Attenuation Measurement Method to Control Clay Slurries: Application of Dams Water

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ABSTRACT
We propose to study the behavior of diluated suspensions of clay and non colloidal particles by a combination of experiments. We plan to study these diluate particulate systems by changing the masse fraction of clay. We have developed a technique based on the ultrasound, by measuring ultrasonic attenuation waves in clay slurries. This technique makes it possible to control in real time the presence of the clay grains whose dimension is about 10 micron, using an interface conceived under Lab*view* program. The slurries with different weight of clay were controlled. The detection of weak amount of clay's grains and colloid were provided by the transducer 30Mhz. High sensitivity is obtained by analyzing the attenuation measurements founded from multiple paths through the slurry. The experimental results obtained show that the attenuation of waves due to particles varies linearly with mass fraction and the frequency of transducers. Therefore, such measures of the attenuation at a given frequency give the concentration of clay in the suspension. These frequency charts will be used for the quality control of the dam's water.

General Terms
0.N.E.P: Office National de l'eau Potable, (National office of drinking water).

FFT: Fast Fourier Transform.

Keywords
Clay suspension characterization, diluate clay suspensions, ultrasonic attenuation, attenuation measurement method, clay concentration in distilled water, clay's slurries control, dam's water measurement.

1. INTRODUCTION
Using ultrasound measurements were carried out to characterize the liquid, solid and gas for over 60 years. The need for compact, non invasive, real time measurement of density and concentration for waste slurries of clay, fostered the development of an ultrasonic sensing technique based on the reflection and transmission of ultrasonic signal at the sensor-fluid interface. While the ultrasonic attenuation spectrometers witch available on the market have was entirely used, [1].But imprecise measurements of these devices require us to use another method of measuring the scale of our laboratory. One problematic area is the region of application of the particle size or smaller than 10 micron. Most work applies to the measurement of ultrasonic process by focusing on the application of density, flow measurement and detection interface. The dam water contains different sizes of clay grains. The knowledge of the concentration of clay present in water will make possible to optimize the addition of the chemicals products which allows the clay recovery. The suspensions of clay studied are between 5 and 50g/l. Theses concentrations range were proposed by (0.N.E.P) the National Office of Drinking Water in the region of Agadir city in Morocco. Each concentration corresponds at an output rate of water into the basins and tanks treatment, (see Table 1).

Table1. Clay concentrations versus barrier water flow

Clay concentrations (g/l)	Water flow (m^3/s)	
5 to 10	50	Maximum flow
10 to 20	38	Average flow
20 to 30	19	Low flow
40 to 50	0	Water cut

2. TECHNIQUE OF MEASURING THE ATTENUATION
Ultrasonic velocity is the distance which the wave cast through the sample for a unit of time. The attenuation coefficient is the measurement of the reduction in the amplitude of ultrasonic wave for a unit distance, [2-3]. (see Equation 1).

$$\alpha = -\frac{1}{d}\ln\left(\xi_{ref}\frac{A_d}{A_0}\right)$$

(Eq.1)

A_0 is the ultrasonic amplitude at the position x=0
A_d is the amplitude after having cover a distance x=d
ξ_{ref} is the ratio of the acoustic impedances of the extreme mediums.
The attenuation coefficient of the sample is given with same preceding manner. If we use only one transducer in the

reflexion method, we must replace the distance *d* by *2d* in the (Equation 1), because the wave made two alleys and return in the container, (see Figure 1), [4].
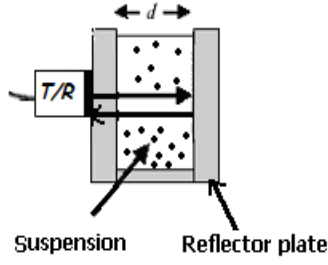

Fig 1 : Wave trajectory into the container

The distribution of the particles and their size in slurries are connected, with the determination of the attenuation coefficient [5], or/and the velocity of sound.

