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The Analysis of Pulsed Electromagnetic Field Effect on Solution Conductivity

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Abstract

This paper presents the observation of magnetization process variables which influenced the conductivity of $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ solution. Some of the survey results revealed that there was a decrease in the rate of particle formation of $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ of the ions in the sample of the magnetized hard water. This study compared the conductivity of $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ solution before and after the pulsed electromagnetic field with a concentration level of 0.1 M was given. Electromagnetic Water Treatment (EW) was used to generate the electromagnetic pulse wit 9.3 mT pulsed electromagnetic filed. Tools The measurement of solution conductivity level conducted using Bench Conductivity Meter was calibrated by Control Company with certificate number 4163-4997748 and traceable to the National Institute of Standards and Technology. The measurement was conducted by observing the time function of solution conductivity of $FeSO_4$, $MnSO_4$, $MgCl_2$, and $CaCl_2$. The results showed that pulsed electromagnetic fields affected the conductivity of $FeSO_4$ and $CaCl_2$ solution by74% and 67%, respectively. Meanwhile, the lower conductivity was observed from $MnSO_4$ and $MgCl_2$ solution with 6% due to process of magnetization which caused the instability of the ionic bonding in the solution.

1. INTRODUCTION

Water is a very important function for all living beings, including humans. In its function as a living creature needs, the availability of clean water is a matter that must be met. In the industrialized world, the availability of clean water is needed, especially as feed water to the boiler. Feed water used is water that does not contain elements which could form a crust on the boiler, the water that does not contain elements which could lead to corrosion in the boiler and its supporting systems, as well as water that does not contain elements which can cause foaming of the boiler water. Several studies have been conducted to determine the effect of the magnetic field on the conductivity of the solution. The changes caused by MF depend on many factors, such as the field strength [1], the direction of the applied field [2], the time of the magnetic exposure [3], the flow rate of the solutions[4], the additives present in the system [5], and the pulse magnetic effect on Solutions [6]. Especially, MF effects on calcium carbonate and calcium sulfate precipitation processes and their suspensions have been investigated extensively [7].

We need a technology to improve the quality of physical-chemical treatment for water. This paper develops a method to improve the water quality physicochemical by using Electromagnetic Resonance (EMR). One of the benefits of the use of magnetic fields is to improve water quality which help preventing the use of expensive chemicals or corrosive materials and endangering human health or harm the environment. This study was conducted by observing the conductivity parameters [8]. Observations were carried out using $FeSO_4$, $MnSO_4$, $CaCl_2$ and $MgCl_2$ solution.

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2. THEORY

2.1. Boiler Water Resources

Indonesia has 2,838 km3 of surface water (renewable) and 455 km^3 groundwater. National water uses about 80 billion m^3/year with the highest utilization rate in Java and Bali about 60 %, while the purpose of its use, especially for drinking water, domestic, urban, industrial, agricultural, and others. From the water balance data of 2003 could be seen that the water needs in the dry season in Java and Bali which amounted to 38.4 billion cubic meters, only about 25.3 billion cubic meters or only about 66 %. This deficit is expected to be higher in 2020, where the number of population and economic activity increased significantly [9]. The main problem of water resources in Indonesia includes the quantity of water that has been unable to meet the growing need and quality of water. Industrial activities, domestic, and other activities have a negative impact on water resources. One of them led to a decrease in water quality. This condition can certainly cause disruption, damage, and harmful to all living things that depend on water resources [10]. The industry itself requires a water treatment unit before being fed into the boiler (feed water) which chemical characteristics vary depend on the source. Before the water was fed into the boiler, it must be processed first to reduce levels of minerals contained in it. However, not all industries do that. If the process water was fed into the boiler untreated, it can form a crust (scale) and corrosion (rust) as shown in Fig. 1. This can hinder the process of water evaporation and damage the boiler wall, so a lot of wasted heat energy and thus damaged the boiler and affect on production costs swell. Therefore, process water for boiler feed water needs to be treated both before and during the process of evaporation of water takes place [11].

Fig 1. Scale and Rust on pipe Boiler.

2.2. EMR Effect

Research on water quality improvement using EMR has many publications that explain the effect of magnetic fields on the components of water molecules. Lucyna Holysz, et al explains that magnetic fields can affect the conductivity of the solution, such as KCl, NaCl, Na_3PO_4, and $CaCl_2$, as shown by the graph in Fig. 2 [12].

