THE ELECTROMAGNETIC HYDROCYCLONE FILTER FORCES ANALYSES

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There are a great number of different kind organic and natural admixtures (sand, ferrous, nuclear particles, phenols, oil, etc.) in technological liquids and gases, which can drop production quality for the worse. That is why improved universal treatment devices (filters, separators, etc) for these liquids and gases are in great need. From the other hand the waste liquids and gases should be filtered before disposal because they damage environment. The importance of the environmental pollution control and treatment is undoubtedly the key factor in the human future. This paper deals with design of fine treatment technique for the technological and waste liquids and gases (separation of microscopic suspended water, sand, oil and other organic and not organic components). The paper briefly reviews existing processes and technique for liquids and gases treatment and is focused on construction of electromagnetic hydrocyclone. The effect of main forces (centrifugal, electrical and magnetic) on the separation of very small-size admixtures (smaller than 10 microns) is analyzed and compared. Some delicate technologies are shown where even a very small amount of even micro admixtures can bring misfortune or accident.

INTRODUCTION

Technological and waste liquids and gases usually have a great number of different kind admixtures (ferrous, phenol, oil, organic, nuclear particles, etc.) which can change production quality for the worse. That is why improved cleaning devices (filters, separators etc) for these liquids and gases are in immense need. Waste liquids and gases should be filtered before disposal because they damage environment. Otherwise, the producers have to pay a heavy emission fees. There are a lot of methods and filter constructions to separate the above mentioned particles from technological and waste liquids and gases and main of them are hydro or gas cyclones, magnetic or electrostatic traps etc. In most cases they meat the all demands of the industries if very small (less then 10 microns) impurities do not disturb their main processes. The efficiencies of the above mentioned filters and traps are high and very well known for different types of admixture in liquids and gases [1-4]. But there are some delicate technologies where even a very small amount of even micro admixtures can bring misfortune or accident. To empathize this more clearly, some matter-of-fact examples are given below:

1. There is a very little amount of microscopic water bolls in plane fuel (less than 0.01% or 100gr in a ton) that can cause sometimes accident. The water may freeze at any valve or at narrow pipe and fuel will not be pumped into engine. The filtration process of these micron size water particles is possible by the help of some chemical methods or centrifugal machine, but difficult and expensive.
2. There is a tiny quantity of some phenols and other light organic particles (up to molecule size) in the distil water of thermal plant boilers. These particles separation by the help of mechanical or chemical methods is extremely difficult and expensive. Nevertheless that those particles are too small, but they are very dangerous. They make thousands small bursts on the inner surface of high temperature and pressure boiler pipes, pluck out micro particles of the metal, slowly damage (erode) the pipes and increase risk of the boiler steam leakage or even explosion.
3. One of the method of different liquids (in particular sea water) desalination or demineralization is mixing them with another active sprayed liquid (or a subtle powder), that is able to entrap the appropriate mineral salts, and then separate the liquid or the powder from the main one. The smaller micro particles of the entrapping liquid or the powder the more effective the entrapping process. One of these active and rather cheap liquids is kerosene. But to separate these salty micro particles from main liquid by ordinary hydrocyclone is very difficult and more expensive. Electric and magnetic forces here are more effective than only centrifugal force.
4. Finding and filtering out different nuclear particles from liquids and gases, especially after Chernobyl Nuclear Station accident, became a very important issue. It is used in UKRAINE to reveal and to filter the electrically charged nuclear particles in milk by the help of electric and magnetic forces.
5. Textile manufacturing is a very important branch of Turkish industry. Multi-cycle painting processes in textile industry use huge amount water: the higher quality water, the higher quality textile. There are more than twelve different operations during panting process of a textile tela (fabric, cloth) and every one of them demands new portion good quality water or recycled waste water. It is very ease to take out rather big specific textile particles (rubbish) from waste water, but taking out small admixtures less than 50 microns and especially less than 10 microns (dust, pant particles etc) is extremely difficult. Here is reasonable to apply more effective electrical or magnetic forces for separation and to recycle waste water or, as a minimum, bring it to the required waste limit norm.

