Journal of Optoelectronics and Advanced Materials Vol. 6, No. 2, June 2004, p. 709 - 712

MAGNETIC FILTER WITH HGMF MATRIX FOR INDUSTRIAL GASES DEPOLLUTION

M. Curuia*, M. Iliescu, I. Stefanescu, Gh. Iacob[a], H. Chiriac[a]

[a]INCDTCI-ICSI , POB10, Ramnicu Valcea, Romania
National Institute of Research and Development for Technical Physics, Iasi, Romania

An efficient method to reduce the pollution of industrial residual gases based on a non conventional technique is high gradient magnetic filtration (HGMF). The principle of the HGMF is simple and similar to that of conventional deep-bed filters. The main difference lies in the direct attraction between particles and filtration matrix, which is achieved through the magnetic force. An experimental set-up of a HGMF magnetic filter is presented. The active part of the magnetic filter is constituted by a ferromagnetic matrix which is realized from very thin wires of amorphous magnetic alloy. A set of experiments with the magnetic filter was realized. The efficiency of the magnetic filtration was almost 100% for the gas flow velocity between 25.25 cm/s and 34.72 cm/s.

(Received April 26, 2004; accepted June 3, 2004)

Keywords: Magnetic filter, HGMF matrix, Gases depollution

1. Introduction

Among the sources of atmospheric pollution there are solid particles of milli-, micro-, and nanometer dimensions. The residual gases resulted from metallurgical industries contain a lot of ferrous small magnetic particles or compounds with magnetic properties (85%).

This type of particles emissions are controlled more or less successfully using conventional technologies, like electrostatic filtration, mechanical filtration (type sack filters), scrubbers etc. Taking into account the magnetic character of these particles (strongly paramagnetic, ferri- or ferromagnetic), different magnetic filtration and separation methods are suggested. The experimental determined efficiency of these methods was the best for ferri- and ferromagnetic particles having dimensions over 50 μm (more of 92%) and almost good (between 40% and 70%) for those with dimensions of 2 to 5 μm. For the small particles (dimensions of 0.2 to 2 μm), the conventional magnetic filtration and separation efficiency did not exceed 32%. Unfortunately, these are the most dangerous particles, because of their great specific area, encouraging the toxic elements adherence and because there are easily inhaled, producing different diseases (especially lung diseases).

The only method making possible good efficiency filtration and separation of micron and sub-micron particles is the high gradient magnetic filtration.

2. Theoretical considerations upon the HGMF method

The high gradient magnetic filtration is essentially a magnetic separation process. However, unlike the magnetic separation, which divides a mixture in magnetic and non-magnetic compounds, the magnetic filtration consists in the capture of the magnetic particles (considered as impurities and having generally low concentrations) from a fluid [1], [2].

The magnetic force acting on the magnetic particle is:

* Corresponding author: marian@icsi.ro.

$$F_m = V_p M_p \, gradB, \qquad (1)$$

where V_p is the particle volume, M_p is its magnetization and B is the magnetic field induction. As the formula (1) shows, the magnetic force equally depends on the particle magnetization and on the value of the magnetic field non-uniformities.

There are two different ways to obtain a high gradient magnetic field. One possibility is a special design of the polar pieces (edges, peaks etc.) that limit the filtration volume. In this case, *gradB* value is often strong enough to capture the small sized magnetic particles that are placed at a relatively long distance from the polar pieces. The other possibility is by adding some small and easily magnetizable ferromagnetic elements (wires, balls, net etc.) within the filtration volume. The role of these elements is to create high local gradients of the magnetic field; these gradients allow the appearance of very intense magnetic forces with short-range action. This setup of ferromagnetic elements that disturb the background magnetic field forms a HGMF matrix that is the characteristic component of a HGMF filter. These matrix elements, having characteristic dimension of 10-10^3 μm, create a significant number of capture places, so the matrix provides a large active surface with a small occupied volume, of 15% from the total working space, and the hydraulic resistance to the fluid stream becomes negligible.

The most used matrices are made from thin wires obtained from soft magnetic alloys. The wires can be disorderly packed or can be arranged in an ordered net. The ordered matrices have some advantages compared to the random ones: they have a constant packing factor throughout the entire volume, the local fluid velocity variations are small and the removal of the captured particles is easier [3].

