A STUDY ON THE EFFECTIVENESS OF IN-SITU HIGH INTENSITY ULTRASONIC (HIU) IN INCREASING THE RATE OF FILTRATION IN PALM OIL REFINING INDUSTRIES

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"Dengan nama Allah yang Maha Pemurah lagi Maha Penyayang. Selawat dan Salam ke atas junjungan besar Nabi Muhammad S.A.W."

"Specially dedicated to my wife and mum, sister, brothers and all of my friends."

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ABSTRACT

Application of ultrasound wave fields in the filtration and separation technology is a new and clean technology and offers an attractive alternative to the classical cleaning processes. Fouling phenomenon is a major bottleneck in this separation technology, as expected in the industrial application of such finely porous media. As the filtration process continues, the concentration of solute keeps building up on the filter surface to form a filter cake. This results in a continuous decline of the flux. In this study, the effect of intermittent application of ultrasound wave fields on the filtration of bentonite in Refined Bleached Deodorized (RBD) oil suspension is presented. In general, the intermittent application of ultrasound fields increased the overall flux of the filtration. The main mechanism responsible in reducing the thickness of the filter cake, and hence increasing the rate of filtration, is the cavitation phenomenon. Four parameters affecting the ultrasound assisted filtration were investigated. The parameters include the filtration cycle time, sonication cycle time, applied pressure, and ultrasound intensity. The highest percentage of improvement achieved in the study was 88.47%, conducted at 5 minutes filtration cycle time and 12 minutes sonication cycle time. The result also showed that the degree of flux improvement was initially increased with the increase in the applied pressure. However, as the pressure was further increased, compaction of cake layer took place which constricted the filtrate path, and hence, reduced the degree of flux improvement. On the other hand, the degree of flux improvement was linearly related to the ultrasound intensity. In this study, the highest flux was obtained when the ultrasound intensity was set at 1.2109 W/cm^2. An Ultrasonic Clean-in-Place (UCIP) method of cleaning the filtration system was also developed in this study. The UCIP method showed an effective method of cleaning, with 71.5% flux recovery achieved after only 15 minutes of UCIP cleaning processes. Empirical models were developed in this study to represent the profile of the filtration process. The developed model showed good fits with the experimental data, with error not more than 5%.

ABSTRAK

Penggunaan medan gelombang ultrabunyi di dalam teknologi penurasan dan pemisahan adalah baru dan teknologi pembersihan menawarkan alternatif kepada pembersihan secara klasik. Fenomena Penyumbatan adalah gangguan terbesar di dalam teknologi pemisahan ini. Semasa proses penapisan berterusan, kepekatan daripada suspensi akan membentuk lapisan kek di atas permukaan penapis dan ini menyebabkan penurunan kepada fluks secara berterusan. Di dalam kajian ini, kesan sela pengaplikasian gelombang ultrabunyi ke atas penapisan lumpur teraktif di dalam penapisan, pelunturan dan penyahbauan (RBD) suspensi minyak adalah diterangkan. Secara umum, pengaplikasian gelombang daya ultrabunyi bersela meningkatkan keseluruhan fluks di dalam penapisan. Mekanisma utama yang bertanggungjawab di dalam mengurangkan ketebalan kek dan seterusnya meningkatkan kadar penapisan adalah fenomena peronggaan. Empat parameter yang memberi kesan kepada penapisan berbantukan ultrabunyi telah dikaji. Parameter itu termasuk kitaran masa penapisan, kitaran masa sonikasi, kesan tekanan dan keamatan ultrabunyi. Peratus tertinggi peningkatan kadar penurasan yang dicapai di dalam kajian ini adalah 88.47% yang dijalankan pada 5 minit kitaran masa penapisan dan 12 minit kitaran masa sonikasi. Keputusan juga menunjukkan bahawa darjah pembaikan fluks telah pada awalnya meningkat dengan peningkatan di dalam kesan tekanan. Oleh sebab itu, apabila tekanan ditingkatkan kek akan menjadi padat. Seterusnya, darjah pembaikan fluks akan berkurang. Sebaliknya, darjah pembaikan fluks dihubungkan secara linear terhadap keamatan ultrabunyi. Di dalam kajian ini, fluks tertinggi yang dicapai apabila keamatan ultrabunyi telah disetkan pada 1.2109 W/cm^2. Kaedah sistem penapisan Pembersihan Setempat Ultrabunyi (UCIP) juga telah dibangunkan di dalam kajian ini. Kaedah UCIP menunjukkan keberkesan kaedah pembersihan dengan 71.5% mendapat kembali fluks yang dicapai selepas hanya 15 minit proses pembersihan UCIP. Model empirik telah dibangunkan di dalam kajian ini untuk mewakili profil proses penapisan. Model yang dibangunkan menunjukkan kesesuaian yang baik dengan data eksperimen dengan ralat tidak melebihi 5%.