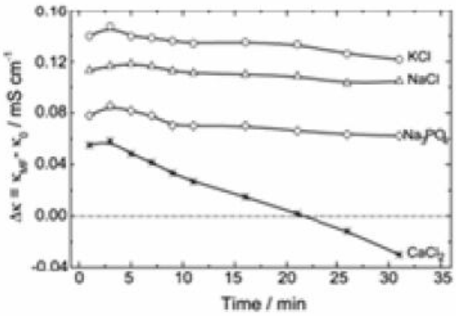

Fig. 2. Graph difference in the conductivity of the solution before and after processing the magnetic field [12].

Water is a polar substance, which tends to be attracted to one another in the presence of hydrogen bonds and form clusters as illustrated in Fig. 3 [13]. Merging and splitting water molecules occurs at thermodynamic equilibrium. In general, each individual cluster contains approximately 100 molecules of water at room temperature, as illustrated in Fig. 4 [14]. In a magnetic field, the magnetic force can break the water clusters into a single molecule or molecules smaller so that the water activity will increase [15].

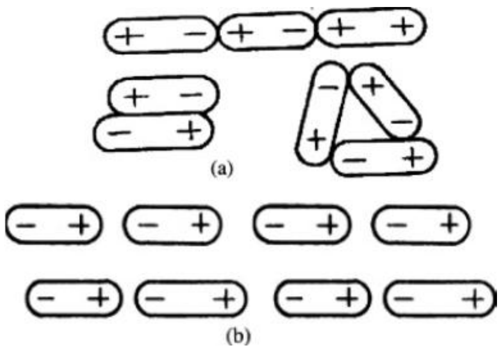

Fig. 3. Effect of magnetic fields on molecules of water: (a) Cluster of water at thermodynamic equilibrium, (b) after the water molecules pass through a magnetic field.

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Fig. 4. The molecular structure of water clusters.

Some researchers mention that the water can not easily magnetize and magnetic nature is only temporary [16]. In a quiet fluid, fine particles will collide due to Brownian motion, thus forming larger particles, but the establishment or incorporation of particles in a manner as above takes place very slowly. Collisions between particles can be improved by stirring slowly, a process called flocculation. This process produced solid particles precipitated from a highly concentrated colloidal easily. For low concentration colloids, a coagulant addition was needed to produce large floc particles. This can be explained by the theory of magnetic field gradient. The gradient magnetic field is an area where there is a change in field strength as a function of position. If a substance with weak magnetic properties (paramagnetic) passes on the the gradient magnetic field, it will undergo a magnetic force between particles of substances that can be formulated in equation (1) as follows [17]:

$$F_m = \left(\frac{X}{\text{«}_0}\right) B \left(\frac{dB}{dz}\right) \qquad (1)$$

where,
Fm = Magnetic force (N)
X = Substance magnetism
μ0 = Permeability = 4π.10-7
B = magnetic field (weber/m2)
(dB/dz) = magnetic field gradient in z

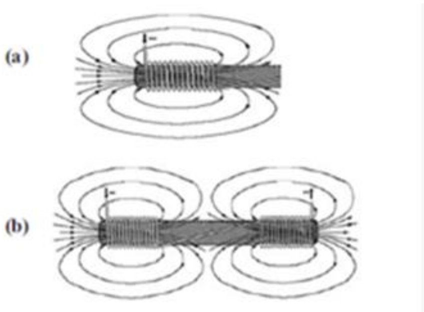

Fig. 5. The distribution pattern of the magnetic field on (a) 1 coil configuration and (b) 2 coil configuration.

Fig. 5(a) shows the pipe with one coil, there are two regions of magnetic field gradient coil, which are the flow of incoming and outgoing coil. Meanwhile, the pipe with two coils Fig. 5(b), has four areas of magnetic field gradient. For pipe with 3 coils, the fluid flow will pass through six local magnetic field gradient.

3. METHODS

The measurement of the pulsed electromagnetic field effect on the conductivity of a $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ solutions was conducted using coil which according to method as shown in Fig. 6. Testing was conducted using coil which contained magnetic pulses and the changes of conductivity before and after given electromagnetic pulse of the $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ synthesis solution with a concentration level of 0.1 M were observed.