3. SLURRIES PROPERTIES

Slurries of clay properties include mixture density (ρ_m), mass fraction (C_m) or volume fraction (C_v), mean size particle of clay's grains $< a >$, and bulk density of the solid (ρ_c). The mass of the slurry (M_m) is: $M_m = M_f + M_c$, where M_f is the mass of fluid and M_c is the volume of the particulate of clay. The volume of slurry (V_m) is: $V_m = V_f + V_c$, where V_f is the volume of fluid and V_c is the volume of the particulate of clay's grains. The mass fraction of slurry is determined by the ratio, (see Equation 3).

$$C_m = \frac{M_c}{\left(M_c + M_f\right)} = \frac{\rho_c\left(\rho_m - \rho_f\right)}{\rho_m\left(\rho_c - \rho_f\right)} \qquad (Eq.3)$$

Where ρ_f is the fluid density. The corresponding volume

fraction relationship is C_v, (see Equation 4).

$$C_v = \frac{C_m}{\left[C_m + S\left(1 - C_m\right)\right]} \qquad (Eq.4)$$

Where S is the relative density of clay's grains (ρ_p/ρ_f). The volume fraction is proportional to the number of particles per unit volume (n). Suppose there are N particles in the total volume (V_T) and each particle occupies a given volume (V_P). The average particle size of clay's grains is about $10\mu m$. The density of the slurry was obtained also by weighing a known volume of clay. The density of the slurry was also obtained from the known weight percentage of the slurry, the density of clay (2680 kg/m³), and the density of water (1 kg/m³), [6]. When the particulate of clay is insoluble in the liquid, the relationship is given by using (see Equation 5). For process control for a given type of particulate in the slurry, the instrument calibration provides the attenuation as a function of weight percentage. When the instrument operates in-line, the attenuation in turn is related to the weight percentage of clay's grains in the slurry.

$$Wt\% = \frac{\rho_w\left(\rho_s - \rho_w\right)}{\rho_w\left(\rho_c - \rho_w\right)} \times 100\% \qquad (Eq.5)$$

Where ρ_w is the density of water, ρ_c is the density of the clay, and ρ_s is the density of the slurry.

4. EXPERIMENTAL DEVICE

The measuring apparatus used in this work, made up of : a generator of pulse, an oscilloscope, a container and transducer (see Figure 2).
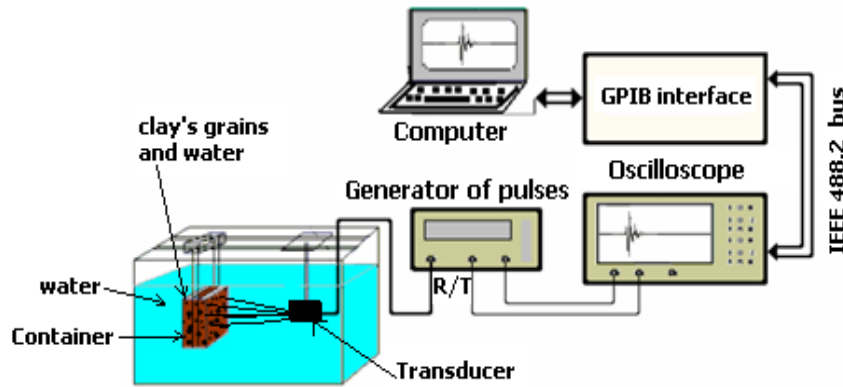

Fig 1: Experimental device, (method by reflexion)

5. REAL TIME CONTROL OF THE CLAY'S PARTICLES SEDIMENTAION

We begin the control with the acquisition of the signals illustrated on the screen of the oscilloscope by an application under the graphic programming language Lab*view*, [7]. The developed interface makes it possible to specify the number of acquisitions wanted during the experiment and time separating two successive acquisitions. The Lab*view* program collects 10 signals each time and carries out an average to neutralize the interfering signals. The resulting signal represents for the user only one acquisition,[8-9]. An example of an experimental signal retrodiffused by the container which contains the sample is shown in (see Figure 3).
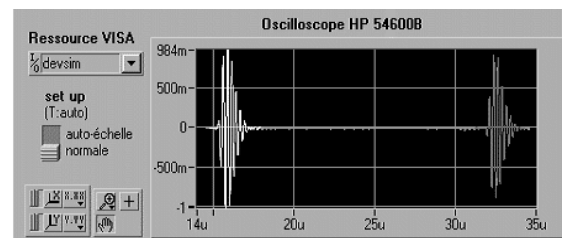

