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Cleaning of Domestic and Industrial Waste Water from Ferrous Particles Using Magnetic Filter

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Abstract: In this paper, separation of dispersed magnetic particles from waste water using magnetic filtration technology was investigated. For this purpose, the mixture of water and corrosion particles is processed with detergent, acidic and basic materials, and then passed through an magnetic filter. Effects of viscosity, detergent concentration and pH value of the waste water on the separation efficiencies of the magnetic filter used were investigated. It was found that the efficiency of the filter separation decreases as the viscosity and detergent concentration of the waste water increase. Furthermore, it was recorded that the pH value of the waste water changes the efficiency of magnetic filter. The separation efficiency was found to be rather low in the absence of the magnetic field compared to those obtained in the presence of the magnetic field.

Keywords: Filtration, Waste Water, Magnetic Filter, Ferrous Compounds, Detergent

1. Introduction

Water is an important process fluid used for many industrial applications. Therefore, increases in consumption with the developments of the industrial fields and the world population led scientists to seek other ways rather than using clean water sources. Recently, re-use of disposed water resources by cleaning them from the dispersed impurities and hence acquainting them high quality characteristics has become important. In general, waste waters contain inorganic and organic impurities such as ferrous compounds, Fe_3O_4, γ-Fe_2O_3, Fe_2O_3, and detergents. These mixtures may have a value of up to 75-80% in iron-steel, power generation pipelines, mining and oil industry. Although concentration and size of these compounds is around 10^{-6}-10^{-8} ppm and 0.1-100 microns respectively, they can cause serious problems in power generation, chemical and petrol industry. Using the methods for the separation of these particles from liquids and gases results in very low cleaning efficiencies. The particles have either poor paramagnetic or ferromagnetic characteristics. The particles in liquid and gas media magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3) are corrosive and magnetic particles. Magnetic filtration is an effective separation and purification method in removal magnetic particles from both liquid and gas media. Magnetic filter can withstand to high temperatures and corrosive mediums, mechanical and hydrodynamical effects. For this reason, magnetic filters are widely used mineral, glass, ceramic, oil, power generation industry, water and wastewater treatment in order to remove heavy metal ions, phosphate and corrosion products [1-9].

On the other hand, washing-up waters of the small or large scale plants such as restaurants, automotive, textile may contain detergents and are disposed to the environment most of the time. However, there are not many investigations have been made either on the separation of the mediums contaminated with detergents. An investigation is reported on the cleaning efficiency of the detergent containing restaurant disposal water by using electro-coagulation method [10]. Another investigation, on the other hand, is made on the use of the detergents in order to keep the minimization of the forces between the particles in the magnetic filtration process [11]. In their work, the bed elements, steel wires, increased the porosity of the bed resulting in low cleaning efficiency.

Magnetic filtration is an effective separation and purification method in removal magnetic particles from the treatment and waste water. Also, the magnetic filtration is economic the method because the process is not need high pressure, high temperature and solvent. Magnetic filters are composed of the magnetized packed bed that can be easily magnetized in an external magnetic field. The bed elements are usually steel balls, steel wools and metal chips. The local high gradient magnetic fields are formed around the touching points of these elements, which are responsible for the capturing of the particles in the active areas, thus a liquid or gas media when containing any dispersed impurities is passed through these active areas. Magnetized particles even also the micron and sub-micron particles are captured here and low concentrations such as 10^{-3}-10^{-5} ppm liquid or a gas media is thus cleaned. Magnetic filtration performance depend on many factors such as magnetic characteristics and size of the filter elements, filter length, etc [1, 12-16].

The cleaning efficiencies and performance of the magnetic filters depend on several factors such hydrodynamic, magnetic, rheological and geometrical parameters of the system. In the recent years, although some the parameters mentioned above have been investigated, effects of the rheological and physicochemical structure on the cleaning mediums have not been investigated. Therefore in this article, we aimed to investigate effect of the external magnetic field, size of the filter matrix elements and filter length on cleaning efficiency of the magnetic filters using waste water contaminated with ferrous compounds, acids, bases and detergents.

2. Experimental Methods

In this article, the magnetic filter used in the experimental studies consisted of non magnetic filter body and the metal balls as the filter elements. As the external magnetizing medium, multipurpose electromagnetic magnetizing equipment (AC/DC, 0-220 V, and 0-20 A) has been used. The experimental studies were carried out by placing an magnetic filter into this equipment which has a 48 mm diameter. Magnetic field intensity (B) was within the range of 0-1.0 T. The local magnetic field intensities are measured and evaluated using GM 05 Gauss meter (Hirst Magnetic Instruments Ltd.). The average magnetic field intensity was determined by taking the average of three different values.