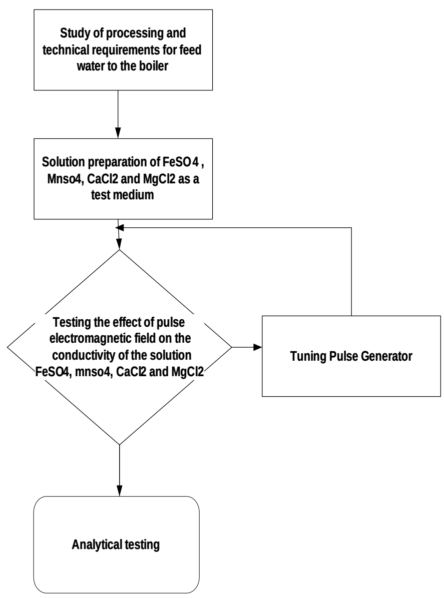

Fig. 6. Test execution method

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4. EXPERIMENT

The equipment for generating the electromagnetic pulse is Electromagnet Water Treatment (EWT) with pulse electromagnetic field of 9.3 mT, as shown in Fig. 6. The level of conductivity of the solution was measured using the Bench Conductivity Meter which has calibrated by Control Company with Certificate No. 4163-4997748 and traceable to the National Institute of Standards and Technology. The test was conducted by observing the time function of the conductivity of the $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ solutions.

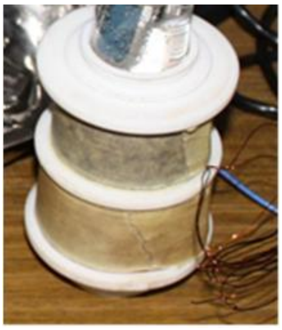

Fig. 7. Tools for generating an electromagnetic pulse.

Test tubes containing $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ solution were incorporated into the electromagnetic coil located on a water bath at room temperature (± 25 °C). The role of water was to keep the electromagnetic coil temperature remains at room temperature. Therefore, the conductivity measurement data is not affected by the temperature changes of the coil. Fig. 7 shows the design of electromagnetic pulse measurements in a solution

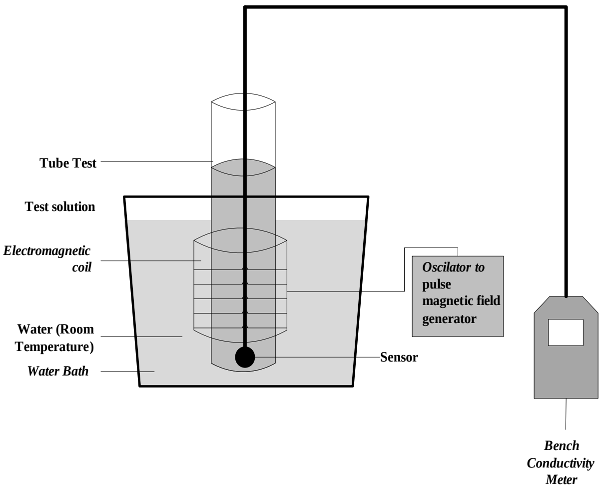

Fig. 8. A schematic diagram of the solution conductivity testing $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$.

5. RESULTS

The results of the pulse electromagnetic field effect (9.3 mT) in $MnSO_4$ solution with a concentration level of 0.1 M are shown in Fig. 9.

From the graph, it was observed that the conductivity Δ of $MnSO_4$ solution with a concentration of 0.1 M are at a positive value due to the strong electrical conductivity in the span of 30 minutes. The positive conductivity difference (Δk) indicated that there was a strong ionic bonds between cations and anions in $MnSO_4$ solution. This caused the hydration of ions in $MnSO_4$ solution and slowed down the precipitation.

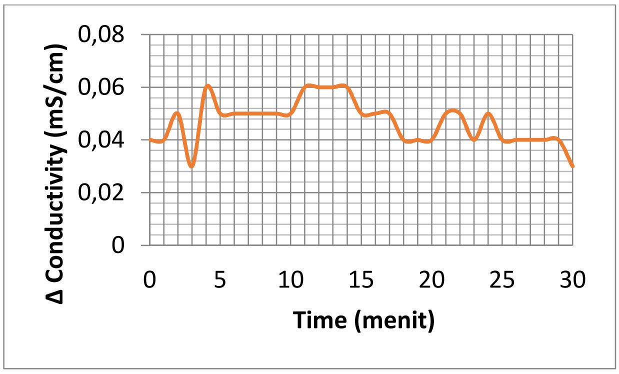

Fig. 9. The graph Δ Conductivity $MnSO_4$ concentration of 0.1 M.