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LIST OF SYMBOLS

˚C	-	Degree Celsius
ΔP	-	Pressure Drop
A	-	Cross-sectional area
CPO	-	Crude Palm Oil
F	-	Frequency
G	-	gram
HIU	-	High Intensity Ultrasonic
I	-	Intensity (W/m^2)
In	-	inches
Kg	-	Kilogram
KHz	-	Kilohertz
L	-	Bed Depth
MPOB	-	Malaysian Palm Oil Board
Pa	-	Pressure in Pascal
PZT	-	Piezoelectric Ceramic Transducer
RBD	-	Refined, Bleached and Deodorized
S	-	time in second
So	-	Specific surface area
UCIP	-	Ultrasonic Clean In Place
U_o	-	Superficial velocity
V	-	Filtrate volume
W	-	Watt
A	-	Specific cake resistance (m/kg)
ε	-	Porosity
μ	-	Liquid viscosity
μm	-	Micrometer
ρ	-	Density (kg/m^3)

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CHAPTER 1

INTRODUCTION

Palm oil industry has been the bread and butter of Malaysian industry ever since palm tree was brought into the country in the 1960's. The fast growth of this industry has made Malaysia to be the largest producer of palm oil for many years. Palm tree is easily grown in tropical climate countries. Hence, the profitable industry has been adopted by neighboring countries such as Thailand, Indonesia, Vietnam, Cambodia, as well as Philippines. Realizing the competitiveness of the industry and the advantages of neighboring countries with large cultivating land, much research has been focused on improving the overall operation of the industry so as to increase its productivity.

In any chemical and oleochemical industry, separation processes are of key importance, whether it is a minor or the main part of operation. Choosing the best separation method for the job is crucial to ensure economic operation. Filtration, for instance, is a typical solid-liquid separation technique commonly used in the industry. It is preferred from other solid-liquid separation techniques because it offers low investment costs, easy to scale up, long lifespan of the filters because of mild operation conditions, compact construction and fast, easy to make installation, low energy, and low chemical consumption.

In the edible/vegetable oil industry, filtration is an important unit operation for the separation of bleaching earth from the treated oil. In this process, pressure leaf filters are most commonly used for this purpose.

During operation, the rate of filtration decreases progressively as a result of filter cake build-up on the surface of the filter medium. The process comes to an end when the whole chamber is filled with solids, normally about 2 ½ hours (for standard size filter) after separating 500 kg of solids from the treated oil. The separating system requires a regeneration process, which normally takes about 1½ hours. The sequence of filtration and regeneration process is repeated for approximately two to three weeks, depending on the condition of the filter medium, before a thorough cleaning method is conducted. The conventional cleaning of the filter leafs include disassembling of the filter unit, immersing the filter leafs in caustic solution, followed by high pressure water cleaning (60- 90 bar) and steam cleaning. The total downtime from disassembling, cleaning, up till assembling of the filter system averages about 2 days. The implication of long downtime period in the plant operation is its higher operation and capital cost in which the plant has to invest on the standby filter unit and on the cleaning operation.

Presently, there has not been much work focusing on developing methods to improve the filtration process. Improvement in the rate of filtration, for instance, will reduce the operation time, and hence, increase the productivity. The present method of knocking or vibrating the filter leaf is only applicable after the filtration process is completed, i.e. during the regeneration of the filter medium. Vibrating or knocking the filter leaf during the filtration is not adopted because it may disrupt the whole formation of the filter cake. This is not acceptable since in filtration processes, filter cake is the true medium performing the solid-liquid separation.