The most important characteristics of the magnetic filters that makes them highly efficient and popular compared to classical filters was the separation of nano particles from the carrier medium with a very high efficiency. For this reason, Scanning Electron Microscope (SEM) analysis was necessarily made in order to determine mean particle sizes of the rust particles that form the suspension. From the measurements taken from the 11 different points of sample, particle size distribution for the samples have been determined in terms of micrometers (µm). As result of SEM analysis, the mean particle sizes vary between 0.2-2 µm. However, in this work, the mean particle size of corrosion product was taken as 2 µm (δ) for the calculation purposes.

Experiments were carried for various conditions, such as the filtration velocity of 0.15 m/s, water viscosity of 0.8-11 cp, external magnetic field intensity of 0-0.35 T, diameter of the filter elements of 6.28 mm, filter length of 10 cm, the waste water pH of 2-12 and detergent concentration of 0-5 %. In order to prevent the coalescence of the corrosion product particles, a continuous mixing was applied. From the total Fe amount, the cleaning efficiency of the filtration process., which also called as quality factor (ψ), was determined using the following equation:

$$\psi = \frac{C_i - C_0}{C_i}\lambda \quad (1)$$

where λ is the magnetic fraction of the mixture, C_i and C_o are the total Fe amount at the inlet and outlet respectively (mg/L). The total Fe amount at the inlet was held constant. The total Fe amount at the inlet is 14,2 mg/L. A 10-g portion of particles was spread over a permanent magnet and the fraction of particles having ferromagnetic properties was weighed. It was determined that 85% of corrosion products showed magnetic properties ($\lambda = 0.85$). The solid/liquid ratio of the suspension used for the experiments was kept as 0.050 g/L. The experiments were carried out at room temperature (23°C±1). In order to prevent the coalescence of the rust particles, a continuous mixing was applied.

3. Results and Discussions

3.1. PH of the Suspension

This part of the experiments were carried out using spheres with a diameter of 6.28 mm and keeping the pH values within the range of 2-12. From the results obtained, it was noted that the efficiency is notably high when the suspension has high pH value as can be seen in Fig. 1. This is because, when the oxidized particles are suspended in solutions having low pH values, they are charged positively by absorbing the protons. On the other hand, the protons are desorbed in solutions with high pH values and therefore, have negative charges. This means that particles are electrically charged and collect the oppositely charged ions around them by forming a cluster of ions. The pH value and the concentration of the medium also affect the zeta potential. Flocculation of the particles occurs at low zeta potential situations as the interactions between the particles are low in low zeta potential values. Therefore, these flocculated particles are easily held by magnetic forces in the filter as a result of the fact that low zeta potential increases the filtration efficiency [12].

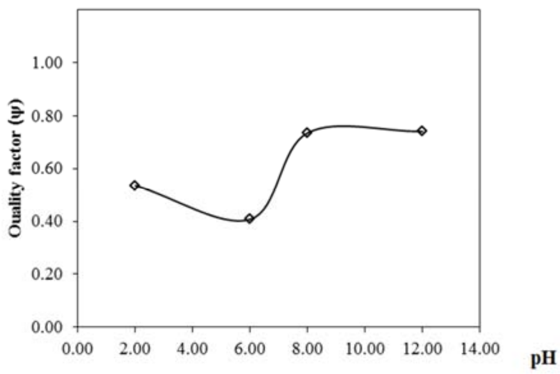

Figure 1. *Variation of the quality factor with the pH value of the waste water containing detergent (B= 0.28 T, d= 6.28 mm, δ= 2µm, V_f = 0.15m/s, %1 detergent (w/v), L= 0.1m).*

On the other hand, the quality factor was affected by the pH values of the wasted water in media without detergent. When the water is acidic, the cleaning performance increased, while decreased when the waste water is basic. This is because, when the oxidized particles are suspended in solutions having low pH values, they are charged positively by absorbing the protons, while, those protons are desorbed in solutions with high pH values and therefore, have negative charges. This means that particles are electrically charged and collect the oppositely charged ions around them by forming a cluster of ions. The pH value and the concentration of the medium also affect the zeta potential. Flocculation of the particles occurs at low zeta potential situations as the interactions between the particles are low in low zeta potential values. Actually, if zeta potential is 0 then the particle capture is maximum, therefore this point is obtained if the waste water pH is between 4-6 as can be seen Fig. 2.