In Fig. 10, it appears that the conductivity Δ $FeSO_4$ solution with a concentration of 0.1 M are at a negative value. Meanwhile, the positive values were observed at 11 and 15 minutes. It was caused by the weak electrical conductivity in the span of 30 minutes. If the difference value is negative then the ionic bonds between cations and anions is weak. This leads to lack of hydration of ions in a solution of $FeSO_4$ which fasten the precipitation.

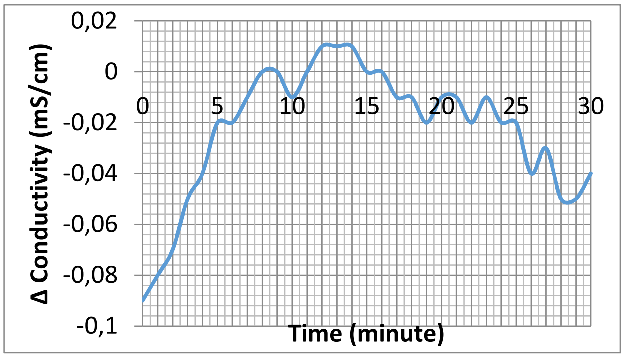

Fig. 10. The graph Δ Conductivity $FeSO_4$ concentration of 0.1 M.

From Fig. 11, it was observed that Δ conductivity of the solution with a concentration of 0.1 M $MgCl_2$ are at a positive value because of the strong electrical conductivity in the span of 30 minutes. If the difference value is positive then there was a strong ionic bonds between cations and anions in the $MgCl_2$ solution. This leads to lack of hydration of ions in $MgCl_2$ solution which slowed down the precipitation.

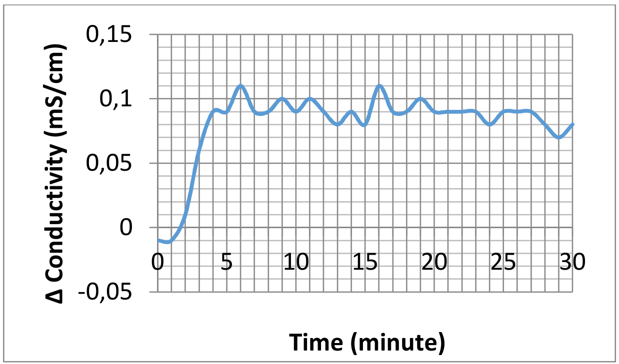

Fig. 11. Graph Δ Conductivity $MgCl_2$ concentration of 0.1 M.

In Fig. 12, it was observed that the conductivity Δ $CaCl_2$ solution with a concentration of 0.1 M is at a positive value because of the strong electrical conductivity in the span of 30 minutes. If the difference value is positive then there was a strong ionic bonds between cations and anions in the $CaCl_2$ solution. This leads to lack of hydration of ions in $CaCl_2$ solution which slowed down the precipitation.

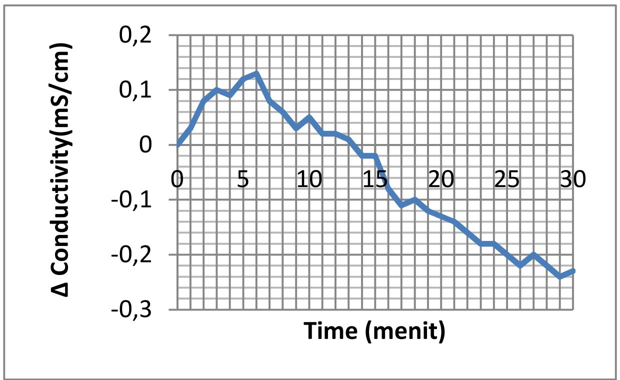

Fig 12. Graph Δ Conductivity CaCl2 concentration of 0.1 M.