Thus, there are some cases where separation (filtration) liquids from all admixtures up to even micro particles is very important and it demands application of more effective forces for micro particles. Here is important to stress that electromagnetic forces can help to rise the total coefficient of filtration efficiency, but a bit - not more than 1%, even less. The main effect is coming from higher quality of the concrete technology, from higher reliability and safety reserve for humanity, ecology and so on.

DISCUSSIONS

Electromagnetic hydro (gas) cyclone (EMH) is a combined apparatus for the technological and waste liquids and gases treatment. A special construction joints collinear influences of electric, magnetic, and centrifugal forces. Similarly to traditional hydrocyclones, there are several different types of EMH construction [4,5,7-10]: cylindrical and conic EMH for two products, EMH for three products etc. First and especially second type of EMH are most useful ones and will be mainly discussed in this paper (fig. 1 and 2). EMH consists of cylindrical diamagnetic metal (or plastic) main body 1, conic or flat ferromagnetic metal inferior body 2, entrance 3 and output 4 nipple pipes (tangential to cylindrical main body), central light product pore out nipple pipe 5 (central electrode), flat ferromagnetic metal cover 6, bobbin around main body 7 and the pipes electrical isolations 8.

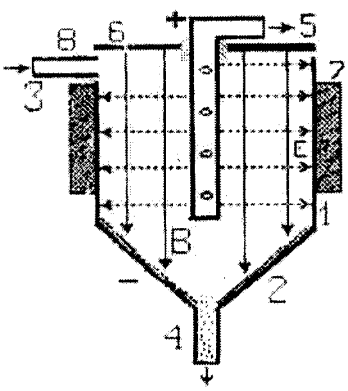

Fig. 1. Conic EMH

As it is illustrated by fig 1 and 2, an electric field force is produced by applied DC voltage between main body and central pour out nipple (electrode). A bobbin around the main body produces a magnetic field force between flat ferromagnetic cover and magnetic conical (or flat) bottom part of the EMH. There is inertial centrifugal force due to liquid (gas) high-speed rotation in cylindrical main body, because of the entrance nipple is tangential to the latter and high incoming flow velocity is equal to liquid (gas) tangential rotation velocity. For some special cases ozone (O_3) can be produced around the central electrode to kill microbes, to fire poisonous natural or organic admixtures in outgoing pipe (central electrode). In such a case an additional high frequency voltage can be applied throw a capacitor to this electrode.

Thus, in two words, technological or waste liquid (gas) enters throw input nozzle and heavy particles, such as sand, metals, silt, etc are displaced by centrifugal force to main body inner cylinder surface, then down and quit from conic exit. While light particles, such as oil and organic traces, gas bubbles etc, are ousting to the central electrode-pipe and pour out of the EMH. In this system quality filtration rises very high (especially for micron size impurities) due to electric and magnetic field application in addition and collinear to the centrifugal force: the three forces act in the same direction.

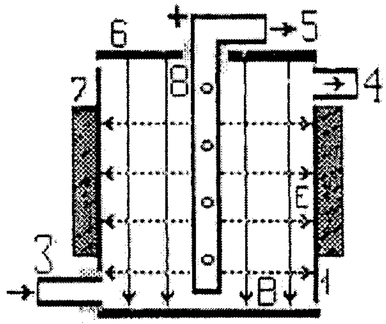

Fig. 1. Cylindrical EMH

There are several vector forces that affect a particle in EMH in a common case:

$$F_m+F_e+F_s+F_i+F_a+F_w+F_c = 0, \qquad (1)$$

where: F_m -magnetic forces, F_e-electric force, F_s - Stokes' force (resistive), F_i -inertia force, F_a – Archimede's force, F_w -weight force, F_c -centrifugal force.