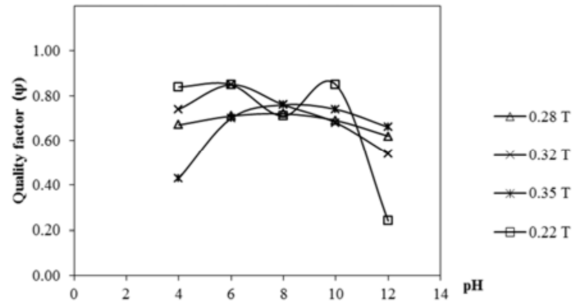

Figure 2. *Variation of the quality factor with the pH value of the waste water containing no detergent (V_f=0.15 m/s, δ= 2μm, d=6.28 mm, L= 0.1 m, C_i= 50 ppm).*

3.2. Viscosity of the Suspension

Effect of viscosity on the cleaning efficiency was investigated under with and without detergent presence in the medium. As can be seen from Fig. 3, any important effect of the waste water viscosity on the filter performance was not recorded in the presence of the magnetic field. However, the filter efficiency decreased up to the viscosity value of 1.8 cp, and then increased if a magnetic field is not applied (B=0 T).

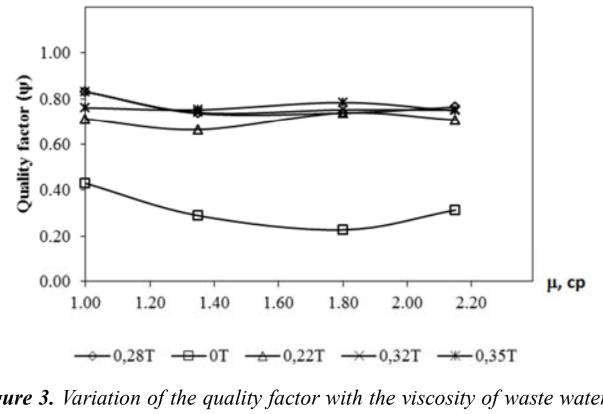

Figure 3. *Variation of the quality factor with the viscosity of waste water in media with detergent (V_f= 0.15 m/s, δ= 2 μm, d= 6.28 mm, L= 0.1 m, C_i= 50 ppm).*

In order to investigate the effect of the waste water viscosity on the cleaning performance of the filter for B= 0.22 and 0.32 T, the viscosity of the waste water in media without detergent was changed within the range of 0.8-11 cp. As can be seen from Fig. 4, the cleaning efficiency decreased recordable up to the value of 1.14 cp and then a somewhat smaller decrease was noticed. Increasing the viscosity made the passage of the waste water from the pores of the filter difficult. Moreover, working with viscous liquids blocked the pores and this problem can be overcome by increasing the temperature and therefore lowering the viscosity. Since EMFs can withstand very high temperatures, separation of magnetic dispersed particle from water that is not temperature sensitive can be made efficiently.

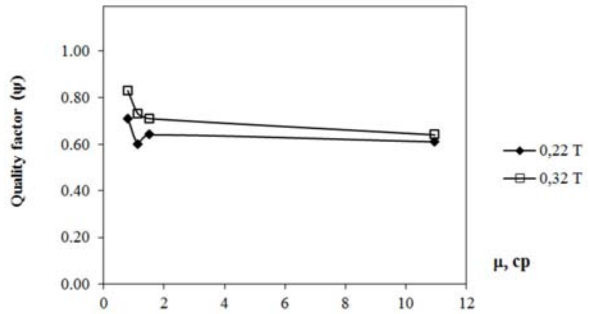

Figure 4. *Variation of the quality factor with the viscosity of waste water (V_f = 0.15 m/s, δ= 2 μm, d=6.28 mm, L=0.1 m, C_i= 50 ppm).*

3.3. Detergent Concentration

The detergent concentration was changed within the range of 0-5% for the experimental purposes. It was recorded that the filtration efficiency was higher when the waste water did not contain detergent. On the other hand for the contaminated solutions, the efficiency was increased up to the detergent concentration of 2% and then a decrease was noted. In the absence of the magnetic field, the filtration efficiency was rather low for both pure and detergent-contaminated solutions as can be seen in Fig. 5. The efficiency was higher for pure solutions. The viscosity of the waste water increased from 1 cp to 2.15 cp with increasing the concentration from 0 to 5%. In return, the surface active material in the detergent lowered the particle-particle and particle-filter elements interactions, while it made easy the waste water to diffuse from the pores of the magnetic filter resulting in more accumulated particles in the pores.