Fig 3: Signal retrodiffused by the container

This signal is composed of two echoes A_2 and A_4 shown successively from left to right on the figure 3. This signal is captured starting from the oscilloscope by the Lab*view*

program developed. We have noted that the water was characterized only by the echoes A_2 (reflexion on the interface between the second face of plate 1, and the mixture of clay's grains/water), and A_4 (reflexion with the interface between the mixture of clay's grains/water, and the first face of plate 2). Then, the program separates the echoes by temporal windows by taking only the echo (A_2 and A_4) however the sites of echoes compared to time (X-coordinate) remain unchanged. The user has the possibility of choosing the first time manually the echo which will take a different color thereafter. The continuous spectra of phase of the echoes A_2 and A_4 are presented on the figure 4.
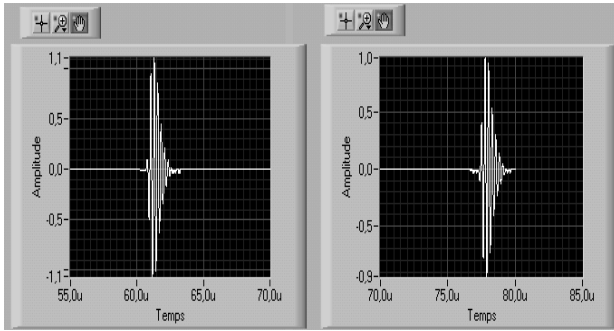

Fig 4: Filtered signal of the echoes A_2 and A_4

The spectral amplitudes, of the echoes A_2 and A_4, are determined by the application of the FFT to the signals of figure 3. The spectra of amplitudes of the two echoes A_2 and A_4 are respectively presented on figure 5.
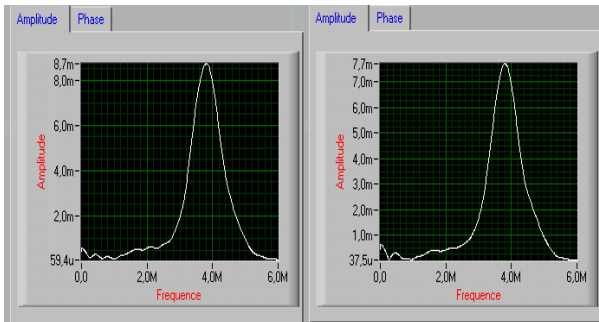

Fig 5: Spectral amplitude of the echoes A_2 and A_4

5.1 Measure the attenuation in suspensions
The attenuation of sound in water and clay mixture is given by the equation 6, [10-11].

$$\alpha = -\frac{1}{2d}\ln\left(\xi_{ref}\frac{A_4}{A_2}\right) \qquad \text{(Eq.6)}$$

With $\xi_{réf} = \dfrac{(Z_{pg} + Z_{Susp})^2}{4Z_{Pg} Z_{Susp}}$ and

$Z_{Pg} = \rho_{pg}.C_{pg}$, Z_{pg} is the acoustic impedance in the Plexiglas.

$Z_{eau+arg} = \rho_{eau+arg}.C_{eau+arg}$, Z_{Susp} is the acoustic impedance in suspension. [12-13-14].

6. RESULTS AND DISCUSSIONS
We prepare the suspension with the method described above. Theses suspensions analyzed were prepared from known quantities of dry clay and distilled water. After sufficient agitation, which provides the average distribution of clay's particles per volume element, we send a pulse on the vessel containing the suspension, we allowed the suspension settled.

