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MAGNETIC FIELD ANALYSIS ON ELECTROMAGNETIC WATER TREATMENT DEVICE

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A short review of magnetic water treatment devices is given. Analysis of electromagnetic industrial units named EM I – IV is presented. The distribution of magnetic flux density of the models was measured and analyzed by the computer program Electromagnetic Field Analysis Tools. Results for EM IV show that an improvement can be achieved by replacing a metallic tooth, used for placing the washer ring, with nonmagnetic material.

Keywords: magnetic water treatment, scale prevention, magnetism

Introduction

Scale deposits by natural waters often lead to numerous technical and economical problems in industrial plants and domestic equipment by blocking the water flow in pipes or limiting heat transfer in heat exchangers. Traditional chemical methods for scale control are effective but significantly change the solution composition and are expensive. Therefore, an interest for physical methods is rising. One of these methods is magnetic water treatment (MWT), where water flows through a magnetic field. In the literature, there is a number of reports about MWT being effective [1-4]. When the device is properly designed, hard scale is prevented by forming sludge or alternatively, linings with low mechanical strength, which can be easily removed. The mechanism how magnetic fields affect the crystallization of calcium carbonate, is still the matter of research. It is the most possible that treatment leads to the formation of calcium carbonate particles in the bulk of the scaling water, which cannot precipitate on the walls of distribution pipes and other equipment [5].

Commercial MWT devices are available in various configurations from numerous manufacturers, some using electromagnets and others using single or arrays of permanent magnets with different orientations of the magnetic field [6]. The most effective arrangements are those with perpendicular or radial magnetic fields *(Fig. 1)*. Furthermore, magnetic fields can be alternating (Fig. 1/a, b) or homogeneous (Fig. 1/c). Alternating fields seem to be more effective [5,7]. Some MWT units are electromagnets using electrical input with alternating current or direct current voltage. Many interesting results of laboratory research were found when samples were exposed to static magnetic field [4,8], but better results are expected when water flows through the magnetic field [9,10]. For practical use, there is a general recommendation that water flows through the magnetic field with the velocity from 0.1 to 2 m/s and the magnetic flux density is more than 0.05 T.

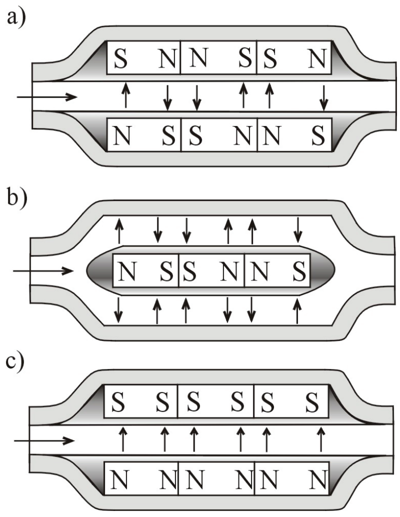

Fig.1: Some basic types of magnetic fields:
(a) Perpendicular (parallel arrangement of magnets)
(b) Radial (magnetic kernel in ferromagnetic tube)
(c) Homogeneous (horse-shoe magnets)

In this article we describe electromagnetic units named EM (shown in *Fig. 2* with basic data given in *Table 1*). They have alternating current electrical input and are designed for different water flow rates (I-IV).

The housing is iron-casting electroplating with nickel. The inner plate is from steel. The electromagnetic winding is a solenoid with rectified alternating currents, which produce pulsating magnetic field. Water enters in the center on the top of the device, overflows the inner plate in radial directions, passes the rubber ring down into the lower zone, flows to the center of the inner plate and leaves out of the device.

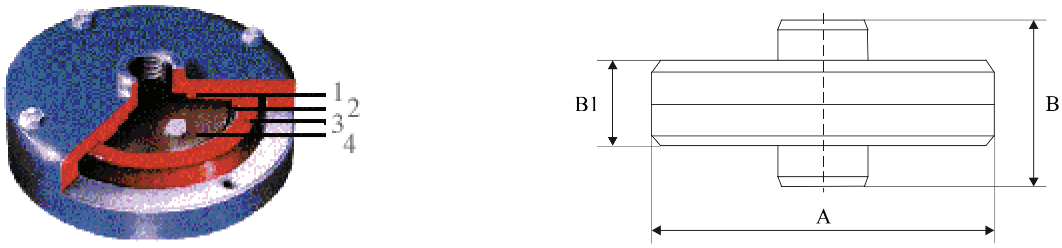

Fig.2: Electromagnetic device, model EM (1 – housing, 2 – rubber ring, 3 – solenoid, 4 – inner plate)

Table 1: Basic data for EM electromagnetic devices

Type	Flow rate (L/min)	Power (W)	Dimensions (mm)			
			A	*B*	B_1	Connection
EM I	10 – 25	40	168	54	40	No 20 (3/4)
EM II	15 – 40	55	168	54	40	No 26 (1)
EM III	25 – 60	75	220	76	51	No 32 (R 5/4)
EM IV	150 - 400	110	320	100	52	No 65 (R 2 1/2)

Measurements of the magnetic field in the device EM I

Electromagnetic measurements and characteristic results of the model EM I were made in the laboratories at Faculty of Electrical Engineering and Computer Science and Faculty of Mechanical Engineering, University of Maribor.