Upon close examination of the filtration process, the main problem which dominates in reducing the flux during the filtration process is the fouling phenomenon. Fouling refers to a combination of flux reducing factors which include the blinding of

filter medium as a result of particles retained on the filter surface as liquid passes through the filter medium, cake formation, and the formation of concentrated layer near the filter surface. Many methods have been proposed to reduce fouling. In general, the methods include sample pretreatment, filter pretreatment, abrasives, filtration aids, back flushing, baffling and oscillatory flow techniques, electric field assisted and ultrasonic field assisted.

The common method used to secure high filtration rate is by pretreating the feed solution before entering the filtration system. The method employs flocculating agent, causing particles to agglomerate into larger entities, thereby preventing them from penetrating inside the pores. Hence, a greater filtrate flux can be achieved during filtration. Another method of reducing the fouling phenomenon is by modification of the filter surface properties. Surface characteristics and filter morphology have a considerable effect on the adsorption of solution and, as a result on the separation. The addition of filtration aid to the feed stream prior to filtration of a suspension increases the filtration rate by modifying the porosity of the filter cake and the particle size distribution which increases its permeability. A common type of filtration aid is diatomaceous earth but the fact that the filtration aid should be retrieved in the blow-down of the stream to be recycled makes this technique rather difficult to apply. This technique is more suitable for dead-end filtration operation, particularly the conventional filtration such as plate and frame filter press, leaf filter, vacuum belt filter etc.

There are reports of the use of abrasive materials, added to the mixture in order to disrupt the layer on the surface of the filter. Another method of reducing the fouling phenomenon is baffling and oscillatory flow techniques. These techniques are to promote and/or increase turbulent condition near the filter surface. These techniques also have been used by several workers in order to improve the filtration flux. The presence of the baffle resulted in a radial flow inside the filter, and hence, the path length was increased. However, these methods are more suitable in membrane filtration rather than in the conventional filtration since they require crossflow mode of filtration to cause the sweeping action on the filtering surface. Back-flushing technique is an effective method

to remove fouling layer from the filtering surface. In this method, the filtrate is negatively pressured to force the liquid to flow back into the system through the filter medium. The back flushing will cause the cake to break/disrupt and forces the particles to reenter the bulk suspension. However, the total disruption of the cake during the filtration operation is not wanted in the conventional filtration since in this kind of filtration, the cake layer is the true medium which performs the separation.

The application of ultrasound wave fields in filtration operation, particularly membrane filtration, has been identified as a new and clean technology and as an alternative to the classical cleaning. The use of ultrasound fields in the control of filter fouling and filter cake formation, especially in the membrane filtration, has been studied and proven by a number of researchers. The application of ultrasound wave field in membrane filtration processes was found to improve the rate of filtration and reduce the rate of filter fouling. Nevertheless, the technique has not been applied in the conventional filtration operation, especially in leaf filtration processes, to increase productivity.

The suitability of each method used in solving the flux decline phenomenon depends on the qualities of the foulants as well as the nature of the filter. The economic and production demands must also be considered in choosing the appropriate method of solution. Another important consideration is the fact that in pressure leaf filter operation a minimal layer of filter cake is required to achieve good separation of solid-liquid suspension. Thus, the acquired technique must be able to reduce the fouling phenomenon without losing the efficacy of the filtration.

Realizing the capability of ultrasound wave fields in cleaning processes, the technique was studied in this research to increase the rate of filtration of leaf filter. The application of high intensity ultrasound in the solid-liquid suspension would cause the occurrence of cavitation microbubbles in the liquid medium which is responsible in

removing particles especially at the interface between the liquid and solids in the suspension.

1.1 Objectives of Study

The objective of the research is to investigate:

i) The possibility of intensifying the filtration operation,
ii) Increasing the rate of filtration,
iii) Reducing the downtime, by means of Ultrasound Wave Fields.

1.2 Scopes of Study

To achieve the objectives, four scopes have been identified in this research. The scopes of this research are listed as below:

1.2.1 To study the effectiveness of In-Situ ultrasonic cleaning system in increasing the rate of filtration of bleaching earth suspension. Several experimental works were carried out to examine the behavior of the filtration in the presence of ultrasound field.

1.2.2 To identify the optimum combination of filtration cycle time and sonication cycle time which give the highest flux increment. The rate of filtration was influenced by the filtration time and by the duration of ultrasound exposure. Thus, research was carried out to determine the optimum condition of the two parameters.

1.2.3 To study the effect of ultrasound intensity on the degree of flux increment. The degree of flux increment was also influenced by the intensity of the ultrasound field. This study established the optimum ultrasound intensity to be used for the system which results in the best flux improvement.