Comparative analyses [1] have shown that influences of F_a, F_i and F_w on a very small (less than 50 micron) dispersed particles are negligible small and they can be omitted. The main influences belongs to forces F_m, F_e, F_c and resistive force F_s (depends on viscosity of a liquid).

The effect of centrifugal force on particle filtration is determined as:

$$F_C = \frac{\pi * d^3(\rho_1 - \rho_2) * v_t^2}{6r}, \qquad (2)$$

where: d - diameter of particle [m],
ρ_1 - density of technological liquids. [kg/m^3],
ρ_2 - density of particles [kg/m^3],
r - average revolving radius [m],
v_t - velocity of particles, m/sec.

In the case of $\rho_1<\rho_2$ (water - ferrous, sand etc admixtures) cleaned liquid exits trough the central pour out tube and mechanical particles are removed from bottom conical product pipe. In the case of $\rho_1>\rho_2$ (water - oil, phenols etc), cleaned liquid is extracted trough bottom conical product tube and oil is removed from central pour out nipple pipe. But most micro particles cannot be removed just by cyclone application due to floatation effects, which presents in liquids and gases: for $d<d_{critical}$ the smaller weight of a micro particle (proportional to d^3 of a particle) the higher floating force (proportional to d^2 of a particle) as compared with weight.

Generally, 70-80% of particles in technologic liquids are charged by negative electric charge [1,2,3]. Electric and magnetic forces effect on the negatively charged particles. They can be pushed or pulled to the electrodes. Due to this fact central pour out tube is often used as a positive electrode and cylindrical body as a negative one. There are some holes on this central tube for collecting light and charged particles such as oil, gas babbles, acetone, phenols, etc. The electric force effect on a charged particle can be found as:

$$F_e = E^* q_m \,, \qquad (3)$$

where: E –electric field strength (V/m), q - average electric charge of a particle (C). EMH radial electric field E (similar to electric field of cylindrical capacitor) can be found as:

$$E = \frac{V}{r \ln \frac{R}{r_{CE}}} \,, \qquad (4)$$

where: R -diameter of outer electrode, r_{CE} -diameter of central electrode-pipe, r - diameter of any cross-section.

Electric field reaches its maximum around the central electrode when $r=r_{CE}$ and its minimum around the outer (cylindrical) electrode when $r=R$.

The average electric charge of a particle can be calculated as:

$$q = \frac{\varepsilon_0 \varepsilon S \xi}{\delta} \quad \text{Coulomb (C)}, \qquad (5)$$

where: ε -relative permittivity $\varepsilon_m/\varepsilon_0$=81, ε_0=8.86x10^{-12} Farad/m,

S -surface area of d=10μm particle πd^2=3,14*10^{-10}m^2,

ξ - electrokinetic potentials ξ=0.1-0.5Volt (for some organic matter higher),

δ - doubled electric areas thickness $\delta=10^{-6}$m.

Thus, it can be obtained for different matter and d=10μm q=(2 – 6) $\cdot 10^{-14}$C, for d=5μm q = (0.5–1.5)$\cdot 10^{-14}$ C and for d=1μm q=(0.125–0.375)$\cdot 10^{-14}$ C.

There are two main magnetic forces that suppose to be taken into account [3,4,6].

The first one is for magnetic particles only:

$$F_{qm}=H \cdot q_m \,, \qquad (6)$$

where: H -magnetic field strength (intensity), q_m -magnetic charge of a particle.

When oil, phenol, etc particles separation from water is concerns, q_m is too small [4,6], magnetic field is homogeneous and this magnetic force can be neglected. On the contrary, the second magnetic force - the Lorenz one, - in some cases can be taken into account: any movement of electrically charged particle in magnetic field creates the Lorenz force that helps filtration process:

$$F_L=q \cdot B \cdot v \,, \qquad (7)$$

where: B - magnetic field induction, v - charged particle velocity.