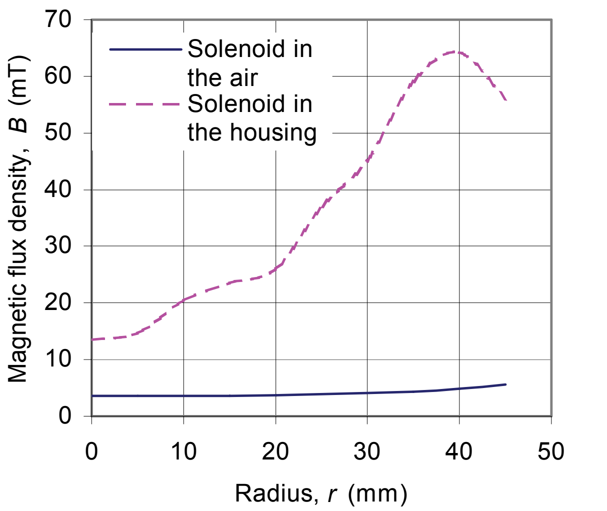

Fig.3: Magnetic flux density of solenoid (a) in the air and (b) of the same solenoid in the housing with inner plate in EM I device.

Radial distributions of the magnetic flux density *B(r)* are presented in *Fig. 3.* The magnetic flux density was measured for solenoid (a) in the air and (b) with inner plate and housing together. Because the value of *B* should be higher than 0.05 T for good efficiency of a magnetic device, EM I model has good values of *B* from radius r_1 = 30 mm to r_2 = 45 mm. Relative effective area $\left(\pi r_2^2 - \pi r_1^2\right)/\pi r_2^2 = 1-\left(r_1/r_2\right)^2$ is 56% of whole area of the inner plate.

Figure 4 shows the measurements for magnetization curve (magnetic flux density, *B* (T), versus magnetic field intensity, H (A/m)) of housing and inner plate for EM I model.

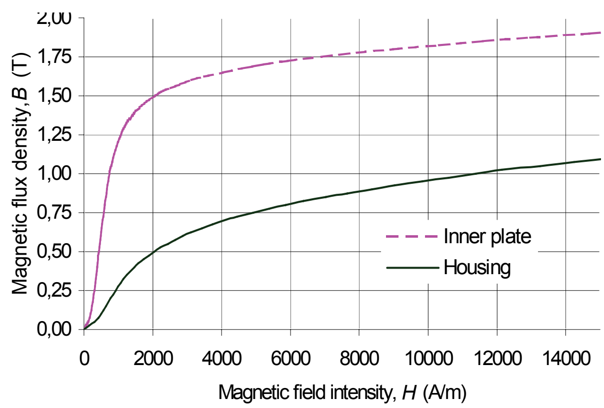

Fig.4: Magnetization curve of housing (GRADE 350) and inner plate (FE360B) for EM I device.

Conditions of *v* and *B* for effective operating of MWT devices were checked. From measurement result of EM I device (Fig. 1), it can be seen that the zone of efficient magnetic field (B > 50 mT) is from r_1 = 30 mm to r_2 = 45 mm. Water flux is for radial flow expressed with the relationship:

$$q_v = 2\cdot\pi\cdot h\cdot v \qquad (1)$$

Parameters are: r = radial distance on the inner plate
h = thickness of the gap = 1 cm
v = water flow velocity

Velocity v decreases with increasing of r, being the lowest at the edge of the inner plate.

For fulfillment of the condition $v > 0.1$ m/s in whole area of the inner plate, the water flux should be 17 L/min (calculated by Eq.1 for $v = 0.1$ m/s at the edge of the plate).

Numerical calculations of the magnetic field in the device EM I

The distribution of magnetic flux density was also analyzed numerically. The computer program **Elec**tromagnetic **F**ield **An**alysis **T**ools (EleFAnT2D, EleFAnT3D) was used. It is developed by IGTE, TU Graz with the purpose for solving two- (2D) and three-dimensional (3D) problems in electromagnetic fields by the finite element method. The program enables us to determine the distribution and the magnitude of static and time depending electromagnetic fields. It comprises:

- 2D and 3D input graphical processors for description of a device geometry, boundary conditions, materials and sources,
- the main program with different mathematical - numerical calculation possibilities (scalar or vector potentials) and
- the postprocessor for numerical and 2D or 3D graphical presentation of device's parameters.