1.2.4 To study the effectiveness of ultrasonic Clean-In-Place (CIP) method in comparison to Conventional method. A Clean-In-Place method was developed in the research study to clean the filter leaf and the filtering chamber without having to disassemble the filtration system. This scope of study compares the effectiveness of the developed method, with the conventional method of cleaning.

1.2.5 Development of an empirical model. From the results gathered in this study, analysis of transport processes taking place in the separation of spent bleaching earth from oil suspension was undertaken. An empirical model was developed which enable the prediction of filtration rate as a function of various parameters.

1.3 Contribution of the study

A positive outcome from the research would bring a new dimension to related industries in improving the rate of production due to an effective and efficient high intensity ultrasonic cleaning and process design for the purpose of In-situ cleaning method, a demonstration process plant, application of advance technology in high intensity ultrasonic cleaning and at the same time offering potential savings in the operational costs.

REFERENCES

Anton Puskar. (1982). " The Use of High Intensity Ultrasonics". New York U.S.A: Elsevier Scientific Publishing Company, Inc. 30 – 55

Bernardini, E. (1983). " Oil Seeds, Oils and Fats: Oils and Fats Processing Volume II". Rome, Italy: Publishing House Via Failla 63.

Christopher Dickenson. (1992). "Filters and filtration handbook". 3rd ed. Oxford : Elsevier Advanced Technology.

Coulson, J.M. and Richardson, J.F.(1991) "Chemical Engineering, Vol. 2. Fourth Ed., "Particle Technology and Separation Processes", Pergamon Press. 282-335

Dahnke S., Swamy .K.M., Keil F.J. (1999). " A comparative study on the modeling of sound pressure field distributions in a sonoreactor with experimental investigation" Journal of Ultrasonics Sonochemistry. Vol. 6. 221-226.

Dahnke S., Swamy K.M., Keil F.J. (1999). " Modelling of three-dimensional pressure fields in sonochemical reactors with an inhomogeneous density distribution of cavitation bubbles. Comparison of theoretical and experimental results" Journal of Ultrasonics Sonochemistry. Vol. 6. 221-226.

Dale Ensminger . (1973). “Ultrasonics-The Low and High Intensity Applications”. Marcel Dekker,Inc. New York. 423-427.

Dezhkunov N.V. (2002). “ Multibubble sonoluminescence intensity dependence on liquid temperature at different ultrasound intensities”. Journal of Ultrasonics Sonochemistry. Vol. 9 103-106

Elliot Goldberg. (1997). “Handbook of Downstream Processing”, Lockwood Green Engineers, Inc., New York. 318-334

Farmer A.D., A.F. Collings, G.J. Jameson (2000). “Effect of ultrasound on surface cleaning of silica particles” International Journal of Mineral Processing. Vol.60.101-113

Geankoplis, C.J. (1995). “Transport Processes and Unit Operations”. 3rd ed. Singapore: Prentice Hall Simon & Schuster (Asia) Pte. Ltd. 800 – 840

John Fuchs. F.. (2002). “Ultrasonic Cleaning: Fundamental Theory & Application”. http://www.variclean.nl / theory.html. Jamestown, NY 14701.

Karleskind, A. (1996). “ Oils and Fats Manual: A Comprehensive Treatise (Properties-Production-Applications) Volume 2”. New Jersey U.S.A : Intercept Ltd. 807 – 893

Mason, T.J. (1990). “ Sonochemistry: The Uses of Ultrasound in Chemistry”. Royal Society of Chemistry, Germany

Mason, T.J. (1995). “Ultrasonic Intensification of Chemical Processing and Related Operations”. Proceeding of The First International Conference on Science, Engineering and Technology of Intensive Processing, 18-20th September 1995, Nottingham, UK.

Ramlan A. Aziz, Hamdani Saidi et al. (1989). “ Initial Study on Crude Palm Oil Filtration”. One day Seminar on The Latest Development in Filtration Technology, Filtech ’89.

Riera E. -Franco de Sarabia, et. Al. (2000). “ Application of high-power ultrasound to enhance fluid/solid particle separation processes”. Journal of Ultrasonics. Vol. 38. 642-646.

