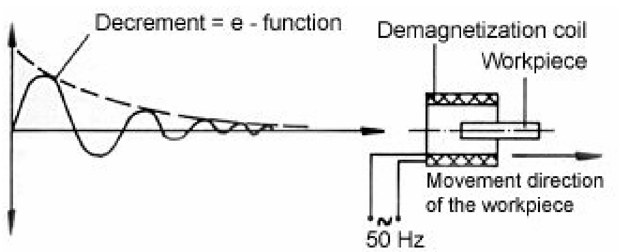

Figure 2 - Demagnetization process.

The dimensions of the coil which has been shielded are:

- Length = 300mm.
- Internal diameter = 450mm.
- External diameter = 500mm.

The coil is connected to the low voltage electric network with a 400V supply establishing a value for the field strength on its centre around 10kA/m. The elevated field strength implies the existence of high field levels not only in the centre of the coil but in all the surroundings. These levels are to be checked and reduced in those zones considered necessary. This will be done through the installation of a magnetic screen which has as main requirement, apart form shielding the magnetic flux in the outside, not to alter the field strength in the centre of the coil since it could damage the functioning of the coil, therefore preventing the goal it has in the industrial process, which is, the removal of remanent magnetic field inside the workpieces.

3. Procedure

A. Initial measurements.

These measurements allow determining the initial situation under normal conditions, in situ. For the registration of the magnetic field values a total number of 13 points were controlled. The representation of the magnetic field in these points could give an idea of the shape and aspect of the field. The scheme of measurements is displayed in figure 3. All the measurements were submitted at the coil's axe height, since they were included like that in the same plane, and the one where the values of magnetic field are maximum referred to the centre of the coil.

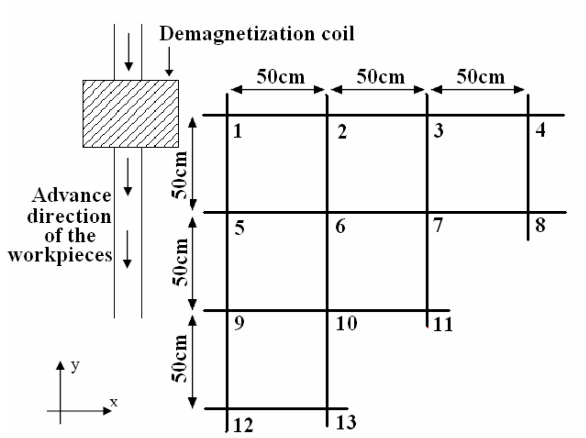

Figure 3 - Map of measurements around the coil.

The values registered are (values of magnetic field density in μT and position in meters being the (0,0) reference point the centre of the coil):

Point	1	2	3	4	5	6
Position X	0.5	1	1.5	2	0.5	1
Position Y	0	0	0	0	-0.5	-0.5
Field (B)	763	85	30	13	456	92

Point	7	8	9	10	11	12	13
Position X	1.5	2	0.5	1	1.5	0.5	1
Position Y	-0.5	-0.5	-1	-1	-1	-1.5	-1.5
Field (B)	26	11	127	46	18	38	24

Table 1 - Values of magnetic field density without screen.

These initial measurements made it possible to characterize the field created by the coil. Once this field was known, a digital model was established. The magnetic field created by this model has the aspect depicted in figure 4 and was developed to correspond exactly with that created by the real coil. This was obtained by the comparison of magnetic field values in the 13 points controlled in situ and the field simulated by the model in those 13 points.

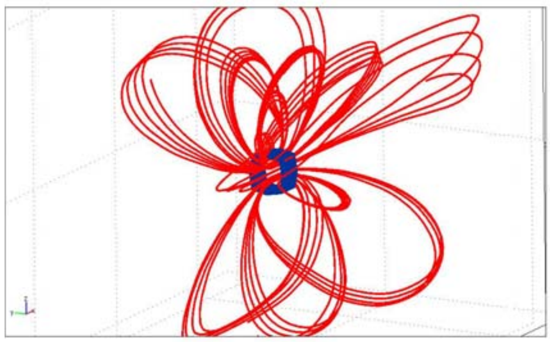
Figure 4 - 3D view of the digital model with the magnetic field flux lines generated by the coil.

The values of magnetic field are useful not only to develop the model but also to have an idea of the initial situation. With this knowledge it is easier to project the type of screen which is going to be necessary in order to fix the magnetic field in the surroundings under the limits.

B. Design of the screen.

In view of the magnetic behaviour of the different materials ([3]-[4]) iron and aluminium were selected as the optimal materials to employ in the construction of the screen. Another important decision to take was the thickness of the plates to install [5], from ([2],[6]), 2mm were selected for both aluminium and iron, trying with this size to optimize the field reduction and the structure weight. Apart from that, the shape for the screen as well as the position had to be chosen, other studies ([2],[7]) helped to decide it should be placed as close to the coil as possible, trying to enclose it inside the screen. There were space limitations due to the industrial environment where the demagnetizing coil was place, though the width of the screen could not be large.

The first option was to introduce 2 iron plates, one on each side of the coil, to analyze the absorption level of magnetic field they were able to perform. The election of iron located on the sides of the coil where the field is parallel to the surface of the plate is because of its good behaviour in that position [2]. The aspect of the field with this first screen was:

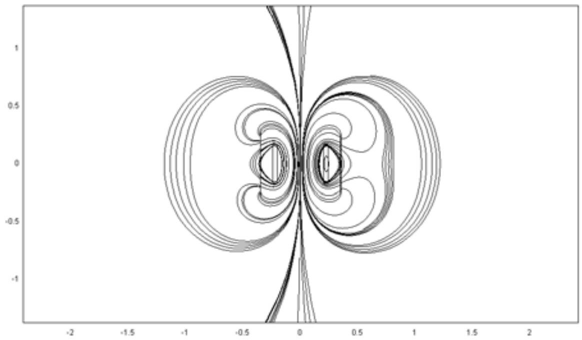

Figure 5 – Flux lines distributions with the first screen.