A HGMF ordered matrix could be made in three flow - capture variants: transversal configuration (T) for which the fluid flow, the magnetic field and the wires are reciprocally perpendicular; longitudinal configuration (L) for which the fluid flow and the magnetic field are parallel with each other and perpendicular to the wires; axial configuration (A) for which the flow and the collecting wires are parallel and the magnetic field is transversal (Fig. 1).

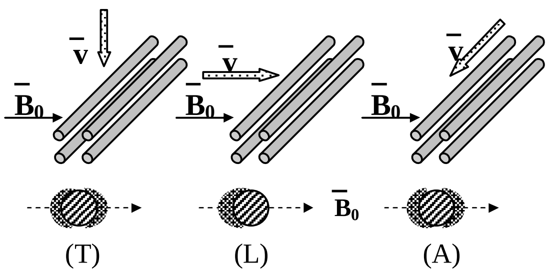

Fig. 1. HGMF ordered matrix configurations.

A magnetized wire can capture a magnetic particle if F_m is at least equal to the drag force, F_d ($F_m \geq F_d$) [4]. Because the particles in suspension have small dimensions, the gravitational force F_g acting on them is negligible ($F_g \approx 0$). Fig. 2 shows the structure of a magnetic capture place between two ferromagnetic wires of a HGMF matrix.

The parameters which influence the HGMF efficiency are: the magnetic field intensity, the gas velocity passing the matrix, the packing factor of the matrix, the diameter of the ferromagnetic wires, the dimension of the particles being captured, the length of the matrix.

3. Experimental results

The experimental set-up of a magnetic filter (Fig. 3) based on an original technical solution was realized [5]. The magnetic filter has three components: the ferromagnetic matrix, the magnetic field source (two permanent magnets) and the magnetic circuit. The HGMF matrix was made by thin wires (0.36 - 0.1 mm diameter) of amorphous magnetic alloy (IFT Iasi product), packing factor being 2.63 %. The volume occupied by the matrix was 250 cm^3.

The background magnetic field generated by the permanent magnets was between 770 Gs (peripheral area) and 1720 Gs (central area).

The tests were made with artificially impurified air with magnetic powder (dimensions between 0.5 - 32 μm) collected from an industrial source of residual gas.

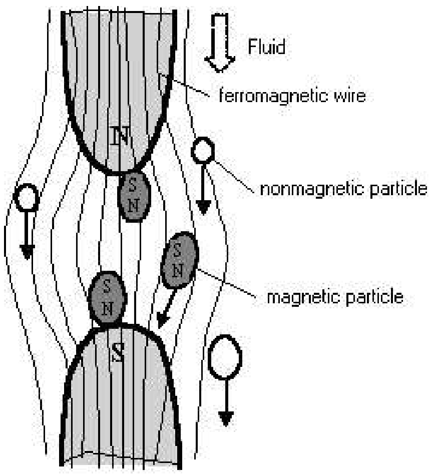

Fig. 2. The structure of a magnetic capture place.

Fig. 3. Experimental set-up of a HGMF magnetic filter for gases deppolution.

The results of the experimental tests concerning the efficiency of magnetic filtration are presented in the Table 1.

Table 1. Experimental results.

Residual gas flow [l/h]	Average velocity through HGMF matrix [cm/s]	The quantity of magnetic powder passed through magnetic filter [g]	The quantity of magnetic powder collected behind magnetic filter [g]	Efficiency of magnetic filtration [%]
800	25.25	20	0	100
900	28.41	20	0	100
1000	31.57	20	0	100
1100	34.72	20	traces	≈100

4. Conclusions

A set-up of a magnetic filter with HGMF matrix from thin ferromagnetic wires was made. The magnetic filter was tested for the filtration of an artificially impurified gas with magnetic microparticles. The efficiency of magnetic filtration had the highest possible values (almost 100%) at gas flow velocity between 25.25 cm/s and 34.72 cm/s.

The high gradient magnetic filtration can represent in certain cases an alternative for the residual gas depollution more efficient than the present conventional methods.

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