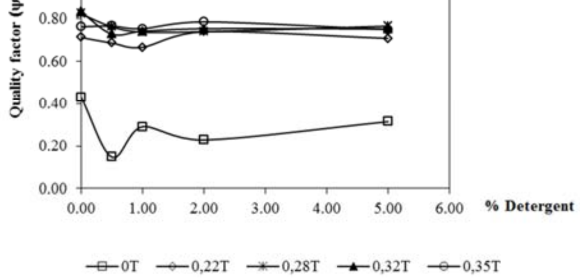

Figure 5. *Variation of the quality factor with the detergent concentration (V_f = 0.15 m/s, δ= 2 μm, d= 6.28 mm, L=0.1m, C_i= 50 ppm).*

4. Conclusions

Effect of various parameters mentioned above on the removal of ferrous compounds from the prepared waste water suspensions with / without detergents, acid and base was investigated. As a results of the experimental studies, it can be seen that the parameters of the magnetic filtration process play a vital role on the efficiency of the particle capture in the active areas. It is also clear that both pure, acidic, basic and detergent containing solutions can be effectively cleaned using an magnetic filter. Moreover, this method is a rather simple and quite environment-friendly separation process as it does not require any chemical or biological solutions and heavy conditions such as high temperature or pressure. Also the it can be simply installed and cleaned. However, the theory of magnetic filters should be corrected for the solutions containing detergents by considering the physical properties of the media to be cleaned in order to make this separation process advantageous.

From the results reported above it can be clearly seen that the filtration efficiency decreases by increasing detergent concentration and waste water viscosity. In the practical applications, on the other hand, the variations of these parameters must be kept within some certain limits. For example, for the cleaning of industrial waste water, the external magnetic field intensity should be higher than 0.35 T, filter length lower than 1 m, detergent concentration lower than 2% and the size of the filter matrix elements can be as high as 5-6 mm. In this case, the filtration efficiency can be as high as 78% resulting in notable savings in electricity costs. In these filters, savings can also be made by constructing the matrix elements using fixed magnets. However, this makes the filter regeneration difficult. For this reason, the construction of the filter matrix elements from the ferromagnetic spheres and chips that can be easily magnetized in an external magnetic field is strongly recommended.

References

[1] Abbasov T., *Electromagnetic filtration processes*, Seckin Publishers, Ankara, 2002.

[2] Svoboda J., *Magnetic techniques for the treatment of materials*. Kluwer Acdemic Publishers, USA, 2004.

[3] Sandulyak A. V., *Magnetic filtration of liquids and gases*, Moscow: Ximiya, 1988.

[4] Song M., Kim S., Lee K., Development of a magnetic filter system using permanent magnets for separating radioactive corrosion products from nuclear power plants, *Separation Science and Technology,*39 1037–1057, 2005.

[5] Gıllet G., Dıot F., Lenoır M., Removal of heavy metal ions by superconducting magnetic separation*. Separation Science and Technology*, 34 (10), 2023–2037, 1999.

[6] Franzreb M., Holl W. H.,Phosphate removal by high-gradient magnetic separation using permanent magnets, *IEEE Transactions on Magnetics*, Mag-10, 923-926, 2000.

[7] Mishimo F., Takeda S., Fukushima M., Nishijima S., A superconducting magnetic separation system of ferromagnetic fine particles from a viscous fluid, *Physica C*, 463-465, 1302-1305, 2007.

[8] Cerff M., Morweiser M., Dillschneider R., Michel A., Menzel K., Posten C., Harvesting fresh water and marine algae by magnetic separation: Screening of separation parameters and high gradient magnetic filtration, *Bioresource Technology*, 118 289–295, 2012.

[9] Menzel K., Windt C. W., Lindner J. A., Michel A., Nirschl H., Dipolar openable Halbach magnet design for High-Gradient Magnetic Filtration, *Separation and Purification Technology*, 105 114–120, 2013.

[10] Tsouris C., Noonan J., Ying T., Yiacoumi S., Surfactant effects on the mechanism of particle capture inhigh-gradient magnetic filtration, *Separation and Purification Technology*, 51 201–209, 2006.

[11] Murthy Z. V. P., Nancy C., Kant A., Separation of Pollutants from Restaurant Wastewater by Electrocoagulation, *Separation Science and Technology*, 42 819–833, 2007.

[12] Abbasov T., Magnetic filtration with magnetized granular beds: Basic principles and filter performance, *China Particuology,* 5 71–83, 2007.

[13] Ebner N. A., Gomes C. S. G., Hobley T. J., Thomas O. R. T., Franzreb M., Filter capacity predictions for the capture of magnetic microparticles by high-gradient magnetic separation, IEEE Transactions on Magnetics, 43, 2007.

[14] Sato S., Mitsuhashi K., Ohara T., Effect of zeta potential of particles dispersed in an aqueous solution on magnetic filtration efficiency, *IEEE Transactions on Applied Superconductivity*, 14, 2004.

[15] Yuceer M., Yıldız Z., Abbasov T., Evaluatıon of Electromagnetıc Fıltratıon Effıcıency Usıng LS-SVM", *Physicochemical Problems of Mineral Processing, 51 (1), 173−180, 2015.*

[16] Abbasov T., Gögebakan V., Karadağ T., Particle capture modeling for an axial magnetic filter with a bounded non-Newtonian flow field, *Powder Technology*,291 223–228, 2016.