Results from this redistribution of the magnetic field were not successful, even increasing the width of the iron from the initial 0.5m to nearly 2m the reduction was not enough.

The second option was then the introduction of a second iron plate on each lateral. Different simulations were performed, varying the width of the plates as well as the distance between them. The optimal distance was concluded to be 5cm. With this new disposition, a great reduction was obtained on the x direction but it was still poor in the y direction. The aspect of the field distribution can be observed in figure 6.

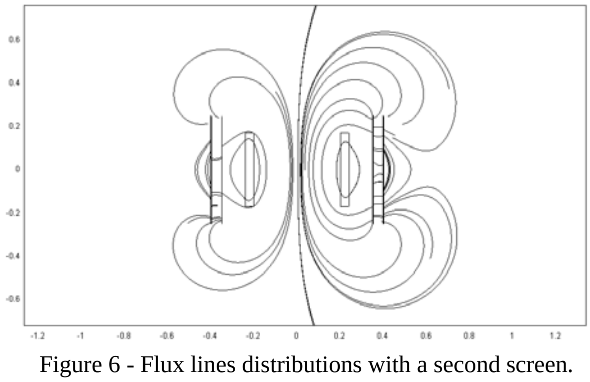

Figure 6 - Flux lines distributions with a second screen.

It was decided, instead of incrementing the lateral volume of the screen, and due to problems of space, to install other parts of the screen in the y direction. So, aluminium was used to close the screen around the coil placing 2 wings of this material, with an angle of 60º, on each of the exterior iron plates. The resulting structure was as follows:

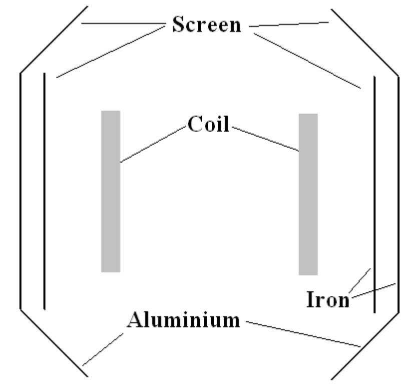

Figure 7 - Section of the final design of the screen surrounding the coil.

Various angles for the wings were simulated. Equally, fixing them to the interior iron plate was tried too. Form all the possibilities, the previous distribution was found to be the best. This solution adopted as definitive creates a distortion of the magnetic field as is visualized below.

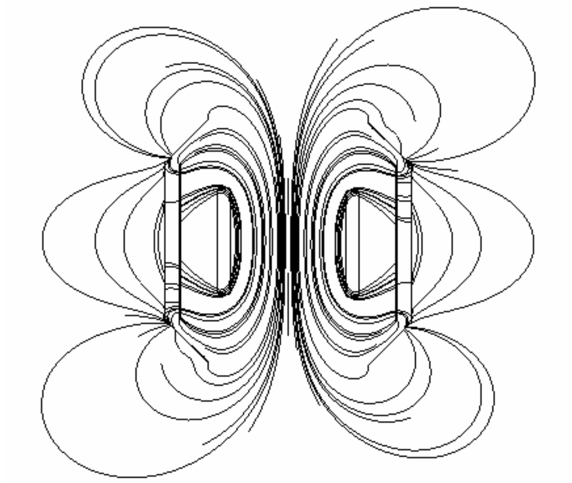

Figure 8 - Magnetic flux lines simulated with the coil shielded.

Once simulated and the designed values obtained under the limits and with a certain security margin, the screen was constructed and installed.

C. Final measurements.

After the design, construction and installation of the screen, new measurements were performed in order to check the efficiency of the shielding and verify the calculations and simulations carried out during the design. The results are summarized in table 2. Once again the magnetic field density is expressed in μT and the position in meters having as the (0,0) reference the centre of the coil.

Point	1	2	3	4	5	6
Position X	0.5	1	1.5	2	0.5	1
Position Y	0	0	0	0	-0.5	-0.5
Field (B)	91	36	14	6	88	34

Point	7	8	9	10	11	12	13
Position X	1.5	2	0.5	1	1.5	0.5	1
Position Y	-0.5	-0.5	-1	-1	-1	-1.5	-1.5
Field (B)	12	4	45	21	14	20	11

Table 2 - Values of magnetic field density with screen.

By comparing tables 1 and 2, it is clearly observed that the values of magnetic field have registered a big reduction in all the point, except point number 9. This is due to the fact that the screen reduces the field absorbing magnetic flux lines and confining this energy into the material, but also deflects the unabsorbed flux lines. This phenomenon makes it possible to increase the magnetic field in some regions of the space due to the concentration of magnetic lines of higher field intensity. This is the case of point 9 as has been seen during the design. It is located close of the axe of the coil were magnetic field lines are concentred.

Apart from that, the goal of the reduction of magnetic flux density under the limits has been accomplished for all the points. None of them rests above 100µT which was the requirement. The percentage of reduction varies from the 88% obtained in point 1 to the 20% of point 11. The smaller the field was at the beginning, the smaller the reduction obtained. Anyway, for the rest of the points the reductions are all important but different, due to the deformation registered by the screen.

4. Conclusions

The whole design of a magnetic screen has been performed throughout measurements and simulations.

The magnetic field reduction achieved by means of the installation of the screen goes beyond the 88% in the most critical points referred to the initial situation. The combination of two kinds of materials as well as the good selection of the relative position has been fundamental in order to obtain such a large reduction.

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