In the designed construction of EMH tree of the above mentioned forces (centrifugal, electric and magnetic) effect along the same direction and help the filtration process especially in the case of micro particles. For comparison of the centrifugal and electric forces effects on a particle all calculations were made for this type of EMH: particles diameter d=1; 5 and 10μm, average revolving radius r=0.1m, velocity of input water and charged particle v=0.5–1.0m/sec, particle charge q=(6–0.375)*10^{-14} coulomb, applied voltage V=600V, volume capacity V_v=5 liters, r_{CE}=25mm, r_{in}=25mm. An emulsion of water with small amount phenol was taken as a liquid under treatment. The calculations for several variants of particle diameter d and its charging ability ξ (electrokinetic potential) influence of electrical field force 5–15 times more efficient than centrifugal force (the smaller diameter, the higher efficiency: for d=1 μm and ξ=0.3 V F_C=0.026$\cdot 10^{-8}$Newton (N), while F_E=0.225$\cdot 10^{-8}$N. The special particles pre-charging technique can rise these figure two-three times and even more. The electric field also helps particles to coagulate (get bigger size) and simplify the separation process. It needs only 400-600V electrical voltage on main electrode. The Lorenz force influence for this particular emulsion is very small and can be neglected (F_L=4.1$\cdot 10^{-10}$N).

CONCLUSION

The special construction of EMH was designed for filtration and separation processes of different liquids and gases, which have micro admixtures along with rather big particles. Similarly, special constructions can be designed for many kinds of technological and waist liquids and gases taking into account their parameters, demands and performance attributes. Some advantages of the EMH are the following:

1. It is a combined system designed to use the main three forces in the same direction.
2. There is no any active rotating mechanical part in EMH. Because of that this type EMH can be used in high-pressure technological systems without any risk.
3. Simple process control by electric and magnetic fields (applied voltage and current).
4. Available for many separating matters (liquid/liquid, liquid/gas, liquid/solid particles, liquid/ferromagnetic particles, etc.)
5. Possibility of ozone formation (by high frequency AC) in terms to burn left as a residue poisonous organic admixtures, microbes and microorganisms at the end of filtration.
6. EMH is an ecology improving system.

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ELEKTROMAQNİT HİDROSİKLON SÜZGƏCLƏRDƏ TƏSİR GÖSTƏRƏN QÜVVƏLƏRİN ANALİZİ

Məqalə, tullantı mayelərin və qazların aşqarlardan təmizlənməsinin müasir üsullarının işlənməsinə həsr olunmuşdur. Məqalədə, maye və qazların təmizlənməsi qurğularının və üsullarının qısa icmalı verilmişdir. Elektromaqnit hidrosiklon süzgəcin konstruksiyası və iş prinsipi geniş şərh olunur. Kiçik ölçülü (10 mikrona qədər) aşqarların separasiya prosesinə təsir edən (mərkəzdənqaçma, elektrik və maqnit) quvvələrin, müqayisəli səkildə, analizi verilmişdir. Qeyd olunur ki, bəzi incə proseslərdə, çox kiçik ölçülü, az miqdarda aşqarların mövcudluğunu arzuolunmaz halların əmələ gəlməsinə səbəb ola bilər.

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АНАЛИЗ СИЛ, ДЕЙСТВУЮЩИХ В ЭЛЕКТРОМАГНИТНОМ ГИДРОЦИКЛОННОМ ФИЛЬТРЕ

Настоящая статья посвящена разработке оборудования для тонкой очистки сточных жидкостей и газов (сепарация микропримесей воды, песка, нефти и др. органических и неорганических компонентов). В статье содержится краткий обзор методов и устройств, для очистки жидкостей и газов и подробное описание конструкции электромагнитного гидроциклонного фильтра. Анализируется и сравнивается влияние основных сил (центробежных, электрических и магнитных) на сепарацию примесей очень малых размеров (менее 10 микрон). Отмечены некоторые тонкие процессы, в которых даже очень малое количество очень мелких примесей может привести к нежелательному эффекту.

Received: 14.12.01