Rushton A., A.S. Ward, R.G. Holdich. (1996). “Solid-Liquid Filtration and Separation Technology”. 1st ed. VCH Publishers, Inc., New York, NY (USA). 33-77

Rushton A., A.S. Ward, R.G. Holdich. (1996). “Solid-Liquid Filtration and Separation Technology”. 1st ed. VCH Publishers, Inc., New York, NY (USA). 397 – 478

Sa’ari Mustapha, Yahya Sukirman. (1996). “ Mathematical Modelling of Coupling Flow and Cake Formation in Filtration Process”. Proceedings Volume 1: 7th World Filtration Congress Budapest, Hungary. Hungarian Chemical Society.

Sukti Majumdar, P. Senthil Kumar, A.B. Pandit. (1998). “ Effect of liquid-phase properties on ultrasound intensity and cavitational activity” Journal of Ultrasonics Sonochemistry. Vol. 5. 113-118.

Sulaiman A.Z., Yunus, R.M**.** (2001) "Intensified Niagara Leaf Filtration Via In-Situ Ultrasonic wave Fields." S*ymposium of Malaysian Chemical Engineers (SomChe)* Johor Bahru, Malaysia.

Sulaiman A.Z,Yunus, R.M**.**Radzuan Junin.(2001) "Development of High Intensity Ultrasonic (HIU) for Stainless Steel Filter Leaf Cleaning." *Regional Symposium on Chemical Engineering (RSCE),* Institute Technology Bandung, Indonesia

Sulaiman A.Z,Yunus, R.M., H. Abdullah (2002), " Modelling of Ultrasonic in Increasing The Rate of Filtration in Palm Oil Industry. *World Engineering Congress (WEC)* Kuching Sarawak

Tsochatzidis N.A., Guiraud. P., Wilhelm. A.M., Delmas .H.. (2001). " Determination of velocity, size and concentration of ultrasonic cavitation bubbles by the phase-Doppler Technique" Journal of Chemical Engineering Science. Vol. 56. 1831-1840.

Veldkamp F.G. (1987). "Paper On The Various Filtration Steps In Edible/Vegetable Oil Processing", Symposium Of Oil Processing, Curacao/Na

Wakeman, R.J (1982), "Effect of Solids Concentration and pH on Electrofiltration." Filtration and separation, pp 316-319

Wakeman, R.J and Tarleton, E.s (1987), "Membrane Fouling Prevention in Crossflow Microfiltration by the Use of Electric Fields." Chem. Eng.Sci.,Vol 42,No4, pp 829-842.

Wakeman, R.J and Tarleton,E.S (1986), "Membrane Filtration", Filtration and Separation, pp 174-176

William, A.R (1983), “Ultrasound : Biological Effects and Potential Hazards” Medical Physics Series, Academic Press.

Yunus, R.M. (1996). “Ultrasound Fields In Crossflow Microfiltration”, Ph. D Thesis, University of Wales Swansea

PUBLICATIONS

Sulaiman A.Z., Yunus, R.M**.** Intensified Niagara Leaf Filtration Via In-Situ Ultrasonic wave Fields. S*ymposium of Malaysian Chemical Engineers (SomChe) 2001* , September 2001, Johor Bahru, Malaysia.

Sulaiman A.Z,Yunus, R.M**.**Radzuan Junin. Development of High Intensity Ultrasonic (HIU) for Stainless Steel Filter Leaf Cleaning. *Regional Symposium on Chemical Engineering (RSCE) 2001* , October 2001, Institute Technology Bandung, Indonesia

Sulaiman A.Z,Yunus, R.M., H. Abdullah " Modelling of Ultrasonic in Increasing The Rate of Filtration in Palm Oil Industry. *World Engineering Congress (WEC) 2002*, July 2002, Kuching Sarawak

Sulaiman A.Z,Yunus R.M, Effect of Sonication For In-Situ Stainless Steel Leaf Filtration. Asian Pacific of Chemical Engineering Conference (APPCHE 2004) 17 to 21 October 2004 at Kitakyushu, JAPAN

Sulaiman A.Z,Yunus R.M, A Study on the Effectiveness of In-Situ High Intensity Ultrasonic (HIU) in Increasing the Rate of Filtration in Palm Oil Refining Industries. 4th Seminar National Science Fellowship (NSF), Ministry of Science, Technology & Innovation Malaysia, 20 to 21 Disember 2004 at Vistana Hotel, Penang (*Silver Medal Award Presenter)*

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