6.1 Attenuation measurement on the scale frequency of 4 to 8 MHz
Attenuation was calculated based on the frequency of 4 to 8 MHz with an increment of 1 MHz for five concentrations (5g/l, 10g/l, 20g/l, 30g/l and 40g/l). For each suspension, the data were obtained for a first measurement M1, followed by a second measurement M2 after 12 hours, because after this period in distilled water the clay's grains swell and their sizes become larger, which will influence the attenuation values (see Figure 6). The Analysis of these curves shows that the attenuation increases when the clay concentration increases. And that in each case, the data of M2 are higher than those obtained in M1. This is explained by the fact that the clay's particles reacted with distilled water, causing a slight increase in the volume of clay's particles, and a small amount of air bubbles in the suspensions were contributed to rising values of the attenuation data M2.
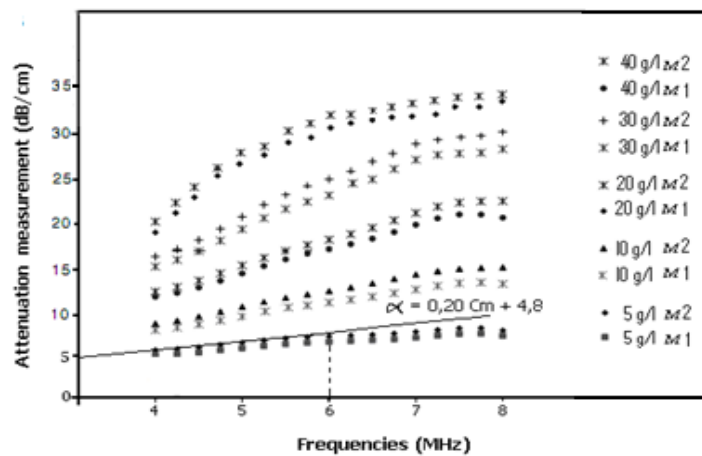

Fig 6: Attenuation curves as a function of the frequencies, for two measurements M1 and M2 after (12 hours)

For a given frequency, the slope of the curve representing the attenuation α as a function of the concentration of clay (C_m),

displays a straight line. For example, the concentration of 5g/l at the frequency 6 MHz, the slope is given by the equation 7.

$$\alpha = 0.2\,C_m + 4.8 \qquad\qquad (Eq.7)$$

Where the slope is expressed in (dB/cm C_m). Indeed, similar results were found for the other frequencies of 3 to 5 MHz, where the slopes respectively are (0.23-0.25-0.29). Therefore, a measure of the attenuation at a given frequency gives the amount of clay present in the suspension, and vise versa. We also note that the last measurement 40g/l, we note that the linear aspect disappears, because we fall within the range of concentrated suspension, and interactions forces begin to take place.These charts built will serve us to control the amount of clay present in each suspension, and optimize the addition of chemicals products that will serve us to recover the clay and the quality control of the dam's water.

6.2 Attenuation measurement at high frequency 30 MHz (transmission method)

The transmission method differs in principe from the reflection method, it consist to measure the difference of attenuation Δα versus the time of sedimentation. The difference of attenuation was followed for three concentrations of clay suspensions (0.5g/l, 4g/l and 40g/l, respectively on the figures (Fig 7.a), (Fig 7.b) and (Fig 7.c).
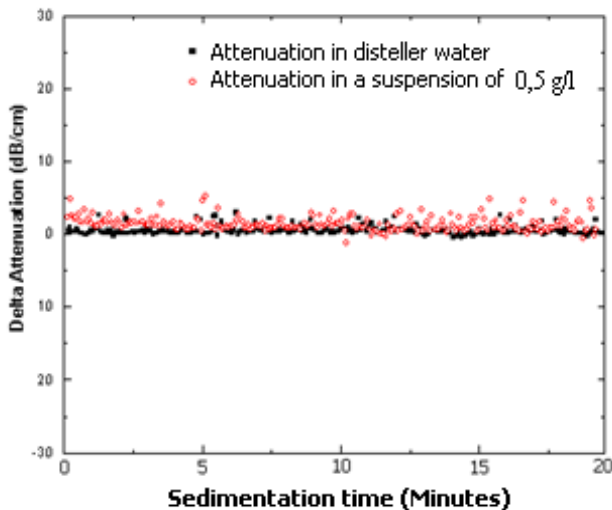