Figure 5 presents 3D mesh for EM model.

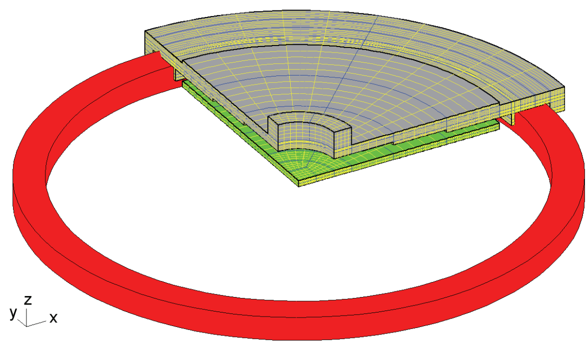

Fig.5: 3D – mesh of EM model

The numerical calculation was made for dimensions of the model EM IV in 2D-axisisymmetric mesh. *Figure 6* presents the magnetic flux density distribution. It is obvious that "a magnetic bridge" occurs due to the metallic tooth used for placing the rubber ring. The magnetic field very weakly penetrates into the zone of water flow and the inner plate.

For constructing an improved model, a good solution was replacing the metallic tooth with a nonmagnetic ring. Results are presented in *Fig. 7.* Distribution of the magnetic flux density is now favorable. Magnetic field in water zone is stronger and perpendicular to the water flow direction. Both facts are important for the effectiveness of the device. The comparison of the magnetic flux density curve between the manufacturer's and the improved model is presented in *Fig. 8.*

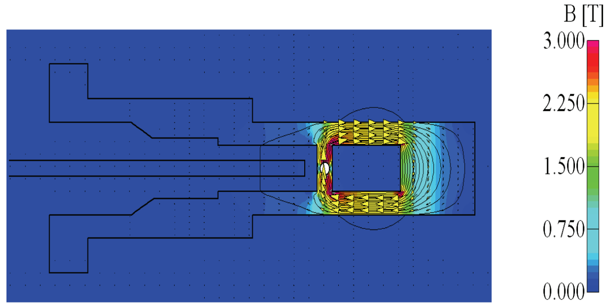

Fig.6: The distribution of the magnetic flux density, B_z, in the manufacturer's model EM

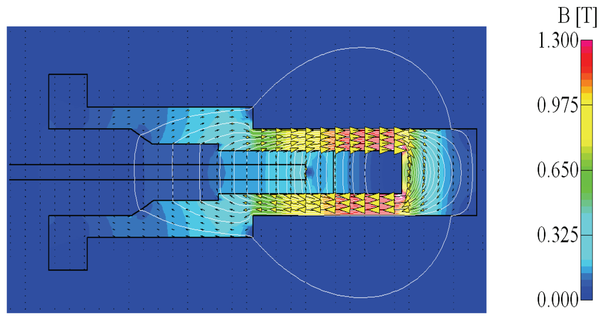

Fig.7: The distribution of the magnetic flux density, B_z, in the improved model EM

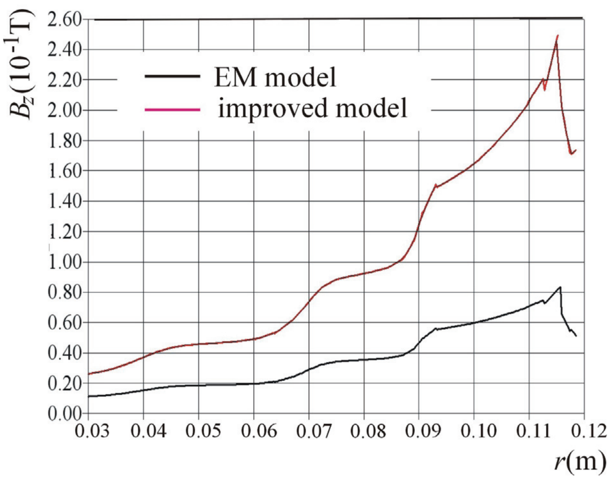

Fig.8: Distribution of magnetic flux density for EM model and for the improved model.

Results of the numerical analysis of the improved model EM IV (Fig. 8) show that the zone of efficient magnetic field ($B > 50$ mT) is from $r_1 = 60$ mm to $r_2 = 105$ mm at the edge of the inner plate. Relative effective area is 67%.

Conclusion

We analyzed EM magnetic devices, which have been used in industry for many years and show good results in scale prevention. Laboratory measurements and numerical calculations with EleFAnT computer program of magnetic field distribution in these devices are in good agreement. It was found that the metallic tooth considerably reduces the magnetic flux density in the water zone. Therefore, we made a computer simulation with nonmagnetic material, which gave much better distribution of the magnetic field.

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