From the experimental results, each $FeSO_4$ electrolyte solutions that have a positive bonding of Fe^{2+} ions surrounded by water molecules is directed toward the negative end of the cation while SO_4^{2-} which is surrounded by a number of water molecules leads to a positive end toward the anion. The ion magnetization process of SO_4^{2-} in solution can stabilize or prevent the ions forming precipitation with Fe^{2+} which led to the formation of a crust. It caused the difference in conductivity values (Δk) of $FeSO_4$ solution is in the region of negative, therefore, it accelerates the deposition process. The Mn^{2+} ion in $MnSO_4$ solution which is surrounded by the water molecules pointed toward the negative end of the cation while SO_4^{2-} which is surrounded by a number of water molecules toward the positive end of the anion. The ion magnetization process of SO_4^{2-} in the solution cannot stabilize or prevent the ions forming a precipitation with Mn^{2+} which led to the formation of a crust. It caused the difference in conductivity values (Δk) on the $MnSO_4$ solution is in the region of positive thus slowing the deposition process. Similarly, $MgCl_2$ solution has positive bonding Mg^{2+} ions surrounded by water molecules point toward the negative end of the cation while Cl^- is surrounded by a number of water molecules toward the positive end of the anion. The ion magnetization process of Cl^- ions in the solution cannot stabilize or prevent the ions forming a precipitation with Mg^{2+} which led to the formation of a crust. It caused the difference in conductivity values (Δk) in $MgCl_2$ solution is in the region of positive thus slowing the deposition process. For $CaCl_2$ solution, magnetization process occurred in the first 15 minutes of $CaCl_2$ solution, Cl^- ions cannot stabilize or prevent the ions from the precipitating with Ca^{2+} to form a crust. It caused the difference in conductivity values (Δk) in the $CaCl_2$ solution is in the region of positive actions which can slow down the process of deposition. However, during 15 minutes, there was an impaired conductivity difference (Δk) where the magnetization caused stability or prevent Cl^- ions from precipitating with Ca^{2+} to form a crust so as to accelerate the process of deposition differences conductivity value of the difference (Δk) of each solution is shown in the Fig. 13.

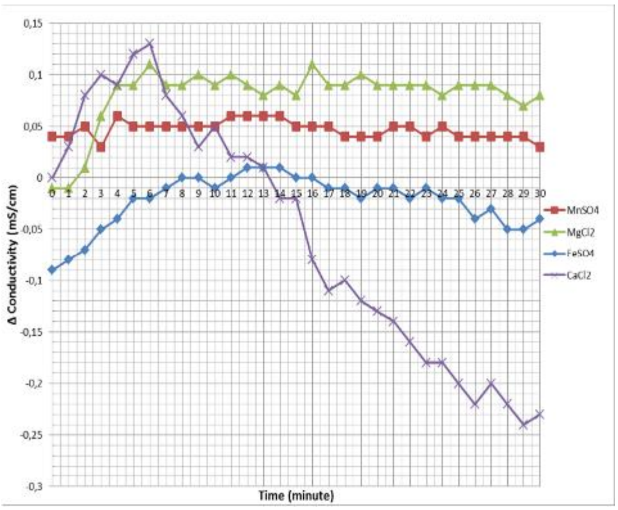

Fig. 13. Solution conductivity characteristics comparison chart $FeSO_4$, $MnSO_4$, $MgCl_2$ and $CaCl_2$ before and after a given pulse magnetic field of 9.3 mT.

6. CONCLUSION

The test results showed that pulsed electromagnetic fields can affect the conductivity of $FeSO_4$ solution. The deposition of $FeSO_4$ solution occured faster in a field of 9.3 mT electromagnetic pulse due to the difference in conductivity values (Δk) in $FeSO_4$ solution is in the region of negative which caused the acceleration process of deposition. Magnetization process resulted a decrease in the conductivity of a solution of $FeSO_4$ difference by 74%. This means that the increase in the diameter of the ion hydrate and the weaker hydrate ionic bonds. While $CaCl_2$ solution has a conductivity difference (Δk) in the positive region at a specific time period and the subsequent period of the conductivity difference is in the region of negative which accelerated the deposition and formation process of the crust by 67%. $MnSO_4$ solution and $MgCl_2$ solution have a conductivity difference in the region positive which the precipitation occurred at an accelerating rate for $MnSO_4$ solution due to the value of conductivity difference (Δk) which is lower by 6% than $MgCl_2$ solution. The mechanism of the effect of particles and the Lorentz force led to a nucleation and precipitation of the solution during and after magnetization occurred. The use of the electromagnetic field strength of 9.3 mT on the condition of proportional numbers already showed a significant decrease in conductivity difference, especially on $FeSO_4$ and $CaCl_2$ solution.

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