Fig 7.a: Attenuation measurement versus sedimentation time for a suspension of 0.5g/l
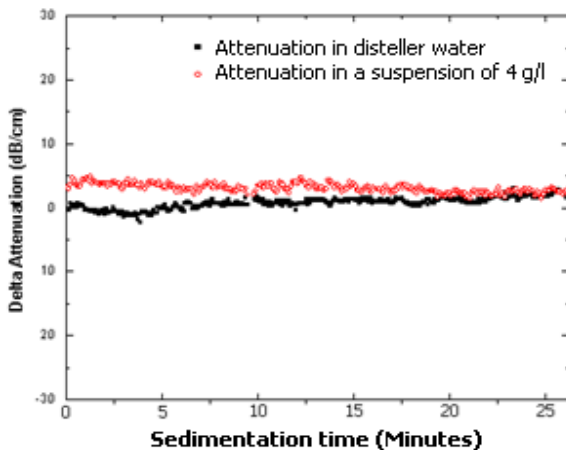

Fig 7.b: Attenuation measurement versus sedimentation time for a suspension of 4g/l
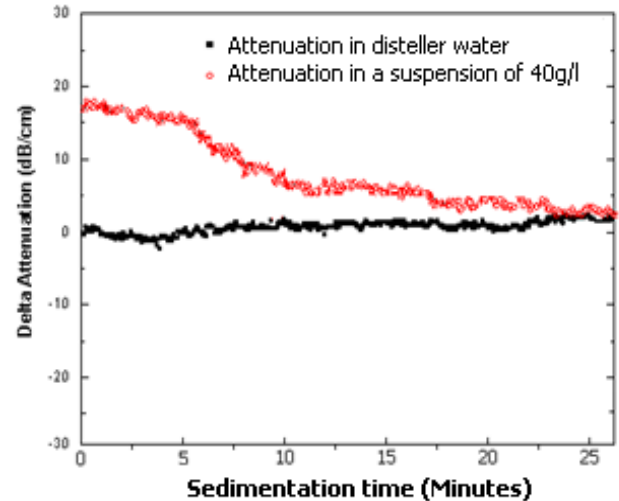

Fig 7.c: Attenuation measurement versus sedimentation time for a mixture of 40g/l

The analysis of these figures shows that when the concentration of clay increases in distilled water, the difference of attenuation Δα increases. We note that the linear characters of the last curve above disappear. The curve shows attenuation fall during three minutes of the starting experiment, because the suspension becomes very concentrated in clay and the interactions forces between clay's grains begins to take place.

The transducer of 30 MHz is very sensitive for detecting the presence of small amounts of clay. We can use high frequency transducers to detect colloids and very small clay particles.

7. Conclusion

The results obtained show that the attenuation of ultrasonic varies linearly almost with frequency scale between 4 to 8 MHz with 1 MHz increment and this only for the low levels of clay. We also note that the attenuation values increase as a function of the amount quantities of clay in suspension. Therefore, a measure of the attenuation at a given frequency in any suspension gives the quantity of clay present in the suspension. These charts built will serve us to control the small quantity of clay present in any suspension, and optimize the addition of chemicals products that will serve us to recover the clay grains after having promote their agglomeration. These results will serve us in our future field work for the quality control of the dam's water.

Using a transducer with high frequency 30 MHz used to detect fine clay particles and colloids. In this case also, we note that the difference of attenuation varies linearly with the clay mass fraction in each suspension. Such measures may indeed be used for detecting contaminants and allow to the very precise measurements of the small concentrations of clay in any suspension. Finally, we also note that when we increase the quantity of clay in suspension, the linear character of the curves disappear because the interaction between particles strengths and becomes very important.

In this case, if we want to study such suspensions, it is necessary to use other ultrasonic methods of characterizing concentrated clay's suspensions.

8. ACKNOWLEDGMENTS

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